AN ONLINE INVESTIGATION OF VERB TRANSITIVITY BIASES IN THE DISCOURSE OF PERSONS WITH APHASIA

BY

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ABSTRACT

The literature examining verb transitivity bias, i.e., speakers' sensitivity to a verb's preference for either a transitive or intransitive sentence structure, following aphasia has yielded conflicting results. We examined verb transitivity bias in the discourse of healthy controls and persons with aphasia (PWA) by measuring pause times, an online index not utilized previously to investigate this issue. Mean pre-verb pause times for transitive verbs were approximately double that observed for intransitive verbs in fluent and nonfluent aphasic speakers while post-verb pause times varied widely. The pattern suggests that healthy controls and PWA activate transitivity bias prior to production of the verb. PWA exhibited the same intransitive or transitive biases for 4/6 of verbs, however did not for 2/6 verbs. This indicates that transitivity bias may not always be activated or applied in a timely and accurate manner during discourse production. An analysis of pause times occurring before and after verb production in matched and mismatched conditions was limited by number of data points across conditions. It was, however observed that for the 3 participants that exhibited pause times in the pre-verb position, all 3 participants displayed longer pause times in matched conditions relative to mismatched conditions. Overall, these findings suggest that both fluent and nonfluent PWA exhibit the transitivity bias.

INTRODUCTION

It is well known that, during sentence processing, the structure and interpretation of a sentence is influenced by the characteristics of the verb. That is, some verbs will select for an intransitive sentence structure, some will select for a transitive sentence structure, and some will select for a structure that allows for a prepositional phrase and/or additional phrasal complements. This characteristic is referred to as the verb's transitivity bias. Investigations of whether people with aphasia (PWA) are sensitive to this verb characteristic have utilized online and offline experimental paradigms across a number of comprehension and production tasks. Online paradigms examine cognitive processing at the time in which a stimulus is encountered and processed, while offline paradigms investigate the effects of processing after the stimulus is encountered. Early comprehension studies utilizing an online cross-modal lexical decision (CMLD) task have found that PWA diagnosed with nonfluent aphasia types (Broca, Transcortical Motor, Global) do exhibit a transitivity bias but that those with fluent aphasia types (Wernicke, Transcortical Sensory, Conduction, Anomia) do not (Russo, Peach, & Shapiro, 1998). A later comprehension study utilizing the offline plausibility judgement task yielded results that conflicted with previous findings (Gahl, 2002). More recently, transitivity bias has been investigated using online self-paced reading (DeDe, 2013) and later, an error analysis of sentences produced by PWA (DiLallo, Mettler, & DeDe, 2017). These studies suggested that speakers with both nonfluent and fluent aphasia are sensitive to transitivity bias during sentence production.

A method that has been used to index language processing online (i.e., when the operation unfolds in real time) is pause time analysis (e.g., Ellis & Peach, 2009; Peach, 2013; Peach & Coelho, 2016). Long pause durations, also referred to as silent or empty pauses, are thought to index language processing load (Angelopoulou et al., 2018). The studies that have used pause time analysis have found longer and more frequent pauses in the speech of PWA relative to healthy controls (Deloche, Jean-Louis, & Seron, 1979), especially prior to the production of errors like neologisms (Butterworth, 1979). A recent study by Angelopoulou et al. (2018) found a higher median for long pauses and a higher threshold needed to differentiate between short and long pauses in this population in comparison to controls.

To date, the literature has yielded conflicting results regarding whether PWA are sensitive to transitivity bias in sentence processing. This study aims to investigate this issue further using analyses of pausing patterns in sentences produced by PWA during spontaneous discourse.

CHAPTER ONE

LITERATURE REVIEW

Verbs and Sentence Processing

According to Poirier and Shapiro (2012), a sentence is the fundamental unit of language comprehension and production. A sentence is composed of individual words, which are retrieved from our lexicon. The lexicon is a mental compilation of words and their related phonological, semantic, and syntactic characteristics. According to Garrett's model (1980), the verb is the first element of the sentence that is activated during sentence formulation and the remaining sentence is built around it. Consequently, when a verb is retrieved from the lexicon, grammatical constraints become active and determine the syntactic structure of the sentence. These constraints dictate the specific numbers of phrases or clauses (arguments) in the sentence, as well as the types of arguments allowed (subcategorization options). This is referred to as verb-argument structure (VAS).

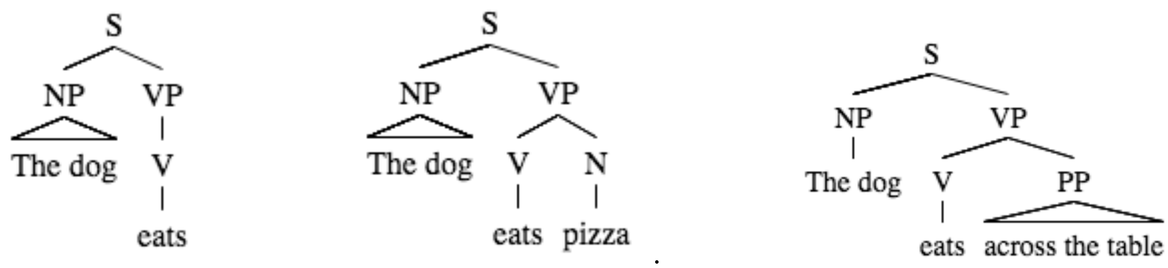
Verb-Argument Structure (VAS) and Transitivity Bias

The VAS dictates the number and types of arguments a verb can support. Arguments may precede or follow the verb. Arguments can act therefore as the subject before the verb, as well as the direct or indirect object of the sentence following the verb. In these cases, the argument is a noun phrase (NP). Arguments following the verb can also be prepositional phrases (PP) that begin with a preposition such as "in" or "with" and end with a noun. When a sentence is processed, we derive the meaning from these phrases. The phrases are a hierarchically -not sequentially- organized set of words. As we hear a sentence, we do not process words in the exact order that they appear, but rather, as words embedded within phrases, as illustrated by the hierarchical syntactic tree diagrams below (Figure 1). For instance, in sentence 1), the verb is *eat*. There is one argument present, which is a noun phrase (NP). In sentence 2), there are two arguments. There is an argument preceding and another argument following the verb. Both arguments are processed as noun phrases (NP) because nouns (*dog, pizza*) appear as the head of each phrase. When we process this sentence hierarchically, the NP following the verb merges with the verb phrase (VP) (*eats*). In the next step, we merge the preceding NP (*dog*) with the VP (*eats pizza*). Sentence 1) presents a syntactic environment with only one argument, yielding an intransitive structure. Sentence 2), on the other hand, presents a syntactic environment with two arguments—a subject and direct object. This is referred to as a transitive structure. Sentence 3) does not feature a direct object following the verb. Therefore, Sentence 3) is intransitive. While all sentences are syntactically correct, the verb *eat* appears more frequently in contexts that support two arguments that are both NPs. This higher occurrence is referred to as the verb's transitivity bias or preference. When a sentence is heard or produced that conflicts with the verb's transitivity bias, there is a transitivity mismatch. This type of mismatch often sounds unnatural to listeners and requires more effortful processing, as evidenced by studies in healthy populations and PWA (Shapiro, Nagel & Levine, 1993; Russo et al., 1998; Gahl, 2002).

Once the number of arguments is determined, the verb imposes another constraint on the sentence structure. This constraint concerns the types of argument that it supports. These are referred to as subcategorization options. Sentences 2) and 3) both have two arguments, in which one follows the verb. These arguments are different. In sentence 2), the argument is an NP (*pizza*), while sentence 3) supports a PP (prepositional phrase). *Eat* can sustain a variety of different phrases as arguments, however not all verbs can.

Figure 1. Verb *eat* in intransitive and transitive frames.

1) The dog eats. 2) The dog eats pizza. 3) The dog eats across the table.



VAS and Transitivity Bias in Aphasia

There is a large body of literature devoted to the study of verb processing and usage in persons with aphasia (PWA). These investigations have found that verb-related deficits underlie many of the language errors in this population. The speech of nonfluent PWA, most notably those diagnosed with the Broca type, is associated with impaired retrieval of verbs more so than nouns (Kim & Thompson, 2000), as well as impoverished verb argument structure in narratives (Marshall, Pring, & Chiat, 1998). There is also evidence of verb- related deficits in people with fluent aphasia like insensitivity to certain properties of verbs like the number of arguments a verb can support (also referred to as complexity; Shapiro & Levine, 1990) and the verb's preference for a certain VAS (transitivity bias; Russo et al., 1998). Insensitivity to the complexity and transitivity preferences of verbs impacts the speed and accuracy of comprehension and production of language. Transitivity bias assists the listener in more efficient processing of sentences and when a mismatch in preference occurs, duration lengthens for tasks (Shapiro et al., 1993; Russo et al., 1998; Dede, 2013). Studies have also found that there is a higher occurrence of language related errors on comprehension and production tasks when there is a transitivity mismatch (Gahl, 2003; DiLallo, 2017). Recent investigations, however, have challenged whether PWA are insensitive to this transitivity bias (Gahl, 2003; Dede, 2013; DiLallo, 2017).

Comprehension Studies.

Shapiro and Levine (1990) investigated sensitivity to verb argument structure in 7 people with nonfluent Broca aphasia, 6 people with fluent aphasia (4 Wernicke, 1 Conduction, 1 Anomia), and 10 healthy control participants. The number of arguments taken by a verb was used to identify the verb's complexity. Therefore, a verb that allows for three subcategorization options (e.g., NP, NP + NP, NP + PP) would be considered to be more complex than a verb that allows for one subcategorization option (e.g., NP). According to the authors, verbs with greater complexity require more processing resources. To examine whether subjects were sensitive to verb complexity, subjects listened to sentences with verbs of various complexities. An online, cross lexical modal decision task (CMLD) was presented to the listener with probes at two points in the sentence —once immediately after the verb and another time after the argument following the verb. The probe required the subject to determine whether a sequence of letters formed a word or not. The investigators postulated that processing of more complex verbs requires increased cognitive load, thus lead to longer reaction times (RTs) on the secondary lexical decision probe task. This was confirmed by Shapiro and Levine's (1990) findings, which demonstrated lower reaction times immediately after less complex verbs in both controls and nonfluent PWA. RTs on secondary tasks that were presented much later after the verb showed no difference between less and more complex verbs. The authors concluded that activation of all VAS possibilities takes place immediately after the encounter of the verb and not later in the sentence. Furthermore, Shapiro and Levine (1990) did not see these patterns in the people with fluent aphasia. There were no RT differences on the secondary task immediately after the verb across less and more complex verbs. While the examiners noted slightly reduced RT's for more complex verbs, this pattern was not significant, thus leading to the conclusion that fluent PWA are not sensitive to verb complexity.

Shapiro, Nagel, and Levine (1993) examined verb preference for specific arguments in a total of 224 healthy control participants. The investigation was composed of three experiments. In the first experiment, Shapiro et al. (1993) established a consensus of the biases each verb exhibits. The healthy participants heard verbs in both transitive and intransitive sentences as in 4) and 5) below.

4) The ageing pianist taught his solo with great dignity

5) The ageing pianist taught with his entire family.

At the end of each sentence, participants were then asked which one 'they 'preferred, sounded better, felt right.' Based on these responses, Shapiro et al. (1993) determined the individual preferences for these verbs. In a second experiment, the authors examined the effects of presenting a verb in its non-preferred environment. Participants heard partially complete sentences where the argument following the verb was not fully provided. However, the participant was given enough information to deduce whether the argument was an NP or PP. For instance, the following sentence would be presented: "The ageing pianist taught his" or "The ageing pianist taught with." When an online probe was presented after *his*, the listener was prompted to believe that a direct object or an NP will follow, thus yielding a transitive sentence. When the probe was presented after *with,* the listener was prompted to believe that the argument is a PP, thus yielding an intransitive sentence. At this point, a secondary task requiring participants to determine whether a sequence of letters was a word or nonword was presented. Shapiro et al. (1993) postulated that since *teach* is a transitively biased verb and if it appears in a mismatched intransitive context and therefore, with a PP, the RTs should be longer relative to the verb appearing in a matched transitive context with an NP. The authors found that in matched conditions, RT's were lower in comparison to when the arguments conflicted with the verb's preferred structure.

Russo, Peach, and Shapiro (1998) expanded on the work of Shapiro et al. (1993) and examined sensitivity to verb transitivity in PWA. Participants were 5 people with fluent aphasia and 5 healthy control participants. The methodology and stimuli were the same as those used in Shapiro et al. (1993). Verbs with known preferences were presented in transitive and intransitive sentences. For example, the verb *teach* has a transitive preference and when it appears in a transitive sentence, it is in its preferred sentence structure. When *teach* appeared in an intransitive context like "the ageing pianist taught with his entire family" (Shapiro, et al. 1993, p. 105; Russo et al., 1998, p. 540), the verb would then be in its non-preferred structure. Online probes were placed immediately at the offset of the pronoun signaling a direct object in the transitive sentence, or immediately after the preposition signaling an intransitive use of the verb. It was found that these fluent aphasic speakers showed no differences in reaction times to the secondary task when verbs were presented in non- preferred sentences. Russo et al. (1998) found that these patterns persisted regardless of the severity of aphasia. The absence of transitivity bias in fluent aphasic speakers was attributed to either deficient retrieval or application of verb biases during processing or a combination of both.

Gahl (2002) investigated sensitivity to transitivity bias in 6 people with nonfluent aphasia, 12 people with fluent aphasia, and 5 healthy controls. Verbs with certain transitivity preferences, as determined by the frequency in which they occurred in specific frames in available corpora (e.g., the British National Corpus) were presented auditorily in active transitive, passive transitive and intransitive sentences. Sentences that matched a verb's preferred sentence structure were described as concordant (matched) and those that did not match the verb's preferred sentence structure were described as discordant (or mismatched). A plausibility judgment task was used to assess comprehension. Implausible sentences were derived from their plausible counterparts by reversing the order of the noun phrases, e.g. "The butter melted the cook." Participants responded to the question of "whether the sentence made sense or not" and accuracy was recorded. Gahl (2002) postulated that if participants were sensitive to the transitivity bias, they would make more errors on the plausibility judgement task after being presented sentences with mismatched conditions. As expected, Gahl (2002) found that controls made relatively few errors, however in the few instances that they did, the errors occurred in mismatched conditions. Like the controls, the group of fluent aphasic participants also exhibited statistically significant errors in mismatched conditions. However, subgroup analyses (6 participants with Anomic aphasia, 6 participants with Wernicke or Conduction aphasia) did not demonstrate a significant effect of sentence match. She also found no significant effect for sentence match in her nonfluent aphasic speakers. Despite the fact that none of the aphasic speakers, when analyzed by subgroup, demonstrated a significant effect of sentence match (concordant vs. discordant) (an observation shared by DeDe [2013]), Gahl (2002) suggested that her findings contradicted those of Russo et al. (1998) perhaps because the omnibus analysis for the fluent speakers was significant for the effects of sentence match. Overall, Gahl (2002) concluded that, while further inquiry is needed, PWA may in fact exhibit verb transitivity bias. Because PWA have been shown to be sensitive to other frequency effects like improved retrieval of more commonly occurring words, Gahl (2002) maintains that PWA may still exhibit this sensitivity to other lexical characteristics like the transitivity preferences of verbs.

Dede (2013) investigated transitivity bias utilizing an online measure of self-paced reading in 10 PWA (1 Conduction, 2 Broca, 4 Anomic, 2 mixed, 1 borderline Anomic) and 10 healthy control participants. Dede's rationale and predictions for the investigation were similar to prior studies (e.g., Russo et al., 1998, Gahl, 2002), i.e., whether PWA are sensitive to transitivity bias effects in transitive or intransitive sentences. To test for this, participants read transitive and intransitive sentences with verbs of varying transitivity preferences, which were obtained from previous studies. Each sentence was broken down into 5 segments that were revealed incrementally whenever the participant indicated he or she was ready to read the next segment. Reading times were recorded after the first argument (segment 1), for the segment containing the verb (segment 2), for the segment containing the prepositional phrase following the verb (segment 3), for the segment containing the NP or PP (segment 4), and for the remaining sentence (segment 5). After the participant read all segments, he or she was presented with a yes/ no comprehension question. Overall, reading times were longer for PWA across most conditions and segments. At segment 2, PWA, but not controls, read more slowly when there was a mismatch. At the third segment, both PWA and controls read more slowly when presented intransitive sentences with transitively biased verbs. This pattern, however was not observed in transitive sentences with intransitively biased verbs. Otherwise, no effects of verb mismatch were found in either the fourth or fifth segments. Dede (2013) interpreted the slowing down of reading times in PWA at segments 2 and 3 as evidence for the presence of transitivity bias. At early segments like 2 and 3, participants are unaware of whether the sentence will take an intransitive or transitive structure. Russo et al. (1998), in contrast, presented a secondary task immediately after a clue following the verb that tips off the participant as to whether the preceding part of the sentence will be transitive or intransitive.

Production Studies.

More recent investigations have focused on studying sensitivity to verb preferences in spontaneous speech. This approach gives researchers insight into whether and how verb preferences might operate in less restricted, more naturalistic conditions. Such studies provide additional evidence regarding the presence or absence of verb transitivity bias following aphasia.

Malyutina, Richardson, and den Ouden (2016) investigated the influence of verb complexity in discourse samples obtained from *AphasiaBank*, a shared database of multimedia interactions for the study of communication in aphasia. Participants were 137 controls, 135 fluent PWA (20 Wernicke, 41 Conduction, 74 Anomic) and 53 nonfluent PWA (Broca) PWA. The discourse genre selected for this study was the Cinderella narrative, in which the participant was asked to tell the story of Cinderella. Verbs from these discourse samples were scored based on their complexity, i.e., the number of subcategorization options they support. Verbs that can be only be used intransitively (i.e., one subcategorization option) were assigned 1 point, those that can be used intransitively and transitively were assigned 2 points, and those that can also select for a prepositional phrase were assigned 3 points, etc. Once a list of verbs was compiled, along with the sentence structures in which they appeared, coders analyzed the sentences for errors argument number and argument type among other measures. Malyutina et al. found that the controls and PWA, except for those with Broca aphasia, produced more verbs with a preference for intransitivity. Intransitive verbs are considered to be less complex because they support less arguments. Participants with Broca aphasia, however produced as many transitive verbs as they did intransitive, similar to the findings of Shapiro and Levine (1990). Investigators also noted that nonfluent PWA and especially fluent PWA used verbs with more subcategorization options, which conflicts with the notion that these participants would use verbs that require less processing. Malyutina et al. (2016) suggested that verbs with higher subcategorization options may facilitate activation of arguments. Investigators also found relatively equal error rates across verbs with varying subcategorization options providing further evidence that verbs with more subcategorization options do not increase cognitive processing load. Overall, PWA, however made more errors than controls. There were no statistically significant error differences amongst the fluent and nonfluent PWA. Given that PWA produce a variety of complex verbs with varying subcategorization options yet relied overall on more simple VAS structures, Malyutina et al. (2016) postulated that PWA do access more complex verbs and their lexical information, but do not apply that information correctly. These conclusions support the notion that PWA may be sensitive to verb preferences.

DiLallo, Mettler, and DeDe (2017) investigated the presence of transitivity bias in the Cinderella discourse samples of 114 fluent PWA (73 Anomic, 26 Conduction, 15 Wernicke), 122 nonfluent PWA (73 Broca, 14 Global, 7 Transcortical Motor), 28 PWA of unknown type, and 41 control participants. The study examined the usage of 22 frequently occurring verbs with varying biases. Investigators found that PWA and control participants predominantly produced sentences with matched conditions, i.e. transitively biased verbs in transitive sentences. DiLallo et al. (2017) also compared error rates across conditions in the discourse of PWA. Errors analyzed included omission or substitution of incorrect morphemes (morphological), phonemes (phonological), and content and function words. The authors noted that approximately 68.8% of errors were made in mismatched conditions, while 17.5% were made in matched conditions. The participants with aphasia exhibited more errors in the production of intransitive verbs in both matched and mismatched conditions. This conflicted with Dede's (2013) findings of longer reading times in PWA when processing transitively biased verbs in intransitive sentences, but not in intransitively biased words in transitive sentences. DiLallo et al. (2017) also compared error rates across conditions in participants with Broca and Wernicke type aphasias. The two groups exhibited similar rates of errors in matched and mismatched conditions. Given these results, the investigators concluded that there is evidence for the presence of transitivity bias in all PWA.

Pause Duration as an Online Measure of Language Processing

In the preceding studies, two online measures, the CMLD task and the self-paced reading task, were applied to index language processing during discourse. Another online measure that has been used to assess sentence processing in neurologically-compromised speakers is pause time (e.g., Ellis & Peach, 2009; Peach, 2013; Peach & Coelho, 2016). Pauses are silent intervals of time that occur during speech production. There are different types of pauses that serve various purposes (Goldman- Eisler, 1972; Zellner, 1994). Short pauses are brief and take place due to physiological constraints like the need to take a breath or swallow during discourse. Long pauses tend to last approximately 250 ms, however this value is relative to type of production task (e.g., spontaneous speech vs. oral reading) and other variables (Angelopoulou et al., 2018). These long pauses can be intentional or unintentional. Intentional pauses allow the speaker to communicate meaning like emphasis. Unintentional long pauses have cognitive origins and act as an online measure of cognitive processing load (Zellner, 1994; Ellis & Peach, 2009; Peach, 2013; Peach & Coelho, 2016; Angelopoulou et al., 2018).

Language-related operations like lexical retrieval and application of lexical information require cognitive resources, which are allocated accordingly. Therefore, as the demands required for increasing complex mental operations rise, more time is required to allocate limited resources to these processing tasks. This principle underlies the methods from Shapiro and Levine (1990), Shapiro et al. (1993), Russo et al. (1998), and Dede (2013), where longer response times to secondary tasks and longer reading times were associated with increased cognitive load.

Early studies of pause duration in the narratives of PWA have shown a higher number of pauses, as well as longer durations of these pauses (Deloche, Jean-Louis, and Seron, 1979). Butterworth (1979) found that the occurrence of longer pauses preceded the production of neologisms in PWA. This is in line with findings of higher error rates in mismatched conditions (DiLallo et al., 2017). Recent investigations have analyzed pause durations occurring in discourse samples of PWA to study the distribution of pause values (Hird & Kirsner, 2010; Angelopoulou et al., 2018). After measuring all pause durations, investigators found the same bimodal distribution of pauses across PWA and controls. Angelopoulou et al. (2018) noted that controls, as well as PWA, exhibited more long pauses than short pauses overall. Both controls and PWA also showed more short pauses before the production of NP's and long pauses before verb production. Differences, however arose between the two groups. The durations of short and long pauses exhibited by PWA were longer than that of the controls. Unlike the controls that primarily exhibited short pauses between words and long pauses in between sentences, PWA exhibited both short and long pauses in between words. These findings suggest that overall, PWA experience a higher cognitive load than healthy speakers during speech production. Furthermore, these findings suggest that pause duration provides an appropriate online measure to index cognitive load between verbs and arguments in the discourse of healthy controls and PWA.

Summary and Experimental Questions

Using a variety of online and offline measures, the literature examining verb preferences, i.e., transitivity bias, during sentence processing and production in PWA has yielded conflicting results. Shapiro and Levine (1990) reported that people with nonfluent aphasia are sensitive to the VAS characteristics of verbs while people with fluent aphasia are not. A later investigation by Shapiro et al. (1993) showed that healthy participants exhibit preferences for certain arguments that appear in transitive or intransitive sentences. Conversely, an investigation by Russo et al. (1998) found evidence to suggest that people with fluent aphasia were insensitive to verb preferences. A report by Gahl (2002) suggested the opposite pattern from that reported previously, i.e., that people with fluent aphasia show transitivity bias but people with nonfluent aphasia do not. On the other hand, Dede (2013) and DiLallo et al. (2017) found that both fluent and nonfluent PWA exhibit verb transitivity bias.

The purpose of this study is to further investigate verb transitivity bias in speakers with aphasia. This study provides a unique approach to this area of investigation by using an online processing measure, namely pause time analysis, to assess sensitivity to transitivity bias during the spontaneous discourse of healthy controls and PWA. The study proposed that pause times would provide an index of speakers' sensitivity to transitivity bias during sentence production in discourse. Based on the findings of Angelopoulou et al. (2018), we expected that pause times would increase prior to the production of verbs in sentences that do not match their transitivity bias. However, inasmuch as this approach has not been used before, and given the literature regarding slow activation of lexical information in aphasia (Love, Swinney, Walenski, & Zurif, 2008), pause times immediately after the production of verbs was also examined. If it was found that PWA did exhibit longer pause durations before or after verb production in mismatched sentences, we assumed that speakers with aphasia are sensitive to transitivity biases (Dede, 2013; DiLallo et al., 2017). Alternatively, if pause times before or after the production of verbs in mismatched sentences did not vary, we would assume that PWA are not sensitive to verb transitivity biases.

The experimental questions addressed in this study are as follows:

1. Do pause times associated with production of transitive and verbs in spontaneous discourse vary similarly in healthy controls and speakers with aphasia?

2. Do healthy control speakers and speakers with aphasia exhibit the same transitivity biases for transitive and intransitive verbs in spontaneous discourse?

3. Do the pause times associated with verbs produced by healthy control speakers and speakers with aphasia vary similarly in spontaneously produced sentences when the sentence form either matches or does not match the transitivity biases of these verbs?

CHAPTER TWO

METHOD

Data Source

Data for this study came from corpora and audio recordings downloaded from AphasiaBank (https://aphasia.talkbank.org; MacWhinney, Fromm, Forbes, & Holland, 2011). AphasiaBank is a shared database of multimedia interactions for the study of communication in PWA. The discourse sample of interest for this study was the narrative telling of Cinderella story, a routine task for the analysis of language production in people with aphasia.

These discourse samples were organized according to the institution where they were collected. The data were derived from multiple files contained in the *Boston University, Kansas Medical Center, Whiteside, ACWT, and SCALE* collections. These files were selected due to the relative diversity of fluent and nonfluent participants fitting the selection criteria for this study. The samples were obtained from the first 10 fluent and 10 nonfluent participants that met criteria. Discourse samples from 10 healthy control participants were downloaded from the *Wright* collection. This collection was selected due to the relatively large number of participants.

Each file included a video, audio file, and transcript. Transcripts consisted of utterances and Codes for the Human Analysis of Transcripts (CHAT) for use with the Computerized Language Analysis (CLAN) program. Transcripts also included each participant's age and sex and, for the participants with aphasia, their Aphasia Quotient (AQ; Kertesz, 2006) and type of aphasia.

Participants were right-handed, monolingual English speakers aged 50-80 years old with at least 12 years of education and no history of neurodegenerative or psychiatric conditions. Participants with aphasia were at least 6 months removed from the cerebrovascular (CVA) accident that had caused the aphasia. They had an Aphasia Quotient (AQ) between 40 and 93.8 on the *Western Aphasia Battery- Revised* (WAB-R; Kertesz, 2006) and a language profile consistent with a fluent (Anomic, Wernicke, Transcortical Sensory, Conduction; Kertesz, 2006) or nonfluent aphasia (Broca, Transcortical Motor, Global; Kertesz, 2006). Participant information was accessed from the AphasiaBank demographic database (see Tables 1, 2, and 3).

Participant ages ranged from 51.0- 78.5 years, with an average age of 65.87 years, SD of 8.90 years, and median of 65.3 years. Education ranged from 12 to 21 years with an average of 15.88 years, SD of 2.53 years, and a median of 15 years. It should be noted that years of education was unknown for one nonfluent participant (NF_4). Aphasia duration ranged from 0.70 years- 25.75 years with an average of 6.75 years, SD of 5.93 years, and median of 4.23 years. The WAB AQ ranged from 51.5 to 91.5, with an average of 68.38, SD of 12.03, and median of 65.8.

Table 1. Characteristics of healthy control participants.

Participant	Age	Gender	Race	Years of Education
HC_1	66.1	F	WH	13
HC _2	57.5	M	WH	14
HC _3	76.5	M	WH	14
HC _4	60.6	F	WH	13
HC _5	70.0	M	WH	15
HC _6	69.9	M	WH	14
HC _7	51.0	M	AA	16
HC _8	64.1	M	WH	20
HC _9	77.0	F	WH	13
HC _10	73.0	M	WH	13

Table 2. Characteristics of participants with fluent aphasia.

Participant	Age	Gender	Race	Years of Education	Aphasia Duration	WAB AQ	WAB Type
FL_1	62.5	M	WH	16	7.40	85.7	Anomic
FL_2	58.7	M	WH	16	1.50	77.9	Conduction
FL_3	52.4	M	WH	16	2.25	90.6	Anomic
FL_4	78.5	M	WH	20	5.80	65.3	Conduction
FL_5	75.8	M	WH	18	4.25	65.1	Wernicke
FL_6	77.0	M	WH	12	1.60	61.4	Conduction
FL_7	77.4	F	WH	17	0.70	67.4	Wernicke
FL_8	69.5	M	WH	16	10.25	91.5	Anomic
FL_9	60.9	M	WH	21	12.00	77.2	Conduction
FL_10	75.6	F	WH	12	0.80	54.7	Wernicke

Table 3. Characteristics of participants with nonfluent aphasia.

Participant	Age	Gender	Race	Years of Education	Aphasia Duration	WAB AQ	WAB Type
NF_1	52.4	M	WH	16	4.20	51.5	Broca
NF_2	69.9	F	WH	18	11.80	63.9	Broca
NF_3	53.1	F	WH	14	3.30	74.6	Trans. Motor[a]
NF_4	64.5	M	AA	Unknown	1.8	51.5	Broca
NF_5	55.2	M	AA	15	3.2	66.3	Broca
NF_6	63.7	M	AA	13	5.70	73.2	Trans. Motor
NF_7	54.9	M	WH	14	9.10	72.2	Broca
NF_8	63.9	F	HL	18	8.90	61.5	Broca
NF_9	66.3	F	WH	12	1.20	63.5	Trans. Motor
NF_10	78.3	M	WH	18	25.75	52.5	Broca

[a] Trans. Motor = Transcortical Motor

Procedures

Pause Time Measures.

The Codes for the Human Analysis of Transcripts (CHAT) were entered into the Computerized Language Analysis (CLAN) program (MacWhinney, 2000) to identify the verbs in the discourse samples as well as their frequencies. A list of verbs occurring in the transcripts of at least 3 of the 10 participants in each group (fluent, nonfluent, control) was compiled. This level was chosen after iteratively reducing the required number of productions for each verb that yielded the highest number of common verbs overall. Using this criterion, the 6 most frequently-occurring, common verbs observed across all groups were identified (*come, make, tell, say, take, put*). In addition to these first 6 verbs, the experimenter selected 4 additional, frequently-occurring verbs that were unique to each group for the analysis of differences in pause times across transitively and intransitively biased verbs. Thus, a total of 10 verbs (6 common, 4 unique) were analyzed for each group.

An audio file and transcript were then downloaded for each participant. The audio file was converted into an MP3 file. Files were trimmed to include only the participant's retelling of the Cinderella story using the Audacity program. The experimenter then listened to each recording and identified the verbs of interest in the audio file. The cursor was placed along the waveform immediately at the end of the production of the last argument preceding the verb. This was determined to be the beginning of the pre-verb pause. The cursor was then placed immediately at the onset of the verb. This was annotated as the end of the pre-verb pause. The difference between these two values was the duration of the pre-verb pause in milliseconds.

To measure the duration of the post-verb pause, the cursor was placed along the waveform at the offset of the verb. The cursor was then placed along the waveform immediately at the onset of the first word in the second argument. The difference between these two values was the duration of the post-verb pause in milliseconds. Filled pauses like *um* or *hmm,* were included in the analyses. The quality of the recordings varied due to suspected differences in the distances between participants and microphones, as well as the occasional presence of background noise. In such cases, the experimenter used acoustic characteristics to determine the onset of a word. For instance, to determine the boundary between the pause and onset of the first sound of a word in a noisy environment, the experimenter determined the time of the burst of a voiced sound, onset of aspiration of an aspirated sound, etc. Because the quality of the recordings varied, the investigator was unable to make precise measurements under approximately 100 ms for many participants. Abandoned phrases such as "he went to" were omitted from the analysis. Pauses in utterances where a patient produced a semantic or phonemic error, after which a participant had repeated him or herself- such as "she /mæb/ made herself a coffee"- were measured between subject and first attempt at production of verb. If the error took place immediately following the verb, the pause time was measured between the verb and first attempt at production of the argument.

It should be noted that for the 6 common verbs, the healthy control participants exhibited measurable pre-verb pauses for 14/79 verb occurrences, the participants with fluent aphasia exhibited measurable pre-verb pauses for 17/47 verb occurrences, and the participants with nonfluent aphasia exhibited pauses for 19/26 verb occurrences. In the post-verb position, the healthy controls exhibited measurable pauses for only 4/79 occurrences, the participants with fluent aphasia exhibited pauses for 6/47 occurrences, and the participants with nonfluent aphasia exhibited pauses for 12/26 occurrences. Furthermore, pauses were not observed for every condition in each group (pre-verb transitive match, pre-verb transitive mismatch, pre-verb intransitive match, pre-verb intransitive mismatch, post-verb transitive match, post-verb transitive mismatch, post-verb intransitive match, and post-verb intransitive mismatch).

Assessment of Sensitivity to Verb Transitivity Bias.

Transitivity bias for the 6 verbs was determined using sentence patterns obtained from the healthy control participants. If the controls produced a verb in a given sentence frame (transitive, intransitive) 60% of the time or more, that frame would be assigned as the bias for that verb. In this way, the transitivity bias was established for all 6 common verbs.

For each verb, the coder identified all instances of its occurrence in the transcripts and analyzed the sentence structure in which the verb appeared. The sentence structure was defined as transitive if a direct object followed the verb, or intransitive if no direct object or an adverbial phrase appeared after the production of the verb (Quirk, Greenbaum, Leech, & Svartvick, 1985). The sentence patterns used by the PWA for the 6 common verbs were then compared to the usage patterns obtained from the healthy normal controls to determine whether the two matched. For instance, if both the PWA and the healthy controls used a verb in a transitive frame, the PWA production was scored as a *match* and the pattern was interpreted as evidence that the PWA were sensitive to the transitivity bias of the verb for that sentence. If, however the sentence frame produced by the PWA did not match the use of the healthy controls, the PWA production was scored as a *mismatch* and the pattern was interpreted as evidence that the PWA were not sensitive to the transitivity bias of the verb for that sentence. Match/mismatch performance could not be determined for the 4 unique verbs in each group because of the inability to compare these verbs across groups.

Analyses

Descriptive statistics were calculated for the study participants. To analyze the differences across groups in pre- and post-verb pause times for transitive and intransitive verbs, a mixed analysis of variance was computed with one between subjects factor (participant group), and two within-subjects factors (pre-verb vs. post-verb pause times, transitive vs. intransitive verbs). Visual analyses were conducted to determine whether any differences occurred across groups for the transitivity biases of each verb and for the pause times related to verb production in matched and mismatched transitivity conditions. Mean pause times were calculated for each participant according to pre-verb vs. post-verb pause time, transitive vs intransitive verb bias, and matched vs mismatched conditions.

Reliability

Inter-rater reliability was calculated by randomly selecting 2 common verbs produced by all 3 groups and submitting the transcripts and audio files in which they appeared to an independent judge for re-analysis of pause times. These were compared to the measurements completed by the primary rater. The guidelines for analysis of the transitivity of the sentence in which the verb appears, as well as pause duration measurement were reviewed with the independent judge prior to the re- analysis. The independent judge was an advanced graduate student enrolled in the speech- language pathology program at Rush University.

Both judges identified exactly 216 pauses in these transcripts. Of these, the primary judge identified 11% as measurable while the independent judge identified 10% to be measurable. Cronbach's alpha was .998 for the pre-verb pause times and .995 for the post-verb pause times. These results demonstrate excellent reliability in the identification and measurement of the pause times analyzed in this study.

CHAPTER THREE

RESULTS

Pause Time Patterns by Verb Bias

To address the first experimental question, i.e., whether pause times associated with the production of transitive and intransitive verbs vary systematically in healthy controls and speakers with aphasia, means and standard deviations (SD) were calculated for the pause times in each condition. Twenty-five of the 30 participants contributed data to this analysis. The remaining 5 participants (HC_1, HC_9, FL_3, NF_9, NF_10) did not produce any measurable pauses during production of any of their 10 verbs.

Times exceeding ±2 SD from the mean of each group were discarded to achieve equality of variances ($F = 1.358$, $p = .241$). Mean pre-verb pause times for both verb types were approximately equal for the control speakers while the mean pre-verb pause times for transitive verbs were approximately double that observed for intransitive verbs in both groups of aphasic speakers (Table 4). Post-verb pause times varied widely between the two aphasia groups (no control speaker produced an intransitive sentence with an optional post-verb phrase; therefore, post-verb pause times for these speakers could not be determined). Three-way analysis of variance (group, verb type, sentence position) resulted in a significant 3 way interaction ($F = 4.56$, $p = .04$). Post hoc tests of simple effects revealed the source of the interaction to be the post verbal pause times for transitive verbs produced by the nonfluent aphasic speakers.

The findings from this analysis suggest that activation and application of verb characteristics such as transitivity preference occurs in the pre-verb position. The relatively similar pause times between transitive and intransitive utterances exhibited by healthy control participants show that transitivity does not pose additional cognitive load on these speakers. The differences in pause times exhibited by PWA prior to the production of transitive and intransitive sentences shows varying cognitive load in relation to transitivity.

Table 4. Group mean pause times (with standard deviations) for verb types in pre-verb and post-verb sentence locations.

Group	Transitive		Intransitive	
	Pre-Verb	Post-Verb	Pre-Verb	Post-Verb
Control	606.0 (203.0)	825.3 (460.1)	684.0 (698.0)	-
Fluent	647.7 (331.6)	457.3 (394.3)	306.3 (207.2)	523.5 (434.1)
Nonfluent	853.2 (394.3)	1399.0 (710.9)*	451.8 (237.4)	91.0 (75.0)

*p = .002

Sensitivity to Transitivity Bias

To address the second experimental question, i.e., whether healthy control speakers and speakers with aphasia exhibit similar biases for transitive and intransitive verbs in spontaneous discourse, the total number of transitive and intransitive sentences in which each verb appeared were calculated across groups. These data were used to determine the percentage of transitive or intransitive uses for each verb in each group. All of the control participants, 9 of the 10 fluent PWA (FL_1-2, 4-10), and 5 of the 10 nonfluent PWA (NF_1-4, 7) contributed to these data.

The HC participants displayed biases for 5 of the 6 common verbs, i.e., a particular verb appeared in the same sentence frame in a majority (at least 60%) of the total occurrences (Table 5). It was found that the HC participants produced the verbs *come* and *say* in predominantly intransitive frames and the verbs *tell* and *put* in primarily transitive frames. The verb *make* was produced 50% of the time in transitive sentence frames and 50% of the time in intransitive sentence frames. Thus, no bias was assigned to the verb *make.*

Similarly, fluent PWA as a group produced *come* in intransitive frames 94% of the time (Table 6). They produced the verbs *make, tell,* and *take* exclusively in transitive sentence frames and the verb *put* 75% of the time in transitive sentence frames. The verb *say* was produced in transitive sentence frames 56% of the time and in intransitive frames 44% of the time. Thus, it was determined that the fluent PWA did not exhibit a particular bias for the verb *say*.

The nonfluent PWA produced *come* and *say* in intransitive frames, while *tell* and *take* were used transitively (Table 7). The uses of the verb *make* appeared equally in transitively and intransitive utterances of nonfluent aphasic speakers. Thus, the nonfluent PWA did not exhibit any particular bias for *make.*

Overall, the 3 groups demonstrated a transitive bias for the verbs *tell* and *put* and an intransitive bias for the verb *come.* Healthy controls and fluent PWA demonstrated a transitive bias for *take;* healthy controls and nonfluent PWA demonstrated an intransitive bias for *say.* Fluent and nonfluent PWA exhibited an intransitive bias for the verb *make.* No participant with aphasia demonstrated a transitivity bias that differed from that of the healthy controls or, in the case of the verb *make,* from the other group of PWA. This suggests that PWA are typically sensitive to the transitivity preferences of verbs, but, in some cases may behave differently for some verbs or are unable to apply the bias within a timely and accurate manner.

Table 5. Verb biases exhibited by healthy control participants.

Verb	Intransitive Uses	Transitive Uses	Total Uses	Percent Intransitive	Percent Transitive	Bias
come	4	1	5	80	20	Intransitive
make	1	1	2	50	50	Undetermined
tell	1	4	5	20	80	Transitive
say	4	2	6	67	33	Intransitive
take	1	3	4	25	75	Transitive
put	0	4	4	0	100	Transitive

Table 6. Verb biases exhibited by participants with fluent aphasia.

Verb	Intransitive Uses	Transitive Uses	Total Uses	Percent Intransitive	Percent Transitive	Bias
come	16	1	17	94	6	Intransitive
make	0	6	6	0	100	Transitive
tell	0	4	4	0	100	Transitive
say	4	5	9	44	56	Undetermined
take	0	7	7	0	100	Transitive
put	1	3	4	25	75	Transitive

Table 7. Verb biases exhibited by participants with nonfluent aphasia.

Verb	Intransitive Uses	Transitive Uses	Total Uses	Percent Intransitive	Percent Transitive	Bias
come	11	2	13	85	15	Intransitive
make	3	9	12	25	75	Transitive
tell	1	4	5	20	80	Transitive
say	20	13	33	61	39	Intransitive
take	5	5	10	50	50	Undetermined
put	2	4	6	33	67	Transitive

Pause Time Patterns by Sensitivity to Verb Transitivity Bias

To address the third experimental question, i.e. whether pause times associated with verbs produced by healthy control speakers and speakers with aphasia vary systematically when the sentence form either matches or does not match the transitivity biases of these verbs, the mean pre-verb and post-verb pause times were calculated for the 6 common verbs for each participant. Because the healthy control participants did not exhibit a bias for the verb *take*, this verb was discarded from the analysis. The pause times were measured for the 5 remaining common verbs (*come, make, tell, say, put*). Seventeen of the 30 participants (HC_2-7, 10; FL_2, 5-6, 8-9; NF_1-4, 7) contributed data to this analysis. The 13 participants who did not contribute (HC_1, 8-10; FL_3-4, 7, 10; NF_5-6, 8-10) either did not produce any of the 5 common verbs and/ or did not exhibit any pauses pre- or post-verb production of the verb. It should be noted that, for the 5 common verbs, the healthy control participants exhibited measurable pre-verb pauses for 11/69 verb occurrences, the participants with fluent aphasia exhibited pre-verb pause times for 11/40 verb occurrences, and the participants with nonfluent aphasia exhibited pauses for 15/22 verb occurrences. In the post-verb position, the healthy controls exhibited measurable pauses for only 2/69 occurrences, the participants exhibited pauses for 6/40 occurrences, and the participants with nonfluent aphasia exhibited pauses for 9/22 occurrences. Furthermore, pauses were not observed in every condition in each group (pre-verb transitive match, pre-verb transitive mismatch, pre-verb intransitive match, pre-verb intransitive mismatch, post-verb transitive match, post-verb transitive mismatch, post-verb intransitive match, and post-verb intransitive mismatch). The average pause times for each participant, therefore, were calculated only for the conditions for which data were available.

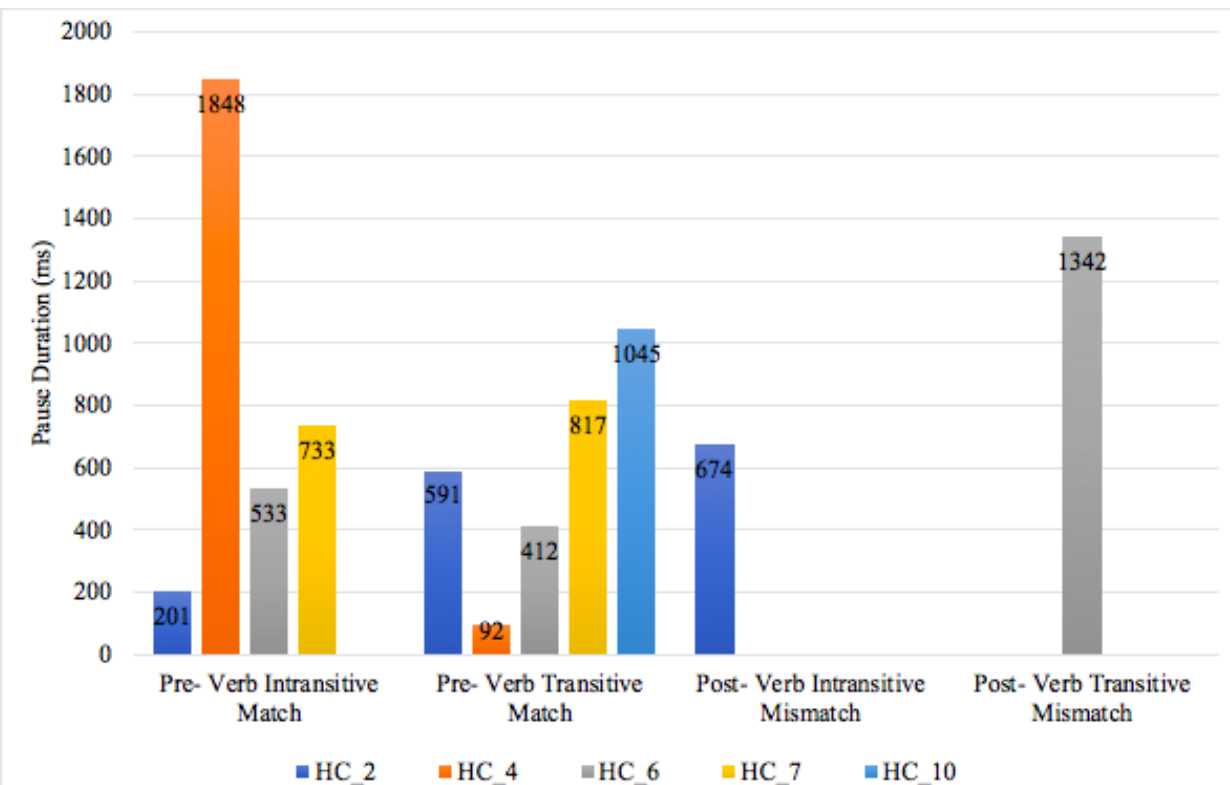
Healthy control participants.

Pauses in the pre-verb position accounted for approximately 82% of the total pauses exhibited by the healthy control participants. These pauses were split nearly evenly between productions of transitively and intransitively biased verbs in matched conditions. The ranges for the pause times in the matched condition varied widely across transitive and intransitive verbs (Figure 2). The mean pause time in matched conditions for intransitive verbs was 829 ms (SD=714 ms). The mean pause time in matched conditions for transitive verbs was 591 ms (SD=423 ms). There were three outlying values that were greater than 2 SD above the mean (1848 ms pause in the pre-verb intransitive match condition, 92 ms in the pre-verb transitive mismatch condition, and 1045 ms in pre-verb mismatched condition). When these values were discarded, the average for the pre-verb intransitive match condition was 633 ms and the average for the pre-verb transitive match was 607 ms. Mean pause times were computed based on multiple data points (pre-verb intransitive match condition for HC_2) and remaining pause times (pre-verb intransitive match for HC_4, HC_6, HC_7; pre-verb transitive match for HC_2, HC_4, HC_6, HC_7, HC_10; post-verb intransitive mismatch for HC_10; post- verb transitive mismatch for HC_6) were single observations (Figure 2).

Overall, healthy control participants produced few sentences with mismatched conditions (approximately 30% of total verb uses were in mismatched conditions). There were only 2 measurable pauses in mismatched conditions. These 2 pauses appeared in the post-verb position, with a pause of 674 ms occurring after an intransitive verb and a pause time of 1342 ms occurring after a transitive verb.

None of the healthy control participants produced comparable conditions (i.e. pause times in pre-verb position for transitive verbs in matched and mismatched conditions), that would allow for exploration of the third experimental question in relation to this group.

Figure 2. Pause times in healthy control participants.



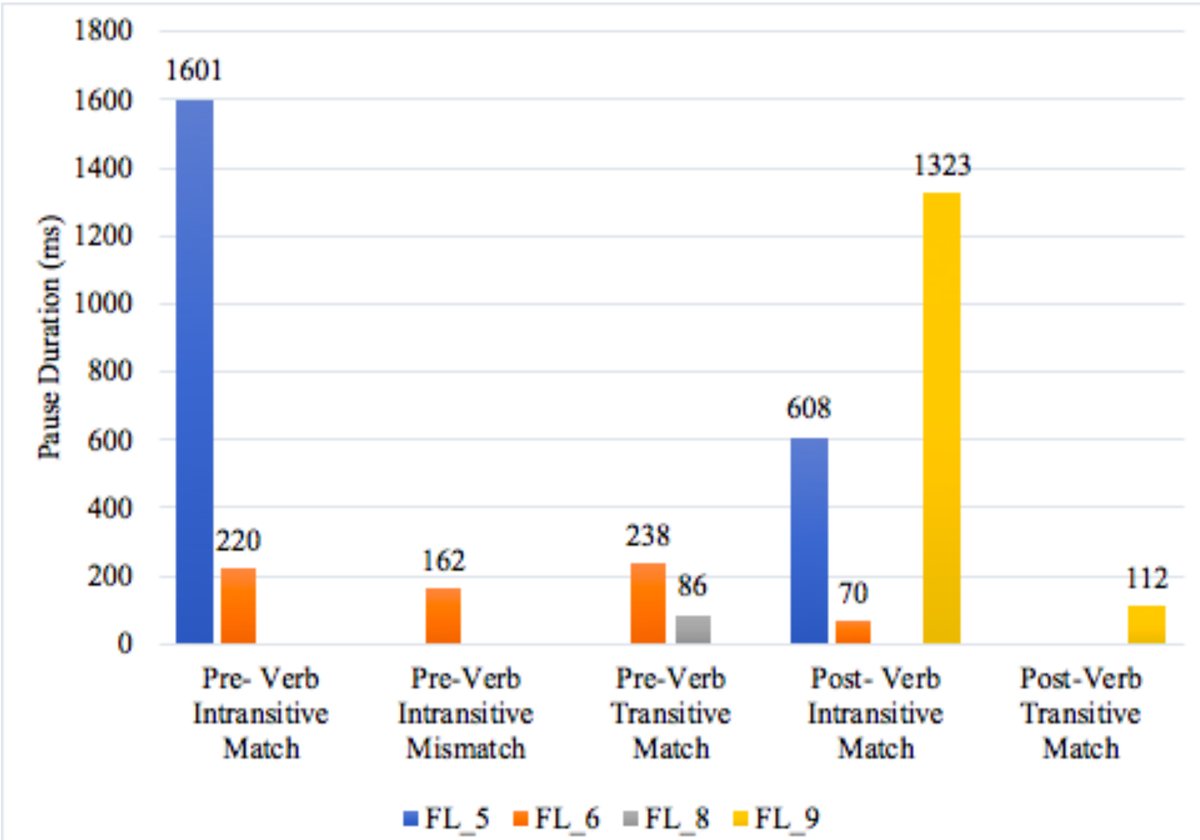
Participants with fluent aphasia.

For the fluent PWA, pauses in the pre-verb position accounted for approximately 64% of their total pauses. These pauses were split nearly evenly between productions of transitively and intransitively biased verbs in matched conditions. The range for average pause times in the matched condition across intransitive verbs was 220-1601 ms and the range for average pause times in the matched transitive verb condition was 86-238 ms (Figure 3). The mean pause time for matched conditions for intransitive verbs was 910.5 ms and the average pause time for matched conditions for transitive verbs was approximately 162 ms. There was only one use of an intransitive verb in mismatched conditions in the pre-verb position (162 ms).

Of all pauses, approximately 36% occurred in the post-verb position. All 4 post-verb pauses occurred in matched conditions. 3 of the 4 post-verb pauses took place after the production of intransitive verbs. The range of these pauses varied from 70-1323 ms, yielding an average pause duration of 667 ms and SD of 628 ms. There was one instance of a pause of 112 ms after the production of a transitively biased verb in matched conditions. Mean pause times were computed based on multiple data points (pre-verb intransitive match condition, pre-verb transitive match condition, and post-verb intransitive match condition for FL_6) and remaining were single observations.

Of the four fluent participants, one participant (FL_6) exhibited comparable conditions that allowed for the exploration of the third experimental question. This participant exhibited a 220 ms pause prior to the production of an intransitively biased verb in matched conditions, while the pause in mismatched conditions was 162 ms. The fluent participant (FL_6) produced longer pauses in matched conditions.

Figure 3. Pause times in fluent PWA.



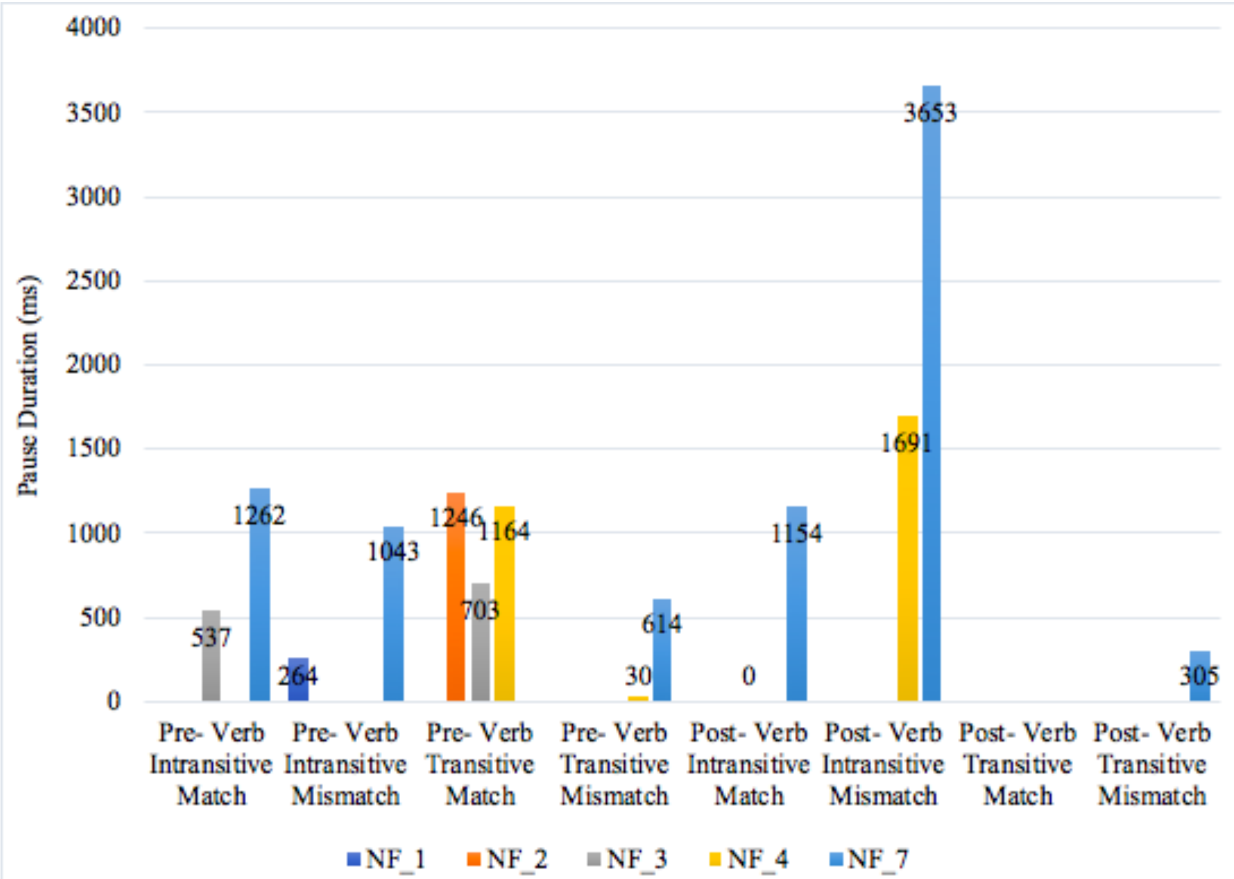
Participants with nonfluent aphasia.

The nonfluent PWA exhibited pauses in the pre-verb position for over 69% of the total pauses. The pre-verb pauses occurred nearly evenly across transitive and intransitive verbs. The ranges for these pause times in the matched condition across transitive and intransitive verbs varied widely (Figure 4). The mean pause time for matched conditions for intransitive verbs was 829 ms. The mean pause time for matched conditions for transitive verbs was 1037 ms (SD = 293 ms). For the transitive mismatched conditions, the range of average pause durations for two participants was 264-1043 ms, while for intransitive mismatched conditions it was 30-614 ms. The nonfluent PWA were the only group to exhibit pauses before the production of transitively biased verbs in mismatched conditions.

There were 3 pauses that occurred in the post-verb position. In the intransitive match condition, one participant produced a pause of 1154 ms. Another pause was produced at 1691 ms in the intransitive mismatch condition. Another participant produced a pause of 305 ms in the post-verb transitive mismatch condition. Mean pause times were computed based on multiple data points (pre-verb transitive match condition for NF_4, pre-verb intransitive match condition and post-verb intransitive match condition for NF_1) and remaining were single observations.

Of the five fluent participants, two participants (NF_1, NF_4) exhibited comparable conditions that allowed for the exploration of the third experimental question. Participant NF_1 exhibited a 1262 ms pause prior to the production of an intransitively biased verb in matched conditions, while the pause in mismatched conditions was 1043 ms. Participant NF_4 exhibited an 1164 ms pause in matched conditions for transitively biased verbs, while the pause in mismatched conditions was 30 ms. Like the fluent participant (FL_6), both of the participants with nonfluent aphasia (NF_1, NF_4) produced longer pauses in matched conditions.

Figure 4. Pause times in nonfluent PWA.



CHAPTER FOUR

DISCUSSION

This investigation examined the sensitivity to transitivity biases in fluent and nonfluent PWA through the analysis of pause times before and after the production of verbs. The experimental questions addressed in this study were as follows:

1. Do pause times associated with production of transitive and verbs in spontaneous discourse vary systematically in healthy controls and speakers with aphasia?
2. Do healthy control speakers and speakers with aphasia exhibit the same transitivity biases for transitive and intransitive verbs in spontaneous discourse?
3. Do the pause times associated with verbs produced by healthy control speakers and speakers with aphasia vary systematically in spontaneously produced sentences when the sentence form either matches or does not match the transitivity biases of these verbs?

We proposed that pause times would provide an index of speakers' sensitivity to transitivity bias during sentence production in discourse. If it was found that PWA did exhibit longer pause durations before or after verb production in mismatched sentences, we assumed that speakers with aphasia are sensitive to transitivity biases. Alternatively, if pause times before or after the production of verbs in mismatched sentences did not vary, we would assume that PWA are not sensitive to verb transitivity biases.

Following our first analysis, it was found that mean pre-verb pause times for transitive and intransitive verbs produced by the healthy control speakers were approximately equal but that those observed for transitive verbs produced by both groups of speakers with aphasic were approximately double of that for intransitive verbs (Table 4). These differences however were not statistically significant, likely owing to the high variability among these values. Nonetheless, there was a clear pattern of increased pause times for transitive versus intransitive verbs in the participants with aphasia. Post-verb pause times also varied widely between the two aphasia groups such that a discernable pattern was not evident. While the nonfluent PWA exhibited a statistically significant difference in pause times for transitive verbs in the post-verb position, no pattern was discernible regarding post-verb pause times across verbs.

These findings suggest that persons with fluent and nonfluent aphasia are sensitive to the transitivity biases of verbs and access this information prior to the production of the verb. Inasmuch as transitive verbs have a more complex verb-argument structure, increased pause times would be expected for these verbs when compared to intransitive verbs, which have a simpler argument structure. This was in fact the case. These results suggest therefore that pause times might index the processing requirements for these verbs. Recall that Malyutina et al. (2016) found that their healthy controls and fluent PWA showed a preference for the production of intransitive verbs. Our findings provide a possible explanation for this observation, at least in speakers with aphasia. Since mean pre-verb pause times for transitive verbs were approximately double that observed for intransitive verbs in the PWA, these verbs may be more complex than intransitive verbs and place more of a cognitive load on the speaker.

Our findings show that both fluent and nonfluent PWA exhibited more difficulty with transitive than intransitive verbs. This is consistent with the findings of DiLallo et al. (2017), who reported that PWA and control participants produced more intransitively biased words. However, Malyutina et al. (2016) noted that this pattern did not hold up for participants with Broca type aphasia, who produced as many transitive verbs as they did intransitive. This is similar to the findings of Shapiro and Levine (1990). While this study did not investigate the frequency of use for transitive and intransitive verbs, it would be expected that speakers with aphasia would produce more intransitive verbs, that is, those that pose less of a cognitive load.

The results also support previous work suggesting that the increased difficulty people with nonfluent aphasia experience with transitive verbs may be related to problems in planning the phrasal structures associated with transitive versus intransitive verbs. Malyutina et al. (2016) postulated that PWA do access more complex verbs and their lexical information fully, but do not apply that information correctly. Our results demonstrated that the post-verb pause times for the nonfluent PWA were significantly higher than those for fluent PWA. It appears that both groups of PWA accessed the lexical information associated with both verb types similarly, but that only the nonfluent PWA had greater difficulty with phrasal production following the verb in transitive structures.

The healthy controls exhibited similar pre-verb pause times across transitive and intransitive verbs. This suggests that access to and application of transitivity bias during discourse production does not increase cognitive processing load for healthy speakers, who are then able to apply lexical information in a timely and accurate way. This is consistent with the findings that PWA exhibit long pauses in between words that healthy control speakers do not (Angelopoulou et al., 2018). Furthermore, the results also demonstrate that pause time is responsive to alterations in verb processing and therefore, offers a potential tool for investigating this aspect of aphasia.

The results from the second analysis revealed that PWA exhibited transitivity biases for most verbs, similarly to controls, but not for the same verbs. Healthy control participants and fluent and nonfluent PWA all exhibited the same biases for *come*, *tell,* and *put.* Healthy control participants did not display a particular bias for either transitive or intransitive use for the verb *take*. Both 3 fluent and 5 nonfluent PWA displayed a bias for transitive use for the verb *take.* For the verb *say,* fluent PWA used the verb transitively in 55% of its 9 uses across 3 speakers, while controls and nonfluent PWA displayed a bias for intransitive use. It should be noted that the nonfluent PWA produced *make* only twice, with one transitive use and another intransitive. Overall, these findings suggest that both fluent and nonfluent PWA do exhibit sensitivity to transitivity biases of verbs, as evidenced by the same biases observed for 4 of 6 verbs across groups. The differences observed in bias (i.e. preference for transitive use of *say* by the fluent PWA) suggest that while PWA activate and apply the transitivity preference in most instances, this activation and application is inconsistent. This may be due to the occasional inability to activate the verb characteristic or activate it in a timely manner. Another possibility is that PWA do activate the bias within a timely manner but then are unable to accurately or timely apply that bias.

Our third analysis investigated pre- and post-verb pause times in sentences that either matched or did not match the transitivity biases of the verbs across all groups. Overall, the healthy control participants and the participants with fluent aphasia did not exhibit many measurable pauses. It is possible that these participants may have produced more pauses, but due to either the fidelity of recordings and difficulties measuring shorter pauses, they were not captured. In the case of the healthy control participants, most measurable pauses occurred in the pre-verb position for both matched and mismatched conditions, which is consistent with the findings of our first analysis. Because the healthy controls produced sentences that primarily matched the transitivity biases of the verbs, there were only 2 instances of mismatched sentences. When the outlying values across matched conditions in the pre- verb position were omitted from the analysis, the average pause durations for intransitive and transitive verbs were similar across matched conditions in the pre-verb position, consistent with findings from the first analysis. None of the healthy control participants produced comparable conditions (i.e. pause times in pre-verb position for transitive verbs in matched and mismatched conditions), that would allow for exploration of the third experimental question in relation to this group.

Similar to the healthy controls, the participants with fluent aphasia exhibited pauses in the pre-verb position with half of productions being of transitively biased verbs and the other half of intransitively biased verbs. Most pauses occurred in matching conditions. The mean pause time for intransitive verbs in matching sentences was much longer than the average pause time for transitive verbs in matching sentences, which is inconsistent with findings from our first analysis.

The nonfluent PWA produced the most pauses in both pre-verb and post- verb conditions. Similar to other groups, nonfluent participants exhibited primarily pauses in the pre-verb position, occurring nearly evenly across transitively and intransitively biased verbs. Pause durations varied widely across all conditions. Two participants (NF_1, NF_4) produced matched and mismatched sentences in the pre-verb position that allowed for comparison to explore the third experimental question. Like the FL_6 participant, both of the nonfluent participants exhibited longer pauses in matched conditions. Based on these observations, all 3 of 3 participants that produced conditions allowing for comparison across matched and mismatched conditions exhibited longer pauses prior to the production of verbs in matched conditions. This supports the idea that the activation and application of the transitivity preference is cognitively taxing for both fluent and nonfluent PWA. The relatively shorter pauses in mismatched sentences observed in the 3 participants suggests that PWA may not be accessing and applying the verb's transitivity preference, as reflected by a lesser cognitive load and errors relating to transitivity.

While previous research has confirmed that PWA do exhibit verb- related impairments, the objective of this study was to pinpoint whether these deficits are related to impaired sensitivity to verb transitivity bias in order to better guide language treatment. Unlike traditional treatment for aphasia (e.g., Peach, 1993, 2001), such an approach exploits a linguistically-focused approach that targets the specific types of language processing impairments that accompany aphasia. The results of this study suggest that both fluent and nonfluent PWA exhibit inconsistent application of the transitivity preference of verbs. This impairment affects how naturally sounding the discourse is to communication partners and most importantly, affects retrieval of complements and overall utterance length.

Thus, when a clinician implements verb treatment, the speech- language pathologist ought to select verbs that vary according to their transitivity biases. For instance, a person with severe nonfluent aphasia of the Broca type that produces single words would benefit from verb treatment first targeting intransitive verbs, i.e., those with a simpler verb-argument structure and, presumably, decreased cognitive processing load. As the patient or client progresses, the clinician may opt to increase difficulty to include production of utterances composed of intransitive verbs in intransitive sentences with adverbial phrases. This would be followed by treatment targeting use of transitive verbs in transitive sentences with a direct object and later, multiple direct objects.

Limitations and future research

The selection of the *Cinderella* story to sample discourse resulted in multiple limitations. While the healthy control participants produced a diverse set of words that were shared by most of the members of the group, the aphasia participants did not produce as many words that were shared among the members of their groups. Given their aphasia, circumlocution, semantic paraphasia, and the use of vague words were common. Furthermore, this discourse genre poses higher cognitive demands than procedural discourse (e.g., telling how to make a peanut butter and jelly sandwich; MacWhinney, 2000). It is also suspected that the diversity of verbs would not be as great, allowing for identification of more commonly occurring words across participants and groups.

The study relied on measuring pause durations in acoustic waveforms, which ideally requires high quality recordings. Inasmuch as these audio files were developed for clinical purposes and not for research purposes, many of the selected recordings did not meet that standard. AphasiaBank includes audio files that were recorded using iOS mobile devices (iPhone, iPad, iPod) and have variable mouth to microphone distances. Furthermore, there are background noises that made it difficult to measure pause durations precisely in some recordings. As discussed above, pauses less than 100 ms were often difficult to measure.

Another limitation of this study relates to the relatively low incidence of pauses. For instance, only 37% of the sentences produced by fluent PWA contained measurable pauses. Because of this, the pause data were derived from a limited subset of utterances that may or may not have been representative of a larger set of observations. Also, participants did not exhibit measurable pauses in every experimental condition. Furthermore, the data in the third analysis were based on anywhere from one to four observations. And, abandoned utterances were discarded from the analysis, although PWA, particularly those with nonfluent aphasia, often produced incomplete sentences. This is related to a theoretical limitation that when a PWA does produce a transitive utterance with an intransitively biased verb, it is because he or she was unable to retrieve the target word for the argument and made the decision to abandon the attempt. In this case, the PWA is sensitive to the bias but presents with anomia that prevents retrieval of that particular argument.

Conclusions

The results support the notion that PWA are sensitive to transitivity biases, consistent with previous findings that people with fluent and nonfluent aphasia are sensitive to verb transitivity. Results also suggest that PWA may activate or apply these biases inconsistently. Furthermore, this investigation provides new insights as to the temporal course regarding when such information is accessed, i.e., at the time the verb is activated during phrasal construction.

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