The Effects of Adult Aging on Syntactic Boundary Anticipation While Listening to Speech*

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ABSTRACT

Various language comprehension studies have used a technique known as 'spontaneous segmentation' (e.g. Wingfield et al., 1989) to demonstrate that, when given a choice, people tend to segment speech at significant syntactic boundaries (i.e., sentence, clause, and phrase boundaries). In spontaneous segmentation studies, participants listen to pre-recorded passages and stop at points of their choosing, for the purpose of immediate verbatim recall. Under these conditions, researchers can study how people would divide segments of speech if they were closely attending to every word.

In order to test age-related comprehension differences, young and older adult participants used the spontaneous segmentation technique to segment passages of prose, which randomly contained one of four delays between the time when the participant pressed the 'stop' button and when the recorded speech actually stopped. Despite the delays, both groups of participants performed similarly. This provides strong support for the preservation of language capacities despite age-related cognitive decline.

1. INTRODUCTION

Although we do not always stop to think about it, people comprehend, process, and respond to speech very quickly. We are able to finish the sentences of those we know well, and we are often able to infer what a friend is about to say. Adult speakers communicate without noticeable effort, listening, interjecting, and trading ideas. While people may appear to communicate easily, the ability to converse takes place as a result of many complicated processes in the human brain. One of these processes includes the ability to plan ahead when generating speech and while listening to speech.

In fact, previous studies have used what is known as spontaneous segmentation to show that people can, and indeed do, just that (Wingfield et al., 1989; Wingfield et al. 2001). Using this method, participants were asked to listen to passages of recorded prose and to stop

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the recordings whenever they wished, recall the segment of speech that they had just heard, and then continue listening to the passage. Later analyses demonstrated that participants had a strong tendency to interrupt the passages at significant syntactic boundaries, such as clause boundaries and sentence endings. Furthermore, it was shown that this tendency held true for both young and older adults, even though one might expect older adults to interrupt the passages more often in order to improve their recall accuracy (Wingfield & Butterworth, 1984; Wingfield & Stine, 1986). Even when the recall of the older adults began to decline, they continued to stop the speech input at syntactic boundaries.

Another method, known as the auditory moving window technique, has also been used to support the human capacity to anticipate speech (Little et al., 2005; Wingfield et al., 2001). As in spontaneous segmentation, this technique requires participants to listen to and recall passage segments, but in this case the researcher presents presegmented passages. In a study by Fallon et al. (2006), participants paced themselves through presegmented passages with instructions to repeat each segment verbatim or to expect comprehension questions after they finished their recall. When the researchers measured the pause times between when the participants stopped and restarted the recordings, it was shown that both young and older adults paused for greater amounts of time after major clause boundaries than they did after other points in the passages. Furthermore, this tendency became even more apparent as the syntactic complexity of the sentences increased. Besides supporting prior evidence that people mentally organize speech in terms of its syntactic structure, these types of studies indicate that people are able to anticipate significant syntactic boundaries before they occur.

These experiments revealed important behavioral information about the complex process of on-line language comprehension. However, there are still many unanswered questions. For instance, it is unclear which factors of speech specifically allow people to anticipate syntactic boundaries. The goal of studying these intricate linguistic phenomena is to better understand the nature of language itself. However, in order to explore syntactic boundary anticipation, it is first necessary to comprehend the mechanisms, processes, and analyses that have led to our current understanding of language.

1.1 A DESCRIPTION OF VERBAL SHORT-TERM MEMORY

Without a doubt, memory is crucial to the human ability to process and comprehend speech. Psychologists have traditionally divided memory into two categories: long-term memory, and short-term memory (Caplan & Waters, 1999). Long-term memory refers to memory for facts and information that can be stored in the brain for years to come. Short-term memory refers to memory for small amounts of information that is retained over a shorter period of time. It may function differently depending on whether it is linguistic, visual, spatial, or any other type of memory. As the overall goal of this thesis is to discuss the intricacies of on-line language processing, this discussion will focus on verbal short-term memory, or memory related to speech.

There are five basic elements that affect the performance of verbal short-term memory: word length, articulatory suppression, phonological similarity, lexicality, and long-term learning (Gathercole, 1997). Word length refers to the "articulatory duration" of a word, not necessarily the number of syllables that it contains but rather the amount of time that it takes to say a word. For example, the word *harpoon* is longer than the word *wicket*. Evidence has shown that word length affects how many words can be recalled from a list. This effect is often linked to the process of word rehearsal, or repetition through memory storage (Klatzky, 1975); lengthier words take longer to rehearse and thus there is a greater chance that they will be forgotten in between rehearsals. However, Gathercole also describes studies suggesting that the word length effect may be a partial consequence of memory decay while recalling lists of long words as opposed to short words.

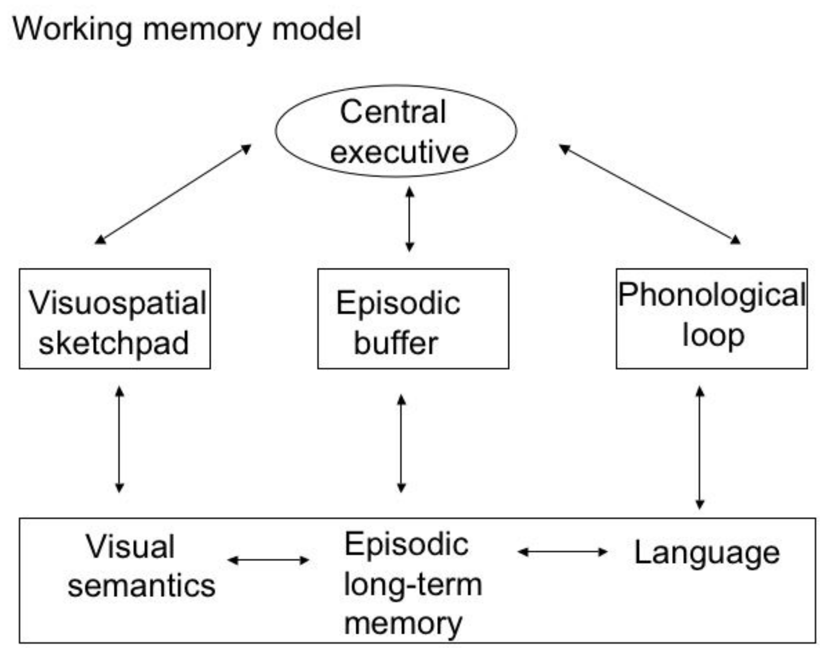
Articulatory suppression refers to the effect that is exhibited when subjects are asked to repeat nonsensical phrases in between words that they are attempting to read and recall. When this is done, word recall is greatly diminished. Again, this effect is attributed to the interruption of word rehearsal. Next, the effect of phonological similarity is that the recall of lists of words is worse if the words are phonologically similar (e.g. book, nook, took) than if they are phonologically different (e.g. book, apple, water). This phenomenon demonstrates that acoustic confusion has a strong effect on memory span (Conrad & Hull, 1964). Lexicality refers to whether or not a word is in fact real; this is significant because people are much better at remembering lists of real words than they are at remembering non-words. Furthermore, people are consistently able to rate non-words based on their similarity to real words. Together, these factors indicate that verbal working memory is strongly influenced by innate knowledge of the phonological structure of a language (Gathercole, 1997). Lastly, studies have shown that there is a correlation between performance on verbal short-term memory tasks and long-term learning. However, the precise relationship between short-term memory and learning is not yet understood.

1.2 MODELS OF SHORT-TERM MEMORY AND WORKING MEMORY

There are four models of short-term memory that have gained attention in cognitive psychology: the working memory model, the network model of the phonological loop, the trace decay model, and the interactive model of phonological memory (Gathercole, 1997). These models offer verbal, computational, and mathematical ways of thinking about the nature of short-term memory.

In 1974, Baddeley and Hitch became famous for describing short-term memory as "working memory." Working memory is defined as a limited-capacity memory system that both stores and manipulates information while a task is being performed. This is different from other definitions of short-term memory that tend to stress its storage properties but not its potential operative properties (Caplan & Waters, 1999). Baddeley and Hitch initially designed a three-part model comprised of a central executive, a phonological loop, and a visuospatial sketchpad (Repovs & Baddeley, 2006). The central executive serves to control working memory in that it is heavily involved in the manipulation of information and in the management of the phonological loop and the visuospatial sketchpad. The phonological loop stores information in phonological form, and the visuospatial sketchpad stores visual and spatial information. Later, another component called the episodic buffer was added (see Figure 1). It was deemed to be a type of limited capacity storage mechanism that allows for the integration of different types of information. This type of model has had an enormous impact on research related to memory and language. Today, the idea of a working memory with the capacity for some form of manipulation is widely accepted.

Figure 1. The multi-component model of working memory, from Repovs & Baddeley, 2006, p. 6

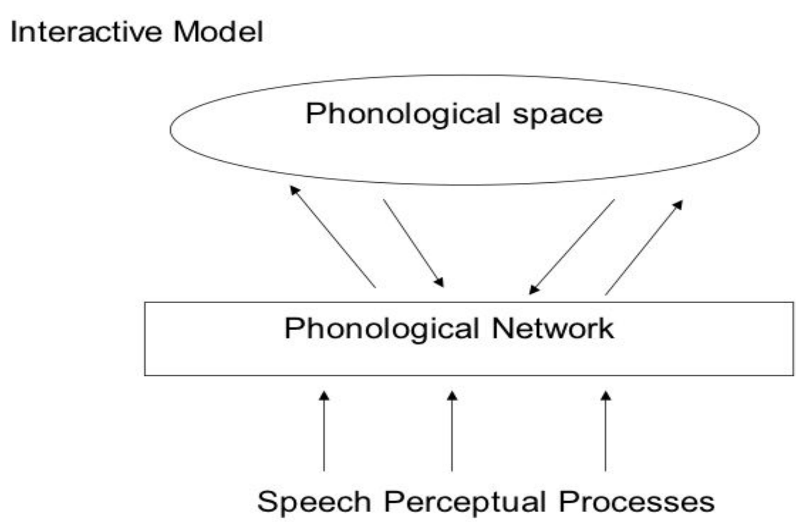


Next, Burgess and Hitch (1992) created a network model of the phonological loop, in order to describe more clearly how it would function (Burgess & Hitch, 1992). This network model is multi-layered and attempts to explain not only how verbal information is retained, but also how individual items are stored in relation to each other. For instance, verbal memory tasks often require subjects to remember specific words in a certain order. Burgess and Hitch surmised that the phonological loop must allow for the retention of "item-item associations" and "item-position associations" (Gathercole, 1997). In addition, it must recognize where a word begins and ends based on the types of phonemes, or individual sounds, that are encountered. Then it must filter word nodes that have already been recognized to allow for concentration on newly encountered phonemes. Therefore, Burgess and Hitch assigned three types of connections to the network model: the relationships between newly encountered phonemes and words, between word nodes and the filter, and between the filter and the output phonemes. (The output phonemes reactivate the phonological loop so that it begins to process the next word in the list.) This computational model is extremely useful for explaining how individual words might be retained.

Another representation, the trace decay model of Brown and Hulme (1995), aimed to explore whether the word length effect in recall could still be a feature of a model with no rehearsal process. Rather than trying to create a more general model to explain short-term memory, as Baddeley and Hitch did, Brown and Hulme tested a more specific hypothesis. Their computational model represents individual words in terms of a "memory trace" composed of "time slices" with one slice equal to 0.1 second. Correspondingly, longer words have more time slices than shorter words. Time slices also account for the time intervals in between words in the memory sequence (e.g. the sequence of words that the subject recalls). The memory trace of a recalled word decays by three different processes (Gathercole, 1997): a) every segment has a 0.95 probability of being correctly recalled, b) a decay value is applied to all segments for every 0.1 second that it takes to recall them, and c) there is always a 10 percent chance that a segment will not be recallable at all. The third process is included to account for any distractions that may have caused the subject to forget a word; this should be noted separately from cases in which a word is forgotten because of memory decay.

While the three models described above provide plausible explanations of short-term memory, they do not address the connection between lexicality and short-term memory performance (that is, the fact that people remember words more easily than non-words), and the relationship between verbal short-term memory and language learning (Gathercole, 1997). The interactive model of phonological memory created by Gathercole and Martin (1996) purports to do just that. Instead of focusing on the idea of a temporary memory system, this model focuses on the idea that verbal short-term memory tasks are facilitated by phonological representations that arise as a consequence of speech perception. In other words, Gathercole and Martin suggest that there is no separate system for storing temporary information. They argue that speech perception in itself is a complicated process involving the manipulation of information. Using their model, the perception of speech activates temporary phonological representations based on phonetic properties of the words that are perceived (see Figure 2). These temporary representations then stimulate a phonological network based on a number of different factors, which in turn activate a "phonological space". The phonological space is a multi-dimensional network in which all potential phonetic combinations in a language are retained (see Gathercole & Martin, 1996; Gathercole, 1997).

Figure 2. A representation of the interactive phonological model of memory, from Gathercole and Martin, 1996.



This model addresses the concerns about lexicality in that phonetic combinations that are likely to exist in a given language would have high levels of activation in the phonological network, and vice versa. That would explain why it is easier for people to remember (and process) words more easily than non-words. Accordingly, the interactive model explains the relationship between short-term memory and learning with its inclusion of activation levels. A real word generates higher activation levels in the phonological network than a non-real word, but if a non-real word is presented a number of times, the levels of activation accumulate and henceforth create a higher level of activation in the phonological space. Thus, phonological learning occurs as a result of repetitive stimulation of the temporary storage area.

The four models described above are by no means the only models that have been developed, but they provide a general illustration of the types of models that have been used thus far.

1.3 LANGUAGE COMPLEXITY AND SENTENCE PROCESSING

While memory is certainly an integral facet of human language, it is also important to understand the overall nature of language itself. It is not enough to memorize vocabulary or to study the grammatical structure of a language; one must interact with speakers of the language on a daily basis until fluency becomes automatic. As of yet, there is no definitive explanation for the development of our ability to comprehend and produce language effortlessly. Research in the field of neuropsychology suggests that factors such as syntactic complexity (Caplan et al., 1999; Carpenter et al., 1994), semantic predictability (Aquino, 1969; Taylor, 1953), and prosody (Lehiste, 1970) all play significant roles in language processing. However, the knowledge that these factors are important does not necessarily reveal why this is so.

Syntactic complexity has probably been singled out for reasons that seem fairly intuitive, and these intuitions have proven to be true. People feel certain, without doing any experimentation, that children learn to read and understand syntactically simple sentences (e.g., ‘See Spot run.’) before syntactically complex ones (e.g., ‘The candidate that the man liked won the election.’). Studies of ‘readability’ have confirmed these intuitions, using methods such as eye fixation tracking to show that people need more time to process syntactically complex sentences than they do to process syntactically simple ones (Flesch, 1951; Carpenter et al., 1994; Rayner & Well, 1996). Several studies have also separated syntactically complex sentences into different categories such as object-relative and subject-relative sentences, as demonstrated below:

Object-relative: The girl that the boy liked had brown hair.
Subject-relative: The girl that liked the boy had brown hair.

These studies showed that it takes longer to process object-relative sentences than subject-relative sentences (Carpenter et al., 1994), because object-relative sentences have a more complex sentence structure. In general, studies of non-canonical sentences have demonstrated quite convincingly that sentences that are syntactically complex require more processing time than their canonical counterparts. After isolating the various linguistic properties that create syntactic complexity and cause comprehension difficulties, the next step is to decipher these properties in order to understand why they cause these difficulties.

In addition to syntactic complexity, semantic predictability is also a salient factor in on-line language processing. It seems intuitive that words which are used frequently in everyday speech should be processed more easily than less common words. Indeed, studies have shown that speech containing high-frequency words is more quickly processed than speech containing lower-frequency words (Marslen-Wilson & Tyler, 1980). This notion supports the interactive phonological model of memory (Gathercole & Martin, 1996). If that model is in fact accurate, words that are used most often should have a higher level of phonological activation and thus would be accessed more easily than low-frequency words.

However, while syntactic complexity is certainly an essential feature of language, the prosodic component of language is also a powerful facilitator of speech processing. Shattuck-Hufnagel and Turk (1996) presented evidence that syntax by itself is not entirely predictive of the way in which utterances are generated. They argue that prosody must also play a key role. Prosody is composed of three main features: pitch variation, word stress or amplitude, and timing. Together, these features create a melodic pattern that supports language production and language comprehension. One of the most important characteristics of prosody is its ability to signal syntactic boundaries (Cooper & Sorensen, 1977; Streeter, 1978). For example, cues such as sharp rises in fundamental frequency or word lengthening are often used to signal the end of a phrase. It is not the case that prosody merely complements the already-sufficient syntactic cues in a phrase—incorrect prosodic cues lead to confusion and slower semantic comprehension (Blasko & Hall, 1998). Also, the complete absence of prosodic cues leads to difficulties interpreting the linguistic structure of speech (Wingfield & Butterworth, 1984). All of these studies highlight the importance of prosody as an essential component of language processing.

1.4 LANGUAGE PROCESSING IN THE CONTEXT OF AGING

There is an established body of literature that describes the effects of age-related cognitive decline. For instance, the natural process of aging can often lead to deficits in hearing (McCoy et al., 2005) and working memory efficiency (Tun et al., 1991), both of which have a direct impact on language processing and comprehension. It is clear that a hearing deficiency would result in decreased language comprehension, because speech can only be processed if the listener can clearly hear what is being said. Also, a working memory deficit could result in decreased language comprehension because a listener must listen to speech, remember it, and process it in order to understand what is being said. In addition, aging may result in a decline in overall processing resources (Tun et al., 1991), posing yet another problem for performance on certain cognitive tasks.

1.5 GOALS AND PREDICTIONS FOR THE CURRENT STUDY

Several studies have demonstrated that both young and older adults use a complex parsing process to comprehend speech (Wingfield & Stine, 1986). In general, healthy older adults do not experience a decline in their language faculties; on the contrary, their knowledge of vocabulary and syntax is conserved regardless of their age. However, we do not know whether older adults are able to perform linguistic tasks as well as young adults do because of a general preservation of linguistic abilities, or because older adults develop a compensatory strategy that allows them to perform as well as young adults on certain tasks.

The overall goal of the current study is to gain a better sense of the on-line planning that takes place as speech is heard, in both young and older adults. The research will focus on examining any age-related differences in planning abilities. Also, this research will address the hypotheses discussed above. The expectation is that planning ability will be affected by age, and that the study will reinforce research showing the connection between language comprehension and age-related cognitive decline.

2. PRELIMINARY EXPERIMENT: EXPLORING THE DELAYED PAUSE PARADIGM

2.1 INTRODUCTION

The purpose of this experiment was to examine on-line linguistic planning by replicating a procedure used in spontaneous segmentation studies (e.g. Wingfield et al., 1989; Wingfield et al., 2001), while integrating a new technique known as "delayed pause" (Piquado, Wingfield Lab, 2006). Using the spontaneous segmentation method, participants are asked to listen to passages and to interrupt them as many times as they wish, for the purpose of immediate verbatim recall. These types of studies consistently show that people tend to stop the passages at significant syntactic boundaries (i.e., sentence, clause, and phrase boundaries.)

The next challenge is to discover how far in advance these stopping decisions are made. A previous study completed by Piquado (Wingfield Lab, 2006) used the spontaneous segmentation technique combined with delayed pause to begin addressing this question. In that study, participants were asked to segment passages of speech wherever they wished, with one modification: participants had to decide in advance where they wanted to stop the speech because the input would continue for several hundred milliseconds after they pressed the "stop" button. The goal was that by learning to anticipate this "delayed pause" of the input, participants would still be able to stop the input at syntactic boundaries – as long as they planned this in advance. While Piquado's study started to address the question of syntactic boundary anticipation, her study only used 2 delay conditions: 0 seconds (sec) of delay and 3 sec of delay. The 0 sec delay condition demonstrated, as expected, that people tended to stop the passages at syntactic boundaries. However, the 3 sec delay condition was too long and participants were unable to learn how to cope with it during the course of the experiment.

Therefore, the goal of the current experiment was to test the delayed pause paradigm again, using more delay conditions to identify the delay lengths that would be appropriate for future studies of syntactic boundary anticipation. The aim was that, over the course of entire passages, participants would adjust to some of the delays and continue to segment the passages at syntactic boundaries. By varying the amount of this "delayed pause," it would then be possible to quantitatively measure the adjustment abilities of the participants. Also, it would be possible to gain a better sense of the longest delays that could be tolerated.

2.2 METHOD

2.2.1 PARTICIPANTS

There were 4 young adult participants in this preliminary study, 1 male and 3 female. They ranged from 20-26 years of age and had a mean of 15.5 years of education. All participants were native speakers of American English and had no history of neurological disorders.

2.2.2 STIMULI

The stimuli consisted of 11 passages of prose, each 147-157 words in length. The passages were created using articles from popular magazines and websites. They covered a wide range of topics such as history, agriculture, and cooking, and included a variety of syntactic forms.

The passages were recorded by a female speaker of American English, in a normal speaking voice, at an average speed of 165 words per minute (WPM). Each passage was integrated into “Pause Staller,” the delayed pause computer program created by Ethan Yetton and Raj Stewart. This program allowed for the creation of different running orders of passages, each containing encoded instructions about controlling the amount of delay between any given “stop” command and the actual interruption of the recording.

Every running order consisted of a practice passage repeated three times, each time with a different amount of delay. (The amount of delay always remained constant within any given passage.) Next, there were ten test passages containing delays ranging from 0 seconds to four seconds. Participants were able to start and stop the passages at will by pressing the return key on a computer.

2.2.3 PROCEDURE

Participants were presented with ten passages containing 5 different amounts of delay between the time when the “stop” button was pressed and when the input actually stopped: 0, .5, 1, 1.5, and 2.5 seconds. The passages were counterbalanced such that every participant heard every passage an equal number of times, with two passages per delay condition. The Pause Staller program recorded the participants’ starting and stopping times at every passage segment, and Audacity (Mazzoni et al., 1991, Free Software Foundation, Inc., Boston, Massachusetts) was used to record all testing sessions. This information was stored for scoring purposes.

The speech passages were presented using Eartone 3A insert earphones (E-A-R Auditory Systems, Aero Company, Indianapolis, Indiana) with the exception of one participant who elected to use headphones. The recordings were routed through a calibrated Grason-Stadler audiometer (Model 1761) to ensure volume accuracy. Volume was adjusted to a comfortable level that remained constant through the duration of the experiment.

All testing sessions consisted of 3 practice passages followed by the 10 test passages, as described above. Participants were instructed to listen to a practice passage and stop the recording whenever they wished, and then give an oral recall of the segment of speech that they had just heard. They were asked to continue with this process until the passage was complete. Accuracy of recall was extremely important because it ensured that participants were concentrating on the task of comprehending the input.

The first practice passage was presented without any delayed pause to allow participants to become acclimated to the nature of the procedure. Next, the practice passage was presented two more times, each time with an increasingly longer amount of delay, again for the purpose of acclimation. The procedure for the 10 test passages was identical to that of the practice passages, except that the test passages were not presented in increasing order of delay condition.

2.2.4 SCORING

The data were scored based on where the participants chose to stop the recordings, emphasizing the point when the input actually stopped as opposed to the point when the participant pressed the "stop" button. (These two points were identical in the 0 sec delay condition, but there was a clear distinction in the other conditions.) Therefore, any references to "stops" in this thesis refer to points when the input stopped, unless otherwise noted. The stops were counted and grouped according to their placement in the following categories: stops at sentence boundaries, clause boundaries, phrase boundaries, "other" stops, and stops that split words. Scoring was fairly strict, so that stops occurring toward the beginning or end of a word were counted as stops that split words, as long as those stops occurred in the main part of the word. For example, a stop that occurred between /m/ and /p/ in "stamps" was counted as a word-splitting stop, whereas a stop that occurred between /p/ and /s/ in the same word was not considered to be a word-splitting stop.

In addition, the data were scored for recall accuracy and segment size. If the recall of a word was mostly correct, the word was counted as a correctly recalled word. Also, if a participant recalled a word in a form that differed slightly from the original input, the word was still counted as correct. For instance, if a participant said "white" when the correct word was "whitish," the participant still received full credit for recalling the word. Only verbatim responses were counted, with paraphrases receiving no credit. A general measure of segment length was determined by counting the number of words occurring between one stop and the next one, regardless of the recall accuracy of the words within any given segment.

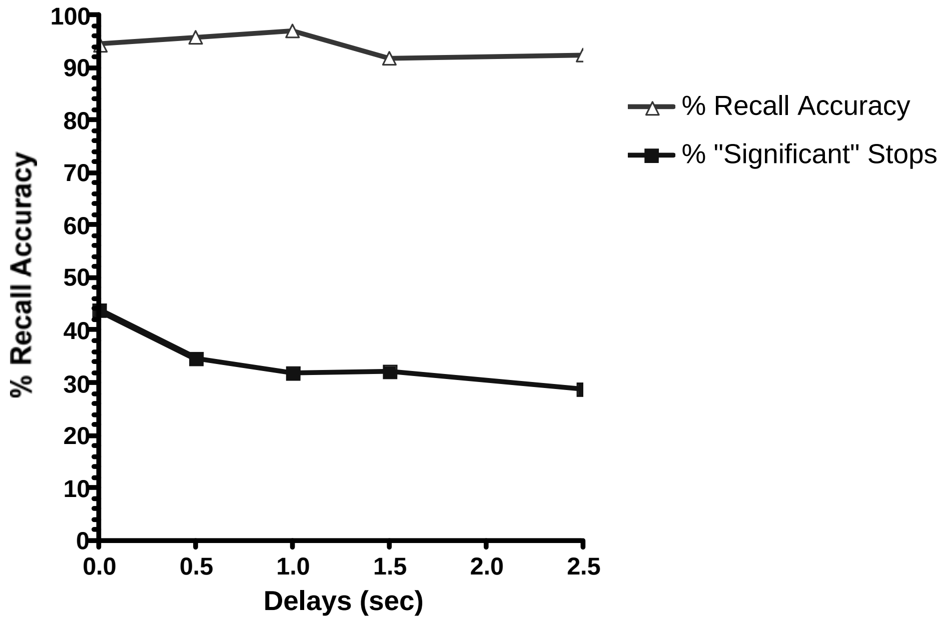
Due to the possible influence of starting and ending effects, any words occurring before the first two stops or after the last two stops in any passage were not counted (participants also did not receive any penalty for this). Correspondingly, the first two stops and the last two stops made in each passage were disregarded.

2.3 RESULTS AND DISCUSSION

As stated earlier, previous spontaneous segmentation studies have shown that people have a tendency to segment speech at syntactic boundaries (Wingfield et al., 1989). The goal of this pilot study was to recreate the results of prior studies, to identify any recall differences across delays, and to decide on appropriate delay lengths for future studies of syntactic boundary anticipation.

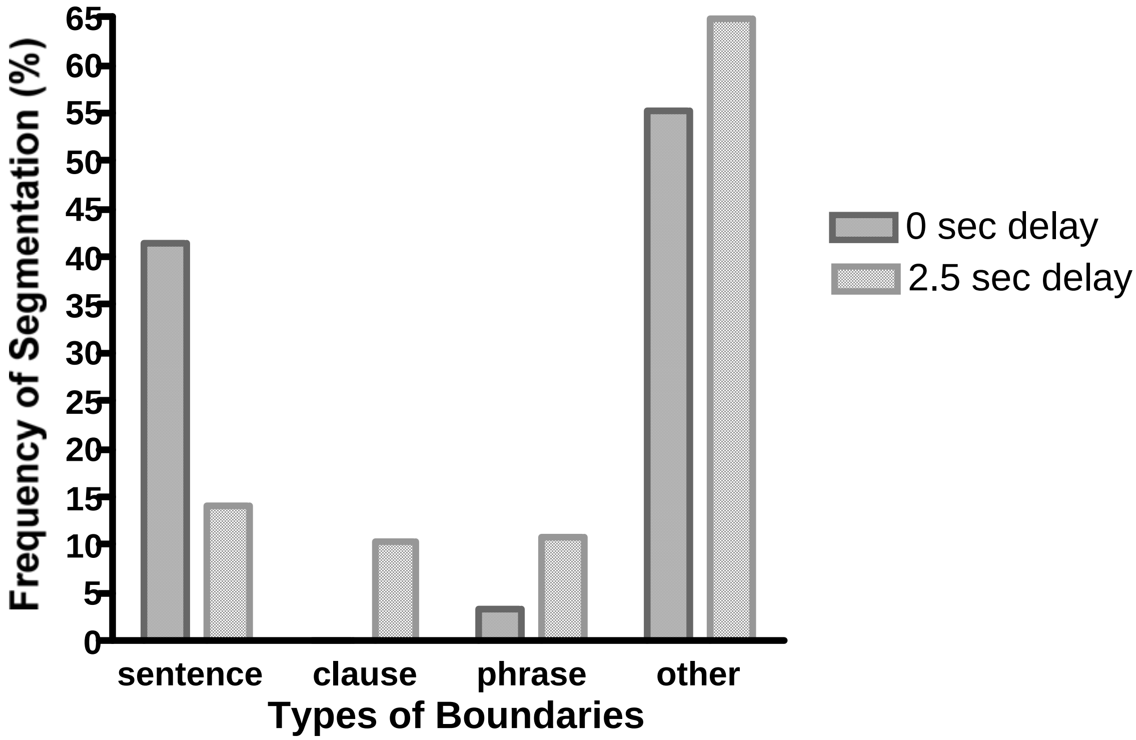
Thus, data analysis focused on recall accuracy and frequency of segmentation at sentence, clause, and phrase boundaries. As shown in Figure 1, recall accuracy remained above 90% across all delays for all participants. This indicates that participants were in fact following the given instructions to be as accurate as possible in recalling the passages. That by itself is significant because it indicates that participants adapted to the delays as they increased in length and became more difficult to cope with. (Presumably, if participants were unable to adapt, recall accuracy would decrease as delay length increased.) Also, as indicated in Figure 1, the percentage of stops at syntactic boundaries ("significant stops") declined as the delays increased, then appeared to plateau.

Figure 3. The upper curve shows the effect of delay condition on the percentage of words correctly recalled. The lower curve shows the effect of delay condition on the percentage of "significant" stops (i.e., stops occurring at sentence, clause, or phrase boundaries).



In general, participants tended to segment speech at syntactic boundaries more often during the shorter delay conditions than during the longer ones. This is consistent with the idea that shorter delays are easier to adjust to. In addition, as Figure 2 shows, segmentations at syntactic boundaries were more likely to occur at sentence boundaries than at clause or phrase boundaries. This graph demonstrates the dramatic difference in performance between the shortest and longest delay conditions.

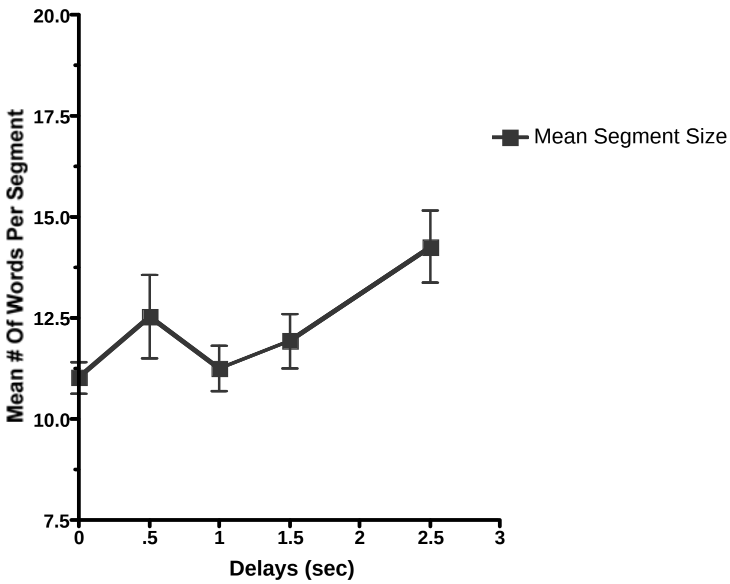
Figure 2. The effects of 0 sec delay or 2.5 sec delay on the percentage of stops that occurred at significant syntactic boundaries.



The above results generally agree with previous findings on this subject. While other studies have shown the frequency of segmentation at syntactic boundaries (together, in total) to occur well above 50% of the time when there is no delay (e.g., Wingfield and Butterworth, 1984), those studies may have used less stringent scoring techniques. The decision to count (or not count) stops occurring in the beginning or end of a word as word-splitting stops could have an enormous impact on the accuracy results described in spontaneous segmentation studies. The following version of this experiment will address this point.

Next, Figure 3 (below) shows a change in the mean length of segments across delays, with longer segments occurring in the longer delay conditions (an increase from 10 to 15 words). Since the average length of a syllable in the test passages was approximately 230 milliseconds, a segment increase of several words (i.e., at least several hundred milliseconds) is a significant change. The average length of a syllable was calculated by dividing the length of the second sentence in each test passage by the number of words in the sentences, and then calculating the overall mean length of a syllable based on the mean for each passage. As within-sentence pauses in speech were not subtracted from the lengths of the sentences, this number is a rough approximation.

Figure 5. Segment size as a function of delay length. Vertical bars represent the standard error of the mean in each delay condition.



In general, the results of Preliminary Experiment 1 agree with the results of previous literature that has been published on this subject. Sources of error may have included unclear instructions, errors in the recording mechanism of the computer program, or human scoring errors. While the experiment gave a sense of the delay lengths that would be appropriate for future studies, more sophisticated testing on a larger scale is necessary.

3. MAIN EXPERIMENT: THE EFFECTS OF THE DELAYED PAUSE PARADIGM ON SYNTACTIC BOUNDARY ANTICIPATION IN YOUNG AND OLDER ADULTS

3.1 INTRODUCTION

The aim of this study is to examine any age-related effects of spontaneous segmentation with delayed pause in a full-scale, more carefully controlled experiment. The previous study examined delay lengths that would be appropriate for young adult participants, but those delays were not tested on older adults. As stated previously, spontaneous segmentation studies (without delayed pause) have demonstrated the robust tendency of older adults to segment passages into syntactically relevant sections, just as young adults do (Wingfield et al., 1989; Fallon et al., 2004). Yet, evidence has shown a direct correlation between aging and a general slowing of cognitive functioning (Salthouse, 1996). Therefore, a spontaneous segmentation task containing a timing element may help explain the process of cognitive functioning in healthy older adults.

The current study addresses whether young and older adults perform similarly in a spontaneous segmentation task containing delayed pause, as described in the Preliminary Experiment. One theory is that, a) older adults will still perform similarly to young adults, using an anticipatory strategy in order to compensate for any deficits related to language processing or reaction time. If this is true, then there should be no difference between the performance of young and older adults, even as the delays increase. Another theory is that, b) the older adults will be differentially impacted by the delays, because even though their language faculties might be perfectly intact, their reaction time is slower than young adults and they may be unable to compensate for this fact. In this case, an increase in the amount of delay should cause the performance of older adults to decline sooner than the performance of young adults. In other words, if good performance is defined as high recall accuracy and the continuing ability to stop the passages at syntactic boundaries, increased delay length should cause these measures to decline in older adults when they are presented with some delay, whereas it would take a longer delay to obtain the same effect in young adults.

3.2 METHOD

3.2.1 PARTICIPANTS

The participants in this study were 12 young adults and 14 older adults[1]. The young adults, 4 males and 8 females, were undergraduate and graduate students at Brandeis University with ages ranging from 18-28 (M = 20.58, SD = 2.57). They had a mean of 14 years of education (SD = 1.65). The older adults were community-dwelling volunteers, with ages ranging from 66-81 (M = 71.93, SD = 4.68). The group had a mean of 17.14 years of education (SD = 2.03). Participants were in good health for their age groups and were selected for their high levels of education. Every participant received an honorarium for participating, with the exception of one participant who refused compensation.

3.2.2 ANCILLARY TESTS

The following ancillary tests were administered in order to make certain that young and older participants were approximately matched in terms of vocabulary ability, and that they had normal hearing for their age groups. This ensured that observed differences within age groups could not be attributed to educational factors or hearing problems.

3.2.2.1 SHIPLEY VOCABULARY TEST

The Shipley Vocabulary Test (Shipley, 1940) is a self-administered, non-timed multiple-choice test of vocabulary. Participants were asked to select the correct definitions for 20 test words. Older participants had a slightly higher average score than the young participants (M_{Young} = 14.41, SD = 1.44; M_{older} = 16.71, SD = 2.23). While this difference was statistically significant, $t(24) = 3.1$, $p < .01$, all scores fell within the normal range for each age group (Shipley 1940).

3.2.2.2 FORWARD AND BACKWARD WORD SPANS

Forward and backward word span tests were given in order to ensure that all participants had normal verbal working memory capacities for their age categories (Tomkins et al., 1994). For this test, participants were asked to listen to unstructured lists of words and to repeat each list after they heard it, keeping the words in the same order. With each successful repetition,

[1] The study was originally designed for 16 young participants and 16 older participants. However, due to several factors, only the data from the participants described above was analyzed in this thesis. In addition to the 12 young adults described above, eight other young adults participated. Their data was excluded due to equipment failure, failure to follow instructions, or non-native English speaker status. One older adult was excluded due to poor performance on audiometric testing.

the lists grew longer and longer until a given participant was no longer able to complete the task. This process was then repeated with new lists of words and participants were asked to repeat each list of words in the reverse order in which it had been heard. The young and older adults had similar mean forward word span scores (M_{Young} = 5.42, SD = 0.90; M_{Older} = 5.07, SD = 0.83), and a t-test confirmed a lack of significant difference between the two groups, $t(24) = 1.0$, $p > .05$. Both groups also performed similarly on the backward word span test (M_{Young} = 4.0, SD = 0.08; M_{Older} = 4.07, SD = 0.73), again confirmed by a lack of significance between the groups, $t(24) = 0.91$, $p > .05$.

3.2.2.3 PURETONE AUDIOMETRIC SCREENING

Before the main experiment, all participants were given an audiometric screening in order to make sure that their hearing abilities were within the normal range for their age group. The test was administered separately for each ear using Eartone 3A insert earphones (E-A-R Auditory Systems, Aero Company, Indianapolis, Indiana). One young participant and three older participants used headphones instead of inserts. Pure tone sounds were delivered using a digitally calibrated Grason-Stadler Clinical Audiometer (Model 1761). The tested frequencies were 250, 500, 1000, 2000, 4000, 5000, and 8000 Hertz (Hz). Young participants had a pure tone average (PTA, average of performance at 500, 1000, and 2000 Hz) of 4.58 dB (SD = 3.49) and older participants had a PTA of 18.21 dB (SD = 6.84). As expected, this difference was significant, $t(24) = 6.2$, $p < .0001$, but most participants were within the normal range for their age group (Harrell, 2002). Three older adults had hearing abilities that were close to, but not within, the range for clinically normal hearing; their PTAs were 26.67 dB, 26.67 dB, and 28.33 dB.

3.2.2.4 SPEECH RECEPTION THRESHOLD

The speech reception threshold (SRT) of all participants was also tested. The purpose of this test, conducted using Eartone 3A insert earphones (E-A-R Auditory Systems, Aero Company, Indianapolis, Indiana), was to reinforce the results of the puretone audiometric screening as well as to provide a specific measure of hearing sensitivity for speech (Brandy, 2002). Young adults had an average best-ear SRT of 0.83 dB (SD = 7.02), and older adults had an average best-ear SRT of 17.38 dB (SD = 5.98), showing a clearly significant age difference, $t(24) = 6.5$, $p < .001$. Most participants tested within the normal range for their age groups (Brandy, 2002). Out of the three older adults described in *Puretone Audiometric Screening*, only one had an SRT that fell outside of the range for clinically normal hearing; that participant's best-ear SRT was 30 dB.

3.2.3 STIMULI

The stimuli consisted of 8 test passages, all taken from those in the Preliminary Experiment (see Appendix). The test passages ranged from 147-157 words in length, and were recorded by a female American English speaker at a rate of approximately 165 wpm. As in the earlier experiment, passages were integrated with the Pause Staller program created by Ethan Yetton and Raj Stewart. In this experiment, 4 syllabic unit-based delay conditions were used, in order to create delay conditions that were more specifically relevant to word structure. Since the average length of a syllable in the test passages was calculated to be approximately 0.230 sec, the delay conditions were based on multiples of this number. The delay conditions were 0 sec, 0.230 sec, 0.920 sec (4 times the average syllable length), and 1.840 sec (8 times the average syllable length). Sixteen separate running orders were created, with one running order per participant, so that young and older participants received the same running orders[2].

Every running order contained 4 short practice passages, each containing a successively longer amount of delay between the time that the participant pressed the return key and the time when the recording actually stopped. All delays remained constant within a given passage. The practice passages were followed by 8 test passages with 2 passages per delay condition, grouped together. Test passages were approximately counterbalanced such that all passages were heard an equal number of times in each delay condition, and all passages were heard an equal number of times by the end of the experiment[3].

3.2.4 PROCEDURE

As in Preliminary Experiment A, participants were instructed to listen to a passage and to stop the recording whenever and wherever they wished, and then to give an accurate oral verbatim recall of the segment of speech that they had just heard. They were instructed to continue with this process until each passage was complete. Participants were asked to focus on recalling the passages with 100% accuracy, in order to ensure that they would closely attend to every word. The reason for this is that people are more careless about organizing speech when they are not focused, so the instructions were designed to encourage a high level of concentration without directly stating the overall goals of the study.

The recording could be stopped and restarted by pressing the return key on a laptop computer. Participants were explicitly instructed to focus on orally recalling the speech segments after each self-initiated stop, to avoid splitting words and to avoid speaking until the recording had actually stopped (in order to prevent a shadowing effect). Instructions regarding word-splitting were included due to the high instance of word-splitting in Preliminary Experiment A.

The stimuli were delivered binaurally through a digitally calibrated Grason-Stadler audiometer (Model 1761), which was adjusted to present speech at 40 Db above the SRT of each participant's best ear. (The Pause Staller program was presented on a laptop that was routed through the audiometer in order to control volume.) Participants wore Eartone 3A insert earphones (E-A-R Auditory Systems, Aero Company, Indianapolis, Indiana), with the exception of 1 young adult and 2 older adults who wore headphones. Recall responses were given orally, audio recorded, and stored for scoring purposes.

3.2.5 SCORING

Scoring was carried out as described in the Preliminary Experiment, with some modifications. Data were again scored for stop placement and number of stops, with emphasis on where the participant caused the recording to stop, rather than on when the return key was pressed. Stops were counted and grouped based on their inclusion in the following categories: stops at sentence boundaries, stops at clause boundaries, stops at phrase boundaries, "other" stops, and stops which split words. Unlike the scoring method used in the Preliminary Experiment, scoring for the current experiment was more generous in terms of words that were counted as correct. Stops that occurred in the beginning or close to the

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[2] Due to the discrepancy in the number of young and older participants, young adults were presented with running orders 1-12 and older adults were presented with running orders 1-14.
[3] The approximate counterbalancing was due to the discrepancy in the number of participants.

end of a word were not counted as split words; a stop was considered to split a word only if it occurred explicitly mid-word. Thus, if a stop occurred in the beginning of the first word in a sentence, the stop was scored as though it occurred at a sentence boundary.

As in the Preliminary Experiment, the data were also scored for recall accuracy and segment size. Words that were half-correct or mostly correct were counted as correctly recalled words. Any correct words that were stated within the correct segment but out of order were also counted as correct. Only verbatim recall was counted as correct, so that paraphrases received no credit.

All data within the range of the first two stops or the last two stops made in each passage was not included in any analysis due to the possibility of starting and ending effects.

3.3 RESULTS

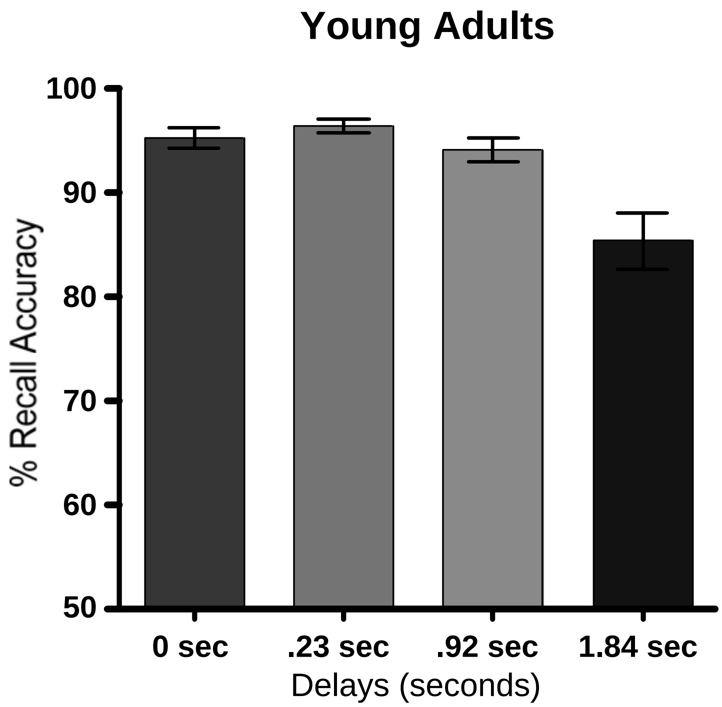
3.3.1 ACCURACY

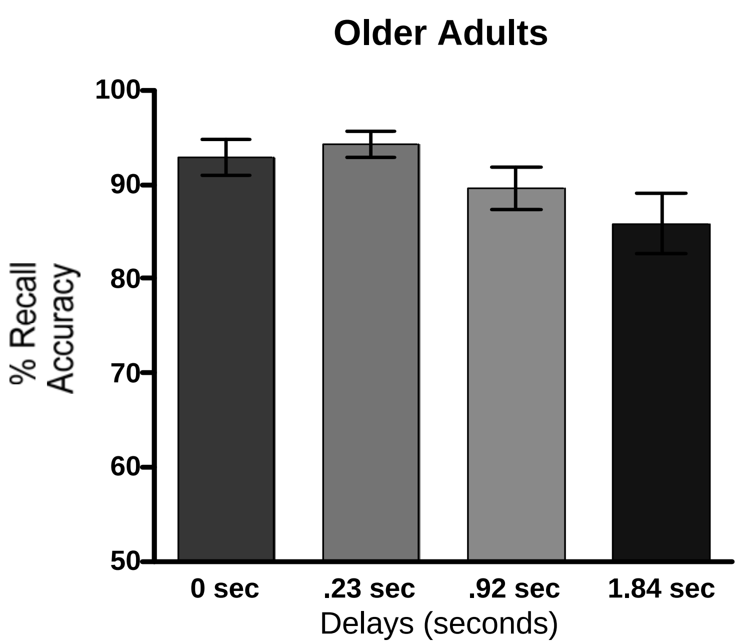
The recall accuracy of the young adults and older adults is summarized in Figure 4. The vertical bars in each graph represent the percentage of words that were correctly recalled from all passages, grouped according to the increasing amounts of delay embedded within them.

As stated earlier, high recall accuracy was essential for the success of the study. Figure 4 demonstrates that both young and older participants were successful in meeting this requirement. Young adult accuracy levels were 95.15% (SD = 4.95) in the 0 sec delay condition, 96.32% (SD = 3.64) in the 0.23 sec delay condition, 94.05% (SD = 5.69) in the 0.92 sec delay condition, and 85.25% (SD = 13.46) in the 1.84 sec delay condition. Correspondingly, older adult accuracy levels were 92.89% (SD = 9.78) in the 0 sec delay condition, 94.24% (SD = 6.99) in the 0.23 sec delay condition, 89.60% (SD = 11.75) in the 0.92 sec delay condition, and 85.81% (SD = 16.84) in the 1.84 sec delay condition. As the graphs show, accuracy performance was similar across the two age groups.

The data were submitted to a two-way mixed design ANOVA (Analysis of Variance) with delay as a within-subjects factor and age as a between-subjects factor. Consistent with the observations, the ANOVA showed a main effect of delay, $F(3, 96) = 4.60$, $p < .01$, but no main effect of age, $F(1, 96) = 1.04$, $p > .05$, nor was there a significant Age x Delay interaction, $F(3, 96) = 0.26$, $p > .05$. As expected, the increasing delays had a strong effect on the performance of both young and older adults, but the performance of the older adults was not impaired to a greater extent than the performance of the young adults.

Figure 6. Recall accuracy of young and older adult participants across all delay conditions. Error bars represent standard error of the mean.

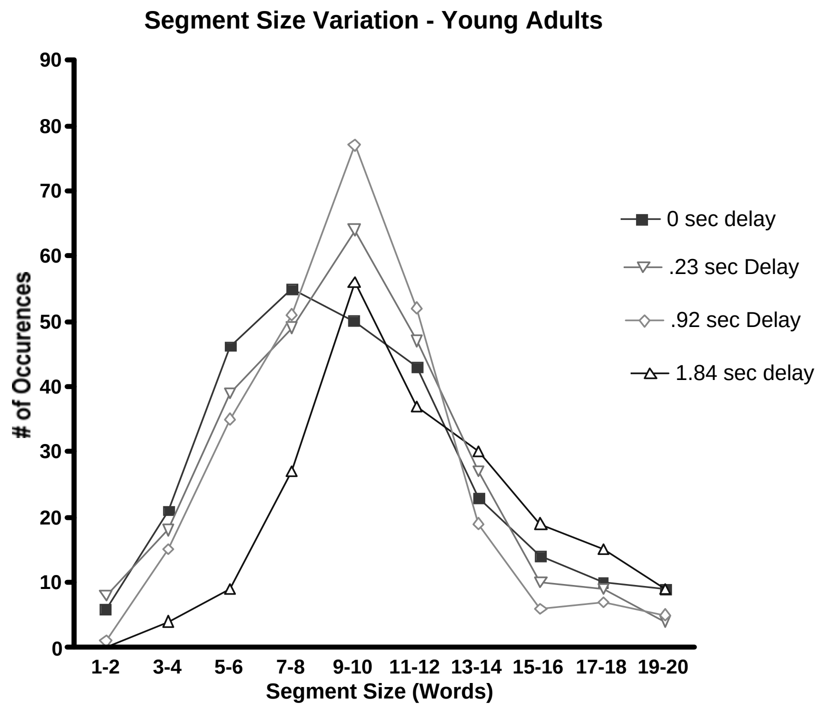


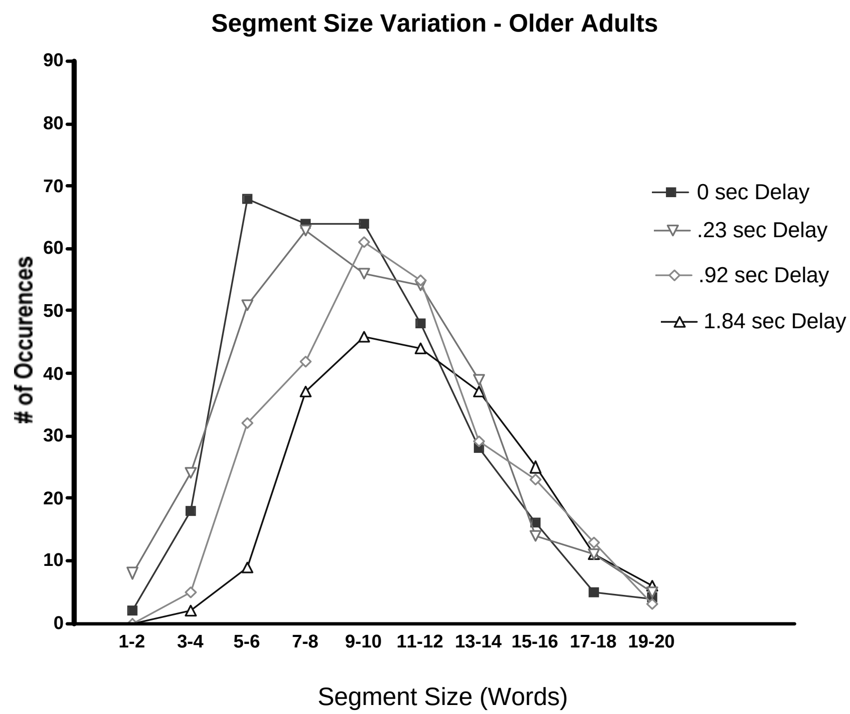


Next, in order to explore other variables that might affect accuracy, the interaction of accuracy and segment size was examined. Due to the fact that delay condition had a significant effect on accuracy, segment sizes in each delay condition were assessed to see whether they changed as the delay conditions increased, and whether this might affect overall accuracy scores. Figure 5 shows the number of occurrences of each segment size in each delay condition for both young and older participants. Average segment sizes of the young adults were 10.24 words (SD = 3.07) in the 0 sec delay condition, 10.11 words (SD = 2.57) in the 0.23 sec delay condition, 9.98 words (SD = 2.76) in the 0.92 sec delay condition, and 10.80 words (SD = 2.02) in the 1.84 sec delay condition. Average segment sizes of the older adults were 9.38 words (SD = 2.02) in the 0 sec delay condition, 9.70 words (SD = 2.21) in the 0.23 sec delay condition, 10.12 words (SD = 2.16) in the 0.92 sec delay condition, and 10.57 words (SD = 1.99) in the 1.84 sec delay condition.

Segment size effects were evaluated using a 2-way (Delay x Age) mixed design ANOVA. The ANOVA showed no main effect of age, $F(1, 96) = 0.55$, $p > .05$, no main effect of delay condition, $F(3, 96) = 0.72$, $p > .05$, and no significant Age x Delay interaction, $F(3, 96) = 0.20$, $p > .05$. The fact that young and older adults showed similar segment size trends *in all delay conditions* suggests that the young and older adults were processing the speech in a similar manner. It is surprising that a general slowing of reaction time in older adults did not appear to affect their average segment size relative to the performance of young adults. This suggests that older adults were not differentially impacted by the delays when compared to the young adults.

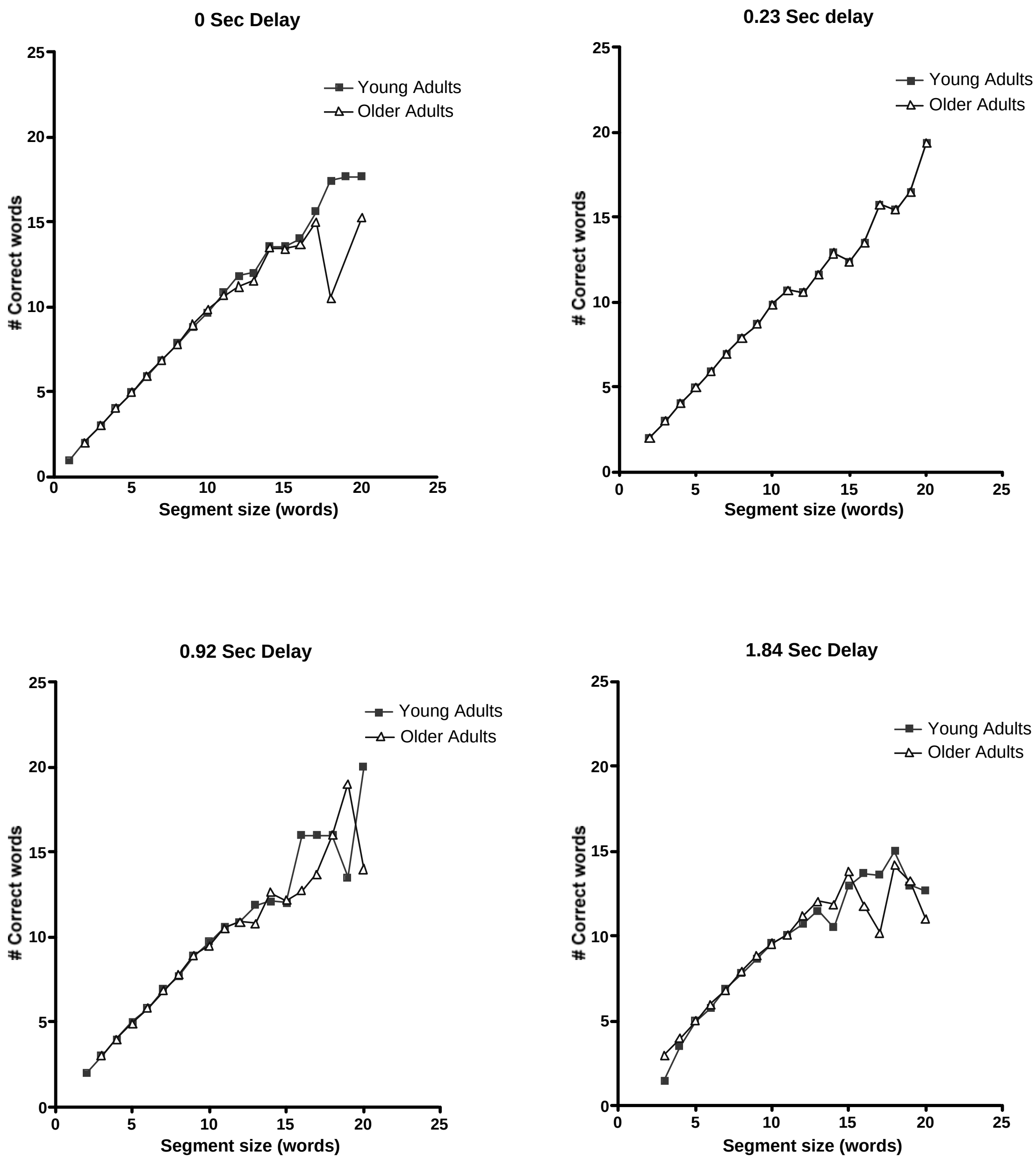
Figure 7. Segment size variation across all delays. Segment sizes were bracketed into groups of two segment lengths, for ease of observing the patterns of data. Instances of segment sizes greater than 20 words are not shown due to their rare occurrence.





In addition, accuracy was examined as a function of segment size. Figure 6 shows accuracy variability as segment sizes increase, within each delay condition. The graphs demonstrate that young and older adults show a similar degree of accuracy in each delay condition for all segment sizes up to approximately 15 words. Accuracy does appear to be affected by segment sizes greater than 15 words, but that is to be expected given ordinary memory constraints.

Figure 8. The effect of segment size on accuracy for young and older adults, across all delay conditions.

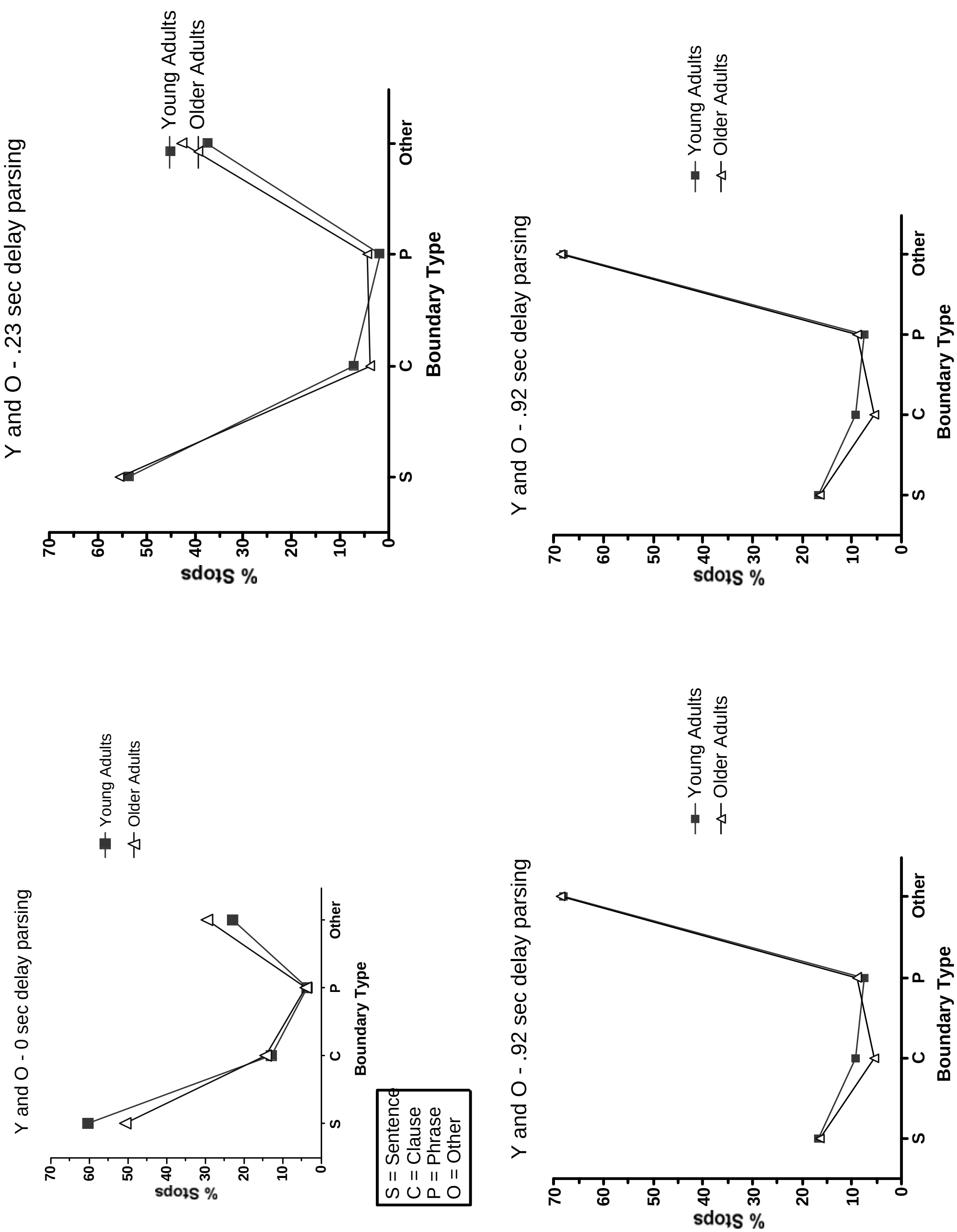


3.3.2 SYNTACTIC PARSING

Since one of the goals of the study was to examine the effect of delayed pause on the participants' placement of stops throughout the passages, it was necessary to perform a syntactic analysis of stop patterns. Previous studies have measured the number of stops at major clause boundaries as a way of examining trends across different age groups and in different conditions (e.g., see Wingfield and Butterworth, 1984). Therefore, the current study classified the stops of the participants based on whether they occurred at several types of syntactic boundaries. Figure 7 shows the stopping patterns of young and older participants in each delay condition. More specifically, the graphs show the percentage of stops that occur at sentence, clause, phrase, or other boundaries. (The "other" category includes all stops not included in the previous three categories.)

A two-way (Delay x Age) mixed design ANOVA of stops at syntactic boundaries (i.e., stops in all boundary categories except "other") confirmed the dramatic results that are illustrated in the graphs. Namely, while there was a significant effect of delay, $F(3, 96) = 28.02$, $p < .0001$, there was no main effect of age, $F(1, 96) = 0.75$, $p > .05$, and no significant Age x Delay interaction, $F(3, 96) = 0.24$, $p > .05$. In other words, young and older adults stopped at syntactic boundaries an equal percentage of the time in all delay conditions, regardless of any factors that might have caused them to perform differently.

Figure 9. Segmentation tendencies of young and older adults across all delay conditions.



3.3.3 DISCUSSION

As demonstrated, recall accuracy of the young and older adults remained fairly high across all delay conditions, never decreasing below 85% accuracy. This indicates that both young and older adults were able to adapt to the different conditions. In fact, there was no statistical difference between the overall accuracy of the young and older adults. However, increasing amounts of delay did prove challenging for both groups.

Also, average segment size was not influenced by age or delay condition. Young and older adults performed in a nearly identical pattern when accuracy was examined as a function of segment size. Therefore, it appears that age does not influence how we naturally parse speech. The most prominent influence on segmentation seems to be the syntactic structure of the speech in question.

Next, this experiment reconfirms Wingfield et al.'s (1989) previous findings that, when presented with a spontaneous segmentation task, participants show a tendency to segment speech at significant syntactic boundaries. Older adults show the same pattern as young adults do, even though one might have expected older adults to interrupt the passages more often (because of self-perceived cognitive deficits) in order to be as accurate as possible in recalling what they hear (Wingfield & Butterworth, 1984; Wingfield & Stine, 1986). It appears that the tendency to parse speech according to its syntactic constituents is strong enough to override any potential intuitions about personal performance.

Furthermore, it is likely that people naturally segment speech into its syntactic constituents because they are aware that this is the easiest, most efficient way to comprehend it. That would explain the lack of segmentation differences between young and older adults. The tendency to segment speech into relevant syntactic units may serve as a "signaling mechanism" for language comprehension. In order for people to understand speech as quickly as they do, neural mechanisms for speech comprehension must operate as resourcefully as possible. If speech is segmented without any regard for syntactic constituency, the neural mechanisms must focus more resources on parsing and language comprehension. Therefore, the current research provides strong evidence that the tendency to organize speech into its syntactic constituents is the most efficient way to contribute to the process of language comprehension.

4. GENERAL DISCUSSION

This study provides strong evidence for the fact that young adults and older adults segment speech in a similar manner. Taking into account the general correlation between aging and increased cognitive deficits, the current study addressed two theories regarding the performance of older adults on tasks requiring syntactic boundary anticipation: a) older adults would perform similarly to young adults because older adults develop excellent anticipatory strategies which allow them to compensate for age-related deficits, and b) the performance of older adults would deviate from the performance of young adults as delay lengths increased, because older adults would not be able to compensate completely for their slower processing and reaction times relative to young adults. As the current study demonstrated, older adults performed similarly to young adults on syntactic boundary anticipation tasks, in terms of recall accuracy, average segment size, and stops at syntactic boundaries. This evidence lends support to the first theory, because the only way for older adults to perform in a similar manner to young adults would be for them to compensate for any shortcomings.

It is both intriguing and uplifting to know that healthy older adults are capable of performing as well as healthy young adults on certain linguistic tasks. If older adults do experience increased difficulties compared to young adults, the older adults have developed extremely effective coping mechanisms. These mechanisms provide undeniable support for the neural plasticity of the human brain, and for the sustainability of linguistic knowledge over time.

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VII. APPENDIX

Experiment 1 Stimuli

1. Bottlenose dolphins (149 words)

The bottlenose dolphin is the most well-known dolphin species. It lives in warm and temperate water and can be found in all oceans except for the Arctic and the Antarctic. It usually has a grey back and a whitish underside, and can range from six to thirteen feet long. It generally lives with a 'pod,' or a group of dolphins, consisting of up to twelve animals. In terms of interaction with humans, bottlenose dolphins are known for their friendliness and curiosity. They are notorious for rescuing injured divers and have even protected swimmers from sharks. However, bottlenose dolphins are wild animals and should be approached with caution. They can be aggressive during mating season, when male dolphins often compete for females by engaging in head-butting activities. Swimmers should keep in mind that although dolphins have a reputation for being gentle and friendly, they should still be treated with respect.

2. Growing tomatoes (147 words)

While it may seem daunting at first, many people take pleasure in growing their own fresh vegetables. For example, even inexperienced gardeners can grow tomatoes in their backyard, provided they take proper care of the plants. First, you should have a general idea of the tomato varieties that would be well suited to the local climate. Then you are ready to choose the type of tomato you would like to grow. Some people prefer small cherry tomatoes, while others prefer larger varieties.

Once it is springtime, be sure to till the soil and add some fertilizer. Next, plant the tomato seeds or plants, and moisten the soil around them. Always support your plants with stakes or wire cages, otherwise they may be ruined by a strong wind. With a little patience, care, and luck, you will soon be able to enjoy fresh tomatoes from your own backyard.

3. Stamp collecting (151 words)

Stamp collecting can be a fun and educational hobby for people of any age. It does not require a large budget, and it can be as complicated or as simple as the collector wishes. Beginners can start by saving stamps from letters and packages that they receive in the mail. They can choose to store entire envelopes, or to remove each stamp from its envelope by soaking it in water until the stamp becomes dislodged. The stamps can then be stored in many types of containers, from special albums to shoeboxes. The most important thing is to protect the stamps from damage. Avid collectors can purchase additional equipment, such as a magnifying glass, or a gauge to measure perforations along the edge of a stamp. People who are interested in knowing the value of their stamps should consult a stamp catalog. Before long, stamp collecting may develop into a lifelong hobby.

4. Garment labels (149 words)

When you buy a garment, a fabric, or a fur in a store, it often carries a label telling who made it or from where it was originally purchased. Some of these labels carry so much status that buyers secretly wish they might be worn in plain view. On the other hand, buyers who deal with the cheapest products would be pleased to do away with labels entirely.

However, there is another label more important than the one which shows where the article was purchased. Wool, fur, and textile products have labels stating what the product is made of. The label is required by law. It must be easy to find, and it must list the product’s ingredients clearly. The reason for this is that manufacturing industries are now able to produce such flawless fake materials that simple examination alone does not provide adequate assurance of a product’s authenticity.

5. Water pollution (148 words)

Many years ago, most streams and lakes in America were sparkling clean. People could swim and fish in them without becoming sick. As the nation grew bigger, we built towns and factories on the banks of these streams and lakes. Each year, more and more waste was dumped into the water.

People incorrectly thought that the water would carry the waste away and purify itself. However, as the amount of waste increased, it overloaded the earth’s natural water recycling system. Now, many streams and lakes show signs of manmade abuse. Even the ocean depths have shown signs of human pollution. This, in turn, has affected aquatic life, sea birds, and beaches. Pollution has also made it increasingly difficult for humans to find suitable drinking water. Former sources of fresh water, even those far below the earth’s surface, have become contaminated by waste that leaks through to the soil.

6. History of Cats (156 words)

Throughout history, the cat has been both adored and loathed. Five thousand years ago, the Egyptians domesticated the cat when they realized that cats ate the rats that had been infesting their grain. People began to leave food out for cats to encourage them to stay close to human homes and eliminate rodent problems. The king eventually declared all cats to be demigods. Suddenly, the status of the cat dramatically increased. Anyone who killed a cat would be put to death, and owning many cats was considered to bring good luck. The domestication of cats took place in other countries as well. However, in Europe the cat was viewed as an evil creature and possibly a carrier of the plague. By the fifteenth century, cats were nearly extinct in Europe, due to the church's view of cats as disciples of the devil. Since that time, the view of cats has undergone drastic changes around the world.

7. Trying new foods (154 words)

When children are young, parents should encourage them to try new foods. Besides adding variety to their diet, this practice will make them less picky eaters as adults. There are many ways to encourage children to taste unfamiliar foods. For instance, offer a new food before a familiar food. Hunger might increase a child's willingness to try something unusual. Also, be sure to try a new food with your child, and do not voice your opinion if it is something you do not like. Next, remember to offer each new food at least two or three times, and cook it in different ways. New foods might have to be tasted several times before children will accept them as a part of a regular diet. In general, parents should encourage their children to take a few bites of the food, but they should also try to stay calm and relaxed. No child will like everything.

8. Boiling an egg (157 words)

Boiled eggs provide a nutritious source of protein when eaten as a part of a healthy diet. In order to boil an egg, first place it in a saucepan. Then, fill the saucepan with water until the water level is approximately one inch above the egg, add a little salt, and bring the water to a boil. The salt will prevent the eggshell from cracking. Once the water is boiling, reduce the heat to low. For a soft-boiled egg, simmer it for two to three minutes. For a hard-boiled egg, simmer it for ten to fifteen minutes. Once the egg has finished cooking, carefully remove it with a spoon, and either let it cool on its own or run cool water over it. Boiled eggs are excellent on their own, or they can be eaten in sandwiches or with other dishes. If cooked in advance, they can be stored in the refrigerator for up to a week.