Roles of shifting attention, alternating attention and inhibition on temporary syntactic ambiguity resolution and use of context in younger and older adults

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Roles of Shifting Attention, Alternating Attention and Inhibition on Temporary Syntactic Ambiguity Resolution and Use of Context in Younger and Older Adults

by

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Abstract

ROLES OF SHIFTING ATTENTION, ALTERNATING ATTENTION AND INHIBITION ON TEMPORARY SYNTACTIC AMBIGUITY RESOLUTION AND USE OF CONTEXT IN YOUNGER AND OLDER ADULTS

by

Youngmi Park

Adviser: Dr. Loraine K. Obler

Twenty-four younger adults (20-35 years, mean: 25.88) and thirty-four older adults (65-79 years, mean: 71.82) read sentences via a word-by-word self-paced reading paradigm. Study 1 examined how older and young adults resolve sentences containing Noun Phrase (NP) and Verb Phrase (VP)-attached Prepositional Phrases (PPs) yielding temporary syntactic ambiguity, and which cognitive factors (working memory capacity, inhibition, shifting attention, alternating attention, and cognitive processing speed) contribute to temporary syntactic ambiguity resolution.

Study 2 was designed to investigate how both age groups utilize contextual information while resolving PP-attachment, and which cognitive functions play a role in the use of referential context during syntactic ambiguity resolution. Specifically, Study 2A examined the effect of the presence of context by comparing reading times of ambiguous NP-attached PP in a null context versus a NP-supporting 2-referent context. In addition, the study asked which cognitive functions contribute to the use of supporting referential context during processing of NP-attached PP. Study 2B investigated efficiency of context use through manipulation of syntactic ambiguity (ambiguous NP-attached PP vs. unambiguous unreduced relative clause [URC]) and referential context (NP-supporting 2-referent context vs. VP-supporting 1-referent context). Additionally, this study asked which cognitive functions are related to the ability to overcome conflicting and misleading referential context during processing of NP-attached PP.

Except for alternating attention skills, older adults performed worse on cognitive skills than younger adults, exhibiting smaller working memory capacity, poorer inhibition and shifting attention skills, and slower cognitive processing speed. Across studies, older adults required longer processing times than younger adults. Older adults' slower processing across studies was assumed to be related to their poorer inhibition and shifting attention skills.
In Study 1, older adults had more difficulty processing NP-attachment than VP-attachment, whereas younger adults had comparable processing skills between NP-attachment and VP-attachment. Among cognitive functions, shifting attention and inhibition skills were related to ability to resolve PP-attachment ambiguity. Comparable performance patterns between younger and older adults were observed in Studies 2A and 2B. In Study 2A, when NP-attachment was presented in a NP-supporting 2-referent context, both age groups performed faster than in the null context condition. In Study 2B, both age groups utilized the 2-referent context as efficiently as the 1-referent context. However, older adults showed sensitivity to syntactic ambiguity (ambiguous NP-attached PP vs. URC), which was not observed in younger adults. Alternating attention skills were linked to the use of supporting context (Study 2A), and inhibition skills were related to the ability to overcome conflicting context (Study 2B) during NP-attachment ambiguity resolution.

Cognitive decline in aging is known to yield detrimental effects in syntactic processing. The results of this dissertation suggest that older adults are affected by syntactic constraints more than younger adults. However, older adults utilize referential context when encountering PP-attachment ambiguity as efficiently as young adults. In terms of contribution of cognitive functions to syntactic ambiguity resolution, among various cognitive functions, following cognitive functions only have been previously tested and reported their effects: working memory capacity, shifting attention and inhibition in younger adults and only working memory capacity in older adults. When five different cognitive functions were tested, the results show different cognitive functions were linked to the ability to resolve PP-attachment ambiguity in null (e.g., shifting attention and inhibition), supporting (e.g., alternating attention), and conflicting contexts (e.g., inhibition) for both age groups.
Dedication

This dissertation is dedicated to my loving parents, Raejoon Park and Eunsook Kim, who have been a constant source of teaching, encouragement, and endless support. I also dedicate this dissertation to my husband, Hanseung Yoo, for being there for me throughout the process. I will always appreciate all they have done.
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Chapter 1: Introduction

People process a sentence incrementally as words are heard or read sequentially. When a sequence of words in a sentence is compatible with several grammatical structures, the sentence becomes ambiguous. In this case, people immediately determine one of the multiple possible syntactic interpretations based on syntactic or semantic preferences. However, when the following words hold substantial information that conflicts with the initial interpretation, people may temporarily experience confusion. They realize that their initial syntactic or semantic analysis was incorrect and revise it, selecting an alternative interpretation. This resolves the temporary syntactic ambiguity but slows processing of the sentence, resulting in increased reading or listening times.

To date, some groups of researchers have examined the effect of preceding context on temporary syntactic ambiguity resolution, but these studies focus on young adults (e.g., Altmann & Steedman, 1988; Trueswell, Sekerina, Hill, & Logrip, 1999). When syntactic ambiguity resolution is compared between young and older adults, older adults perform less efficiently than young adults (e.g., Kemtes & Kemper, 1997). Other researchers have extended their research interests to the underlying resources that operate multiple syntactic structures during syntactic ambiguity resolution (e.g., January, Trueswell, & Thompson-Schill, 2008). Past studies have reported that the operation of multiple interpretations is related to cognitive functions and that a decline in working memory capacity limits the simultaneous operation of multiple syntactic structures; Individual differences in syntactic ambiguity resolution have been linked to working memory. Researchers who investigated roles of cognitive functions during syntactic ambiguity resolution focus on age-related cognitive differences. Since older adults show cognitive changes with aging, these researchers claim that reduced working memory capacity has a detrimental effect on syntactic ambiguity resolution (e.g., Just & Carpenter, 1992).

Although researchers have intensively investigated temporary syntactic ambiguity resolution from various points of view, there are still unanswered issues to be examined. First, while processing a sentence with temporary syntactic ambiguity, it is unclear the extent to which older adults use the preceding context, which is utilized by young adults. There is some evidence that older adults can overcome challenges in sentence processing (e.g., syntactic complexity, less sensitive sensory input) using a supportive context or internally stored knowledge (e.g., Gordon et al., 2009; Pichora-Fuller, 2008; Sommers & Danielson, 1999),
but most research on how aging affects syntactic ambiguity resolution has not explored the effect of context on syntactic ambiguity resolution.

Second, among cognitive abilities, only working memory has been included when age-related differences in syntactic ambiguity resolution are investigated. Along with working memory capacity, cognitive psychologists have postulated that other cognitive functions such as inhibition, set-switching, and alternating attention skills contribute to sentence processing skills in aging as well. Moreover, although various cognitive functions have been considered possible predictors of sentence processing skills, manipulation of syntactic complexity (i.e., having a multiple range of constituents to understand the surface structure of the sentence), rather than ambiguity, has been the focus (e.g., Goral et al., 2011). Although psycholinguists have used different types of sentences to examine syntactic complexity (e.g., subject-relative vs. object-relative clause complexity) vs. syntactic ambiguity (e.g., main verb vs. reduced relative clause ambiguity), it is important to note that distinguishing syntactic ambiguity from syntactic complexity is not a clear-cut task, as it is possible for syntactically ambiguous sentences to have varying degrees of complexity. As cognitive functions change with aging and various syntactic types may be affected differentially by age-related cognitive differences, it is necessary to investigate whether various cognitive functions contribute to the processing of sentences with syntactic ambiguity.

This dissertation investigates how cognitive differences between younger and older adults may affect use of supporting and conflicting contexts during temporary syntactic ambiguity resolution, and which cognitive functions predict syntactic ambiguity resolution in younger and older adults. For this purpose, I examined prepositional phrase (PP)-attachment ambiguity resolution in null and supporting or conflicting referential contexts during on-line sentence processing. The participants’ word-by-word reading times were obtained from a self-paced moving window paradigm (MacDonald et al., 1992). Following that, several cognitive functions were measured: working memory capacity was measured by the Digit and Word Ordering Span tasks (Kempler, Almor, Tyler, Anderson, & MacDonald, 1998), inhibition by the Stroop task (Stroop, 1935), shifting attention based on the Wisconsin Card Sorting Test (WCST; Heaton, 1993), and alternating attention and cognitive processing speed by the Trail Making Tests (Spreen & Strauss, 1998). These cognitive functions were used as predictors of PP-attachment ambiguity resolution in null and supporting/conflicting referential context in both age groups.
So far, research on syntactic ambiguity resolution without discourse context in older adults has focused on ambiguity involving the main verb versus a reduced relative clause (RRC). However, a more frequently investigated syntactic structure yielding temporary ambiguity in children and young adults is PP-attachment. According to Britt and Perfetti (1992), PP-attachment ambiguity is more easily resolved and more affected by discourse context than past participles in reduced relative clauses. PP-attachment requires local attachment decisions (deciding to select one syntactic structure over the other syntactic structure) within a major constituent (a word or a group of words that functions as a single grammatical unit), and such decisions can be informed by argument structure or referential information. By contrast, reduced relative clauses are less susceptible to context because attachment decisions do not occur within a major constituent but rather across a major constituent boundary. See sentence (1).

(1) The florist sent the flowers was pleased.

As mentioned earlier, sentence processing involves online construction of grammatical strings, so people interpret sent in sentence (1) as a main verb belonging to a verb phrase (VP) constituent. However, when another verb, was, is encountered, people realize that sent is a past participle in a reduced relative clause that belongs instead to a noun phrase (NP) constituent. The major constituents consisting of the NP, the florist, and the VP, sent the flowers, are represented in Figure 1.1. This initial structure is reconstructed so that the VP is integrated into the NP as illustrated in Figure 1.2. This reconstruction of the major constituent is required in order to resolve the ambiguity.

![Figure 1.1. Syntactic structures showing the initial interpretation of the sentence (1)](image-url)
Due to this complicated process of ambiguity resolution, the referential context may be used less effectively for ambiguities involving attachment of reduced relative clauses compared to ambiguities involving PP-attachment. Although effects of referential context on ambiguity resolution of past participles and PP-attachment have been intensively investigated in young adults, consistent results were only shown for PP-attachment. As a result, PP-attachment was regarded as the most appropriate structure for this dissertation in order to investigate how older adults utilize context during syntactic ambiguity resolution.

The structure of the present dissertation is as follows. In Chapter 1, I outline the various psycholinguistic perspectives on syntactic ambiguity resolution. First, I contrast different psycholinguistic models of sentence processing that predict how young adults, who have intact cognition, resolve temporary ambiguity of PP-attachment in null and referential contexts. Next, I address which cognitive functions have been found to be linked to the processing of PP-attachment in null and referential contexts. After addressing models of young adults’ sentence processing, I will explain older adults’ resolution of ambiguous PP-attachment based on cognitive-psychological points of view and give an overview of possible cognitive functions that may be linked to PP-attachment ambiguity resolution in older adults. Chapter 1 ends with the specific aims of this dissertation. Chapter 2 addresses the research design, including the characteristics of the participants and the experimental materials. Then, the procedure of the three experimental studies will be introduced.
Chapters 3, 4, and 5 introduce three studies that investigated the specific aims of this research. Chapter 3 focuses on how PP-attachment ambiguity resolution in older adults are different from those in younger adults and which specific cognitive factors are related to PP-attachment ambiguity resolution without dividing groups based on age. Chapters 4 and 5 discuss the effects of the preceding referential context on PP-attachment ambiguity resolution in aging and which specific cognitive functions are linked to context use during PP-attachment resolution. In Chapter 4, PP-attachment is presented either in isolation or in a supporting referential context to see if older adults can use referential context during on-line sentence processing as well as younger adults. Then the role of various cognitive functions in predicting the sensitivity to the existence of context (i.e., efficiency of context use) is investigated. In Chapter 5, NP-attachment and unreduced relative clauses are presented within NP-biased and VP-biased referential contexts to examine how older adults use supporting and conflicting contexts to resolve PP-attachment ambiguity compared to younger adults. Then, which cognitive functions are linked to the sensitivity to conflicting context (i.e., efficiency overcoming the conflicting context) is examined. Lastly, a general discussion of this research and conclusions follow in Chapter 6.

1.1. Syntactic ambiguity resolution by young adults

This section summarizes previous findings to posit which mechanisms or resources are required for syntactic ambiguity resolution in young adults. First, I will introduce what has been reported to date about syntactic ambiguity resolution in null contexts starting with classical psycholinguistic models of sentence processing, followed by modern cognitive psychological approaches, which explore the contribution of cognitive functions for syntactic ambiguity resolution. Secondly, studies about syntactic ambiguity resolution in context will be introduced.

1.1.1. Syntactic ambiguity resolution in null contexts

1.1.1.1. How to resolve syntactic ambiguity in null contexts

The incremental nature of sentence processing sometimes leads to construction of an incorrect grammatical structure when a sequence of words yields more than one possible structure. As a result,
readers experience confusion until subsequent information helps them revise the initial incorrect analysis.

Consider the following sentences (from Altmann & Steedmann, 1988):

(2) The historian had to study the map with the magnifying glass so as to value it.

(3) The historian had to study the map with the appalling tear so as to value it.

In sentences (2) and (3), a temporary syntactic ambiguity arises at the preposition with, making it possible to attach the entire prepositional phrase (PP) (with the magnifying glass or with the appalling tear) to either the VP, to study, or to the NP, the map. When two syntactic analyses are possible at an ambiguous region (the underlined words in sentences (2) and (3)), people are initially biased toward interpreting the prepositional phrase as the Instrument of the verb (described henceforth as “VP-attached PP”) (e.g., Rayner, Carlson, & Frazier, 1983; Traban & McClelland, 1983). However, if people encounter a pragmatic implausibility (i.e., unexpectedness), as in (3), then a reanalysis of the syntactic structure based on semantics and/or plausibility occurs that requires considering the dispreferred structure. For example, upon reading with the appalling tear, people realize that instead of modifying the VP, to study, and being interpreted as an Instrument, the PP should modify the NP, the map, and be interpreted as a Modification. Such temporarily ambiguous sentences are referred to as garden-path sentences, and this phenomenon is called the garden-path effect.

Since the seminal study published by Bever (1970), the use of garden-path sentences has been critical in developing and testing models of syntactic processing in psycholinguistics (e.g., Frazier & Fodor, 1978; Frazier & Clifton, 1996). Although theories of syntactic processing do not differ in terms of what kinds of information sources are used in ambiguity resolution (e.g., syntactic, semantic, pragmatic or referential context information), they differ in describing the stage at which those sources of information are used (e.g., in serial, parallel, or interactive fashion). The garden-path model proposed by Frazier (1979) employs a heuristic called Minimal Attachment, which explains how people prefer the least complex syntactic analysis with the fewest syntactic nodes during sentence processing and that this preference is applied at a point of temporary ambiguity. According to this model, attachment of the PP to the VP does not require the construction of new nodes when people encounter the preposition with (the point of temporary ambiguity), thus predicting that people will be biased to VP-attachment in both sentences (2) and (3). After this syntactic
preference is established at the first stage, evaluation and revision may follow at the second stage. For instance, people may experience the garden-path effect and notice that the initially built syntactic structure should be changed from VP-attachment to NP-attachment, which was initially avoided because it would have created an additional NP node. See Figures 1.3 and 1.4 for tree structures showing attachment of the PP to the VP (1.3) and to the NP (1.4).

![Figure 1.3. Syntactic structure for sentence (2) showing VP-attached PP](image1)

![Figure 1.4. Syntactic structure for sentence (3) showing NP-attached PP](image2)

In sum, the main notion of the garden-path model is that a preferred structure is immediately constructed based on syntactic constraints (e.g., Minimal Attachment), and this immediately constructed structure is subsequently checked against non-syntactic information such as semantic/lexical information, pragmatic plausibility, and referential discourse context at a second stage in processing. Thus, the garden-path model proposes delayed use of non-syntactic information during syntactic ambiguity resolution.
Experimental studies have investigated and supported the garden-path model. For example, Rayner, Carlson, and Frazier (1983) used sentences with temporary syntactic ambiguity similar to sentences (2) and (3). In their Experiment 2, twenty college students read each sentence type while their eye movements were recorded. To confirm their comprehension, after reading each sentence, the participants were asked to paraphrase the sentence that they had read. To analyze on-line sentence processing, the researchers divided the sentence into three regions and calculated the reading time per character (in milliseconds). The initial region of the sentence consisted of all words from the beginning of the sentence to the main verb (e.g., The historian had to study). Then, the ambiguous region of the sentence consisted of the postverbal noun phrase and the preposition (e.g., the map with). Lastly, the disambiguating region began with the rest of the prepositional phrase and included all subsequent words (e.g., the magnifying glass or the appalling tear). At the disambiguating region, the participants showed longer reading times for sentences with a NP-attached PP (non-minimal attachment) than for sentences with a VP-attached PP. The results confirmed that young adults initially constructed one syntactic analysis of a sentence and that at a later point the semantic plausibility of the sentence was adjudicated.

1.1.1.2. Contributions of cognitive functions for syntactic ambiguity resolution

In addition to syntactic constraints, the role of cognitive functions for syntactic ambiguity resolution in young adults has been investigated. According to Acheson and MacDonald (2009), cognition may affect individuals’ ability to plan the serial order of linguistic elements within a sentence. So far, cognitive psychologists have reported that sufficient working memory capacity, inhibition (also known as selective attention), and shifting attention skills are required for efficient syntactic ambiguity resolution.

a. Working Memory Capacity

Working memory is the collection of processes that are required for on-line maintenance and manipulation of information needed to execute cognitive operations (Baddeley & Hitch, 1994). The most well-known working memory theory for language comprehension is the capacity-constrained comprehension theory, proposed by Just and Carpenter (1992). According to this theory, written or spoken text needs to be activated in the mind. Additionally, maintenance (storage) and manipulation (central execution) of information are important for successful sentence processing. Just and Carpenter claimed
that during sentence processing, various sources of information (syntactic, semantic, and pragmatic features of the sentence) are processed simultaneously. However, if the components are large (e.g., the information cannot fit into the storage space or the computational needs are too complicated), the amount of activation could exceed working memory capacity. In this case, processing speed will slow down or processed information may be partially forgotten. Therefore, the speed and amount of sentential processing information depend on the capacity for storage and manipulation in working memory.

Tasks that are designed to assess verbal working memory capacity are constructed to measure the processing and storage resources of working memory (e.g., the Reading Span task, and the Digit Ordering and Month Ordering tasks). To test the capacity-constrained comprehension theory, Just and Carpenter (1992) assessed working memory capacity using the Reading Span task (Daneman & Carpenter, 1980). The participants were required to read a set of unrelated sentences and to recall the final word of each sentence. The number of sentences per set was increased after each successful recall. The maximum set number at which the participant could recall the final word of a sentence was defined as the reading span. Language processing skills and reading spans were highly correlated (Daneman & Carpenter, 1980).

For syntactic ambiguity resolution in null context, the capacity-constrained comprehension theory proposes that the presence of more than one interpretation of the ambiguous sentence would demand additional capacity. Therefore, based on this theory, people with larger working memory capacities should be better able to maintain multiple syntactic interpretations based on frequency, syntactic complexity, and pragmatic plausibility, providing them with better chances for resolving the syntactic ambiguity successfully at the end of the sentence. In contrast, people with smaller working memory capacities may have no ability or a reduced ability to maintain multiple syntactic interpretations, and as a result, they may abandon the less preferred interpretation and hold on to only the preferred interpretation. Therefore, the constraints based on working memory capacity result in less successful ambiguity resolution for less preferred structures in people with reduced working memory capacity.

To support their claim, Just and Carpenter cited a study by MacDonald, Just, and Carpenter (1992), which showed that processing time and ability to overcome the garden-path effect depended on working memory capacity. MacDonald et al. divided young adults into high- and low-span groups based on working memory capacity for language, measured by the Reading Span task (Daneman & Carpenter, 1980). Using
ambiguity involving the interpretation of a word as either the main verb or a reduced relative clause, the researchers compared reading times between the two working memory span groups.

Just and Carpenter found differences in processing times between the two groups: unlike low-span participants, high-span participants spent a longer time at the final disambiguating region during the ambiguous condition. They interpreted the results as demonstrating that people with large working memory capacities showed increased reading times due to “the cost of maintaining both interpretations” (Just & Carpenter, 1992, p.132). Moreover, they postulated that the higher accuracy rate for the comprehension questions by people with large working memory capacities provided further evidence that these individuals were not led down the garden path as they maintained multiple representations, so they could successfully select the correct syntactic structure at the end.

b. Inhibition/Selective Attention

Another cognitive function linked to syntactic ambiguity resolution in young adults is inhibition, also known as selective attention. To measure inhibition, the Stroop Test (Stroop, 1935) is widely used. During the Stroop Test, participants are asked to read colored words and subsequently to name the color of the ink that the words are printed in as quickly as possible in two minutes. During the test, conflict occurs when the internal representation (the automatically triggered name of the word) is incompatible with another representation (the color of the ink). To resolve this conflict, the name of the word must be inhibited and the name of the ink color must be selected. Response time or the number correct difference between the two conditions within the limited time (e.g., two minutes) is used to estimate individuals’ inhibition skills.

According to the Left Inferior Frontal Gyrus (LIFG)-based Cognitive Control hypothesis (Novick, Trueswell, & Thompson-Schill, 2005), inhibition skills are required for sentence processing, and the LIFG is responsible for controlling inhibition skills; that is, the detection and resolution of conflicting information occur in LIFG. For successful syntactic ambiguity resolution, people must suppress their initial syntactic analysis based on the internal syntactic analysis knowledge that has been successfully applied to most previous sentences. Instead, people need to promote the alternative, less preferred syntactic analysis. In such instances, Novick et al. proposed that syntactic ambiguity resolution abilities are closely related with conflict resolution abilities such as inhibition skills. An experimental study conducted by January, Trueswell,
and Thompson-Schill (2008) found the co-localization of activation patterns for the Stroop and for syntactic ambiguity resolution in Broca’s area using functional magnetic resonance imaging.

c. Shifting attention

Shifting attention skills are also known to predict syntactic ambiguity resolution in young adults. Shifting attention skills are often measured using the Wisconsin Card Sorting Test (WCST; Heaton et al., 1993). The WCST involves sorting cards based on color, shape, or number. Without being provided a sorting criterion and only receiving positive or negative feedback after selecting a card, the participants must derive the sorting criterion. If ten cards are sorted correctly, the sorting criterion changes without warning, and then the participants must identify what the new criterion is. This test is presumed to require cognitive flexibility because the participants must be flexible to respond to feedback and avoid the tendency to perseverate. Therefore, the results of this test represent the efficiency of shifting attention between sorting sets.

In a study by Mendelsohn (2002), sentences containing verbs that could be used either intransitively or transitively were manipulated to yield temporary syntactic ambiguity. See sentence (4) which is more preferred, and sentence (5) which is less preferred in general.

(4) Bill knew the truth.

(5) Bill knew the truth was being kept from him.

For successful ambiguity resolution in sentence (5), the participants were required to reanalyze their initial interpretation of the NP following the verb (the truth) as a direct object and assign it a new interpretation, as a sentential complement. Correlational analysis revealed a high degree of correlation between performance on the WCST revised by Mendelsohn and syntactic ambiguity resolution based on the reading time difference between the ambiguous and unambiguous sentence comprehension trials and performance on the WCST. Therefore, when the less preferred structure was presented, people with good WCST performance could promptly shift their attention from the preferred syntactic structure to the new one.
d. Speed of cognitive processing

Cognitive processing speed has been one of the most crucial cognitive functions in older adults’ sentence processing. However, no theories exist that consider a relationship between that of young adults and their sentence processing.

1.1.2. Syntactic ambiguity resolution in context

1.1.2.1. How to utilize context during syntactic ambiguity resolution

The previous section described studies showing that if syntactic ambiguity is presented in a null context, syntactic constraints on structure building were the primary determinants for syntactic ambiguity resolution. However, when such syntactic ambiguity is presented within a context containing syntactically relevant information that supports the less preferred structure, the context information guides syntactic ambiguity resolution early in structure building. People are able to process a less preferred structure such as NP-attachment, which is relatively difficult to process and requires a longer processing time in the null context but requires little difficulty when it occurs in a supporting context.

Consider the case when one of two preambles, (6) or (7) (from Altmann & Steedman, 1988) precedes our exemplar sentence (2) The historian had to study the map with the magnifying glass so as to value it and (3) The historian had to study the map with the appalling tear so as to value it. The difference between (6) and (7) is the number of referents for the map: there is 1 referent, a map which had an appalling tear in (6), and there are 2 referents, a map which had an appalling tear and a map which seemed in perfect condition, in (7).

(6) A historian was working in the British Museum holding a magnifying glass.
He’d sat down to study a map. On his desk there was a map which had an appalling tear and a manuscript which seemed in perfect condition.

(VP-supporting context via presentation of 1 referent)

(7) A historian was working in the British Museum holding a magnifying glass.
He’d sat down to study a map. On his desk there was a map which had an appalling tear and a map which seemed in perfect condition.

(NP-supporting context via presentation of 2 referents)
Based on referential theory (Altmann & Steedman, 1988; Crain & Steedman, 1985), a simple definite NP, *the map*, is preferred if there is a unique referent in the preceding context. However, if two or more referents exist in an individual’s internal interpretation of the context, a complex NP, *the map with the appalling tear*, is favored over the other interpretation because each referent needs to be uniquely distinguished from the other. Therefore, in the 2-referent context, (7), attachment of the PP to the NP is expected. In essence, this type of referential context reverses the general syntactic preference for VP-attachment that is observed in the null context. The referential theory proposes that possible syntactic structures (e.g., NP-attachment and VP-attachment) are developed in parallel, but the immediate effects of referential context enable people to select an appropriate syntactic structure quickly and to override syntactic preferences.

This nullification of the garden-path effect in the 2-referent discourse context was also confirmed experimentally. Altmann and Steedman (1988) used similar preambles as in (4) and (5), which had either a 1-referent context supporting VP-attachment or a 2-referent context biasing NP-attachment preceding the target sentences. The target sentences, containing either VP-attachment or NP-attachment, as in (2) and (3), were presented phrase-by-phrase to a group of college students, who read them at their own reading pace.

The study showed that the context containing 2 referents was strong enough to make the young adults expect NP-attachment for the target sentence: when the 2-referent context was presented followed by the sentence containing NP-attachment, the reading time for the region containing the PP (e.g., *with the appalling tear* in sentence (3)) was faster than for the VP-attached PP (e.g., *with the magnifying glass* in sentence (2)). Thus, the results showed that the participants used the referential context to avoid the garden-path effect, which would have been observed if the target sentence containing the NP-attachment had been presented in isolation.

Along with the referential theory, the constraint-based model (Trueswell, Tanenhaus, & Garnsey, 1994) also considers multiple constraints (e.g., syntactic, referential context, and lexical information) to be processed simultaneously. The constraint-based model proposes that multiple constraints operate in parallel, but that the most reliable information guides people to select a certain syntactic structure among several candidates. Unlike the referential theory, which proposes equal availability of alternatives, the
constraint-based model predicts that possible alternatives are activated to a larger or smaller degree based on the different relevance or influence of various information sources. Therefore, ambiguity resolution is viewed as continuous and interactive; instead of all possible syntactic representations being available initially, the constraint-based model postulates that only the syntactic structure that is strongly supported by the given information is activated, and the other alternative is deactivated immediately. Sometimes, however, a source of information that is the most reliable initially may lead to an incorrect syntactic analysis, and it is in this case that the garden-path effect occurs (Spivey-Knowlton, Trueswell, & Tanenhaus, 1993).

1.1.2.2. Contributions of cognitive functions for syntactic ambiguity resolution in context

As described above in section 1.1.1.2., in null contexts, working memory capacity, inhibition, and shifting attention skills predict the ability to resolve syntactic ambiguities. In the case of use of context during syntactic ambiguity resolution in young adults, Pearlmutter and MacDonald (1995) have reported that people with a smaller working memory capacity were less able to use context in resolving syntactic ambiguity. Besides working memory capacity, however, there has been no research on the roles of different cognitive functions (e.g., inhibition and shifting attention) when the context is used during syntactic ambiguity resolution in young adults.

1.2. Syntactic ambiguity resolution by older adults

This section describes previous research on processing syntactic ambiguity in older adults and the possible contribution of cognitive functions on ambiguity resolution in this population. Compared to young adults, there are very few theories that explain syntactic ambiguity resolution in older adults and no findings are available describing PP-attachment ambiguity resolution. The only type of ambiguity that has been studied with older adults is RRC, so it will be introduced instead. Next, previous findings focusing on the use of context during syntactic ambiguity resolution in older adults will be addressed, as well as cognitive functions that may contribute to the efficient use of context.
1.2.1. Syntactic ambiguity resolution in null context

1.2.1.1. How to resolve syntactic ambiguity in null context

The majority of psycholinguistic studies that focus on syntactic processing have investigated the performance of young adults and tested the psycholinguistic models that were presented in Section 1.1. These models assume that the syntactic processing strategies can be generalized to all populations. Therefore, no special psycholinguistic models accounting for syntactic ambiguity resolution in older adults exist. Nevertheless, experimental studies are available that describe sentence processing skills in older adults, but most of them have focused on syntactic complexity (e.g., Obler, Nicholas, & Albert, 1991; Stine-Morrow et al., 2010; Wingfield et al., 2006). Very few studies have examined how older adults process sentences with temporary syntactic ambiguity, and those that have used RRCs only.

For example, Kemtes and Kemper (1997) and Kemper et al. (2004) conducted studies involving self-paced reading and eye-tracking during reading experiments to examine how older adults process temporary syntactic ambiguity using RRC ambiguity, such as the example in (8), in null context.

(8) The florist sent the flowers was busy.

By misinterpreting the past participle in the RRC as a main verb, both younger and older adults exhibited the garden-path effect at the past participle, (e.g., sent), but the effect was stronger for older adults. Compared to younger adults, older adults demonstrated longer reading times and lower accuracy in the self-paced reading study (Kemtes & Kemper, 1997) as well as longer total fixation times and more regressions in the eye-tracking study (Kemper et al., 2004).

Based on the garden-path model, preference for interpreting the ambiguous word as the main verb in the main clause as opposed to the past participle in a RRC is expected because fewer nodes are needed in the construction of the main verb than for the reduced relative clause. According to the principle of Minimal Attachment, when people process sentences like (8), the past participle, sent, in the RRC is misinterpreted as the main verb in the main clause, because rather than starting a new clause at the verb, which would be required under the RRC interpretation (e.g., The florist [that was] sent…), people attach sent to the main clause and assign it the role of the main verb. However, both younger and older participants stumbled when encountering the true main verb, was, because the introduction of another finite verb is
incompatible with the syntactic construction built to that point. Due to the grammatical incompatibility of the two verbs, the participants must reanalyze the sentence structure and reassign the first verb, *sent*, as the past participle of a RRC instead of as the main verb of the main clause.

The cause of readers’ stumbling and reanalyzing the structure is different in RRC from what is seen for PP-attachment ambiguity. However, it is obvious that reanalysis is required in both cases to process temporarily ambiguous sentences appropriately. Therefore, the garden-path model can make predictions about the general syntactic ambiguity resolution patterns of both younger and older adults, but it does not explain the differential age-related garden-path effect.

The present study uses PP-attachment to investigate how older adults process temporarily ambiguous syntactic structures because relatively consistent results have been reported for ambiguous PP-attachment with and without contextual information compared to other types of syntactic ambiguities such as RRCs. However, no experimental research exists investigating PP-attachment in older adults. Based on the results of the previous studies focused on main verb versus RRC ambiguity, we can assume that older adults may have special characteristics that make them process syntactic ambiguity similarly to, but somewhat differently from, younger adults. However, as already mentioned, classical psycholinguistic models fail to provide predictions of age-related differences in syntactic ambiguity resolution.

1.2.1.2. Contributions of cognitive functions for syntactic ambiguity resolution

Cognitive psychologists have attempted to find reasons for the differences in resolution of temporary syntactic ambiguity based on age-related cognitive changes. It is well known that language processing and cognitive functions are closely related and that cognitive functions decline with aging. Thus, older adults have reduced cognitive abilities and may exhibit different language processing skills when compared to young adults with intact cognition. That is, the same performance patterns for younger and older adults cannot be expected for syntactic processing due to age-related cognitive changes.

Furthermore, the slowing of cognitive processing speed and decline of various cognitive functions including working memory capacity have been reported as possible factors resulting in differential syntactic processing skills, such as the processing of syntactic complexity, between younger and older adults. Yet, only working memory capacity has been identified as a possible contributor to age-related syntactic
ambiguity resolution differences so far. Other cognitive functions have not been investigated to see whether
cognitive skills besides working memory are also crucial for syntactic ambiguity resolution in younger and
older adults.

Studies investigating the effects of age-related cognitive changes on the comprehension of
syntactically complex sentences have reported that, along with working memory capacity, other cognitive
functions, such as inhibition, shifting attention, and alternating attention may predict syntactic processing
skills in aging (e.g., Goral et al., 2011). Among these, inhibition and shifting attention are important factors
for syntactic ambiguity resolution among young adults. Therefore, although direct effects have not been
reported yet, cognitive functions that have been investigated for dealing with syntactic complexity in aging
and syntactic ambiguity resolution in young adults should be considered for potential contributions to
syntactic ambiguity resolution in aging.

a. Working Memory Capacity

Kemtes and Kemper (1997) and Kemper et al. (2004) investigated what brings about the difference
in syntactic ambiguity resolution between younger and older adults. In both studies, the researchers claimed
that working memory capacity contributes to differential performance (disproportionally stronger garden-
path effects in older adults) between younger and older adults because older adults with high working
memory spans performed as well as young adults. Their results confirmed that sentences with syntactic
ambiguity are difficult enough to demand working memory resources similar to sentences with syntactic
complexity. Moreover, limited working memory capacity in older adults resulted in relatively stronger
garden-path effects shown as increased reading times for the less preferred structure during on-line
sentence processing.

Working memory is one of the most important variables in the field of cognitive aging (Light &
Anderson, 1985; Salthouse, 1990). The capacity-constrained comprehension theory (Just & Carpenter,
1992), which was previously mentioned when the contribution of working memory to syntactic ambiguity in
young adults was introduced, also proposes that cognitive deficits in older adults are due to their
fundamental deficit in working memory capacity. Based on this hypothesis, it is predicted that a decline in
working memory capacity in aging results in age-related differences in sentence processing performance.
When compared to young adults, the effect of working memory capacity on sentence processing may be
stronger in older adults. The capacity-constrained comprehension theory predicts that syntactic constructions that involve a greater demand on working memory capacity for young adults (e.g., syntactic ambiguity resolution) yield detrimental effects in older adults. Moreover, the performance of older adults is somewhat similar to that of young adults with a low working memory capacity.

Additionally, age-related cognitive deficits become more pronounced when the working memory demands of the task increase. The theory suggests that when language tasks carry a small processing load, despite working memory capacity differences between younger and older adults, language processing skills will be comparable between the two age groups. However, once syntactic structures become complex and thus place greater demands on working memory, overall performance will decline more dramatically for older adults due to the decreased working memory capacity associated with aging.

The concept of working memory capacity may play a crucial role in predicting age-related differences in syntactic ambiguity resolution. Based on the results of the studies conducted by Kemtes and Kemper (1997) and Kemper et al. (2004), it can be assumed that another type of syntactic ambiguity, PP-attachment ambiguity, may place demands on working memory as well. Thus, as working memory capacity declines with advancing age, older adults may experience a more detrimental effect of reduced working memory capacity during PP-attachment ambiguity resolution. Therefore, working memory capacity appears to be a strong predictor of PP-attachment ambiguity resolution.

b. Inhibition/ Selective Attention

Another prominent theory that is widely discussed in the cognitive aging literature is the Inhibition Deficit Hypothesis (Hasher & Zacks, 1988). This hypothesis suggests that inhibition declines with age (Hasher, Zacks, & May, 1999). Under this account, aging is associated with impairments in preventing irrelevant information from entering the working memory system; the irrelevant information then disrupts the encoding and retrieval of relevant information. As a result, this age-related inhibitory deficit contributes to age-related performance declines on cognitive tasks.

Hasher and Zacks propose that three functions of inhibition contribute to age-related differences in processing speed and working memory capacity (Lustig, Hasher, & Zacks, 2007). According to the theory, failure to (a) control access of irrelevant information to the focus of attention contributes to the general slow speed of processing in aging. In order to not be distracted by irrelevant information, control and regulation
of access to attention are necessary. However, difficulty controlling access of irrelevant information to the focus of attention in older adults may make them access target information more slowly due to an overload of information, i.e., a combination of irrelevant and relevant information. This will ultimately result in decreased speed of processing for older adults (e.g., West & Alain, 2000).

Moreover, the theory also suggests that information that was once recognized as relevant in a previous situation can turn into irrelevant information in the current situation. In this case, (b) deleting irrelevant information from attention and working memory is required. Based on this notion, an inefficiency to delete "no-longer-relevant" information in older adults results in age-related differences of working memory capacity (e.g., Lustig, May, & Hasher, 2001). Lastly, older adults have difficulty (c) suppressing or restraining strong, but inappropriate responses. Especially when the context provides a strong but incorrect cue, people with poor inhibition skills fail to abandon this inappropriate cue. Controlling and suppressing abilities are often measured by the Stroop test (e.g., Balota, Cortese, & Wenke, 2001) and the type of inhibition skill it requires declines with advancing age (e.g., West & Alain, 2000).

Although no specific account for syntactic ambiguity resolution in aging is proposed in this theory, it can be predicted that reduced inhibition abilities in older adults result in their poorer performance than younger adults because once-relevant information in a previous context may become irrelevant when they encounter syntactic ambiguity. In addition, as the less preferred response should be selected by inhibiting the strongly preferred but incorrect response, older adults, who have poorer inhibition skills, may experience more difficulty resolving the syntactic ambiguity than younger adults.

The LIFG-based Cognitive Control Hypothesis has not addressed the effect of age, but the concept of cognitive control (shifting attention) in the LIFG-based Cognitive Control Hypothesis seems to be somewhat similar to inhibition in the Inhibition Deficit Hypothesis. Novic et al. (2005) used the same terms that Hasher and Zacks (1988) used to propose their hypothesis such as “relevant” and “irrelevant” information and “suppress.” Additionally, to support their hypotheses, both used the same neuropsychological test, namely, the Stroop test.

c. Shifting attention

Switching attention between two sets (or strategies) is also known to change with advancing age, but not until recently was it also highlighted in sentence processing in aging. Goral and colleagues (2011)
have shown the crucial role of shifting attention for dealing with syntactic complexity and making plausibility judgments on sentence processing tasks by adults aged 55 to 88 years. In their study, shifting attention skills were a critical predictor for successful processing of complex sentences in older age.

To measure shifting attention skills, the WCST is often used. The total number correct, the percent of perseverative errors, and the number of perseverative errors on the WCST are the most commonly used measures for observing shifting attention skills (Miyake et al., 2000). Each of these measures shows the effects of aging (e.g., Axelrod & Henry, 1992; Salhoute, Fristoe, & Rhee, 1996), but the percent of perseverative errors is known to be the most sensitive to age effects (Rhodes, 2004).

Although few studies have dealt directly with resolution of PP-attachment ambiguity, attention switching skills in resolving this type of syntactic ambiguity should be considered and examined. For successful performance on the WCST, the interplay between several processes is required and a selected strategy needs to be constantly evaluated based on feedback along with online maintenance of the relevant information being used (Fristoe, Salhoute, & Woodard, 1997). To resolve syntactic ambiguity successfully, the ability to evaluate the current strategy when feedback is presented and switch to another strategy while holding on to relevant elements of the sentence may be necessary as well. That is, based on the pragmatic plausibility of semantic information, if a selected syntactic structure (e.g., VP-attached PP) is flagged as the incorrect one, then people need to switch (or abandon) their decision from the current syntactic structure to an alternate one (e.g., NP-attached PP). For example, in sentence (3) The historian had to study the map with the appalling tear so as to value it, if people attach the PP, with the appalling tear, to the VP and interpret it first as the Instrument, they will realize that the sentence is not pragmatically plausible as soon as they read tear. Therefore, they need to switch their interpretation of the PP from the role of instrumentation to that of modification.

As Mendelsohn (2002) reported for young adults, there is no reason to assume that older adults do not use shifting attention during syntactic ambiguity resolution. However, it can be assumed that older adults may have poorer shifting attention skills than young adults. In order to process a sentence requiring temporary syntactic ambiguity resolution, while reanalyzing syntactic structures (i.e., switching from one to the other structure), other relevant information (e.g., the lexical information of the words) and the constituents of the sentence should be processed. Upon examination, declines in shifting attention in older
adults may have more detrimental effects on PP-attachment ambiguity resolution compared with young adults who have better shifting attention skills.

d. Alternating attention

Lastly, another cognitive function that can be considered is alternating attention, which represents cognitive abilities including mental tracking, inhibitory control and shifting attention (Sánchez-Cubillo et al., 2009). Alternating attention is also one of the most frequently mentioned cognitive functions linked to aging (e.g., Keys, & White, 2000; May & Hasher, 1998; Periáñez et al., 2007; Ramussen et al., 1998; Tombaugh, 2004).

Few studies have considered alternating attention as a possible predictor for sentence processing skills in aging except that of Goral et al. (2011). Although alternating skills in healthy older adults were worse when compared with those of young adults in their study, they were not a predictor of sentence processing for sentences of varying syntactic complexity (e.g., subject-relative vs. object-relative sentences; Goral et al., 2011). The correlation between limited alternating attention ability and impaired processing of syntactic complexity has, however, been observed in patients with Parkinson’s disease (Lee et al., 2003). Based on these past studies, it can be predicted that poorer alternating attention abilities in healthy aging may not affect syntactic processing. However, this may be an over-generalization of the results from two syntactic structures until further investigation has been conducted. Although there is a possibility that lower alternating attention in healthy aging may not affect syntactic ambiguity resolution as was seen for performance on relative-clauses, I considered it worthwhile to investigate alternating attention as a predictor for syntactic ambiguity resolution in younger and older adults.

Alternating attention is frequently measured using the Trail Making Test (TMT; Spreen & Strauss, 1998). It consists of two parts, A and B (TMT-A and TMT-B). The TMT-A is designed for the participants to connect 25 randomly distributed circled numbers in ascending order. Then the participants are asked to connect 25 randomly distributed circled numbers and letters with alternating numerical and alphabetical sequences in the TMT-B. When participants make an error, they are instructed to correct it and continue the test. Unlike the WCST, the TMT represents the efficiency of switching sequences within a set, although both tests are known to measure cognitive flexibility.
The total times taken for the TMT-A and TMT-B are recorded, and then several derived scores can be used for analysis (e.g., B-A, B:A, (B-A)/A). Both time difference and ratio scores are found to be sensitive to age-related differences (e.g., Keys & White, 2000; May & Hasher, 1998; Ramussen et al., 1998; Tombaugh, 2004). According to Periáñez et al. (2007), however, the ratio scores (B:A and (B-A)/A) are more sensitive than the difference scores (B-A) because the ratio scores represent pure executive control ability regardless of individual differences for visual search and perceptual/motor speed. People with lower ratio scores are assumed to have better alternating attention skills.

e. Speed of cognitive process

Along with decreased working memory capacity, slowed cognitive processing speed is regarded to be another crucial factor in understanding age-related performance changes. The Processing speed theory (Salthouse, 1996) suggests that the speed of cognitive processes/operations decreases with advancing age due to greater noise in the nervous system (Salthouse & Lichty, 1985), weakened linkage strength between neural connections (MacKay & Burke, 1990), or an increase in information lost at each step of processing (Myerson et al., 1990). This decreased processing speed results in slower performance on all tasks regardless of the task type or mental operations involved in the task. Therefore, cognitive processing becomes too slow for successful performance, which results in a proportional increase of errors or a disruption in performance.

The second standard prediction of this theory is that the slow availability of the information that is gathered from different sources for a central processor causes the earlier information to decay or become inactive by the time the later information arrives. As a result, cognitive processing that depends on simultaneous availability of information from different sources may deteriorate. This theory predicts that worsening of processing speed in aging contributes to decreased working memory capacity in older adults. One of the neuropsychological tests that measure cognitive processing speed is TMT-A.

Although this is one of the most widely discussed theories in cognitive aging, no direct prediction of slower processing speed for syntactic ambiguity resolution has been proposed. However, this theory suggests that age-related differences in processing speed are related to age-related differences in working memory capacity. So I assume that older adults may require longer processing times than younger adults in general, and increased processing time due to cognitive slowing will contribute to working memory.
capacity decline in older adults. As a result, older adults may experience difficulty maintaining multiple syntactic representations. Therefore, older adults’ increased reading times, which represent slowing cognitive processing speed, may result in poorer performance on syntactic ambiguity resolution when compared with younger adults.

1.2.2. Syntactic ambiguity resolution in context

1.2.2.1. How to utilize context during syntactic ambiguity resolution

How context affects syntactic ambiguity resolution in young adults has been investigated intensively, as mentioned in Section 1.1.2. These studies have shown positive effects of context for young adults. However, little is known about the effects for older adults. Moreover, no psycholinguistic theories exist regarding this.

One unpublished study investigating whether older and younger adults use context differently during PP-attachment ambiguity resolution was conducted by Thornton (2009). In his study, the initial part of the sentence consisted of context supporting either VP- (9a) or NP-attachment (9b), followed by either a VP- (10a) or NP-attachment (10b) disambiguation.

(9) Context
a. VP-attachment expectation:
The handyman wasn’t sure which tool to use first, so he fixed the television with…
b. NP-attachment expectation:
The handyman wasn’t sure which television to work on first, so he fixed the television with…

(10) Disambiguation
a. VP-attachment: … with a soldering iron…
b. NP-attachment: … with a broken screen…

In the congruent condition (VP-supporting context followed by VP-attachment disambiguation or NP-supporting context followed by NP-attachment disambiguation), neither age group showed a garden-path (GP) effect. In contrast, depending on the context, whether it supported either VP- or NP-attachment expectation, the results were different in the incongruent condition, in which the preceding context did not
support the following syntactic structure. When the context made the participants expect VP-attachment (9a) which was then disambiguated as NP-attachment (10b), both age groups were affected by the conflict between the preceding context and the actual syntactic structure, resulting in difficulty overcoming the initially expected PP-attachment at the end via longer processing times than the corresponding VP-supporting (9a) – VP-attachment (10a) congruent condition. When the context supported NP-attachment (9b), but the sentence was disambiguated as VP-attachment (10a), however, age-related differences were observed; older adults were biased by the NP-supporting context so that processing times became longer when the ambiguity was disambiguated with an unexpected VP-attachment structure compared to the NP-supporting context (9b) – NP-attachment (10b) congruent condition. Young adults, however, did not show any preference with the NP-supporting context, and processing times in the incongruent condition were comparable to those in the corresponding congruent condition. Based on this result, Thornton postulated that the preference for VP-attachment in young adults is not eliminated even given an NP-supporting context at the beginning. However, older adults are more significantly affected by context initially provided and their dependence on context is greater than that of younger adults during PP-attachment ambiguity resolution.

This pattern of similar but somewhat different extent of context use by older adults was also reported in studies focusing on lexical ambiguity resolution. Most studies of context use by older adults have focused on the effects of context information on lexical ambiguity resolution, in particular, whether older adults can benefit from the context when predicting the final word of sentences such as those in (11) and (12) (e.g., Federmeier & Kutas, 2005; Pichora-Fuller et al., 2007; Sommers & Danielson, 1999).

(11) The cold drink was served with a slice of lemon. (Strong context)

(12) The only food left in the barren refrigerator was a moldy lemon. (Weak context)

Although the study design and stimuli are similar, the results of these studies differed depending on whether the task involved on-line or off-line processing. Older adults were able to use the context as well as younger adults during off-line sentence processing (e.g., Pichora-Fuller et al., 2007; Sheldon et al., 2008). When both off-line and on-line sentence processing skills were examined, older adults showed slower and less successful performance (e.g., Federmeier & Kutas, 2005, Federmeier, McLennan, De
Ochoa, & Kutas, 2002). There was no use of context during on-line processing but a substantial use of it during off-line sentence processing (e.g., Dagerman et al., 2006). Therefore, it can be concluded that a somewhat different extent of context use is expected in older adults compared to younger adults, who are efficient at using context for lexical ambiguity during both off-line and on-line sentence processing. In other words, both younger and older adults can use context, but younger adults use the context more rapidly than older adults.

In sum, the results from studies of syntactic and lexical ambiguity resolution in context have shown that rich context is of greater benefit for older adults than for younger adults during sentence processing. However, older adults require more time than younger adults to process such context (Dagerman et al., 2006; Thornton, 2009).

1.2.2.2. Contributions of cognitive functions to syntactic ambiguity resolution in context

To date, nobody has investigated the role of cognitive functions on syntactic ambiguity resolution in context. Therefore, I hypothesize that several cognitive functions (e.g., working memory capacity, inhibition, shifting attention, alternating attention, & cognitive processing speed) may play important roles in syntactic ambiguity resolution in context for older adults. To understand the underlying cognitive resources that facilitate use of context during PP-attachment ambiguity resolution in older adults who have declined cognitive functions, it is necessary to investigate whether older adults use the same or different cognitive functions when compared with younger adults, and which cognitive functions are necessary or useful for older adults.

1.3. Research Questions and Research Overview

The present study was designed to investigate whether the role of cognitive functions during syntactic ambiguity resolution in null and in supporting or conflicting context changes with advancing age. In Study 1, by manipulating ambiguous PP-attachment in null context, I attempted (1) to examine whether PP-attachment ambiguity resolution in null context changes with aging by measuring self-paced reading times per word and comparing them between age groups as Kemtes and Kemper (1997) did. This established the baseline performance of NP- and VP-attachment resolution in null context for both age
groups. As previously mentioned, many studies using PP-attachment ambiguity have focused on the performance of young adults, but no experimental studies about PP-attachment ambiguity resolution in older adults exist. Therefore, it was necessary to establish a baseline for both age groups on PP-attachment ambiguity resolution before moving forward. I then attempted (2) to find out which cognitive functions play a role in PP-attachment ambiguity resolution. Correlation analysis among the processing times of NP-attachment, five cognitive functions (working memory capacity, inhibition, shifting attention, alternating attention, and cognitive processing speed), and age was conducted without dividing participants into age groups.

The next goals were (3) to examine whether use of context during PP-attachment resolution changes with aging and (4) to find out which cognitive functions play a role in referential context use during PP-attachment ambiguity resolution; these goals led to Study 2A and Study 2B, respectively. Study 2A examined (3a) whether the ability to use supporting context during NP-attachment resolution changes with aging. To determine this, the processing times of NP-attachment in isolation and within NP-supporting 2-referent contexts were measured and compared. Then, to examine (4a) which cognitive functions are correlated with use of preceding contexts that support PP-attachment ambiguity resolution, correlation analysis among processing times for NP-attached PP in 2-referent contexts, five cognitive functions, and age was conducted.

Study 2B explored (3b) the efficiency of referential context use during NP-attachment resolution and how it changes with aging by manipulating syntactic types (ambiguous NP-attachment vs. unambiguous Unreduced Relative Clause (URC)) and biasing context (1- vs. 2-referent context). I then examined (4b) which cognitive functions contribute to overcoming a preceding context that is in conflict with PP-attachment ambiguity resolution by conducting a correlation analysis among the processing times of NP-attachment in 1-referent context, five cognitive functions, and age.

To answer the above-mentioned research questions, I present data from two self-paced reading experiments and four cognitive measures (working memory capacity, inhibition, shifting attention, and alternating attention). Reading Experiment 1 was designed to establish the baseline, i.e., how older adults process PP-attachment ambiguity in null context, as this type of ambiguity has not yet been examined. In Reading Experiment 1, sentences containing an ambiguous PP that could be attached to VP (VP-
attachment) or to NP (NP-attachment) were presented without context. The processing times of NP-attached and VP-attached PP were analyzed for Specific Aims 1 and 2 (Study 1). Then, the processing times of NP-attached PP in null context from Reading Experiment 1 and that of NP-attached PP in 2-referent context from Reading Experiment 2 were compared for Specific Aims 3a and 4a (Study 2A). In Reading Experiment 2, either VP-attachment supporting a 1-referent context or NP-attachment supporting a 2-referent context preceded either ambiguous NP-attached PP or unambiguous URC. The processing times of each of the four conditions were evaluated for Specific Aims 3b and 4b (Study 2B). The cognitive measures were included for Specific Aims 2, 4a, and 4b.
Chapter 2: Design and Procedure

2.1. Participants

Twenty-four older adult (65-79 years, mean: 71.82) and thirty-three young adults (20-35 years, mean: 25.88) participated in this research. The participants were native speakers of American English and not fluent in any foreign languages. Some of the participants were selected from the Research Participant Pool collected in the Neurolinguistics Lab at the CUNY Graduate Center. These participants, who had had participated in previous studies and had agreed to be contacted for participation in future experiments, were contacted via phone calls or emails for recruitment according to their stated preference. The rest of the participants were recruited via flyers or brochures that were distributed at the CUNY Graduate Center and senior centers in Manhattan. Two hours were required to complete the experimental tasks and all the participants received monetary compensation at a rate of $15/hr.

There was an initial telephone screening for the participants. Information from background questions such as first language, proficiency of any other languages, years of education, types of books read, histories of neurological disorders, learning disabilities and cognitive deficits were collected during the telephone screening. Additionally, a question about hours of reading per day was asked to measure their reading experience. Individuals who were fluent in any foreign languages or had any history of learning disabilities and cognitive deficits were not invited to participate. There was no cut-off for years of education, types of books read, or reading hours per day. Those people who passed the telephone screening were invited to the Neurolinguistics Lab at the CUNY Graduate Center and additionally, on-site vision and cognitive screening tests were administered.

Since this research requires reading sentences presented on a computer screen, to confirm that the participants’ near acuity was within normal range, a vision screening was administered. The Rosenbaum Pocket Vision Screener was used to measure near acuity when it was presented at a distance of 16 inches (40 cm) from the participants (Hamrah & Pavan-Langston, 2008). When corrected contact lenses or reading glasses were needed, the participants’ corrected vision was screened. In addition, to confirm that the participants had no visual difficulty in reading the actual stimuli during the tests, they were asked to read aloud two simple sentences displayed in a 12-point Arial font that was the same style and size of the font used for the reading stimuli.
Along with the on-site vision screening, to rule out people who have cognitive impairments, the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975), one of the most widely used cognitive screening measures, was administered. Exclusion criteria for this study were people who had cognitive impairments based on the results the MMSE (below 24), vision impairments that were not corrected by eyeglasses or contact lenses, a history of neurological disorders (e.g., stroke, dementia), a learning disability, and/or cognitive deficits. Only age distinguished the groups (p < .0001). Years of education, reading hours per day, and vocabulary level (collected from the Reading subtest of the Wide Range Achievement Test, WRAT), and the MMSE scores did not differ between the two age groups. Table 2.1. shows this information for the participants.

Table 2.1. Demographic Information about Participants

<table>
<thead>
<tr>
<th></th>
<th>Older Adults</th>
<th>Young Adults</th>
<th>t (df)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>71.82 (4.71)</td>
<td>25.88 (5.2)</td>
<td>34.81 (55)</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Years of Education</td>
<td>16.18 (2.38)</td>
<td>15.38 (2.24)</td>
<td>1.31 (55)</td>
<td>.2</td>
</tr>
<tr>
<td>WRAT</td>
<td>47.00 (5.83)</td>
<td>46.17 (7.27)</td>
<td>.46 (52)</td>
<td>.65</td>
</tr>
<tr>
<td>MMSE</td>
<td>28.82 (1.01)</td>
<td>29.29 (.95)</td>
<td>-1.78 (55)</td>
<td>.08</td>
</tr>
<tr>
<td>Reading Hours per Day</td>
<td>2.19 (1.32)</td>
<td>2.23 (1.16)</td>
<td>-.12 (55)</td>
<td>.91</td>
</tr>
</tbody>
</table>

2.2. Materials

2.2.1. Reading Experiments

Two reading experiments were designed to measure both off-line and on-line sentence processing skills. Reading Experiment 1 had a 2 x 2 design, crossing PP-attachment (NP-attachment ambiguity vs. VP-attachment ambiguity) and age (young adults vs. older adults): a sentence was presented to the participants in a self-paced reading format, and the reading time per word and accuracy on comprehension questions (one per sentence) were recorded. Sentences (13) and (14) are example of the sentences with NP-attachment ambiguity and VP-attachment ambiguity.

(13) NP-attachment ambiguity
The spy saw the cop with a revolver but the cop didn’t see him.

(14) VP-attachment ambiguity
The spy saw the cop with binoculars but the cop didn’t see him.
Reading Experiment 2 had a 2 x 2 x 2 design, crossing referential information (1-referent vs. 2-referent), syntactic ambiguity (referring to temporary syntactic ambiguity of NP-attached PP which is disambiguated by semantic plausibility information vs. syntactic unambiguity of Unreduced Relative Clause, URC), and age (young adults vs. older adults). Unlike the stimuli in the first reading experiment, each stimulus item for the second reading experiment consisted of four sentences and a comprehension question. The first three sentences of each stimulus for the second reading task were presented to bias either NP-supporting context (2-referent) or VP-supporting context (1-referent) with manipulation of the referential information. The fourth sentence ended with a NP-attached PP or URC. In Reading Experiment 2, VP-attached PP which was used in Reading Experiment 1 was not used. In (15), examples of ambiguous NP-attached PP and unambiguous URC in 1- and 2-referent context can be found. In the 2-referent context, a strongbox was replaced by a safe. In addition, instead of with at the target sentence, which had was used to make it unambiguous.

(15) A burglar broke into a bank carrying some dynamite. He planned to blow open a safe. Once inside he saw that there was a safe which had a new lock and a strongbox (a safe) which had an old lock. The burglar blew open the safe with (which had) the new lock and made off with the loot.

2.2.1.1. Selection of Target Verbs

Before creating sentence stimuli, I first selected target verbs that would be used in the target sentences as lexical/semantic information contributes importantly to syntactic ambiguity resolution (e.g., Britt, 1994, Spivey-Knowlton, Trueswell, & Tanenhaus, 1993; Spivey-Knowlton & Sedivy, 1995; Trueswell & Tanenhaus, 1992). For instance, Spivey-Knowlton and Sedivy (1995) found that people tend to expect VP-attached PP for action verbs which involve an agentive subject and a direct object (e.g., study in sentences (1) and (2), work, put, wipe and so on). In contrast, either NP-attached PP or VP-attached PP was expected for psych and perception verbs representing mental states or perception (e.g., anticipate, horrify); neither should elicit a strong preference for a certain type of attachment. Snedecker & Trueswell (2004) also claimed that readers expect some verbs to be more likely followed by a PP that modifies the verb (VP-attached PP), other verbs by a PP that modifies the noun (NP-attached PP), and a third group of verbs by a PP that modifies either the verb or the noun.
Due to the effect of this verb bias on sentence processing, I decided to select only verbs that prefer VP-attached PP to control the characteristics of the verbs for this present study. In total, 46 verbs were selected for the study. There were 12 original items from the second experiment of Rayner, Carlson and Frazier (1983) and 32 items previously used in the study of Altmann and Steedman (1988), while two additional new items (lift up with, find in) were selected for the verb bias rating measurement. To obtain ratings of verb bias, we generated incomplete sentences containing 46 verbs, and 10 raters (26-35 years of age, mean: 28), all native speakers of American English, were asked to complete each sentence (e.g., “The spy saw the cop with...”), individually. The sentences were presented using Microsoft PowerPoint. To measure the raters’ prompt responses of the PP types on verb, only one sentence was shown at a time and then, after the raters completed it, the next sentence was presented. Additionally, the raters were not allowed to return to previous sentences that they had already completed and were encouraged to generate the endings as rapidly as possible. (Please see Appendix A for the instructions given to raters and the items that were used for the verb bias rating.)

The generated endings were analyzed with regard to whether they reflected VP modification, NP modification, or other types of PP. Among the 46 items, only the verbs that were completed with a VP-attached PP by at least 7 raters were selected for this study as we assumed these verbs were biased to select VP-attached PP. Using this criterion, the following items from the Rayner, Carlson, and Frazier study (1983) were excluded: “read the book on the train,” read the news on Sundays”, “read in,” and “see on.” Please see Table 2.2. for the results of the verb bias rating.

Table 2.2. Verb bias rating results

<table>
<thead>
<tr>
<th>Item</th>
<th>Verb</th>
<th>Preposition</th>
<th>% of VP-bias</th>
<th>% of NP-bias</th>
<th>% of others</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>see</td>
<td>with</td>
<td>90</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>cut</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>paint</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>play</td>
<td>with</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>read</td>
<td>on (e.g. on the train)</td>
<td>50</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>read</td>
<td>on (e.g., on Sundays)</td>
<td>20</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>call</td>
<td>on</td>
<td>70</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>play</td>
<td>on</td>
<td>70</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>see</td>
<td>on</td>
<td>20</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>read</td>
<td>in</td>
<td>20</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>11</td>
<td>examine</td>
<td>with</td>
<td>70</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>12</td>
<td>hit</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13</td>
<td>blow open</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>change</td>
<td>with</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>lunge at</td>
<td>with</td>
<td>70</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>16</td>
<td>beat</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>play</td>
<td>with</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>study</td>
<td>with</td>
<td>70</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>19</td>
<td>knock over</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>wipe</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>21</td>
<td>cut through</td>
<td>with</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>22</td>
<td>break into</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>eat</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>24</td>
<td>repair</td>
<td>with</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>25</td>
<td>attack</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>26</td>
<td>cut</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>27</td>
<td>smash down</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>cut</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>29</td>
<td>heat</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>smash</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>31</td>
<td>tranquilize</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>32</td>
<td>kill</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>33</td>
<td>demolish</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>34</td>
<td>strip</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>35</td>
<td>examine</td>
<td>with</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>36</td>
<td>type up</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>37</td>
<td>open</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>38</td>
<td>clean</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>39</td>
<td>repair</td>
<td>with</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>break</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>41</td>
<td>make</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>42</td>
<td>cut down</td>
<td>with</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>43</td>
<td>watch</td>
<td>with</td>
<td>80</td>
<td>0</td>
<td>20</td>
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<tr>
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<td>paint</td>
<td>with</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>45</td>
<td>lift up</td>
<td>with</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>46</td>
<td>find</td>
<td>in</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Note.* The bolded items were excluded. Other than NP- or VP-attached PP were regarded as "others" in the table.
2.2.1.2. Constructing Stimuli for the Reading Experiment 1

(1) Target Items

The stimuli were designed to investigate whether older adults use verb bias information (e.g., biasing VP-attached PP) when resolving PP-attachment ambiguity as well as young adults do. The basic structure of a target item was a sentence containing a past tense verb that is biased to VP-attachment, followed by either an NP-attached PP (e.g., *The spy saw the cop with a revolver but the cop didn't see him.*) or a VP-attached PP (e.g., *The spy saw the cop with binoculars but the cop didn't see him.*)). The materials consisted of 24 pairs of sentences, with each base sentence containing either a VP- or an NP-attached PP, for a total of 48 target sentences. These 24 pairs of sentences contained 24 verbs selected from 42 in Table 2.2. As mentioned above, four verbs were excluded from the 12 original items used in the Rayner, Carlson and Frazier study. Among the targets, eight sets (eight unambiguous and eight ambiguous items) were modified based on the stimulus items from the second experiment in Rayner, Carlson, and Frazier (1983) and the remaining 16 sets (32 items) were newly created for this experiment.

The total of 48 target items were divided into two stimulus lists, each with 12 items interpreted as VP-attached PP and 12 items interpreted as NP-attached PP. Each base sentence was used only once in each list. Thus, if a verb (e.g., *see*) was used in the sentence which disambiguated VP-attached PP for List 1, the same verb was then used in an NP-attachment version for List 2, and vice versa. Each participant saw only one version of each pair, following a Latin-Square design. To confirm the participants’ sentence comprehension ability, one yes/no question per pair was created and the same question was used for both versions: one comprehension question (e.g., *Did the cop see the spy?*) for the NP- and VP-attachment versions containing the same verb. Half of the questions required an answer of “Yes” and the other half of the questions “No.” (See Appendix B for the target items and corresponding comprehension questions used in the Reading Experiment 1.)

(2) Filler Items

Along with the target items, 48 filler items were created. The fillers were structured similarly to the target items in that they contained past tense verbs, but did not contain VP- and NP-attachments. For comprehension questions, one yes/no question was created for each filler item with half of the answers
requiring “Yes” and the other half requiring “No,” following the same format that I had created for the target items. The stimuli were pseudo-randomly presented to the participants with the target items separated by two filler items. See Appendix C for the filler items and their corresponding comprehension questions used in the Reading Experiment 1.

2.2.1.3 Constructing Stimuli for Reading Experiment 2

(1) Target Items

The stimuli in the second reading experiment were designed to investigate the effect of referential context information on PP-attachment ambiguity resolution. Each target item consisted of four sentences: The first two sentences introduce a subject, a setting, and an event and then the third sentence provides information about one or two nouns that are potential referents for the fourth sentence. A sentence containing one potential referent was, “a safe which had a new lock and a strongbox which had an old lock” while a sentence containing two possible referents was, “a safe which had a new lock and a safe which had an old lock” The number of referents yields either a VP-supporting context (i.e., 1-Ref context) or an NP-supporting context (e.g., 2-referent context) in the fourth sentence. As mentioned previously, if only one referent is provided, due to the referential effect, the readers expect VP-attachment in the fourth sentence. If 2-referent is provided, however, the readers expect NP-attachment in the fourth sentence. Despite the expectations of the readers, the fourth sentences were constructed such that the PP was attached either to the NP to make the sentence temporarily ambiguous or the PP was transformed into an URC by replacing “with” with “which had” to make the sentence unambiguous (e.g., NP-attached PP: the safe with the new lock vs. URC: the safe which had the new lock).

There were 4 conditions: 1-referent context and ambiguous NP-attached PP, 2-referent context and ambiguous NP-attached PP, 1-referent context and unambiguous URC, and 2-referent context and unambiguous URC. After an introductory 1-referent context, since the 1-referent biases readers toward a VP-supporting context, VP-attachment is expected. However, instead of VP-attachment, presence of unexpected NP-attachment may make the sentence temporarily ambiguous. NP-attached PP in null context is not preferred as it results in temporary ambiguity. However, when 2-referent context is followed by NP-attachment, otherwise preferred and expected VP-attachment in null context may not be preferred and
expected. Rather, 2-referent context biases readers toward NP-supporting context so that NP-attachment is expected. I call this the 2-referent (NP-supporting context) ambiguous (NP-attachment) condition as the structure of NP-attached PP in isolation is more ambiguous than the structure of URC. As to the third and fourth conditions, I used URC that does not contain any types of PP-attachment to make the sentence syntactically unambiguous (third condition: 1-referent, unambiguous control corresponding to 1-referent and ambiguous condition); (fourth condition: 2-referent, unambiguous control corresponding to 2-referent and ambiguous condition). The whole paragraph items of the first two conditions were borrowed from the stimuli used in the study of Altmann and Steedman (1988), and the items making up the third and fourth conditions were created by the author. See Table 2.3. for the structure of the target items used in Reading Experiment 2.

Table 2.3. Structures of the target items for reading experiment 2

<table>
<thead>
<tr>
<th>Target Condition</th>
<th>Sentence Order</th>
<th>Characteristics</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-referent/ Ambiguous</td>
<td>Sentence 1</td>
<td>A character, Setting</td>
<td>A burglar broke into a bank carrying some dynamite.</td>
</tr>
<tr>
<td></td>
<td>Sentence 2</td>
<td>A plot</td>
<td>He planned to blow open a safe.</td>
</tr>
<tr>
<td></td>
<td>Sentence 3</td>
<td>1-referent</td>
<td>Once inside he saw that there was a safe which had a new lock and a strongbox which had an old lock.</td>
</tr>
<tr>
<td></td>
<td>Sentence 4</td>
<td>NP-attachment</td>
<td>The burglar blew open the safe with the new lock and made off with the loot.</td>
</tr>
<tr>
<td>2-referent/ Ambiguous</td>
<td>Sentence 1</td>
<td>A character, Setting</td>
<td>A burglar broke into a bank carrying some dynamite.</td>
</tr>
<tr>
<td></td>
<td>Sentence 2</td>
<td>A plot</td>
<td>He planned to blow open a safe.</td>
</tr>
<tr>
<td></td>
<td>Sentence 3</td>
<td>2-referent</td>
<td>Once inside he saw that there was a safe which had a new lock and a safe which had an old lock.</td>
</tr>
<tr>
<td></td>
<td>Sentence 4</td>
<td>NP-attachment</td>
<td>The burglar blew open the safe with the new lock and made off with the loot.</td>
</tr>
<tr>
<td>1-referent/ Unambiguous</td>
<td>Sentence 1</td>
<td>A character, Setting</td>
<td>A burglar broke into a bank carrying some dynamite.</td>
</tr>
<tr>
<td></td>
<td>Sentence 2</td>
<td>A plot</td>
<td>He planned to blow open a safe.</td>
</tr>
<tr>
<td></td>
<td>Sentence 3</td>
<td>1-referent</td>
<td>Once inside he saw that there was a safe which had a new lock and a strongbox which had an old lock.</td>
</tr>
<tr>
<td></td>
<td>Sentence 4</td>
<td>Unreduced relative clause</td>
<td>The burglar blew open the safe which had the new lock and made off with the loot.</td>
</tr>
<tr>
<td>2-referent/ Unambiguous</td>
<td>Sentence 1</td>
<td>A character, Setting</td>
<td>A burglar broke into a bank carrying some dynamite.</td>
</tr>
<tr>
<td></td>
<td>Sentence 2</td>
<td>A plot</td>
<td>He planned to blow open a safe.</td>
</tr>
<tr>
<td></td>
<td>Sentence 3</td>
<td>2-referent</td>
<td>Once inside he saw that there was a safe which had a new lock and a safe which had an old lock.</td>
</tr>
<tr>
<td></td>
<td>Sentence 4</td>
<td>Unreduced relative clause</td>
<td>The burglar blew open the safe which had the new lock and made off with the loot.</td>
</tr>
</tbody>
</table>

The stimulus materials consisted of 24 sets of paragraphs, each with four different versions (24 sets x 4 versions), which were divided into 4 experimental lists of 24 items each: six 1-referent/ambiguous,
six 2-referent/ambiguous items, six 1-referent/unambiguous, and six 2-referent/unambiguous items. Based on the Latin-Square design, the participants were randomly assigned to one of the four experimental lists so that they would not be exposed to the same item more than once. Twenty-four yes/no questions (one question per set) were created to confirm the participants’ comprehension abilities with half of the answers requiring “Yes” and the other half requiring “No.” See Appendix D for the target items and corresponding comprehension questions used in Reading Experiment 2.

(2) Filler Items

The structure of the filler items was similar to that of the target items: 48 items were created and each item consisted of four sentences and also had four versions. See Table 2.4. for the structure of filler items used in Reading Experiment 2. Across the four types, the first two sentences were about a subject, a setting, and an event. The differences were manipulated either in the third or fourth sentence. Filler type 1 resembled the 1-referent context in the third sentence, but neither PP-attachment nor URC were used at the fourth sentence. Filler type 2 also resembled the 1-referent context in the third sentence, but the fourth sentence contained a VP-attached PP. Filler type 3 was designed to resemble the 2-referent context in the third sentence, but the pronoun ‘them’ was used instead of mentioning one of the nouns from the third sentence in the fourth sentence, and VP-attachment and URC were not used. Filler type 4 contained only one object in the third sentence, and VP-/NP-attachments and URCs were not used in the fourth sentence. Forty-eight yes/no comprehension questions were created (one question per item) and half of the questions were designed to elicit the answer ‘yes’ and the other half were designed to elicit the answer ‘no.’ See Appendix E for the filler items and corresponding comprehension questions that used in Reading Experiment 2.
Table 2.4. Structures of the filler items for reading experiment 2

<table>
<thead>
<tr>
<th>Filler Condition</th>
<th>Sentence Order</th>
<th>Characteristics</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-referent/ Simple unambiguous (No PP-attachment &amp; No unreduced relative clause Condition)</td>
<td>Sentence 1</td>
<td>A character, Setting</td>
<td>A handyman went to the house carrying a screwdriver.</td>
</tr>
<tr>
<td></td>
<td>Sentence 2</td>
<td>A plot</td>
<td>He thought he would fix some small home appliances.</td>
</tr>
<tr>
<td></td>
<td>Sentence 3</td>
<td>1-referent</td>
<td>Once there, unexpectedly he was asked to repair a door which had a broken knob and a car which had a flat tire.</td>
</tr>
<tr>
<td></td>
<td>Sentence 4</td>
<td>No PP-attachment/ No unreduced relative clause</td>
<td>The handyman fixed the door first and it didn’t take long.</td>
</tr>
<tr>
<td>1-referent/ VP-attachment</td>
<td>Sentence 1</td>
<td>A character, Setting</td>
<td>A hunter carrying a shotgun was chasing a reindeer.</td>
</tr>
<tr>
<td></td>
<td>Sentence 2</td>
<td>A plot</td>
<td>He intended to sell its antlers on the black market.</td>
</tr>
<tr>
<td></td>
<td>Sentence 3</td>
<td>1-referent</td>
<td>Near the hillside of a mountain he found a reindeer which had large antlers and a wild pig which had very long and sharp fangs.</td>
</tr>
<tr>
<td></td>
<td>Sentence 4</td>
<td>VP-attachment</td>
<td>The hunter killed the reindeer with the shotgun and cut off its antlers very carefully.</td>
</tr>
<tr>
<td>2-referent/ Simple unambiguous</td>
<td>Sentence 1</td>
<td>A character, Setting</td>
<td>An actress wanted to look stunning on the stage.</td>
</tr>
<tr>
<td></td>
<td>Sentence 2</td>
<td>A plot</td>
<td>She asked her assistant to bring any accessories that she could wear on her dress.</td>
</tr>
<tr>
<td></td>
<td>Sentence 3</td>
<td>2-referent</td>
<td>Her assistant brought a brooch with a blue feather and a brooch with sparkling small diamonds.</td>
</tr>
<tr>
<td></td>
<td>Sentence 4</td>
<td>Pronoun 'them'</td>
<td>The actress yelled at her assistant as soon as she saw them because they were given by her recent ex-boyfriend.</td>
</tr>
<tr>
<td>1 object/ Simple unambiguous</td>
<td>Sentence 1</td>
<td>A character, Setting</td>
<td>A woman was jogging in Central Park in the morning.</td>
</tr>
<tr>
<td></td>
<td>Sentence 2</td>
<td>A plot</td>
<td>Suddenly, she felt nauseous and dizzy.</td>
</tr>
<tr>
<td></td>
<td>Sentence 3</td>
<td>1 object</td>
<td>She remembered a pill that was prescribed last month.</td>
</tr>
<tr>
<td></td>
<td>Sentence 4</td>
<td>No PP-attachment/ No unreduced relative clause</td>
<td>She took the pill first and then, called 911 to ask for help.</td>
</tr>
</tbody>
</table>

2.2.2. Measures of Cognitive Functions

To examine the contribution of age-related cognitive functions to syntactic ambiguity resolution and context use in aging, the following cognitive functions were measured: working memory capacity using the month ordering and digit ordering tasks (Kempler et al., 1998), inhibition skills based on the Stroop task (Stroop, 1935), shifting attention from WCST (Heaton et al., 1993), alternating attention and cognitive processing speed measured by the TMT (Spreen & Strauss, 1998).
2.3. Procedure

After completing the screening tests, participants were assigned to do either the neuropsychological tests or the reading experiments first. For example, if the reading experiments were administered first, then the neuropsychological tests were administered later. The assessment order of neuropsychological tests and reading experiments were random for the participants, but the order of the subtests used for cognitive measures (Working Memory: month ordering span → digit ordering span → the TMT: Part A → Part B → the Stroop Color and Word Test: color page → word - color page → the WCST) and the order of the two reading experiments (1st reading experiment → 2nd reading experiment) remained consistent across participants. See Figure 2.1. for a schematic representation of the experimental procedure.

During the two reading experiments, the participants’ word-by-word reading times were obtained using the moving window paradigm for self-paced word-by-word reading tasks (MacDonald, Just, & Carpenter, 1992). Unlike the stimulus items in Reading Experiment 1 in which an item consisted of just one sentence, the stimulus items in Reading Experiment 2 were presented sentence-by-sentence except for the fourth sentence, which was presented in a word-by-word format. This was done to minimize participant fatigue during reading.

![Figure 2.1. Schematic representation of the experimental procedure](image)
The participants pressed the space bar to begin a trial, after which rows of dashes appeared on the screen. A dash represented a character and rows of dashes represented the length of the sentences. After pressing the space bar again, the dashes representing the first word were simultaneously replaced by the characters in the first word. The participants pressed the button again to read the next word and so on. The previously shown word was replaced by a group of dashes again, so that the words were seen in a non-cumulative fashion.

After reading the last word, the button press displayed a yes/no comprehension question. After answering the question by pressing one of two keys marked “yes” and “no” on the keyboard, there were a short break time indicated by a “+” in the middle of the screen, and the participants were permitted to rest as long as they want before continuing. When they decided to proceed, they could do so by pressing a button. However, they were encouraged to finish the reading task without taking any breaks while the screen with dashes was displayed. Participants selected their preferred hand for the button-press response.

The participants were instructed to read the sentences silently at a comfortable pace and to read carefully in order to be able to answer the questions correctly. To control the stimulus presentation and to collect the participants’ reading time per word based on their button press and responses to comprehension questions, E-prime software (Psychology Software Tools Inc., Pittsburgh, USA) was used. The reading experiments lasted approximately 50 minutes. As mentioned in Section 1.3, this dissertation consists of 3 studies based on 2 reading experiments. See Figure 2.2 for the summary of reading experiments and studies. As the figure indicates, the participants experienced these three studies as two experiments with a break between them.
Figure 2.2. Scheme of Reading Experiments and Studies
3.1. Does PP-attachment resolution in null context change with aging?

The first study was conducted to examine whether PP-attachment resolution in null context changes with normal aging. To answer this question, the data from Reading Experiment 1 was analyzed. Both age groups read sentences containing either NP- or VP-attachment, and reading times per word were recorded. Using PP-attachment ambiguity was inspired by Rayner, Carlson and Frazier (1983) and including two age groups was modeled after Kemtes and Kemper (1997). Comprehension questions were presented at the end of each sentence to assess whether participants understood the sentence correctly. For each sentence, the last word within the PP-attachment disambiguated the actual syntactic structure of the sentence (e.g., *with a revolver*).

3.1.1. Hypotheses and Statistical Analysis

3.1.1.1. Hypotheses

Recall that although syntactic ambiguity resolution in aging has been observed in the comprehension of reduced relative clauses, no previous studies regarding PP-attachment ambiguity resolution in aging exist. Following Kemtes and Kemper (1997) and Kemper et al. (2004), I expected two main effects (Age and PP-attachment type), as well as an interaction between reading time for NP-attached PP and age. First, I expected age (young adults vs. older adults) to have a large effect on on-line and off-line sentence processing. I assumed older adults, as a group, would demonstrate lower accuracy for the yes/no comprehension question test than young adults during off-line sentence processing. During on-line processing, reading times of older adults would be longer than those of younger adults, regardless of PP-attachment types. In addition, I expected an interaction between PP-attachment and age; the reading time difference between VP-attachment and NP-attachment would be larger for older adults than young adults. During on-line sentence processing, both age groups would take longer to read NP-attached PPs (e.g., *with a revolver*) than VP-attached PPs (e.g., *with binoculars*). As expected, under the Minimal Attachment principle (Frazier, 1979), NP-attached PPs require 1 more node than VP-attached PPs (see *Figure 1.4*). As a result, both age groups should experience more difficulty with NP-attachment than VP-attachment.
Moreover, because of verb characteristics, verb frequency, and the probability of VP-attachment in language corpora, participants/readers might expect VP-attachment at the ambiguous points in both NP- and VP-attached PPs, as supported by the constraint-based model (Trueswell, Tanenhaus, & Garnsey, 1994). In contrast, NP-attachment, as a more complex alternative syntactic structure that is less frequently observed in the language corpora, would not be supported. Thus, the reconstruction of NP-attachment in sentences due to pragmatic plausibility would make both age groups experience a garden-path effect. Experimental data from previous findings of how young and older adults resolve main verb/RRC ambiguity prompted this hypothesis (e.g., Kemtes & Kemper, 1997; Kemper et al., 2004; Rayner et al., 1983).

3.1.1.2. Statistical Analysis

Comprehension Question Accuracy

To assess off-line sentence processing skills, the two age groups were compared based on total accuracy on the comprehension questions (regardless of PP-attachment types) and accuracy on each of the two types of target items (NP-attached PP vs. VP-attached PP) from Reading Experiment 1 using independent samples t-tests. Only the performance on the target items was analyzed.

Self-paced Reading Times

To investigate on-line sentence processing skills, the participants’ reading time in milliseconds (ms) per word from correctly answered items was recorded. Among all the words in the sentence, regions composed of 5 to 7 critical words containing NP- and VP-attachment ambiguity in each target item were selected for statistical analysis (e.g., The spy saw the cop with a revolver but the cop didn’t see him). Most target items contained the following words in the critical region in the following order: Article 1 – Noun 1- Preposition – Article 2 – Noun 2. However, some items contained either more or less words due to the different number of components in the NPs. For example, some NPs were combined with another noun or adjective (e.g., barn door or stained glass), while other nouns did not need articles (e.g., the cop with binoculars vs. the cop with a revolver). If the critical region consisted of 7 words, the items were presented in the following order: Article 1 – Adjective 1– Noun 1 – Preposition – Article 2 – Adjective 2 – Noun 2. See Table 3.1 for examples of critical word regions (i.e., W1 through W7) based on structural conditions.
Table 3.1. Reading experiment 1: Examples of 7 critical regions

<table>
<thead>
<tr>
<th>Syntactic Conditions</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
<th>W6</th>
<th>W7</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP-attachment ambiguity</td>
<td>the</td>
<td>-</td>
<td>cop</td>
<td>with</td>
<td>a</td>
<td>-</td>
<td>revolver</td>
</tr>
<tr>
<td></td>
<td>the</td>
<td>-</td>
<td>apple</td>
<td>with</td>
<td>-</td>
<td>plastic</td>
<td>knives</td>
</tr>
<tr>
<td></td>
<td>the</td>
<td>barn</td>
<td>door</td>
<td>with</td>
<td>the</td>
<td>stained</td>
<td>glass</td>
</tr>
<tr>
<td>VP-attachment ambiguity</td>
<td>the</td>
<td>-</td>
<td>cop</td>
<td>with</td>
<td>-</td>
<td>-</td>
<td>binoculars</td>
</tr>
<tr>
<td></td>
<td>the</td>
<td>-</td>
<td>apple</td>
<td>with</td>
<td>-</td>
<td>plastic</td>
<td>coating</td>
</tr>
<tr>
<td></td>
<td>the</td>
<td>barn</td>
<td>door</td>
<td>with</td>
<td>the</td>
<td>chain</td>
<td>saw</td>
</tr>
</tbody>
</table>

To adjust for differences in individual reading speed and string length (number of characters) per word, a regression analysis using the raw reading times was conducted. Combining all the words from fillers and target items, a regression equation was derived that could predict reading times from string length for each participant (Ferreira, & Clifton, 1986; Trueswell, Tanenhaus, & Garnsey, 1994). For the regression equation, only words in the critical regions were calculated. For each critical region, the predicted value from the participant’s regression equation was subtracted from the actual reading time for that item. For example, assume a word within the critical region consists of five characters, and a participant’s regression equation predicts that the reading time for a word 5 characters in length would be 100 ms. If the actual reading time for this region turned out to be 170 ms, the differential value between the predicted and actual times would then be calculated (170 ms - 100 ms) to obtain a residual reading time (RRT) of 70 ms. After calculating the RRT for all the critical regions for each participant, the group mean of each critical region was calculated. Raw reading time values that were more than three SD from the mean residual reading time for a region within a condition were excluded from the analysis.

After obtaining RRTs for the critical regions in young and older adults, I conducted a univariate General Linear Model (GLM) analysis, in which I simultaneously tested the main effects of age group (younger vs. older adults) and PP-attachment (NP-attachment vs. VP-attachment). RRT of the most crucial target word, W7, was a fixed factor during the analysis.
3.1.2. Results

**Comprehension Question Accuracy**

Unlike my prediction, no age-related differences were observed in off-line sentence processing skills, and PP-attachment ambiguity conditions did not affect accuracy between age groups. Total accuracy of older adults ($M = 95.04\%$, $SD = 5.43$) was comparable to that of young adults ($M = 96.69\%$, $SD = 3.88$) ($t(55) = -1.27$, $p > .05$). Accuracy differences between the NP-attached PP and VP-attached PP conditions were neither different between ($p > .05$) nor within age groups ($p > .05$). *Table 3.2.* shows accuracy between age groups and PP-attachment types.

**Table 3.2. Accuracy between age groups and PP-attachment types**

<table>
<thead>
<tr>
<th></th>
<th>Older Adults Mean (SD)</th>
<th>Young Adults Mean (SD)</th>
<th>$t$ ($df$)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP-attachment</td>
<td>95.46 (4.7)</td>
<td>96.88 (4.12)</td>
<td>-1.19 (55)</td>
<td>.24</td>
</tr>
<tr>
<td>VP-attachment</td>
<td>94.16 (7.4)</td>
<td>96.53 (5.98)</td>
<td>-1.06 (55)</td>
<td>.3</td>
</tr>
<tr>
<td>$t$ ($df$)</td>
<td>.85 (64)</td>
<td>.25 (46)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p$</td>
<td>.4</td>
<td>.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Self-paced Reading Times**

Raw reading times (ms) of the critical regions in the two PP-attachment types were significantly longer in older adults ($M = 8685$ ms, $SD = 2436$) than young adults ($M = 6056$ ms, $SD = 2406.2$) ($t(55) = 4.04$, $p < .05$). Based on regression analyses addressed in section 3.1.1., each participant’s RRTs at critical regions were computed. Then, the mean RRT in each critical region was computed. Recall that the number of words in the critical regions was not identical. Therefore, the mean RRT in each critical region was not based on the same number of items. See RRT trends of critical words across age groups and PP-attachment types in *Figures 3.1.* and *3.2.* In addition, *Figure 3.3.* presents the RRT of the target word W7.
Figure 3.1. Mean residual reading times of older adults across critical words in Study 1

<table>
<thead>
<tr>
<th></th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
<th>W6</th>
<th>W7</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP</td>
<td>-35.353</td>
<td>91.324</td>
<td>64.357</td>
<td>-36.584</td>
<td>-19.836</td>
<td>44.333</td>
<td>221.879</td>
</tr>
</tbody>
</table>

Note. NP = NP-attachment, VP = VP-attachment

Figure 3.2. Mean residual reading times of young adults across critical words in Study 1

<table>
<thead>
<tr>
<th></th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
<th>W6</th>
<th>W7</th>
</tr>
</thead>
<tbody>
<tr>
<td>VP</td>
<td>-4.108</td>
<td>81.142</td>
<td>44.895</td>
<td>26.397</td>
<td>-12.792</td>
<td>69.031</td>
<td>48.344</td>
</tr>
</tbody>
</table>

Note. NP = NP-attachment, VP = VP-attachment
At the most crucial point, W7, main effects of age group \((p < .05)\) and PP-attachment \((p < .05)\) were found; older adults processed W7 slower than younger adults, and NP-attachment required longer processing times than VP-attachment. There was also an interaction between age group and PP-attachment, indicating RRT of age group differed according to PP-attachment type. A summary of the GLM analysis is presented in Table 3.3.

Table 3.3. Study 1: A 2 x 2 univariate GLM analysis

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>3</td>
<td>328823.96</td>
<td>109607.99</td>
<td>5.52</td>
<td>.002**</td>
</tr>
<tr>
<td>Intercept</td>
<td>1</td>
<td>563258.87</td>
<td>563258.87</td>
<td>28.33</td>
<td>.001**</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>105141.18</td>
<td>105141.18</td>
<td>5.29</td>
<td>.024*</td>
</tr>
<tr>
<td>PP-attachment</td>
<td>1</td>
<td>105952.29</td>
<td>105952.29</td>
<td>5.33</td>
<td>.023*</td>
</tr>
<tr>
<td>Age x PP-attachment</td>
<td>1</td>
<td>108410.94</td>
<td>108410.94</td>
<td>5.45</td>
<td>.022*</td>
</tr>
<tr>
<td>Error</td>
<td>92</td>
<td>1828919.67</td>
<td>19879.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>2742479.79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>95</td>
<td>2157743.63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. Significant findings are bolded: ** for \(p < .01\), * for \(p < .05\)*

As the interaction was significant, it was necessary to apply statistical analysis to identify the source of the interaction. An independent samples t-test showed that young adults’ RRTs of W7 for NP-attachment \((M = 43.16, SD = 116.56)\) and those for VP-attachment \((M = 43.95, SD = 107.49)\) were not significantly different \((t(23) = .20, p = .89)\). In contrast, older adults’ RRTs of W7 for NP-attachment \((M = 176.67, SD =\)
and those for VP-attachment ($M = 42.9$, $SD = 112.26$) were significantly different ($t(25) = 2.9$, $p = .02$). From this, it can be concluded that a main effect of PP-attachment resulted from older adults’ different processing between NP-attachment and VP-attachment, and that this disproportional difference resulted in the interaction between age group and PP-attachment.

3.2. Which cognitive functions are related to better PP-attachment ambiguity resolution?

3.2.1. Hypotheses and Statistical Analysis

I assumed that processing time of the most critical word (W7) in the NP-attachment condition would demonstrate the participants’ ability to overcome the garden-path effect. I also expected older adults to have poorer cognitive functions than young adults. Therefore, I hypothesized that the individual’s different ability to overcome garden-path effects would be correlated with different degrees of various cognitive functions in addition to age.

To find out which cognitive factors are related to the garden-path effect and age, cognitive functions were measured using neuropsychological tests. These cognitive functions and their corresponding neuropsychological tests, along with what items were measured and the test abbreviations used for correlation and regression analyses, are listed in Table 3.4.

### Table 3.4. Cognitive functions and corresponding neuropsychological tests

<table>
<thead>
<tr>
<th>Cognitive Function</th>
<th>Test</th>
<th>Measure</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working memory capacity</td>
<td>Month ordering task</td>
<td>Month span</td>
<td>WM_M</td>
</tr>
<tr>
<td></td>
<td>Digit ordering task</td>
<td>Digit span</td>
<td>WM_D</td>
</tr>
<tr>
<td>Inhibition</td>
<td>Stroop task</td>
<td>Derived performance time</td>
<td>Stroop</td>
</tr>
<tr>
<td></td>
<td></td>
<td>difference between the word</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>reading and color–labeling</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>conditions</td>
<td></td>
</tr>
<tr>
<td>Shifting attention</td>
<td>Wisconsin Card Sorting Test</td>
<td>a. Number of target responses</td>
<td>WCST_T</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b. Percentage of perseverative</td>
<td>WCST_P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>errors</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>c. Number of completed</td>
<td>WCST_C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>categories</td>
<td></td>
</tr>
<tr>
<td>Alternating attention</td>
<td>Trail Making Test</td>
<td>derived performance time</td>
<td>TMT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>difference between Part B and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part A</td>
<td></td>
</tr>
<tr>
<td>Cognitive processing</td>
<td>Trail Making Test: Part A</td>
<td>Performance time</td>
<td>TMT_A</td>
</tr>
</tbody>
</table>

A correlation analysis was conducted using both age groups’ RRTs of W7 in the NP-attachment condition, the participants’ ages, and working memory capacity (WM_M, WM_D), inhibition (Stroop), shifting
attention (WCST_T, WCST_P, WCST_C), alternating attention (TMT), and cognitive processing speed (TMT_A).

3.2.2. Results

Except for digit span from the digit ordering task, the total number of correct responses from the WCST, and derived time difference between Part A and Part B from the TMT, the following measures showed a correlation with age: working memory capacity from the month ordering task ($r(48) = .34, p < .05$), inhibition from the Stroop task ($r(48) = .59, p < .01$), shifting attention represented by both percentage of perseverative errors ($r(48) = .49, p < .01$) and number of completed categories ($r(48) = .42, p < .01$) from the WCST, and cognitive processing speed from the TMT-A ($r(48) = .36, p < .05$). This indicates that significant declines in cognitive functions were observed in older adults compared to the younger adults across four cognitive functions, but not for alternating attention based on the TMT.

A main effect of age group, observed in section 3.1.3, was replicated in the correlation analysis results: RRT of W7 in the NP-attachment condition was correlated with age ($r(48) = .38, p < .01$). Among cognitive functions, inhibition ($r(48) = .32, p < .05$) from the Stroop task and shifting attention ($r(48) = .35, p < .05$), measured by the percentage of perseverative error from the WCST, were positively correlated with reading times for NP-attachment ambiguity resolution; poorer inhibition and shifting attention skills based on the Stroop and the WCST-P, respectively, were linked to slower reading times at W7 in the NP-attachment condition. To summarize, along with age, effects of inhibition and shifting attention on NP-attachment ambiguity resolution were observed. See Table 3.5. for the results of the correlation analyses.
Table 3.5. Correlation among ability resolving PP-attachment ambiguity, cognitive functions and age

<table>
<thead>
<tr>
<th></th>
<th>NP</th>
<th>WM_M</th>
<th>WM_D</th>
<th>Stroop</th>
<th>WCST_T</th>
<th>WCST_P</th>
<th>WCST_C</th>
<th>TMT</th>
<th>TMT_A</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WM_M</td>
<td>-.15</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WM_D</td>
<td>.02</td>
<td>.67**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroop</td>
<td>.32*</td>
<td>-.39*</td>
<td>-.22</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCST_T</td>
<td>.1</td>
<td>.12</td>
<td>.22</td>
<td>.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCST_P</td>
<td>.35**</td>
<td>-.29*</td>
<td>-.22</td>
<td>.33*</td>
<td>-.06</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WCST_C</td>
<td>-.21</td>
<td>.29*</td>
<td>.16</td>
<td>-.39**</td>
<td>.13</td>
<td>-.74**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMT</td>
<td>.04</td>
<td>-.12</td>
<td>-.15</td>
<td>.24</td>
<td>.05</td>
<td>.17</td>
<td>-.05</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMT_A</td>
<td>.16</td>
<td>-.37**</td>
<td>-.16</td>
<td>.23</td>
<td>-.14</td>
<td>.47**</td>
<td>-.48**</td>
<td>-.32*</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>AGE</td>
<td>.38**</td>
<td>-.34*</td>
<td>-.14</td>
<td>.59**</td>
<td>-.09</td>
<td>.49**</td>
<td>-.42**</td>
<td>.16</td>
<td>.36*</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note.* Significant findings are bolded: **for p < .01, *for p < .05

NP = RRT of the most critical word in NP-attachment

3.3. Discussion

To examine whether PP-attachment resolution in null context changes with aging, NP-attached PP (less preferred) and VP-attached PP (more preferred) were presented to young and older participants. Both age groups experienced temporary syntactic ambiguity in the less preferred syntactic condition; processing of NP-attached PP was slower than that of VP-attached PP. At the most crucial point (W7), where syntactic disambiguation occurs based on pragmatic/semantic plausibility information (e.g., *the cop with a revolver vs. the cop with binoculars*), slower processing speed in older adults was observed. Moreover, the degree of the garden-path effect was disproportionally different between young and older adults (i.e., there was an interaction). The results of Study 1 indicate that older adults process more slowly than young adults in general and are less efficient in overcoming temporary syntactic ambiguity when compared with young adults, requiring disproportionately longer processing times at NP-attachment.

Preference for VP-attached PP was predicted by the garden-path model (Frazier, 1979), as it necessitates fewer nodes during syntactic processing when compared with NP-attached PP. Unlike the results of Rayner, Carlson, and Frazier (1983) which showed young adults’ VP-attachment preference, the results of Study 1 showed that young adults’ less sensitivity to syntactic constraints. According to Van Gompel, Pickering, & Traxler (2001), information differentiating NP- from VP-attachment is based on the
semantic and pragmatic information provided by the most critical word and semantic information has a weaker influence than syntactic information. Therefore, I assume that as young adults use subtle semantic and pragmatic information promptly during PP-attachment ambiguity resolution, the self-paced reading paradigm which I used in this study may be less sensitive to detect young adults’ PP-attachment ambiguity resolution when compared with the eye-tracking paradigm used in Rayner, Carlson, and Frazier (1983). Additionally, it seems that newly created experimental stimuli might have not been challenging enough for younger adults to make them experience PP-attachment ambiguity in the current study, although verbs in the experimental stimuli were biased to VP-attached PP based on the results of the verb selection test. Note that only 8 out of 24 experimental stimuli items were borrowed from Rayner, Carlson, and Frazier (1983). However, age-related differences in degrees of difficulty in overcoming temporary ambiguity, as represented by increased reading time (e.g., Kemtes & Kemper, 1997) in the less preferred syntactic ambiguity condition, were observed in the current study; older adults initially expected that PP would be attached to VP in the NP-attachment condition, but then reanalyzed their syntactic interpretation from VP-attachment to NP-attachment at the point of disambiguation by integrating knowledge of syntax and pragmatic plausibility.

Older adults exhibited poorer cognitive functions than young adults in working memory capacity, inhibition, shifting attention, and cognitive processing speed, but not alternate attention skills, which were comparable for the two age groups. Ability overcoming temporary syntactic ambiguity (seen as processing speed at W7 in the NP-attached PP condition) was correlated with age, inhibition, and shifting attention skills; people who were older or had poorer shifting attention and/or inhibition skills required longer processing times to overcome temporary syntactic ambiguity in the null context. In terms of age, it should be noted that as age was found to be correlated with several cognitive functions. Therefore, “age” as a variable should be regarded as representing a combination of various cognitive functions, which were ultimately found to be correlated with inefficient NP-attachment ambiguity resolution. As reported in the studies of Mendelsohn (2002) and January, Trueswell, and Thompson-Schill (2008), roles of shifting attention and inhibition on temporary syntactic ambiguity resolution were also observed in the current study; people with better shifting attention and inhibition skills tended to deal with temporary syntactic ambiguity more efficiently.
In contrast, a role of working memory capacity on temporary syntactic ambiguity resolution was not observed in Study 1, unlike in the study of Just and Carpenter (1992), where an effect of working memory capacity on temporary syntactic ambiguity resolution was highlighted. In their study, people with greater working memory capacity processed sentences more slowly than those with less working memory capacity at the disambiguation point, while showing a higher accuracy rate for the comprehension questions. The importance of working memory capacity on temporary syntactic ambiguity resolution was also observed by Kemper and Kemtes (1997), but the results were the opposite; older adults who had smaller working memory capacity showed slower processing at the disambiguation point than young adults who had greater working memory capacity. Results of the current study, however, support neither Just and Carpenter nor Kemper and Kemtes’ findings. The results of Study 1 showed no evidence of a contribution of differential working memory capacity between young and older adults in PP-attachment ambiguity resolution; young adults who had better working memory capacity did not require longer processing times at the disambiguation point, and their accuracy rate for the yes/no comprehension questions did not differ from that of older adults.

Finding no influence of working memory capacity on temporary syntactic ambiguity resolution in this study may have been due to the characteristics of the experimental stimuli, which in this case was PP-attachment ambiguity. According to the capacity-constrained comprehension theory (Just & Carpenter, 1992), when language tasks carry a small processing load, comparable language processing skills can be observed between young and older adults, despite working memory capacity differences. In addition, complex syntactic structures (which may require greater demands on working memory) can cause a decline in older adults’ sentence processing skills, as older adults generally have decreased cognitive capacity. In contrast, simple syntactic structures may not exceed working memory capacity, and overall performance skills may not be affected by different working memory capacities between young and older adults (Kemtes & Kemper, 1997). Unlike main verb vs. RRC ambiguity, PP-attachment ambiguity may not have been complex enough to overload working memory capacity for either age group, although it was confirmed that processing of NP-attached PP proved more difficult than VP-attached PP.

In summary, older adults processed PP-attachment ambiguity resolution more slowly than young adults across the board. In addition, processing patterns (e.g., preference for VP-attachment, proportional...
processing time differences between NP-attachment and VP-attachment) were different between age groups. Age, inhibition, and shifting attention skills were correlated with the ability to overcome temporary syntactic ambiguity (NP-attachment). In Study 1, the baseline performance of NP- and VP-attachment ambiguity resolution in both young and older adults was established. Following Study 1, in Study 2A, the effect of supporting context during PP-attachment ambiguity resolution in both age groups was investigated through manipulating the presence and absence of a preceding context during the resolution of the less preferred syntactic structure, NP-attached PP.
Chapter 4: Study 2A Use of referential context during PP-attachment ambiguity: Use of NP-supporting context during NP-attachment resolution

4.1. Does the ability to use a 2-referent context during NP-attachment resolution change with aging?

4.1.1. Hypotheses and Statistical Analysis

4.1.1.1. Hypotheses

Study 2A examined the effect of a 2-referent context (with the temporarily ambiguous PP attached to the NP) in relation to aging to find out whether older adults can use context to resolve syntactic ambiguity as well as young adults. According to the Constrained-based model, when a 2-referent context precedes a PP that would be semantically disambiguated toward NP-attachment, readers may avoid the garden-path effect altogether, as the 2-referent context promotes the activation of NP-attachment and deactivates VP-attachment immediately. In contrast, if a 2-referent context does not precede the phrase, NP-attachment in isolation is not preferred and therefore less expected.

I expected the presence of context to substantially affect resolution; if NP-attached PP is presented in a 2-referent context, both age groups would process the phrase faster than NP-attached PP in the null context. As observed in young adults (e.g., Altmann & Steedman, 1998), although NP-attached PP is neither the preferred nor expected syntactic structure in general, if it is located within a referential context that supports NP-attachment (e.g., a 2-referent context: a map which had an appalling tear and a map which seemed in perfect condition), older adults will benefit during NP-attachment ambiguity resolution. I also expected that, consistent with the results of Study 1, older adults would present longer reading times for the critical region than young adults, regardless of the presence of referential context (i.e., a main effect of age group). In addition, as observed in Thornton (2009), context use would be more beneficial to older adults, i.e., I predicted an interaction between presence of referential context and age group; older adults would depend on context more than young adults, showing a greater difference in reading times between NP-attachment with and without context when compared with young adults.
4.1.1.2. Statistical Analysis

Comprehension Question Accuracy

To assess off-line sentence processing skills, comprehension question accuracy of NP-attached PP without context (partial data from Reading Experiment 1) and comprehension question accuracy of NP-attached PP with a 2-referent context (partial data set from Reading Experiment 2) were analyzed. Two age groups were compared, based on total accuracy in answering comprehension questions and accuracy on two types of target items based on presence of context (NP-attached PPs without context vs. NP-attached PPs with a 2-referent context), via independent samples and paired samples t-tests.

Self-paced Reading Times

A 2 x 2 univariate analysis using a GLM was performed to evaluate the effects of age group (younger and older adults) and context (presence and absence of context) on NP-attachment ambiguity resolution, focusing on RRT of the most crucial point of the sentence, W7. As in Study 1, the last word of the critical word region (W7) is assumed to be the crucial point at which contextual use can be detected; when there is an absence of context, processing time increases at W7 as reanalysis is required from VP-attachment to NP-attachment while resolving NP-attached PP. In contrast, when 2-referent context (which supports an NP-attachment interpretation) precedes NP-attached PP, increasing of processing time at W7 will not be observed if this context is efficiently used.

Based on regression analyses addressed in section 3.1.1., a trend of RRT changes was also calculated. There were seven critical regions in the NP-attachment in null context (Reading Experiment 1) versus six critical regions in the NP-attachment within a 2-referent context (Reading Experiment 2). To compare the corresponding word regions, then, W2 from Reading Experiment 1 was excluded for data analysis, while Article 1 – Noun 1 – Preposition – Article 2 – Adjective 2 – Noun 2 were included. As a result, W1 (Article 1) – W3 (Noun 1) – W4 (Preposition) – W5 (Article 2) – W6 (Adjective 2) – W7 (Noun 2) from Reading Experiment 1 were compared with W1 (Article 1) – W2 (Noun 1) – W3 (Preposition) – W5 (Article 2) – W6 (Adjective) – W7 (Noun 2) from Reading Experiment 2. As an example, in the presence of a 2-referent context, a preamble preceded the target sentence, and then a target sentence followed. Again, critical words that were used for data analysis were from the target sentences. See preamble (16) and target sentence (17). In the null context, a preamble providing referent context information was not required;
thus, only the target sentence was presented. Critical words used for data analysis are underlined in sentence (17).

(16) A burglar broke into a bank carrying some dynamite. He planned to blow open a safe.
Once inside he saw that there was a safe which had a new lock and a safe which had an old lock. (2 referents: a safe with a new lock and a safe with an old lock)
(17) The burglar blew open the safe with the new lock and made off with the loot.

4.1.2. Results

Comprehension Question Accuracy

Both age groups showed comparable total accuracy (t(55) = -1.49, p > .05). A benefit of referential context was not observed in comprehension accuracy when comparing NP-attached PP in the null and 2-referent contexts (t(55) = .71, p > .05); comprehension accuracy was comparable between the two conditions. Regardless of whether the NP-supporting 2-referent context was present, comprehension accuracy between age groups (null context: t(55) = -1.19, p > .05, 2-referent context: t(55) = -.94, p > .05) and within age groups (older adults: t(32) = .51, p > .05, young adults: t(23) = .82, p > .05) was not affected.

See accuracy data of Study 2A in Table 4.1.

Table 4.1. Comprehension accuracy of NP-attachment ambiguity without/ with 2-referent context

<table>
<thead>
<tr>
<th></th>
<th>Older Adults Mean(SD)</th>
<th>Young Adults Mean (SD)</th>
<th>t (df)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Total accuracy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Accuracy</td>
<td>96.80 (4.31)</td>
<td>97.99 (3.75)</td>
<td>-1.49 (55)</td>
<td>.14</td>
</tr>
<tr>
<td>(2) Accuracy between NP-attachment in null context and in 2-referent context (based on presence of context)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>95.87 (4.71)</td>
<td>94.91 (10.10)</td>
<td>.71 (55)</td>
<td>.48</td>
</tr>
<tr>
<td>(3) Accuracy between age group and presence of context</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Older Adults Mean(SD)</td>
<td>Young Adults Mean (SD)</td>
<td>t (df)</td>
<td>p</td>
</tr>
<tr>
<td>Null Context</td>
<td>95.46 (4.70)</td>
<td>96.88 (4.12)</td>
<td>-1.19 (55)</td>
<td>.24</td>
</tr>
<tr>
<td>2-referent Context</td>
<td>93.84 (11.76)</td>
<td>96.39 (7.22)</td>
<td>-.94 (55)</td>
<td>.06</td>
</tr>
<tr>
<td>t (df)</td>
<td>.68 (32)</td>
<td>.23 (23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>.51</td>
<td>.82</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Self-paced Reading Times**

Based on regression analyses, each participant’s RRTs at critical regions were computed. *Figures 4.1 and 4.2.* show the average RRT for critical words with and without context in the two age groups. In addition, *Figure 4.3.* focuses on RRT of W7 across age groups and presence of context.

![Figure 4.1](image1.png)

**Figure 4.1.** Mean residual reading times of older adults across critical words in Study 2A

<table>
<thead>
<tr>
<th>W1</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
<th>W6</th>
<th>W7</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP</td>
<td>-35.353</td>
<td>64.357</td>
<td>-36.584</td>
<td>-19.836</td>
<td>44.333</td>
</tr>
<tr>
<td>2NP</td>
<td>-63.363</td>
<td>-27.605</td>
<td>-67.424</td>
<td>-69.797</td>
<td>29.734</td>
</tr>
</tbody>
</table>

**Note.** NP = NP-attached PP in null context, 2NP = NP-attached PP in 2-referent context

![Figure 4.2](image2.png)

**Figure 4.2.** Mean residual reading times of young adults across critical words in Study 2A

<table>
<thead>
<tr>
<th>W1</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
<th>W6</th>
<th>W7</th>
</tr>
</thead>
</table>
At W7, main effects of age group ($p < .01$) and context presence ($p < .01$) were observed. Older adults required longer processing times than young adults, and both age groups were able to utilize context in overcoming the garden-path effect. However, contrary to my prediction, no interaction between age group and context presence was observed ($p > .05$); magnitude of the garden-path effect between NP-attachment in isolation and NP-attachment in referential context was comparable for both age groups. A summary of the GLM analysis can be found in Table 4.2.

Table 4.2. *Study 2A: A 2 x 2 univariate GLM analysis*

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>3</td>
<td>453788.47</td>
<td>151262.82</td>
<td>9.76</td>
<td>.001**</td>
</tr>
<tr>
<td>Intercept</td>
<td>1</td>
<td>395262.89</td>
<td>395262.89</td>
<td>25.49</td>
<td>.001**</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>205950.30</td>
<td>205950.30</td>
<td>13.28</td>
<td>.001**</td>
</tr>
<tr>
<td>Context Presence</td>
<td>1</td>
<td>200085.79</td>
<td>200085.79</td>
<td>12.90</td>
<td>.001**</td>
</tr>
<tr>
<td>Age x Context Presence</td>
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<td>39878.29</td>
<td>39878.29</td>
<td>2.57</td>
<td>.112</td>
</tr>
<tr>
<td>Error</td>
<td>92</td>
<td>1426541.52</td>
<td>15505.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>96</td>
<td>2300456.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>95</td>
<td>1880329.99</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Significant results are bolded: ** for $p < .01$
4.2. Which cognitive functions contribute to use of NP-supporting context during NP-attachment resolution?

4.2.1. Hypotheses and Statistical Analysis

Although older adults required a longer processing time at W7, both age groups benefited from the presence of context during temporary syntactic ambiguity resolution. Therefore, I hypothesized that ability utilizing contextual information that supports temporary syntactic ambiguity resolution would be correlated with several types of cognitive functions, along with age.

To investigate which cognitive functions were related to the ability of utilizing supporting context during PP-attachment ambiguity resolution, correlation analyses were conducted using the participants’ ages, RRTs of W7 in a 2-referent context, working memory capacity (WM_M, WM_D), inhibition (Stroop), shifting attention (WCST_T, WCST_P, WCST_C), alternating attention(TMT), and cognitive processing speed (TMT_A).

4.2.2. Results

A main effect of age (previously observed in section 4.1.3) was replicated in the correlation analysis results: RRT of W7 in the 2-referent context was correlated with age (r(48) = .34, p < .05). Among cognitive functions, only alternating attention (measured by the derived performance time difference between Parts B and A of the TMT) was correlated with RRT of W7 in a 2-referent context (r(48) = .30, p < .05), indicating efficiency in utilizing NP-supporting context during temporary syntactic ambiguity resolution. The results indicate increased age and poor alternating attention skills are related to inefficient utilization of NP-supporting context during NP-attachment ambiguity resolution, represented by longer processing times at W7. See Table 4.3. for results of the correlation analysis.
4.3. Discussion

To examine whether the ability to use context during PP-attachment ambiguity resolution changes with aging, this study manipulated the presence or absence of context that preceded sentences containing PP modifying NP. Specifically, the study attempted to answer the question of whether the presence of context allowed participants to avoid a garden-path effect in both young and older adults. At the point of temporary syntactic disambiguation (W7), both age groups utilized supporting context, exhibiting faster processing times when context was present. The benefit of context was comparable for both age groups. However, the processing of older adults was slower than that of young adults, regardless of whether context was present, as previously seen with the null context condition (Study 1). In the null context condition, the verb within the sentence yielded a bias toward a VP-attachment interpretation that was reanalyzed into a NP-attachment due to pragmatic/semantic knowledge. In contrast, when a context introducing 2 referents preceded sentences containing NP-attached PP, both age groups were able to take advantage of the supporting context, resulting in faster processing times in favor of the NP-attached PP. Although older adults exhibited slower processing times, the processing itself was not qualitatively different from that of young adults in terms of using context.
In the literature, although the ability to use context has been observed across a number of age groups, the question of whether young and older adults are equally efficient at using context has remained controversial, as mentioned in section 1.2.2. The current study shows that older adults have the ability to use context, as Federmeier and Kutas (2005) reported. Moreover, older adults utilized context as efficiently as young adults, exhibiting faster processing times in the presence of context, compared with processing times in its absence during NP-attachment ambiguity resolution. While no interaction between age groups and types of context (presence vs. absence) was observed in the current study, no direct comparisons within the literature are possible due to the absence of previous studies examining the effect of context presence and absence on syntactic processing. Based on reading time results, quantitative processing was different between age groups as seen in Study 1, while qualitative processing was not.

When examining which cognitive functions are related to the ability to utilize supporting context, I observed that alternating attention skills (measured in derived performance time differences between Parts B and A on the TMT) correlated with NP-attachment ambiguity resolution in supporting context, along with age. From this, it can be concluded that people who are younger and/or have better alternating attention skills benefit more from contextual information when resolving temporary syntactic ambiguity than their counterparts.

In summary, Study 2A reveals the remarkable finding that older adults appear to be able to override their cognitive disadvantages when using context during NP-attachment ambiguity resolution, resulting in comparable abilities between both age groups. After Study 2A confirmed that older adults were able to utilize context in overcoming temporary syntactic ambiguity, Study 2B was conducted to examine efficiency of context use by young and older adults, comparing processing times of NP-attached PP and URC when preceded by either supporting or conflicting contexts.
Chapter 5: Study 2B  PP-attachment ambiguity resolution in referential context: Overcoming conflicting context during NP-attachment resolution

5.1. Does efficiency of referential context use during PP-attachment resolution change with aging?

5.1.1. Hypotheses and Statistical Analysis

5.1.1.1. Hypotheses

Based on Reading Experiment 2, Study 2B investigated how efficiently young and older adults use context during temporary ambiguity sentence processing. Specifically, the study examined whether the existence of a NP-supporting 2-referent context assists readers in overcoming a garden-path effect by processing NP-attachments as quickly as URCs. Study 2B also looked at whether, by processing NP-attachment as fast as URCs, readers are able to overcome conflicting context; specifically, in the form of a VP-supporting 1-referent context that conflicts with a subsequent NP-attachment.

In line with Study 2A, I expected that both age groups would be able to efficiently use referential context in processing syntactically ambiguous PP, as Trueswell et al. (1999) and Thornton (2009) reported. When the context favors VP-attachment interpretation over the NP-attachment, i.e., in 1-referent contexts, both age groups would require longer processing times for the subsequent NP-attachment (VP-supporting context, NP disambiguation), as compared to the 2-referent contexts preceding ambiguous NP-attachment (NP-supporting context, NP disambiguation). Processing times of URCs in 1- and 2-referent contexts, however, would be comparable to those of NP-attached PPs in 2-referent contexts. In the 2-referent context condition supporting NP-attachment, I hypothesized that participants would efficiently avoid the garden-path effect (despite NP-attached PPs being syntactically ambiguous), and that processing times would be as fast as those for URCs (which are syntactically unambiguous). However, as observed in Thornton (2009), in the presence of conflicting context, I hypothesized older adults would be more confused by the preceding referential context than young adults. Therefore, the magnitude of difference between NP-attachment in the 1-referent context and NP-attachment in the 2-referent context would be greater for older than for young adults.
5.1.2. Statistical Analysis

Comprehension Question Accuracy

To assess off-line sentence processing skills, total accuracy of comprehension questions and accuracy for each of the four experimental conditions (two referential contexts [1-referent vs. 2-referent] and two ambiguity-based syntax types [syntactically ambiguous NP-attached PP vs. syntactically unambiguous URC]) were analyzed between age groups using independent samples t-tests. Only performance on target items was used for statistical analysis.

Self-paced Reading Times

For statistical analysis, 6 critical word regions within ambiguous NP-attached PP and 7 critical word regions within unambiguous URC were selected from the target items in Reading Experiment 2. Critical word regions in the ambiguous NP-attached PP condition consisted of Article 1 – Noun 1 – Preposition – Article 2 – Adjective – Noun 2. Critical word regions in the unambiguous URC condition consisted of Article 1 – Noun 1 – which – had – Article 2 – Adjective - Noun 2. Because the preposition that was used in the ambiguous condition was replaced by “which had” in the unambiguous condition, the number of critical words differed between the two conditions. Examples of critical regions in Study 2B are provided in Table 5.1.

Table 5.1. Reading Experiment 2: Examples of Critical Regions

<table>
<thead>
<tr>
<th>Referent Conditions</th>
<th>Ambiguity Conditions</th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
<th>W6</th>
<th>W7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Referent</td>
<td>Ambiguous NP-attached PP</td>
<td>the</td>
<td>safe</td>
<td>with</td>
<td>–</td>
<td>the</td>
<td>new</td>
<td>lock</td>
</tr>
<tr>
<td>2-Referent</td>
<td>Ambiguous NP-attached PP</td>
<td>the</td>
<td>safe</td>
<td>with</td>
<td>–</td>
<td>the</td>
<td>new</td>
<td>lock</td>
</tr>
<tr>
<td>1-Referent</td>
<td>Unambiguous URC</td>
<td>the</td>
<td>safe</td>
<td>which</td>
<td>had</td>
<td>the</td>
<td>new</td>
<td>lock</td>
</tr>
<tr>
<td>2-Referent</td>
<td>Unambiguous URC</td>
<td>the</td>
<td>safe</td>
<td>which</td>
<td>had</td>
<td>the</td>
<td>new</td>
<td>lock</td>
</tr>
</tbody>
</table>

Individual RRTs were also calculated using the same method as in the previous two studies. After obtaining RRTs of critical word regions, a 2 x 2 x 2 multivariate GLM analysis was conducted. Three independent variables were included in the analysis: age group (younger and older adults), syntactic ambiguity type (syntactically ambiguous NP-attached PP and syntactically unambiguous URC), and referential context (1-referent and 2-referent), with RRT of W7 as a fixed factor. For each critical word region, the most important component was the last word, W7. As mentioned in section 3.1.1., W7 was
assumed to be the specific location where participants experienced a mismatch between their initial syntactic interpretation (created by the referential context) and the actual syntactic representation, where the garden-path effect would be nullified. W7 was therefore regarded as a sensitive region for observing dependence on referential context.

5.1.2. Results

Comprehension Question Accuracy

Off-line sentence processing skills showed no differences between or within age groups. Total accuracy between young and older adults was comparable ($t(55) = -1.08$, $p > .05$). In addition, no effects of syntactic type or referential context on accuracy were observed ($p > .05$). Table 5.2. shows that older adults performed as well as young adults during off-line sentence processing.

Table 5.2. Off-line processing of referent context

(1) Total Accuracy

<table>
<thead>
<tr>
<th></th>
<th>Older Adults Mean(SD)</th>
<th>Young Adults Mean (SD)</th>
<th>$t$ (df)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Accuracy</td>
<td>94.63 (7.42)</td>
<td>96.50 (4.55)</td>
<td>-1.08 (55)</td>
<td>.28</td>
</tr>
</tbody>
</table>

(2) Accuracy between Age Groups and Ambiguity

<table>
<thead>
<tr>
<th></th>
<th>Older Adults Mean(SD)</th>
<th>Young Adults Mean (SD)</th>
<th>$t$ (df)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambiguous Condition</td>
<td>93.62 (9.11)</td>
<td>96.50 (5.48)</td>
<td>1.38 (55)</td>
<td>.17</td>
</tr>
<tr>
<td>Unambiguous Condition</td>
<td>95.66 (7.08)</td>
<td>96.63 (5.45)</td>
<td>.48 (55)</td>
<td>.63</td>
</tr>
<tr>
<td>$t$ (df)</td>
<td>-.99 (32)</td>
<td>-.02 (23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p$</td>
<td>.33</td>
<td>.98</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(3) Accuracy between Age Groups and Context Types

<table>
<thead>
<tr>
<th></th>
<th>Older Adults Mean(SD)</th>
<th>Young Adults Mean (SD)</th>
<th>$t$ (df)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-referent</td>
<td>93.39 (9.77)</td>
<td>96.18 (5.42)</td>
<td>1.26 (55)</td>
<td>.21</td>
</tr>
<tr>
<td>2-referent</td>
<td>95.89 (6.35)</td>
<td>96.81 (5.39)</td>
<td>.57 (55)</td>
<td>.57</td>
</tr>
<tr>
<td>$t$ (df)</td>
<td>-1.23 (32)</td>
<td>-.4 (23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p$</td>
<td>.22</td>
<td>.69</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(4) Accuracy between Ambiguity and Context Types

<table>
<thead>
<tr>
<th></th>
<th>Ambiguous Condition Mean(SD)</th>
<th>Unambiguous Condition Mean (SD)</th>
<th>$t$ (df)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-referent</td>
<td>94.74 (8.43)</td>
<td>94.91 (11.13)</td>
<td>-.1 (22)</td>
<td>.92</td>
</tr>
<tr>
<td>2-referent</td>
<td>94.91 (10.1)</td>
<td>97.66 (6.64)</td>
<td>-1.72 (22)</td>
<td>.09</td>
</tr>
<tr>
<td>$t$ (df)</td>
<td>-.1 (10)</td>
<td>-1.91 (10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p$</td>
<td>.92</td>
<td>.06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Self-paced Reading Times

The raw reading times (ms) at the critical regions for the four experimental conditions were significantly longer for older adults ($M = 12019.2$, $SD = 3255.1$) than young adults ($M = 8797.5$, $SD = 2702.6$) ($t(55) = 3.96$, $p < .001$). Regression analyses were conducted to calculate RRTs. RRTs of the critical regions across age groups and across the four experimental conditions are shown in Figures 5.1 and 5.2 for older and young adults, respectively, while Figure 5.3 focuses on the RRT of W7 in Study 2B.

---

**Figure 5.1.** Mean residual reading times of older adults across critical words in Study 2B

**Figure 5.2.** Mean residual reading times of young adults across critical words in Study 2B
Based on the GLM analysis, main effects of age group \((p < .001)\) and syntactic ambiguity \((p < .001)\) were found at W7. An interaction between age group and syntactic ambiguity type was also observed \((p < .05)\). No other statistical significance was found. See Table 5.3. for results of the GLM analysis.

Table 5.3. Study 2B: A 2 x 2 x 2 multivariate GLM analysis

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>(F)</th>
<th>(p)</th>
</tr>
</thead>
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<tr>
<td>Corrected Model</td>
<td>7</td>
<td>184728.33</td>
<td>26389.76</td>
<td>6.11</td>
<td>.001**</td>
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<tr>
<td>Intercept</td>
<td>1</td>
<td>31099.17</td>
<td>31099.17</td>
<td>7.20</td>
<td>.008**</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>95461.13</td>
<td>95461.13</td>
<td>22.10</td>
<td>.001**</td>
</tr>
<tr>
<td>Referential context</td>
<td>1</td>
<td>5420.61</td>
<td>5420.61</td>
<td>1.26</td>
<td>.264</td>
</tr>
<tr>
<td>Syntactic ambiguity</td>
<td>1</td>
<td>53635.30</td>
<td>53635.30</td>
<td>12.42</td>
<td>.001**</td>
</tr>
<tr>
<td>Age x Referential context</td>
<td>1</td>
<td>1625.09</td>
<td>1625.09</td>
<td>.38</td>
<td>.540</td>
</tr>
<tr>
<td>Age x Syntactic ambiguity</td>
<td>1</td>
<td>18281.39</td>
<td>18281.39</td>
<td>4.23</td>
<td>.041*</td>
</tr>
<tr>
<td>Referential context x Syntactic ambiguity</td>
<td>1</td>
<td>5420.61</td>
<td>5420.61</td>
<td>1.26</td>
<td>.264</td>
</tr>
<tr>
<td>Age x Referential context x Syntactic ambiguity</td>
<td>184</td>
<td>1625.09</td>
<td>1625.09</td>
<td>.38</td>
<td>.540</td>
</tr>
<tr>
<td>Error</td>
<td>192</td>
<td>794852.35</td>
<td>4319.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>191</td>
<td>1015448.37</td>
<td>4319.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>979580.68</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Significant results are bolded: ** for \(p < .01\), * for \(p < .05\)

Upon finding the interaction between age group and syntactic ambiguity type to be significant, I then investigated the source of the interaction. Independent samples t-tests showed that young adults’ W7 RRTs in the ambiguous NP-attachment condition \((M = -2.62, SD = 41.05)\) and those in the unambiguous URC condition \((M = -16.54, SD = 28.02)\) were not significantly different \((t(46) = .19, p = .061)\). In contrast,
older adults’ W7 RRTs in the ambiguous NP-attachment condition ($M = 61.55$, $SD = 88.25$) and those in the unambiguous URC condition ($M = 8.56$, $SD = 80.40$) were significantly different ($t(50) = 3.14$, $p = .002$). Therefore, a main effect of syntactic ambiguity type could be seen resulting from older adults’ relatively longer processing of the RRTs between NP-attachment and URC, and it was this disproportional difference that resulted in the interaction between age group and syntactic ambiguity type.

5.2. Which cognitive functions play roles in efficiency of context use during PP-attachment ambiguity resolution?

5.2.1. Hypothesis and Statistical Analysis

To utilize context efficiently, readers need to use supporting context as well as overcome conflicting context. Because the cognitive functions underlying the ability to use supporting context were already analyzed in Chapter 4, the focus here will be how efficiently readers overcome conflicting context during PP-attachment ambiguity resolution. I hypothesized that, along with age, various types of cognitive functions would predict the ability to overcome conflicting context during NP-attachment ambiguity resolution.

To investigate which cognitive functions play a role in processing conflicting context during PP-attachment ambiguity resolution, reading times for the 1-referent context/ambiguous NP-attachment condition were used, as conflict occurs only when syntactic structure differs from the expected structure that was once supported by the preceding context. Correlation analysis was conducted using cognitive measures and W7 RRTs in the 1-referent/NP-attachment condition from Reading Experiment 2. I assumed that higher RRTs in the 1-referent/ambiguous NP-attachment condition represented inefficiency in overcoming conflicting and incongruent context as well as a lack of flexibility in modifying one’s initial syntactic decision.

5.2.2. Results

As in Study 2A, a main effect of age, as observed by GLM, was replicated in the correlation analysis results: RRT of W7 in the conflicting and incongruent context condition (1-referent/NP-attached PP) was significantly correlated with age ($r(48) = .41$, $p < .01$). Among cognitive functions, only inhibition (measured
in derived performance time differences between color reading and ink–color labeling conditions from the Stroop) showed a correlation with RRT of W7 in conflicting and incongruent contexts ($r(48) = .37$, $p < .05$). See Table 5.4 for results of the correlation analyses.

Table 5.4. Correlation among ability overcoming conflicting context, cognitive functions and age

<table>
<thead>
<tr>
<th></th>
<th>1A</th>
<th>WM_M</th>
<th>WM_D</th>
<th>Stroop</th>
<th>WCST_T</th>
<th>WCST_P</th>
<th>WCST_C</th>
<th>TMT</th>
<th>TMT_A</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td></td>
<td>-</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WM_M</td>
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<td>-</td>
<td>-.15</td>
<td>.37*</td>
<td>-.39*</td>
<td>-.22</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WM_D</td>
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<td>.67*</td>
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<tr>
<td>WCST_T</td>
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<td>WCST_P</td>
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<td>-.22</td>
<td>.33*</td>
<td>-.33</td>
<td>-.06</td>
<td>-</td>
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<tr>
<td>WCST_C</td>
<td>.04</td>
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<td>.16</td>
<td>-.39*</td>
<td>.13</td>
<td>-.74**</td>
<td>-</td>
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</tr>
<tr>
<td>TMT_A</td>
<td>.23</td>
<td>-.37**</td>
<td>-.16</td>
<td>.23</td>
<td>-.14</td>
<td>.47**</td>
<td>-.48**</td>
<td>-.32*</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>AGE</td>
<td>.41**</td>
<td>-.34*</td>
<td>-.14</td>
<td>.59**</td>
<td>-.09</td>
<td>.49**</td>
<td>-.42**</td>
<td>.16</td>
<td>.36*</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. Significant results are bolded: ** for $p < .01$, * for $p < .05$

1A = RRT of the most critical word in 1-referent context/NP-attachment

Although it was clear that specific cognitive functions played a role in overcoming the garden-path effect (Study 1) during temporary syntactic ambiguity resolution through utilizing supportive context information (Study 2A) as well as when overcoming conflicting context information (Study 2B), the question remained of what made older adults process these constructions slower than young adults across the three studies. A post-hoc study was thus conducted to examine which cognitive functions played a role in the slower processing of older adults. First, based on a correlation analysis, it was clear that, except for the VP-attachment and 1-ref URC conditions, older adults’ processing time was longer than that of young adults. See Table 5.5, for results of the correlation analysis.

Following the correlation analysis, a multiple regression analysis was conducted, using age as the dependent variable and the following cognitive functions correlated with age (see Table 3.5) as predictor variables: working memory capacity from the month ordering task, inhibition from the Stroop task, shifting attention skills from the WCST, and cognitive processing speed from the TMT_A. Among the predictor variables, inhibition (Stroop) ($t = 6.72; p < .01$) and shifting attention (WCST_P) ($t = 2.90; p < .01$) were
significant predictors of age. The best fitting model shows that approximately 90% of the variance in age-related performance could be explained by the regression model with inhibition and shifting attention as predictors ($F(2, 46) = 200.78; p < .01$). Based on these results, it can be assumed that poorer inhibition and shifting attention related with age may result in slow processing across the three reading studies. See Table 5.6. for results of the multiple regression analysis

Table 5.5. Correlation among RRT across six conditions used in three studies and age

<table>
<thead>
<tr>
<th></th>
<th>NP</th>
<th>VP</th>
<th>A2</th>
<th>A1</th>
<th>U2</th>
<th>U1</th>
<th>AGE</th>
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<tr>
<td>NP</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
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<td>-</td>
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</tr>
<tr>
<td>A2</td>
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<td>.21</td>
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<td></td>
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<td>.11</td>
<td>-</td>
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<td>.32*</td>
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<td>-</td>
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</tbody>
</table>

Note. Significant effects are bolded: ** for $p < .01$, * for $p < .05$

NP means NP-attached PP condition in null context used in Study 1 and Study 2A.
VP means VP-attached PP condition in null context used in Study 1.
A2 means 2-referent/ambiguous condition used in Study 2A and Study 2B.
A1 means 1-referent/ambiguous condition used in Study 2B.
U2 means 2-referent/unambiguous condition used in Study 2B.
U1 means 1-referent/unambiguous condition used in Study 2B.

Table 5.6. Regression analysis for age

<table>
<thead>
<tr>
<th>Variables</th>
<th>B</th>
<th>SE $b$</th>
<th>$\beta$</th>
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</thead>
<tbody>
<tr>
<td>Inhibition from the Stroop Task:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Derived performance time difference between</td>
<td>15.54</td>
<td>2.31</td>
<td>.68**</td>
</tr>
<tr>
<td>color reading and ink–color labeling conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shifting attention from the Wisconsin Card</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorting Test:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of Perseverative Error</td>
<td>1.08</td>
<td>.37</td>
<td>.29**</td>
</tr>
</tbody>
</table>

Note. **. Correlation is significant at the 0.01 level

5.3. Discussion

Both age groups in Study 2B showed the ability to overcome conflicting context (i.e., when a 1-referent context supporting VP-modification of PP was followed by NP-attachment disambiguation), as seen by the ability to disambiguate NP-attached PP as quickly as disambiguating NP-attachment in a supporting context. Younger adults showed efficiency in using supporting (i.e., NP supporting 2-referent context) and conflicting contexts so that processing time of NP-attached PP was as fast as that of URC. In contrast, older adults were affected by syntactic ambiguity type, so their general processing time at NP-attachment was slower than at URC in both the 1- and 2-referent contexts. In addition, older adults showed slower
processing speed across types of referential context (2-referent supporting vs. 1-referent conflicting context) and types of syntactic ambiguity (ambiguous NP-attached PP vs. unambiguous URC) when compared with young adults.

The results of Study 2B were quite different from previous findings. First, an effect of referential context (supporting vs. conflicting contexts) was previously observed in young adults. As noted in Chapter 2, experimental stimuli used in Study 2B were partially borrowed from Altmann and Steedman (1998), who reported that young adults’ processing times became slower when the preceding context conflicted with the subsequent syntactic structure (e.g., Conflicting and incongruent context: NP-attached PP in 1-referent context & VP-attached PP in 2-referent context vs. Supporting and congruent context: NP-attached PP in 2-referent context & VP-attached PP in 1-referent context). In their study, Altmann and Steedman observed that processing-time differences of VP- and NP-attachment in the 2-referent context were greater than those of VP- and NP-attachment in the 1-referent context. It should be noted again that the current study compared processing times of NP-attachment and URC in 1- and 2-referent contexts. Since the 1-referent context does not yield a bias to VP-attached PP as much as the 2-referent context does toward NP-attached PP, it seems our participants did not show the effect of referential context types.

Different presentation modes may have made the results of this study inconsistent with Altmann and Steedman’s findings. Although both studies presented experimental stimuli to participants via the self-paced moving window paradigm, sentences were presented phrase-by-phrase in Altmann and Steedman (1988) and word-by-word in the current study. Criticisms have been made on using a word-by-word presentation of the reading stimuli. According to Schmitt and Underwood (2004), word-by-word presentation may disrupt what they call the “holistic” processing of formulaic sequences. In addition, Spivey-Knowlton and Sedivy (1995) were concerned that word-by-word presentation might delay detection of syntactic ambiguity or disambiguation. According to them, once the task becomes familiar during the experiment, participants may automatically press the keyboard. As a result, their habitual button press may happen on the target word without spending the necessary time to process the syntax. In this case, they may consume more time at the following word to catch up their previous processing that they missed by their habitual button press.
Nevertheless, it is overly cautious to conclude that the results of the current study may not present the actual processing of temporary syntactic ambiguity resolution when compared with Altmann and Steedman’s study, which utilized the phrase-by-phrase presentation mode. To date, reading studies using a phrase-by-phrase presentation mode have yet to show similar findings with eye-tracking methodologies. In contrast, validity of the word-by-word presentation mode has already been reported. In an eye-tracking study that used one- and two-word presentation modes, Spivey and Tanenhaus (1998) replicated the results of the Spivey-Knowlton, Trueswell, and Tanenhaus’ study (1993).

In addition, many studies using the moving window paradigm have presented the words non-cumulatively to enable the participants to focus on processing each word as it currently appears on the screen. Altmann and Steedman, however, presented the experimental stimuli cumulatively; as a result, processing time of the most recently appearing word may have included some regression toward the previously presented words. Moreover, instead of residual reading times, raw reading times were analyzed in Altmann and Steedman’s study, although raw reading time may not have been sensitive enough to reflect individual processing speed, and thus may have precluded the ability to evaluate any potential influence of string length per word. Therefore, cumulative phrases and the use of raw reading time for analysis in Altmann and Steedman (1988) may have resulted in the inconsistency of results with the current study.

Second, patterns of context use in older adults were similar to, yet somewhat different from, previous studies. In Federmeier and Kutas (2005) and Federmeier et al. (2002), situational relatedness was manipulated to investigate use of context in younger and older adults. Both studies observed that both younger and older adults showed qualitatively similar N400 constraint effects when utilizing context. Differences, however, were noted between the age groups. For example, in older adults, slower and less efficient context use was observed. Also, although both younger and older adults showed similar N400 responses in strongly constrained contexts in terms of the timing and size of the N400 responses, older adults showed smaller positives and delays in the peak of the N400 effect. The authors claimed that these effects represented slower and less successful information use of older adults as compared with younger adults. Although the results of Study 2B replicated Federmeier’s findings of older adults’ relative slowness during context use, the age-related decline in efficiency by manipulating different types of contexts was not observed, as there was no significant interaction found between age group and referential context type (i.e.,
the 1-/2-referential contexts at the most critical word region from Study 2B). It appears that older adults seem to be able to utilize context efficiently enough in referential but no in situationally related contexts.

In addition, when compared with young adults, older adults in the current study did not show greater dependence on the preceding context, in contrast with Thornton (2009). As discussed in the introduction, it has been known that older adults’ decreased efficiency of context use is due to cognitive decline. Although the group of older adults in the current study showed poorer cognitive functions and slower processing in general than young adults, qualitative processing in terms of overcoming conflicting context was not different between young and older adults; no interaction was seen between age group and syntactic ambiguity, age group and referential context, and, among age group, syntactic ambiguity and referential context.

With the exception of processing speed, older adults showed an efficiency utilizing supporting and overcoming conflicting contexts comparable to that of younger adults, although, unlike younger adults, older adults were affected by syntactic ambiguity type. Although there is no age-related difference in terms of using different types of contexts, older adults showed more difficulty processing sentences with syntactic ambiguity (e.g., NP-attached PP) than sentences without syntactic ambiguity (e.g., URC). The results showed that older adults’ sentence processing was more sensitive to types of syntactic structure than those of referential context. Most studies that investigated the use of context in older adults reported that older adults showed no age-related difference when context contained rich information. It seems this study’s 1-referent context was not strong enough to bias the participants in expecting a VP-attachment interpretation, so older adults were able to overcome the influence of conflicting context. However, an effect of syntactic ambiguity type was observed in Study 2B, as observed by the effect of PP-attachment in Study 1.

Ability to overcome conflicting context during temporary syntactic ambiguity resolution was correlated with age and inhibition skill, measured by the Stroop test. The participants with longer processing times in the 1-referent/NP-attachment condition tended to have poorer inhibition skills. Based on the results, it seems that people with poorer inhibition skills have greater difficulty overcoming conflicting contexts that are followed by incongruent syntactic structures. Thus, these participants required longer processing times than those who had better inhibition skills.
The results of Study 2B showed that my older adults were also efficient context users when encountering PP-attachment ambiguity. Although older adults processed context more slowly than young adults across experimental conditions, their qualitative processing of context (rapid processing of NP-attached PP when the context supported the subsequent syntactic structure, and a similar dependence on conflicting context) was comparable to that of young adults. Although it has been known that cognitive decline in older adults has a detrimental effect on sentence processing, the older adults in the current study were able to compensate for their cognitive disadvantage when contextual information was provided. In the following section, I discuss all three studies more generally.
Chapter 6. General Discussion

The present studies were designed to investigate how younger and older groups utilize different types of context when resolving temporary syntactic ambiguity (namely, PP\(^1\)-attachment ambiguity), and which cognitive functions are related with their success in its resolution. Specifically, Study 1 examined whether PP-attachment ambiguity resolution in null context is different between younger and older adults, and which cognitive functions play a role in PP-attachment ambiguity resolution in that context. Then, to examine the role of referential context when it is present, two additional studies were conducted. In Study 2A, PP-attachment ambiguity resolution in null context was compared to the 2-referent context, which supported the NP-attachment interpretation of the PP for younger and older adults. This study was designed to ascertain whether the ability to use supporting context changes with aging, and which cognitive functions contribute to the use of supporting context during NP-attachment ambiguity resolution. Lastly, Study 2B examined whether the efficiency of use of referential context during NP\(^2\)-attachment ambiguity resolution changes with aging. Two different types of context (a 1-referent context, which biases a PP to be VP\(^3\)-attached and a 2-referent context, which supports a NP-attached PP) were followed by either ambiguous NP-attachment or unambiguous URC\(^4\). The study then investigated which cognitive functions are related to the ability to overcome conflicting contexts during NP-attachment ambiguity resolution. Results of the studies based on on-line sentence processing are presented in Table 6.1.

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1 prepositional phrase
2 noun phrase
3 verb phrase
4 unreduced relative clause
### Table 6.1. Research questions and corresponding results based on RRT during on-line sentence processing

<table>
<thead>
<tr>
<th>Study</th>
<th>Research Questions</th>
<th>Findings</th>
</tr>
</thead>
</table>
| 1     | Does ability to resolve PP-attachment ambiguity change with aging? | Yes, there is a quantitative difference in that older adults are slower than younger adults at the point of disambiguation (W7). Moreover, it is qualitatively different: patterns of resolving PP-attachment ambiguity in older adults are different from those in younger adults. Older adults have more difficulty processing NP-attachment than VP-attachment, whereas younger adults have comparable processing skills between NP-attachment and VP-attachment.  
**Statistical significance:** Effect of PP-attachment type, Effect of age group, Interaction between PP-attachment type and age group. |
| 2A    | Does ability to use supporting referential context which makes NP-attachment the preferred during PP-attachment ambiguity resolution change with aging? | No, qualitatively, patterns of using supporting referential context are similar for younger and older adults. When a supporting context is provided, both age groups can overcome syntactic constraints. However, again, there are quantitative differences in that older adults process more slowly than younger adults at the disambiguating point.  
**Statistical significance:** Effect of context presence, Effect of age group. |
| 2B    | Does efficiency of referential context use during PP-attachment resolution change with aging? | No, efficiency of using different types of referential context is qualitatively the same. However, the comparable processing skills between NP-attachment and URC at 2-referent context that are observed in younger adults are not found in older adults. Moreover, quantitative differences are seen in older adults' slower processing than younger adults at the point of disambiguation.  
**Statistical significance:** Effect of age group, Effect of syntactic ambiguity type, Interaction between syntactic ambiguity type and age group. |

### 6.1. PP-attachment ambiguity resolution in null, supporting and conflicting contexts

As mentioned in section 1.1.1, research on temporary syntactic ambiguity resolution has been influential in developing and testing syntactic processing models. The results of the present studies also support the established syntactic processing models. In Study 1, both the garden-path model (Frazier, 1979) and the constraint-based model (Trueswell, Tanenhaus, & Garnsey, 1994) predicted that readers would prefer VP-attachment. According to the garden-path model, VP-attachment is syntactically simpler than NP-attachment, so it is preferred. In contrast, as mentioned in section 1.1.2, only verbs yielding preference to VP-attached PP were selected in the present experiments and the constraint-based model predicted that the readers would prefer VP-attachment by utilizing available sources of information (i.e., characteristics of the verbs) during syntactic processing.
Although the logic supporting VP-attachment preference is different for the two syntactic processing models, predictions from both were confirmed. Faster reading times for VP-attachment than those for NP-attachment and the preference for VP-attachment were observed based on the main effect of PP-attachment type. It should be noted that the referential theory (Altmann & Steedman, 1988; Crain & Steedman, 1985) is not relevant to explain the results of Study 1 as the experimental stimuli were not preceded by any referents (i.e., null context).

In the case of Study 2A, in which the PP-attachment ambiguity biased readers toward attaching the PP to the NP was presented in either null context or a NP-supporting 2-referent context, the prediction of the garden-path model is different from that of the referential theory and the constraint-based model. According to the garden-path model, reading times between the two conditions are expected to be comparable. The garden-path model predicts that readers would prefer minimal attachment, meaning that VP-attachment is always preferred to NP-attachment. Therefore, whether or not a referential context precedes the target, there is no difference in preference between NP-attachment in null context and NP-attachment in 2-referent context because NP-attachment is not preferred nor anticipated whether a context exists or not. On the other hand, the referential theory and the constraint-based model predict that readers would prefer NP-attachment in the 2-referent context. According to these models, the preceding context, which introduces 2 referents, makes the reader expect each referent to be distinguished through some type of modification. Therefore, although NP-attached PP was not preferred in null context, it is preferred and processed faster in the supporting context.

The results of Study 2A support the referential theory and the constraint-based model. At the point disambiguation (W7), reading times in NP-supporting 2-referent context were faster than in null context and no differences between the two age groups were observed. Thus, the findings of Study 2A confirmed again that both younger and older readers use available referential resources during PP-attachment ambiguity resolution.

In Study 2B, when a 1- or 2-referent context is followed by a sentence with either NP-attachment ambiguity or URC, the garden-path model predicts that the existence of the preceding context does not influence ambiguity resolution. Thus, regardless of whether there is a 1-referent or 2-referent context, readers will not utilize the context information immediately and thus will not form expectations of NP-
attachment of the PP. This model predicts that reading times for NP-attachment will be longer than those for URC, which is syntactically simpler than NP-attached PP.

In contrast, the referential theory and the constraint-based model predict that the 2-referent context will lead readers to expect an NP-attached PP in the following sentence and that this supporting context will be influential enough to overcome the garden-path effect that is observed for sentences with NP-attached PPs in isolation. Moreover, the supporting context will be powerful enough to nullify the garden-path effect and the reading times of NP-attached PP in NP-supporting 2-referent context will be similar to that of URC. However, the 1-referent context supports the VP-attached PP and if PP is then disambiguated as NP modification, the readers will experience a garden-path effect in this conflicting context. Moreover, the reading times for NP-attachment in the 1-referent context will be greater than those of URC in 1-referent context, URC in 2-referent context, and NP-attachment in 2-referent context. In brief, an interaction between referential context and syntactic ambiguity is predicted (i.e., significantly longer processing times in 1-referent/NP-attachment conditions than the rest of three conditions, i.e., 2-referent/NP-attachment, 1-referent/URC, 2-referent URC conditions).

Based on the referential theory and the constraint-based model, I hypothesized a main effect of referential context type and an interaction between the referential context and syntactic ambiguity type in Study 2B. The results of Study 2B supported the models by observing a main effect of referential context type. However, an interaction between the referential context and syntactic ambiguity type was not found at W7. Moreover, as observed in Studies 1 and 2A, the efficiency of referential context use during NP-attachment ambiguity resolution did not change with aging.

In summary, the current findings are consistent with the postulations of the existing psycholinguistic theories, and most of the results for the young adults’ performance in this dissertation study replicated previous experimental studies, such as Altmann and Steedman (1988) (e.g., use of referential context during PP-attachment ambiguity resolution), and Trueswell et al. (1999) (e.g., nullification of the garden-path effect with efficiency of use of referential context). There were two differences, however; young adults in Study 1 were not affected by syntactic constraints during PP-attachment ambiguity resolution which was once observed in Rayner, Carlson and Frazier (1983). This inconsistency seems to result from different presentation methods (self-paced reading paradigm vs. eye-tracking paradigm) and/ or possibility of less
impact of newly developed experimental stimuli to yield PP-attachment ambiguity for younger adults. Additionally, young adults in Study 2B did not have any difficulty overcoming the conflicting context (1-referent VP-supporting context/NP-attachment condition). Instead, the young participants overcame the misleading context information, thus performing as fast as they performed the rest of the conditions. When compared with previous experimental studies, this inconsistent finding seems to result from either differences in presentation mode (word-by-word in my study 2B vs. phrase-by-phrase stimulus presentation, e.g., Altmann & Steedman, 1988) or differences in the resources that are necessary for PP-attachment disambiguation (semantic reanalysis using plausibility vs. syntactic reanalysis induced by grammatical incompatibility, e.g., Trueswell et al., 1999).

When compared with syntactically simple and unambiguous sentences, older adults’ noticeable slowness when sentences were syntactically complex (e.g., Stine-Morrow, Ryan & Leonard, 2000) and syntactically ambiguous (e.g., Christianson et al., 2006) was replicated in Study 1 and Study 2B; although older adults showed efficiency in both using supporting contexts and in overcoming conflicting contexts, they showed more difficulty processing NP-attachment than VP-attachment in Study 1 and NP-attachment than URC in Study 2B. In summary, older adults are similar to young adults in their efficiency in utilizing different types of referential context. However, unlike young adults, older adults’ syntactic processing is affected by the difficulty levels of syntactic structures employed in this study.

Nevertheless, a negative effect of slowed processing was not observed on accuracy for yes/no comprehension questions for either group: both age groups showed comparable accuracy across the three studies. This finding is comparable to that of Christianson et al. (2006) who found there was no age-related difference during off-line sentence processing between their younger and older participants. When they examined temporary syntactic ambiguity using reflexive absolute transitive (RAT) (e.g., wash, shave, and dress) and optionally transitive (OT) (e.g., hunter, chew, and read), older adults required a longer time to process the sentences, but the accuracy results of the yes/no comprehension questions were comparable between the two age groups, similar to what we observed in Study 2B. In contrast, Kemtes and Kemper (1997) and Kemper, Crow, and Kemtes (2004) have reported that differential processing speeds based on main verb/RRC ambiguity resulted in different comprehension question accuracies for younger vs older adults.
From observing these results, I hypothesize that different types of temporary syntactic ambiguity may exert different degrees of difficulty at the point of disambiguation. For example, main verb/RRC\textsuperscript{5} ambiguity may be the most difficult for readers to process. While processing main verb/RRC ambiguity, both age groups require greater processing time at the RRC than at the main verb, but older adults are affected disproportionately by RRC ambiguity compared to young adults. Moreover, older adults' comprehension is also negatively affected by their extended processing speed, and their overall comprehension accuracy is poorer than young adults'.

In comparison, PP-attachment ambiguity and RAT/OT verbs appear to be a less difficult type of syntactic ambiguity, based on the following observation: though processing speed was affected by syntactic ambiguity types among older adults, comprehension accuracy was not affected by their longer processing speed, as evidenced by the comparable accuracies between the two age groups. Therefore, in terms of a hierarchy of temporary syntactic ambiguity difficulty, main verb/RRC ambiguity is more difficult to process than both RAT/OPT verbs and PP-attachment ambiguity.

Of course, it should be noted that this study was not designed to test the degree of difficulty for different types of temporary syntactic ambiguity. However, as argued by Dagerman, McDonald, and Harm (2006), this differential degree of difficulty may result from the nature of each type of ambiguity; specifically, the relative frequency of alternative syntactic structures and the frequency differences between NP-attached PP and VP-attached PP may not be equivalent to frequency differences between main verb and RRC ambiguity. Thus, further research may be required to investigate differential effects of different types of temporary syntactic ambiguity.

It has been widely observed in previously published research that cognitive decline in older adults, specifically in working memory capacity, has detrimental effects on general sentence processing. The current studies investigated whether changes in PP-attachment ambiguity resolution and context use occur with aging. It was expected that older adults would be at a disadvantage compared to young adults during sentence processing due to their poorer cognitive functions. In this study, as age was found to be correlated with several cognitive functions (i.e., working memory capacity, inhibition, shifting attention, and cognitive

\footnote{reduced relative clause}
processing speed), the decline in cognitive function observed in older adults was indeed found to affect PP-attachment ambiguity resolution in the different experimental conditions; age was correlated with the ability to resolve PP-attachment ambiguity in null, supporting, and conflicting contexts. However, not all cognitive functions that showed age-related decline played a role in PP-attachment ambiguity resolution. Of the cognitive functions measured in this study, inhibition and shifting attention appeared to play a role in the ability to resolve PP-attachment in null context, alternating attention (which exhibited an age-related decline) was correlated with PP-attachment ambiguity resolution in supporting context, and inhibition was related to the ability in overcoming conflicting context during PP-attachment ambiguity resolution.

This was the first experimental study that investigated the effect of context information during PP-attachment ambiguity resolution in aging, so the current findings cannot be directly compared with any other studies. In null context, changes in temporary syntactic ambiguity resolution with aging were reported by Kemtes and Kemper (1997) and Kemper, Crow, and Kemtes (2004), using a different temporary syntactic ambiguity type; namely, main verb/RRC ambiguity. In their studies, older adults showed greater difficulty processing sentences with temporary syntactic ambiguity than young adults in general, evidenced by slowed reading times. When both age groups were divided according to their working memory spans, high-span older adults and all younger adults processed faster than middle- and low-span older adults. Based on the data, they concluded that this differential pattern resulted from decreased working memory capacity in older adults, but individual cognitive differences should be considered. In the present study, instead of dividing the younger and older participants based on their working memory spans, because my primary focus was on age, it was age that I took into account, rather than working memory. Further analysis would be required to investigate individual cognitive differences by dividing each age group based on working memory span and the other cognitive measures included.

6.2. Roles of cognitive functions during PP-attachment ambiguity resolution

6.2.1. Working Memory Capacity

The surprising finding from the current studies is that working memory capacity was not correlated with differential processing patterns for the two age groups. However, it would be premature to conclude working memory capacity does not play a role in PP-attachment ambiguity resolution in null, supporting,
and conflicting contexts. There are several ways to explain why any effects of working memory capacity on PP-attachment ambiguity resolution and use of context were not observed in the current studies.

First, the experimental stimuli in the current study, which include PP-attachment ambiguity and referential context, may not be complex enough to exceed the working memory capacity of the participants, even older adults who have relatively smaller working memory capacities than young adults. As the capacity-constrained theory (Just and Carpenter, 1992) postulates, language processing may be comparable for the two age groups when language tasks carry a small processing load, despite working memory capacity differences between younger and older adults. PP-attachment ambiguity and referential context may belong to this particular case. Mendelsohn (2002) also reported no relationship between working memory capacity and transitivity verb ambiguity resolution. Based on these findings, it seems that different types of temporary syntactic ambiguity may have different degrees of processing difficulty. Therefore, depending on the difficulty level, working memory capacity may or may not predict success or failure in sentence processing.

Second, different types of working memory capacity tasks may result in different results. When Kemtes and Kemper (1997) and Kemper, Crow, and Kemtes (2004) measured working memory capacity using a Daneman and Carpenter (1980) type of reading span task, they reported a close relation between working memory capacity and MV/RRC ambiguity resolution. In contrast, in the case of Mendelsohn (2002), a Waters and Caplan (1996) type of reading span task was used, where it was found that working memory capacity was not a predictor of temporary ambiguity resolution in young adults. As noted, the month ordering and digit ordering tasks that measured working memory capacity in the current studies have been shown to correlate with working memory capacity, as measured by the Daneman and Carpenter type of reading span task (Almor et al., 1998). Nevertheless, it is possible that our measures may not be sensitive enough to detect processing differences in the particular sentence types employed in these studies, such as sentences with PP-attachment ambiguity.

Third, unlike the capacity-constrained theory (Just & Carpenter, 1992), which claims that general on-line sentence processing relies on general verbal working memory, the separate sentence-interpretation resource (SSIR) theory (Waters & Caplan, 1996) postulates that sentence processing may rely on a domain-specific resource sub-pool within verbal working memory instead. In other words, general verbal
working memory may be related to off-line, but not on-line, sentence processing skills. Therefore, there is also a possibility that month ordering and digit ordering tasks might not have measured the particular type of working memory that is used for on-line sentence processing.

Lastly, working memory capacity was measured within participants permitted an unlimited amount of time in the current study, creating the case where performance on month ordering and digit ordering tasks was not directly related to speed of processing (as also discussed in Goral et al., 2011). Because of the different measurement conditions, working memory capacity may not be the appropriate predictor in the current study. In the future, a more diverse set of tasks to measure working memory should be tested.

Note that in the correlation analysis, as reported in Table 3.5, the working memory capacity measured by the Month Ordering Task did correlate with shifting attention, inhibition and speed of cognitive processing. For age, working memory capacity was correlated with it along with above shifting attention, inhibition and speed of cognitive processing. Among these three cognitive functions, shifting attention and inhibition did affect processing of NP-attachment ambiguity resolution and inhibition was related to ability to overcome conflicting context during NP-attachment ambiguity resolution. These findings thus suggest that working memory measures may indirectly influence processing of NP-attachment in null and in conflicting contexts. In summary, the possibility exists that, although working memory capacity did play a role in PP-attachment ambiguity resolution in null, supporting, and conflicting contexts, its effect was not observed amidst the other cognitive functions in the current study.

6.2.2. Shifting Attention, Alternating Attention and Inhibition

Despite the lack of a significant effect of working memory capacity (measured by the Month and Digit ordering tasks) in this study, other cognitive functions were significantly correlated with PP-attachment ambiguity resolution in both the null and referential contexts. The summary of the role of cognitive functions in predicting PP-attachment ambiguity resolution is presented in Table 6.2. For example, shifting attention, measured by the perseverative errors on the WCST, was correlated with reading times at the disambiguation point (W7) when PP was attached to NP in null context (Study 1). This finding was consistent with studies by Mendelsohn (2002) on shifting attention, although Mendelsohn tested only college students. Therefore, it can be inferred that both young and older readers maintain multiple syntactic
interpretations during on-line sentence processing, appropriately deploying shifting attention from the initially selected interpretation to an alternative interpretation when needed. Effective use of feedback information (which makes it possible for readers to disambiguate their initial interpretation) seems to result in efficient PP-attachment ambiguity resolution throughout adulthood.

Inhibition skills based on the Stroop were related to resolving syntactic ambiguity in January et al. (2008)’s young participants and this was also observed in the current study; both age groups showed a relation between inhibition skills and ability to resolve PP-attached PP in null context. As the Left Inferior Frontal Gyrus (LIFG)-based Cognitive Control hypothesis suggested, it appears that readers were required to overcome their initially created preferred syntactic interpretation (VP-attachment) in order to promote the alternative, less preferred syntactic interpretation (NP-attachment), with both interpretations in conflict with one another as evidenced by the longer times at W7. From the study, we can posit that initial syntactic analyses may be required to be suppressed when syntactic confliction between VP-attachment and NP-attachment) exists.

Table 6.2. Corresponding research questions and findings based on cognitive measures and RRT

<table>
<thead>
<tr>
<th>Study</th>
<th>Research Questions</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Which cognitive functions were related with ability to resolve NP-attachment ambiguity?</td>
<td>Shifting attention from WCST Inhibition from the Stroop</td>
</tr>
<tr>
<td>2A</td>
<td>Which cognitive functions contribute to use of referential context during PP-attachment ambiguity resolution when readers are biased toward NP-attachment?</td>
<td>Alternating attention from TMT</td>
</tr>
<tr>
<td>2B</td>
<td>Which cognitive functions play a role in the ability to overcome conflicting context during PP-attachment ambiguity resolution?</td>
<td>Inhibition from the Stroop</td>
</tr>
</tbody>
</table>

Alternating attention skill, measured by the TMT, was related to successful use of supporting context during PP-attachment ambiguity resolution. To date, the role of alternating attention skills in sentence processing has not been investigated intensively, but it has been shown that impaired processing of syntactic complexity in individuals with Parkinson’s disease correlates with a decline in alternative attention skills (Lee et al., 2003). Along those lines, in a previous study, Goral and her colleagues (2011) did not find a connection between alternating attention and syntactic complexity processing in healthy older
adults. Besides these studies, the current investigation is one of the first to measure alternating attention skills ability in predicting temporary syntactic ambiguity resolution in both younger and older adults.

A preceding 2-referent context that supported NP-attachment preference was efficiently utilized by the readers in this study. Because this dissertation is not focused on investigating psycholinguistic theories, the data should not be interpreted based on any particular perspective of psycholinguistic theory. However, it seems that in cases where the probability of NP-attached PP would be greater than VP-attached PP based on referential context information, readers might not be permanently discarding the less probable interpretation (VP-attached PP). Instead, the possibility exists that a given verb in the target sentence facilitated the interpretation of VP-attached PP with some degree of influence. As mentioned in Chapter 2, the verb in the target sentence influences the reader in preferring PP-attachment to the verb. However, based on previous research data (e.g., Trueswell et al., 1999), when a referential context precedes the t, due to the greater power of contextual information, readers are more influenced by referential context than verb characteristics. There are, then, two cases, where NP-attachment interpretation is promptly expected due to the preceding 2-referent context (based on the constraint-based model), and where two interpretations (both NP- and VP-attachment interpretations) are initially maintained simultaneously (based on the referential theory). These two possibilities of sentence processing are based on a matter of timing. Whether the final interpretation is made promptly or later, the readers ultimately come to utilize context. While expecting a NP-attachment interpretation after processing the context information, the influence of the characteristics of the verb in the target sentence may subconsciously make the readers doubt the appropriateness of their initial interpretation, and whether they should consider VP-attachment as the alternative interpretation. However, in the middle of this decision making process, readers seem to be influenced by the stronger information; in this case, the referential context versus verb characteristics. Therefore, in a supporting context, it appears alternating attention skills are required to choose the most appropriate interpretation, while consideration of verb characteristics is not a strong enough factor for the readers to suppress during sentence processing.

As mentioned previously, although Goral et al. (2011) investigated roles of several cognitive functions, including alternating attention skills on syntactic complexity in older adults, they did not find an effect of alternating attention skills. Therefore, this is the first study to report alternating attention skills as a
predictor for temporary syntactic ambiguity resolution in both age groups; further investigation may be required to confirm this interpretation.

Finally, as mentioned above, the results of Study 2B supports LIFG-based cognitive control hypothesis which claims inhibition skills are required to resolve conflicting information; inhibition skills were found to be related to the ability to overcome conflicting context during NP-attached PP ambiguity resolution. In study 2B, Participants’ syntactic interpretation ability also seemed to be influenced by preceding context information, as observed in Study 2A. Two possibilities should be considered to interpret these results. First, readers may have expected VP-attached PP at the target sentence after promptly utilizing the preceding 1-referent context (based on the constraint-based model). Alternatively, readers may have expected both the NP- and VP-attachment interpretations simultaneously (based on the referential theory), but after processing the preceding 1-referent context, ultimately chose the VP-attachment interpretation, after maintaining both NP- and VP-attachment interpretations during processing. In either case, when readers encounter NP-attachment in the target sentence, I predicted they will experience difficulty revising their initial interpretation due to two factors: not only does the contextual information predominate over the characteristics of the verb which prefers VP-attachment, but the VP-attachment interpretation itself is universally preferred. Therefore, readers may have difficulty suppressing their initial syntactic interpretation, creating the need to be able to abandon or inhibit their initial interpretation and process the available NP-attached PP when they realize it is called for at W7. Efficient inhibition skills seem to be related with this process.

Both Study 2A and Study 2B investigated the utilization of context and whether it facilitated the temporary syntactic ambiguity resolution that followed or not. However, as VP-attachment is more frequently observed in general and is the preferred syntactic structure in isolation (when compared to NP-attachment), it seems that the degree of bias from the context may have differed in the two studies; the bias toward VP-attachment in VP-supporting 1-referent contexts in Study 2B may have been greater than the bias toward NP-attachment created by 2-referent contexts in Study 2A. Therefore, the two studies would differ as a result of the greater effort required in overcoming NP-attachment interpretation in Study 2B compared to the effort required in Study 2A. Also, readers appeared to use different cognitive functions
when maintaining or abandoning previously provided contextual information (alternating attention and inhibition skills, respectively).

6.3. Effect of age on PP-attachment ambiguity resolution

Along with cognitive functions, age was related to NP-attachment ambiguity resolution in null, supporting, and conflicting contexts. Among the skills that were correlated with age (working memory capacity, alternating attention, inhibition, and shifting attention), inhibition and shifting attention skills predicted age-related performance, while different cognitive functions predicted NP-attachment in isolation, the use of supporting context, and the ability to overcome conflicting context for the different age groups. However, processing-time differences between younger and older adults seemed to result from age-related differences in cognitive functions generally (particularly inhibition and shifting attention) across all three studies in this dissertation.

Although older adults showed slower processing times than younger adults, it is remarkable that processing patterns (specifically use of supporting and conflicting contexts) across the three studies were relatively similar for the two age groups. Older adults are known to be at a disadvantage during sentence processing because of poorer cognitive functions than younger adults (e.g., Stine-Morrow et al., 2000). However, based on my study’s comprehension accuracy data, it seems older adults utilized a compensatory strategy to perform as accurately as young adults. According to Shafto and Tyler (2014), although cognitive functions of older adults undergo a decline, neural plasticity is responsible for compensatory bilateral brain network recruitment that preserves syntactic processing skills across the adult life span. Similarly, in the study of Tyler et al. (2009), younger and older adults were asked to detect the target word in grammatically correct and incorrect sentences. While processing these sentences, detection times and patterns of processing did not differ between the age groups. However, imaging data (which analyzed functional brain activation changes) showed that unlike young adults, who showed left-hemisphere brain activity, older adults showed a more bilateral network for syntactic processing. According to Tyler et al., the older adults’ preserved syntactic processing pattern was due to compensatory bilateral brain activity. When syntactic structure is relatively simple, comparable speed of processing can be observed (Kemmer et al., 2004), although event-related potential (ERP) data also show bilateral brain activity in older which was not
observed in younger adults. Therefore, it can be posited that older adults compensate for their poorer cognitive functions by engaging bilateral brain areas while resolving PP-attachment ambiguity resolution in null and different types of referential contexts.

6.4. Conclusion

What the studies in this dissertation contribute to the literature on comprehension in aging, then, are the following points: (1) Although older adults are affected by PP-attachment ambiguity in null context, the ability to use supporting context and to overcome conflicting context during PP-attachment ambiguity resolution is comparable for both age groups. (2) Older adults in the current study perform worse on a number of cognitive functions compared to younger adults, as others have found (e.g., Hasher, Zacks, & May, 1999; Salthouse, Fristoe, & Rhee, 1996). Although cognitive decline in older adults has been reported to relate to inefficient sentence processing in such papers as that of MacDonald, Just, and Carpenter (1992), across the dissertation studies, age-related slowing and declined cognitive functions in older adults did not result in any detrimental effect on PP-attachment ambiguity resolution, either in isolation or in supporting/conflicting context, as evidenced by comparable comprehension accuracy data between younger and older adults (although, qualitatively, older adults were slower than younger adults when sentences required syntactically ambiguous processing; e.g., NP-attachment vs. VP-attachment and NP-attachment vs. URC). (3) Along with age, the importance of cognitive functions (including shifting attention, inhibition, and alternating attention) during temporary syntactic ambiguity in null, supporting, and conflicting contexts was revealed. (4) Moreover, different cognitive functions were shown to play different roles in resolving PP-attachment ambiguity in different types of context: shifting attention for PP-attachment ambiguity resolution in isolation, alternating attention skills for exploiting supporting context, and inhibition skills for overcoming conflicting context during PP-attachment ambiguity resolution. Note that the roles of shifting attention and inhibition skills have been observed in previous studies examining different types of temporary syntactic ambiguity resolution, but observation of alternating attention skills has not been reported to date. (5) Furthermore, working memory capacity has been demonstrated to be crucial for sentence processing in a number of studies, but its effect appears to vary depending on the type of syntactic
structure being investigated. In the current study, other cognitive functions, such as shifting attention, alternating attention, and inhibition, were more crucial factors during PP-attachment ambiguity resolution.

Along with the significance of the findings, several limitations to the present studies also should be considered for future studies. First, in order to confirm whether the same cognitive functions (e.g., alternating attention skills) will predict temporary syntactic ambiguity resolution and use of different types of context, other types of supporting (e.g., 1-referent VP-supporting context and VP-attached PP) or conflicting (e.g., 2-referent NP-supporting context and VP-attached PP) context, or different types of syntactic structures with temporary ambiguity, should be investigated. Second, standard neuropsychological tests such as the Stroop are understood to require more than one cognitive ability (Marton et al., 2014). Therefore, using neuropsychological tests that are developed to measure individual cognitive functions is recommended for the future. Third, as older adults as a group showed poorer on tests of cognitive functions than young adults, slowed processing patterns among the older adults were also observed across three studies. By dividing age groups into levels of cognitive function and comparing the processing skills of a group of older adults with high cognitive functions with a corresponding group of young adults, a future study would be able to answer whether sentence processing speed (i.e., reading times) is affected by individual differences in cognitive function, or whether slower processing is pervasive in older adults regardless of different levels of cognitive functioning. Lastly, to understand the role of specific cognitive functions on processing different types of syntactic structure more thoroughly, cognitive training therapy should be developed to train specific types of cognitive functions related to the processing of specific types of syntactic structure. For example, if individuals with cognitive-function decline due to Parkinson’s disease, Alzheimer’s dementia, or aphasia have comprehension impairments related to temporary syntactic ambiguity resolution or integrating context information while processing syntactic structures, several types of cognitive functions can be trained, and subsequent improvement for sentence processing would be expected.

In summary, older adults, when compared with younger adults, show a decline in their abilities on a number of cognitive functions as well as slowed processing speed during on-line sentence processing. Older adults are more affected by PP-attachment ambiguity in null context, but older adults show an ability to utilize different types of context comparable to that of younger adults when resolving temporary syntactic
ambiguity. In addition, along with age, PP-attachment ambiguity resolution is related to specific cognitive functions, namely, shifting attention and inhibition in null context, alternating attention in supporting context, and inhibition in conflicting context.
APPENDIX A: Verb Bias Rating

Instructions
1. Please generate endings for each one as rapidly as you can.
2. The endings need not be elegant or sensible so long as they are possible English sentences.
3. Please complete the items in the order and do not return to an item that you completed.
4. Please do not attempt to read the items before starting the test.

Sentences for Completion

The first 12 items were from the 2nd experiment of Rayner, Carlson, & Frazier (1983), and then, the following 32 items were from Altmann & Steedman (1988). The last two items were created by the authors.

The spy saw the cop with
The little girl tried to cut the apple with
The landlord painted all the walls with
John played the records with
Jane finally decided to read the books on
The overworked scientist only read the news reports on
The executive only called people on
The kids played all the albums on
Grandmother didn’t see any articles on
Grandfather could only read the numbers in
The doctor examined the patient with
The kid hit the girl with
The burglar blew open the safe with
The mechanic changed the tire with
The convict suddenly lunged at the warder with
The schoolteacher beat the boy with
John decided to play the record with
The historian had to study the map with
The artist accidentally knocked over the bottle with
The window cleaner wiped the window with
The workman cut through the valve with
The man broke into the shop with
The monkey ate the banana with
The caretaker repaired the door with
The skinhead suddenly attacked the policeman with
The dressmaker cut the material with
The fireman smashed down the door with
The little girl tried to cut the orange with
The chemist heated the solution with
The drunk smashed the window with
The vet tranquilized the lion with
The tribesman killed the lion with
The man demolished the house with
The restorer stripped the cabinet with
The doctor examined the woman with
The secretary typed up the report with
The burglar opened the door with
The cleaning lady cleaned the corridor with
The woman repaired the sock with
The boy did accidentally break the window with
The chef started to make the cake with
The gardener cut down the tree with
The detective watched the woman with
The man decided to paint the door with
The student lifted up the book with
Eventually the conductor found the musician in
The parenthesized noun phrases made the participants to convert their syntactic analysis from the preferred VP-modification to the NP-modification.

1. The spy saw the cop with binoculars (a revolver) but the cop didn't see him.
   Did the cop see the spy? (No)

2. The little girl tried to cut the apple with plastic knives (plastic coating) though she wasn't very successful.
   Was the little girl able to cut the apple? (No)

3. The landlord painted all the walls with enamel (cracks) though it didn't help the appearance of the place.
   Did the landlord paint the walls? (Yes)

4. John played the records with Jim's needle (deep scratches) last night to see how bad they sounded.
   Did John play the records? (Yes)

5. The chef started to make the cake with the food mixer (dried fruit) but ran out of eggs.
   Did the chef have enough eggs? (No)

6. The secretary typed up the report with the typewriter (diagrams) and then went to lunch.
   Did the report have diagrams? (Yes)

7. The executive only called people on the phone (payroll) because he was paranoid.
   Was the executive paranoid? (Yes)

8. The kids played all the albums on the stereo (shelf) before they went to bed.
   Did the kids go to the store before they went to bed? (No)

9. The man suddenly lunged at the dog with the knife (necklace) though the dog didn't do anything.
   Did the dog lunge at the man? (No)

10. The maid accidently knocked over the jar with the duster (cookies) and felt bad.
    Did the maid knock over the bottle on purpose? (No)

11. The doctor examined the patient with a stethoscope (toothache) but he couldn't determine what the problem was.
    Did the doctor examine the patient? (Yes)

12. The kid hit the girl with a whip (wart) before he got off the subway.
    Did the kid hit the girl before he got off the subway? (Yes)

13. The student lifted up the book with the large tongs (logo) to avoid touching the sticky surface.
    Was the surface slippery? (No)

14. Eventually the conductor found the musician in a dark corridor (dress) and they went to the meeting room.
    Did the conductor and musician go into the lunchroom? (No)

15. The convict suddenly lunged at the warder with the knife (hat) before running off.
    Did the convict walk off slowly after he lunged at the warder? (No)

16. The artist accidently knocked over the bottle with the brush (paint) and swore loudly.
    Did the artist knock over the bottle? (Yes)

17. The artist started to make the statue with the big chisel (handle) but ran out of clay.
    Did the artist have enough clay? (No)

18. The detective watched the woman with the binoculars (revolver) and then made a phone call.
    Did the detective make a phone call? (Yes)
19. The gardener decided to cut down the tree with a saw (signpost), because the tree was blocking the driveway.
   Was the tree blocking the driveway? (Yes)

20. The construction workers planned to demolish the building with 15 different explosives (stores), but they couldn't complete it due to the strong protest.
    Did the construction worker demolish the building? (No)

21. The police officer opened the barn door with the chain saw (stained glass), because the kidnapper was inside.
    Was the kidnapper outside the barn door? (No)

22. The fire fighter attempted to break down the porch with the log (pet door) and found the arsonist lying on the sofa.
    Was there an arsonist lying on the sofa? (Yes)

23. Sara painted the old box with the paintbrush (dolls) and it looked like a new one.
    Was the box that Sara painted old? (Yes)

24. The jeweler examined the diamond with a microscope (flaw) and graded its quality.
    Did the jeweler examine the diamond? (Yes)
APPENDIX C: Filler Items for Reading Experiment 1

1. The reporter skipped the pumpkin pie during Thanksgiving dinner because he had to control his cholesterol. Did the reporter have to control his cholesterol? (Yes)

2. The bank wired the tourist's money and promised him not to misplace it this time. Did the bank wire the tourist's money? (Yes)

3. The customer who was mailed the information by Macy's found out that certain services would be discontinued immediately. Did Macy's mail information to customers about coupons? (No)

4. The lawyer who was sued for damages lost the lawsuit due to a technicality last year. Did the lawyer win the lawsuit? (No)

5. The performer said that the director sent her the flowers because her play was outstanding on that day. Did the director send the performer chocolate? (No)

6. The judge denied the right to appeal so the defendant became very bitter about the legal system. Was the defendant happy with the legal system when denied an appeal? (No)

7. The dealer sold the teenager the car, although the dealer wasn't sure where the money came from. Did the teenager buy a car from the dealer? (Yes)

8. The visitors who were expected to arrive last week were detained by the unexpected weather conditions. Did weather conditions cause the visitors to be detained? (Yes)

9. Everyone saw the clerk leave the store right away after he was paid the money. Did the clerk leave the store after receiving the money? (Yes)

10. The tenant decided to throw the junk mail in the trash and regretted that he registered for so many websites. Was the tenant happy that he registered for a lot of websites? (No)

11. The governess was convinced that the newspaper had the facts wrong, because she witnessed the car accident. Did the governess think that the newspaper had the facts correct about the car accident? (No)

12. The arrogant tourist asked the townspeople how to get to the post office, but they refused to answer even when they could. Did the townspeople help the tourist get to the post office? (No)

13. The handyman wasn't sure which tool to use first, so he decided to ask his boss who was talking with the clients. Did the handyman decide to ask his boss a question? (Yes)

14. The warrior was horrified after seeing the gigantic lion because he thought it would attack the rabbits. Was the warrior concerned that the lion would attack the rabbits? (Yes)

15. The carpenter was requested to repair the broken legs of the table because he was the most well-known antique repairer. Are the legs on the table broken? (Yes)

16. The oven mitts got too old to use, so the cook decided to buy the innovative silicone oven mitts and enjoyed using them. Did the cook enjoy using the innovative silicone oven mitts? (Yes)

17. The guitarist felt awesome when the audience applauded for his amazing show because he never expected he would play the guitar again. Was the guitarist unhappy when the audience applauded? (No)
18. The model perched on the dais and June took the picture.  
Did June take the picture? (Yes)

19. The winery owner tasted the wine and then decided to throw it away because it was too bitter.  
Did the wine owner keep the wine that he tasted? (No)

20. The boy awarded the prize and gave it to a miniature rabbit, because the prize was a bag of carrots.  
Was the prize awarded to a monkey? (No)

21. The woman offered a lift and said that she could take John to Vegas.  
Did the woman offer John a lift to Vegas? (Yes)

22. The troops who were dropped from the plane opened their parachutes and landed safely.  
Were the troops dropped from a window? (No)

23. The girl wanted to change the bulbs so she pulled out her table to step up on it.  
Did the girl pull out the table? (Yes)

24. The burglar confessed his sin in front of the priest while crying, but the police officer was waiting for him outside.  
Did the burglar laugh while confessing to the priest? (No)

25. Jane felt embarrassed about getting all the attention when she talked with Justin Bieber.  
Did Jane talk with Justin Bieber? (Yes)

26. The knight fell to the ground with a thud, because he didn't expect his squire's betrayal.  
Did the knight expect his squire's betrayal? (No)

27. The guard who watched the woman realized that she was no longer inconspicuous.  
Did the guard watch the woman? (Yes)

28. The mother took her son and daughter shopping with her at Chelsea Market and they couldn't resist eating boiled crabs.  
Did the mother take only the daughter shopping? (No)

29. The old lady was very abusive to certain members of her family and we don't know the reason.  
Was the old lady abusive to some of her family? (Yes)

30. The likely suspect was placed in a line-up with several other men, because the police were looking for a robber.  
Was the likely suspect placed in a line-up by himself? (No)

31. Gabriel decided to buy 10 stamps because he wasn't sure how many stamps should be posted on the envelope.  
Did Gabriel buy 10 stamps? (Yes)

32. The director selected the producer's niece but not the actress, although the actress performed better.  
Did the producer's niece perform better than the actress? (No)

33. The actor attempted to rehearse on stage, but he couldn't do it because the curtains were only half-closed.  
Were the curtains half-closed? (Yes)

34. The woman was weeping while watching the movie, so her husband handed her the tissue.  
Was the woman laughing while watching the movie? (No)

35. The guy could swim while looking at a picture, because the Dead Sea made him float.  
Did the guy look at the picture while swimming? (Yes)

36. The boy conducted an experiment using two rabbits, but decided to raise one of the rabbits himself.  
Did the boy conduct the experiment using only one rabbit? (No)
37. The woman didn't forget her laundry, although she had to rush to the hospital. Did the woman have to rush to the hospital? (Yes)

38. Carolyn decided to take both apples and oranges because they were grown by local farmers. Did Carolyn take only apples grown by local farmers? (No)

39. Elizabeth was excited to visit her grandparents because she hadn't seen them since she was 10 years old. Was Elizabeth excited to visit her grandparents? (Yes)

40. Deborah loved to arrange fashion advertisements, so she volunteered to do it. Did Deborah dislike arranging fashion advertisements? (No)

41. The writer scratched his mother's new table and he knew that it wouldn't be long before she found out. Did the writer scratch his mother's table? (Yes)

42. The monkey distracted the girl's attention and then, snatched her banana. Did the monkey snatch the girl's apple? (No)

43. The man filed his nails while listening to the radio and then was satisfied with his clean nails. Was the man satisfied that he had clean nails? (Yes)

44. The woman forgot who she had an appointment with, so she had to check her scheduler. Did the woman remember who she had an appointment with? (No)

45. The child was pouting when she could not have her way and her mother didn't notice. Was the child pouting? (Yes)

46. Simon didn't recognize Mary because of her new hairstyle, which made her look very stylish. Did Simon recognize Mary? (No)

47. The model thought that she was wearing the store's most expensive garments and behaved arrogantly. Did the model behave arrogantly? (Yes)

48. The couple drove away after they were discovered by the man. Did the couple stay put when they were discovered by the man? (No)
APPENDIX D: Target Items for Reading Experiment 2

First two sentences are identical in each condition. The third sentence introduces either 1 referent or 2 referents (in parentheses). Then, the last sentence presents the PP modifies NP or URC (in parentheses). Nouns in the third sentence make the readers to expect that there are 2 referents and bias readers to expect NP-modification of the PP are parenthesized. In addition, if the unambiguous URC follows at the last sentence, bias toward the NP-modification of the PP is expected to be nullified.

1. A burglar broke into a bank carrying some dynamite. He planned to blow open a safe. Once inside he saw that there was a safe which had a new lock and a strongbox (a safe) which had an old lock. The burglar blew open the safe with (which had) the new lock and made off with the loot.
   Did the burglar make off with the loot? (Yes)

2. A mechanic walked up to a car carrying a monkey wrench. He thought he'd have to change a tire. On examining the car he found that there was a tire which had a faulty valve and a fuel line (a tire) which had a small hole in it. The mechanic changed the tire with (which had) the faulty valve but it took a long time.
   Did the mechanic carry the monkey wrench? (Yes)

3. A schoolteacher walked into class carrying a bamboo cane. He sadistically hoped that he would have to beat a boy. On entering he saw that a boy who had a broken leg and a girl (a boy) who wore glasses didn't stand up for him. The schoolteacher beat the boy with (who had) the broken leg but the boy didn't cry out.
   Did the schoolteacher carry a bamboo cane? (Yes)

4. John had bought a diamond stylus for his stereo. He planned to play a record. He'd been given a record which had a lot of noisy crackle and a cassette (a record) which had a lot of hiss. John decided to play the record with (which had) the noisy crackle but it sounded terrible.
   Did the record sound good? (No)

5. A historian was working in the British Museum holding a magnifying glass. He'd sat down to study a map. On his desk there was a map which had an appalling tear and a manuscript (a map) which seemed in perfect condition. The historian had to study the map with (which had) the appalling tear so as to value it.
   Did the historian sit down to study the map? (Yes)

6. A window cleaner was climbing his ladder clutching a cloth. He'd been asked to wipe a window. Once up the ladder he saw that there was a window which had a lot of dirt on it and a skylight (a window) which was relatively clean. The window cleaner wiped the window with (which had) the dirt while singing to himself.
   Did the window cleaner sing to his friends? (No)

7. A workman climbed down a manhole carrying a saw. He expected to have to cut through a valve. Down the manhole he found a valve which had a lot of rust on it and a section of pipe (a valve) which had been leaking gas. The workman cut through the valve with (which had) the rust before fitting a new one.
   Did the workman carry a ruler? (No)

8. A man was walking up and down a dark street carrying an iron crowbar. He hoped to break into a shop. He noticed that there was a shop which had a broken window and a post office (a shop) which was fitted with a burglar alarm. The man broke into the shop with (which had) the broken window but nobody saw him.
   Did the man break into the post office? (No)

9. A monkey had been trained to eat using a fork. It was supposed to eat a banana. It was given a banana which had a bruise on it and an apple (a banana) which was perfect. The monkey ate the banana with (which had) the bruise much to everyone's surprise.
   Did the monkey throw away the banana? (No)
10. A caretaker was walking along a corridor carrying some nails. He'd been told to repair a door. He saw a door which had a large crack in it and a locker (a door) which had a broken knob. The caretaker repaired the door with (which had) the crack and then took a tea break.
   Did the caretaker take a tea break? (Yes)

11. A dressmaker was working on a dress using a pair of scissors. She had to cut some material for the pockets. She had a piece of material which had a pattern on it and a piece of leather (a piece of material) which was plain. The dressmaker cut the material with (which had) the pattern and then went to have lunch.
   Did the dressmaker go to have dinner? (No)

12. A fireman was running to the scene of a fire carrying a heavy axe. He had to smash down a door. When he got to the scene of the fire, he found a door which had a very rusty lock and a window (a door) which had a warning sign. The fireman smashed down the door with (which had) the rusty lock but smoke overcame him.
   Did the fireman carry a heavy axe? (Yes)

13. A little girl borrowed from the kitchen a bread knife. She wanted to cut an orange into pieces. She found in the fruit bowl an orange which had a very thick rind and a tangerine (an orange) which had a thin rind. The little girl tried to cut the orange with (which had) the thick rind but to no success.
   Did the little girl want to cut the orange? (Yes)

14. A tribesman was running through the forest carrying a long spear. He intended to kill a lion. On arriving at a clearing he found a lion which had very sharp teeth and a tiger (a lion) which had strange colored paws. The tribesman killed the lion with (which had) the sharp teeth and carried it back home.
   Did the tribesman leave the lion in the forest after he killed it? (No)

15. A demolition man was on his way to work in his bulldozer. He'd been told to go to a particular address to demolish a house. Once at the address he found a house which had an ornate fountain in its garden and a church (a house) which had a large statue. The man demolished the house with (which had) the fountain but it wasn't the right one.
   Did the man demolish the right house? (No)

16. A drunk was walking along a street wielding an empty bottle. He felt like smashing a window. In front of him he saw a window made of stained glass and a glass door (a window) which had bars covering it. The drunk smashed the window with (which had) the stained glass and staggered off laughing.
   Did the drunk stagger off laughing? (Yes)

17. A doctor walked into a waiting room carrying a stethoscope. He'd arranged to examine a woman patient. In the waiting room there was a woman who had a temperature and a man (a woman) who seemed to have stomach pains. The doctor examined the woman with (who had) the temperature but couldn't help her.
   Could the doctor help the woman with the temperature? (No)

18. A burglar was trying to break into a house and had a credit card in his hand. He wanted to open a door. He found a door which had a faulty lock and a window (a door) which had a cracked frame. The burglar opened the door with (which had) the faulty lock and quickly slipped inside.
   Did the burglar fail to enter the house? (No)

19. A cleaning lady started on her morning rounds carrying a brush. She would have to clean a corridor that morning. In the building there was a corridor which had lots of plants along it and a lounge (a corridor) which had lots of pictures on the walls. The cleaning lady cleaned the corridor with (which had) the plants and then lit a cigarette.
   Did the cleaning lady light a cigarette? (Yes)

20. A woman was looking through some clothes while holding some darning wool. She needed to repair a sock. She found in the pile of clothes a sock which had a hole in it and a jumper (a sock) which was getting a bit thin. The woman repaired the sock with (which had) the hole but hurt her finger in the process.
   Did the woman throw away the sock? (No)
21. A gardener was working in a garden adjusting a chainsaw. He needed to cut down a tree. He was standing by a tree which had been covered in greenfly and a tall shrub (a tree) which had been dead a long time. The gardener cut down the tree with (which had) the greenfly but was very sad about it.
   Was the gardener sad to cut down the tree? (Yes)

22. A skinhead was walking along a street carrying a large knife. He was planning to attack a policeman. He eventually saw a policeman who had a large scar on his face and a policewoman (a policeman) who had spectacles. The skinhead suddenly attacked the policeman with (who had) the scar and then ran off.
   Did the skinhead sit down after attacking the policeman? (No)

23. A chemist was adjusting a bunsen burner. He was about to heat up a solution. On his bench there was a solution which had blue crystals in it and a powder (a solution) which contained red dye. The chemist heated the solution with (which had) the blue crystals but the gas went out.
   Were the crystals in the solution blue? (Yes)

24. A man was decorating a room and had with him a large brush. He’d decided to paint a door. In the room there was a door which had a Christmas wreath on it and a window (a Christmas wreath) which had many stickers on it. The man decided to paint the door with (which had) the Christmas wreath and do the window later.
   Did he have a large brush? (Yes)
APPENDIX E: Filler Items for Reading Experiment 2

Item 1-12: 1-referent/ Simple unambiguous condition
Item 13-24: 1-referent/VP-attachment
Item 25-36: 2-referent/ Simple unambiguous condition
Item 37-42: 1 object/ Simple unambiguous condition

Note: Simple, unambiguous condition had no PP-attachment & unreduced relative clause condition.

1. A handyman went to the house carrying a screwdriver. He thought he would fix some small home appliances. Once there, unexpectedly he was asked to repair a door which had a broken knob and a car which had a flat tire. The handyman fixed the door first and it didn't take long.
   Did it take long for the handyman to fix the door? (No)

2. A man went to a college library. He wanted to find some references to supplement his term paper on modern art. While looking around the library, he found a book about modern art history and a pictorial magazine on oil paintings. The man decided to buy the book and to find the magazine later.
   Did the man go to the library for references? (Yes)

3. A homeless man was wandering around the streets in the morning. He hadn't eaten anything since yesterday. Fortunately he found a food bank which provided a sandwich containing eggs and cheese and pancakes with butter on it. The homeless man received the sandwich but couldn't get pancakes because of limited rations.
   Did the homeless man get pancakes? (No)

4. A man walked into a hardware store near his house. He wanted to buy some tools for hanging a picture on a wall. Without the aid of a clerk, he could easily find a small hammer with a wooden shaft and an electric drill with no cord. The man purchased the electric drill and then went to a picture frame shop.
   Was the hardware store near the man's house? (Yes)

5. A tourist got lost in the middle of the Central Park. He wanted to find an exit to the Westside of Manhattan. Wandering around a trail, he saw a man reading a book on a bench and a woman walking with her dog. The tourist asked the man where the exit was but unfortunately he couldn't help the tourist.
   Did the tourist know his way around Central Park? (No)

6. A woman went to a gift shop. She wanted to buy a birthday gift for her daughter. A clerk in the store recommended to her a teddy bear wearing a baseball cap and a Barbie doll wearing a dress. The woman chose the Barbie doll and asked the clerk to pack it in a gift box.
   Did the woman buy a Barbie doll? (Yes)

7. A security guard was checking around a government building. One day he found a suspicious bag near the main gate. It indeed contained a knife with a wooden handle and a gun with a muffler. The security guard removed the knife first and then called the police.
   Did the knife have a metal handle? (No)

8. An old lady walked into a pet shop carrying a big gift box. She wanted to buy a pet for her grandson as a birthday gift. Once inside, there was a puppy with white hairs and a kitten with black hairs. The old lady bought the puppy and put it into the box with a card.
   Did the old lady buy a puppy? (Yes)

9. A purse snatcher was prowling along a train platform. He carefully observed people on the platform to search for an unwary target. After a while he found a drunk sleeping on a bench and an old lady carrying a luxurious bag over her shoulder. The purse snatcher approached the drunk and picked his pocket quickly.
   Did the purse snatcher steal from the lady carrying the luxurious bag? (No)

10. A pregnant woman went to a furniture store with her husband. She wanted to prepare a piece of furniture for her baby before her delivery. In the store, she found a crib with two small drawers and a baby bouncer with a mobile. The pregnant woman bought the crib without bargaining and had it shipped to her house.
    Did the pregnant woman buy a crib? (Yes)
11. A brave police officer ran into a burning house carrying an axe. Inside he could hear someone shouting from behind a locked door. After breaking into the room he saw a girl screaming in fear and a dog hiding under the bed. The police officer safely rescued the girl and went into the house again.

   Did the police officer rescue the girl? (Yes)

12. A man was ordering food in an Italian restaurant. He wanted to eat something delicious with red wine. On the menu there was steak with fresh mint sauce and Italian sausage with meat sauce. He ordered the steak along with a glass of red wine and then helped his friend to order food.

   Did the man order white wine? (No)

13. A doctor ran into the emergency room carrying a stethoscope. The room was already full of patients with severe injuries due to a multiple pile-up. Once inside, he saw a woman with a slight injury on her forehead and a boy with a broken leg. The doctor first examined the boy with a stethoscope then sent him to an orthopedist.

   Did the doctor examine the boy? (Yes)

14. A plumber went to the house carrying a monkey wrench. He was the only person who could fix pipes in the town. At the house, he was asked to repair a draining pipe with a huge hole in it in the kitchen sink and a faucet with the cracked casing. The plumber fixed the faucet with the monkey wrench fixed the draining pipe later.

   Did the plumber fix the faucet with the screwdriver? (No)

15. Susan went to a dress shop on black Friday. She wanted to purchase some Christmas gifts for her two-year-old daughter. Upon entering the shop, she found a dress with a big ribbon on the back and a duffle coat with amber studs. Susan bought the dress with her credit card but buy the coat due to its high cost.

   Did Susan use her credit card? (Yes)

16. A witness was sitting in an interrogation room. A detective showed him several pictures of suspects, asking him to point out people who he saw at the scene of the incident. Among the pictures he recognized a man with scar above an eyebrow and a woman wearing red glasses. The witness pinpointed the man with his finger as culprit but didn't identify the woman because of his uncertainty.

   Did the witness identify the woman? (No)

17. A homeless man broke into a house carrying a backpack. He first planned to steal some food only. Once inside, he saw that there was a laptop computer with a cover and a jewelry box full of gems. The homeless man put the jewelry box in his and left the house quickly.

   Did the homeless man carry a backpack? (Yes)

18. An eagle was sitting on a branch, looking for its prey. It could detect all tiny movements from a distance. After a while it could easily find a mouse with a long tail and a rabbit with brown hair. The eagle snatched up the mouse with its strong and went back to its nest with it.

   Did the eagle leave the mouse alone? (No)

19. An undercover cop was wandering around platforms in a subway station. He watched people very carefully to find the pickpocket whose name was on the wanted list. In the meantime, he found a suspicious boy wearing a cap and an old man wearing black gloves. The undercover cop approached the boy with caution and that he showed his ID.

   Did the cop request ID from the boy? (Yes)

20. A detective walked into the scene of a crime carrying his digital camera. He wanted to find decisive evidence to put an end to the case. Luckily he discovered a knife with blood stains and a wallet containing an ID. The detective first took pictures of the knife with camera and then left the place to check the police records for the person on the ID.

   Did the cop find a gun? (No)

21. A man went to the church with his fiancé. He wanted to ask a priest to schedule his marriage. On entering the church office, there was an old lady drinking coffee and a nun reading a bible at the desk. The man bowed to the nun with courtesy and her where he could meet the priest.

   Was the man engaged? (Yes)

22. A manager was decorating a restaurant with Christmas ornaments. He was very excited to decorate the restaurant. In the store there was a window which wouldn't open and a door which had a broken knob. The manager decided to decorate the window with ornaments and do the door after fixing its knob.

   Did the manager decorate the door first? (No)
23. A hunter carrying a shotgun was chasing a reindeer. He intended to sell its antlers on the black market. Near the hillside of a mountain he found a reindeer which had large antlers and a wild pig which had very long and sharp fangs. The hunter killed the reindeer with the shotgun and off its antlers very carefully.
   Did the hunter cut off the reindeer's antlers? (Yes)

24. A farmer went to a field near his house carrying a hoe. He had raised various types of vegetables without using any chemical fertilizer. In the field there were lettuce with large green leaves and potatoes with tiny rootlets. The farmer dug out potatoes with the hoe and them into a sack.
   Did the farmer put the potatoes that he dug out in metal container? (No)

25. A teacher was about to grade students' mid-term exams. He wore his reading glasses and sat at the desk. On his desk, there was a pen which had little ink and a pen which had no cap. He started to grade the exams while holding them his left palm which had been a long time habit.
   Did the teacher wear reading glasses? (Yes)

26. An organizer escorted trustees who were supposed to give a speech at the luncheon. When he entered the main room, he realized that the podium was not prepared yet. He rushed to his office and grabbed a mic which was best for recording voice and a mic which was best for singing. He decided to place them together, because musicians would after the talk.
   Was the podium prepared when the organizer entered the room? (No)

27. An actress wanted to look stunning on stage. She asked her assistant to bring any accessories that she could wear on her dress. Her assistant brought a brooch with a blue feather and a brooch with sparking small diamonds. The actress yelled at her assistant as soon as saw them because they were given by her recent ex-boyfriend.
   Did the assistant bring accessories for the dress? (Yes)

28. An archeologist was thrilled to discover the Pharaoh's biggest pyramid. In the pyramid, remarkable treasures were found too. When he entered the pyramid, he saw a shovel with a wooden handle and a shovel with a stainless steel handle on the ground. As soon as he saw his assistants next to the archeologist asked the assistants to grab them and dig up the ground.
   Was the archeologist sad when he discovered the pyramid? (No)

29. A carpenter got an order from a duchess. The duchess wanted him to make a table in her mansion. The carpenter wasn't sure which tool he needed to bring; a saw with wide blades or a saw with narrow blades. When he couldn't decide, the carpenter decided to bring all to her mansion.
   Did the duchess want the carpenter to make a table? (Yes)

30. A mother was in a hurry to pick up her child. She brushed her teeth quick and ran to the parking lot. When she was about to open the door, she found a key with a basketball keychain and a key with a USB keychain in her jacket. Since it was her mother's car, she wasn't sure key should be used, so she tried them both.
   Did the mother brush her teeth slowly? (No)

31. A stage manager was checking the stage before rehearsal. At that time, the ballerinas told the stage manager that the lights did not make them outstanding. The stage manager found that available lights that he could turn on were a light with purple color and a light with gray jade green color. Since he wasn't sure which one would look good, decided to turn them all on during the rehearsal.
   Did the stage manager check the stage before rehearsal? (Yes)

32. The clerk was very hungry because he couldn't go on breaks for breakfast or dinner because it was Black Friday. Finally he was able to take a rest, so he entered a pantry to heat up his sandwich. As soon as he entered the pantry, he saw a cupcake with frosting and a cupcake with chocolate on the table. Without thinking who brought them, he finished eating right away.
   Did the clerk heat up soup? (No)

33. A teacher asked students to make a line outside the classroom. When the students entered the classroom in order, the teacher asked them to pick up a piece of paper and a pencil that was on the table. After picking up a piece of paper, a girl who was standing at the end found that there was a pencil with a chewed end and a pencil with a broken point. Although she didn't like either of them, she had choose at least one, because these were the only ones available.
   Did the students enter the classroom in order? (Yes)
34. A girl was excited to go to the prom with her new boyfriend. Since she had no appropriate shoes that went well with her dress, she visited a shoe store and tried many shoes on. She wasn’t sure whether she should buy shoes with high heels or shoes with a good arch support. After considering for an hour, she decided not to them in this shoe store, because her friend said the other stores had a better variety of shoes.

Was the girl unhappy about going to the prom? (No)

35. It was Anna’s 60th birthday, so Burke planned to give her a surprise gift. He remembered that Anna was fond of carrying blue colored bags, so he asked a clerk to show him all blue bags. The clerk showed him a bag with a short strap and a bag with an adjustable long strap. He remembered that Anna like them both whenever they the store, so he decided to buy both of them.

Was Anna fond of blue bags? (Yes)

36. A couple went to Costco to buy a clock that would match their new house. They expected to find the right one since they heard that their friend bought a nice clock at Costco last month. Luckily, they found a clock with a white wooden frame and a clock with a glass frame that would look good in their house. They agreed that it would be good to place in the living room and one in the dining room so they decided to buy them both.

Did the couple go to Costco to buy chocolate? (No)

37. A woman was jogging in Central Park in the morning. Suddenly, she felt nauseous and dizzy. She remembered a pill that was prescribed last month. She took the pill first and then, called 911 ask for a help.

Was the woman jogging? (Yes)

38. A musician was standing on a stage with bright lights. During the rehearsal, he gave a sign to the staff and the stage lights dimmed. When he started to play his guitar, he realized that it was not tuned appropriately. He stopped the rehearsal and started to tune the guitar.

Was the musician’s guitar tuned appropriately? (No)

39. A woman went to Macy’s to buy a mattress. A salesperson asked her if there was any preference. She wanted a firm mattress because of her back problem. The salesperson recommended the firm mattress which was in catalogue because there was currently no floor sample.

Did the woman go to Macy’s? (Yes)

40. A man was invited to his girlfriend's house for Christmas. He wasn’t sure what he needed to bring to impress his girlfriend's family. As this was the first time for him to visit her family, he decided to buy a bottle of wine. When he visited her house, he was very nervous dropped the bottle of wine on the floor by accident.

Did the man meet his girlfriend's family before Christmas? (No)

41. A speech therapist was scheduled to evaluate a 50-year-old male yesterday. The speech therapist expected the patient would have swallowing difficulty, but he also had language problems. She looked for a language assessment tool in her bag and started to test him. She was glad that she brought the language assessment today, even though she didn’t expect to use it.

Did the speech therapist use the language assessment tool? (Yes)

42. An audiologist decided to take a train to her speech and hearing clinic instead of driving. While on the train, a teenager sat next to her. The teenager listened to music aloud, although he was wearing earphones. She thought that the quality of earphones was poor worried about the teenager’s hearing.

Did the audiologist ride a bike to the clinic? (No)

43. A newly married man wanted to surprise his wife on her birthday. He searched for the kind of gift that would make her happy. While talking about this surprise with his mother, she recommended for him baking a special cake for her. He liked his mother’s idea and registered for a class right away.

Did the newly married man register for a baking class? (Yes)

44. A waitress was excited to train a new waiter. The waitress wanted to teach him the knowledge that she collected over 20 years. However, the new waiter thought that the waitress treated him unfairly and acted superior to him, so he threw away a tray at the restaurant. The waitress was displeased with his attitude because she wanted to help him.

Was the new waiter happy with the way the waitress treated him? (No)
45. A postman was in the middle of delivering mail. Suddenly, he couldn't breathe well and fell off his bicycle. Paramedics came and provided him an asthma inhaler right away. After waking up, the postman said that this attack worse than usual.
   Did the postman have an asthma attack? (Yes)

46. Tribesmen who couldn't hunt for a month were happy because the rainy season was over and the new moon would come.Carrying bows and arrows, the tribesmen decided to enter the forest because they needed to offer an animal for sacrifice. The brave tribesmen caught a snake and roasted it over the coals all afternoon. It became the centerpiece of their ritual meal to the new moon.
   Did the tribesmen roast a cow? (No)

47. A farmer planned to clear the land for a farm using a new tractor. However, the tractor stopped working, so he decided to use a donkey while it was being repaired. Although he didn't enjoy punishing the animal, the farmer used a whip because the work had to be completed by tomorrow. The donkey worked hard without refusing, therefore the farmer the donkey's cooperation.
   Did the tractor stop working? (Yes)

48. Jillian bought four bags of candy a week before Halloween. She couldn't resist the candy on the table and finally ate all three bags. Since only one bag was left, she gave one piece of candy to each child who visited her house on Halloween. After thirty minutes of the children's visits, all of candy was gone and she regretted eating so much.
   Did Jillian eat all four bags of candies? (No)
REFERENCES


