The Influence of Lexical Characteristics on Sentence Production in Younger and Older Adults

by

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In the study of language production in aging, an important question relates to the relationship between lexical retrieval and syntactic production. Studies have reported changes in syntactic production across the lifespan, but their underlying cause remains unclear. In younger adults, it has been suggested that lexical factors, such as an item’s semantic or phonological representation influence syntactic production; however, the full nature of this influence remains unclear. Studies investigating the type of sentence produced have found semantic facilitation and phonological interference (e.g., Bock, 1986, 1987), but studies investigating response time (e.g., Meyer, 1996) have found the opposite effects.

This investigation sought to examine the influence of lexical level information on sentence production in younger and older adults. This was accomplished by concurrently examining reaction time and sentence type effects.

In Experiment 1, 61 adults (mean age: 21.8 years) were presented with pictures and distractor words (unrelated, or semantically or phonologically related). Three stimulus onset asynchronies (SOA) were used (-1000ms, -150ms and 150ms). Participants were required to describe each picture. Using an analysis of variance, response time was compared across the different conditions and using generalized estimating equations, the type of sentence
produced and the position of the primed word were compared. In Experiment 2, phonological distractors were excluded, and one SOA (-150ms) was used. Testing involved 83 younger adults (mean age: 22.9 years) and 56 older adults (mean age: 74.7 years).

In Experiment 1, semantic distractors resulted in related nouns being produced more often in the subject position. This effect was observed in the analysis of the position of the target noun, but not in the analysis of the type of sentence produced. There were no effects of phonological distractors. In Experiment 2, semantic distractors influenced the type of sentence produced for both age groups. The groups differed only in error production. No reaction time effects were observed in either experiment.

This investigation successfully demonstrated an influence of lexical level information on the syntactic productions of younger and older adults. The two groups were similar in their productions, suggesting that aspects of syntactic production are preserved in older adults.
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**General Introduction**

Our ability to generate novel utterances as quickly and effectively as we do is an impressive feat. In conversation, the average adult is able to produce two to three words per second, with an average of only one to two errors per thousand words (Garnham, Shillcock, Brown, Mill, & Cutler, 1981). Part of what enables us to produce our thoughts so effectively is the ability to combine words in a meaningful way, through syntax. The rapid development of syntactic production in children is easily observable, and has been well documented (see Guasti, 2002 for review). What is less well understood is the manner in which syntactic production also changes as people age. While the changes through adulthood are perhaps more subtle than those in childhood, differences have been observed in the speed, accuracy and variety of structures produced (see Mortensen, Meyer & Humphreys, 2006 for review).

How is a sentence produced by an adult speaker? What factors influence sentence production? How does sentence production differ in older adults compared to younger adults? Two goals were highlighted in the current study to address these questions. The first goal was to examine sentence production in younger adults using the picture-word interference paradigm, which shall be described. Through the use of the same paradigm, the second goal was to compare the manner in which the sentence productions of younger and older adults differed. To begin, models of sentence production and evidence regarding sentence production from both the psycholinguistic and aging literatures will be reviewed.

**HOW DO WE PRODUCE SENTENCES?**

**Sentence Production Models**

What do theoretical models say about the process of sentence production? Why is it, for example that we might utter the passive sentence, “The ball was hit by the girl” rather
than the active sentence, “The girl hit the ball”, which provides essentially the same content? Over the last few decades various models of sentence production have been developed (e.g., Dell, 1986; Garrett, 1980, 1982). Two models will be presented which have evolved out of these previous models: a serial incremental model (Bock & Levelt, 1994) as well as a connectionist dual-path model (Chang, Dell & Bock, 2006).

A Serial Incremental Model

Bock and Levelt’s (1994) serial incremental model of sentence production focuses primarily on the processing between the level of the message and the level of phonological assembly (see Figure 1). Its serial nature implies that a given level can only be influenced by information at the preceding level. The incremental aspect of the model allows that information can be sent to the subsequent level before processing of the entire message is complete. The model consists of four main levels: the message level, the functional level, the positional level and the level of phonological encoding. For our purposes we will focus on the two intermediary levels, which comprise the process of grammatical encoding.

Once the message has been determined, the first set of processes occurs at what the authors called the functional level. It is at this stage that lexical items are selected and grammatical roles (subject, object, etc.) are assigned by the verb to the selected nouns. In the process of lexical selection (for example in a picture naming task), activation spreads from the conceptual nodes to related lexical nodes, called lemmas. A lemma is defined as a lexical constituent that is linked in a one-to-one relationship with a concept node. It is also linked to syntactic information, such as number, gender and, in the case of verbs, tense and the collection of nouns required by a verb, or its subcategorization frame (Levelt, Roelofs &
Figure 1. A serial incremental model of syntactic production (Bock & Levelt, 1994).
Meyer, 1999). Among possible competitors (i.e., semantically related lemmas), the lemma with the highest relative activation level is selected. When selected, both the meaning and syntactic information become available. In this way, information such as a noun’s requirement of a determiner, or a verb’s subcategorizational frame (which contains information regarding required noun arguments) becomes available.

The assignment of grammatical roles also occurs at the functional level. The retrieved nouns fulfill the thematic roles required by the verb and are assigned grammatical roles. Examples of thematic roles are the agent role which represents the do-er of the action and the patient or theme role that denotes the receiver of the action. Bock and Levelt (1994) specified types of information that can influence this assignment, such as lexical characteristics (including the verb itself), animacy, givenness and concreteness. These factors are said to increase the mental prominence, or ‘conceptual accessibility’ (Bock and Warren, 1985) of a particular noun phrase (NP), which is then assigned to the nominative role (or subject position). It is not specifically mentioned by which mechanism (e.g., activation level) conceptual accessibility can cause a noun phrase to be assigned the subject role within this production model. Once the selected lemmas have been retrieved and grammatical roles have been assigned, the information at the functional level proceeds to the positional level. At this stage the selected constituents are ordered within a hierarchical organization, which represents the syntactic dependencies between the selected constituents. Bock and Levelt included the feature of incrementality, such that the phrase structure is created as lemmas and functional assignments become available, rather than adding lemmas all at once into a fully constructed syntactic structure. Information from this level is then passed on to the level of phonological assembly, wherein the lexemes are selected.
A Connectionist Model

Chang et al. (2006) proposed a connectionist model of sentence production to account for both the acquisition of syntax in children as well as syntactic production in adults (see Figure 2). Their model is a dual path simple recurrent network. For our purposes, we will focus primarily on the model’s ability to describe syntactic production in adults. This is a dual path model, in that the message is produced by way of two systems: 1) a meaning system, which contains the information pertaining to the concepts involved and 2) a sequencing system, which processes the ordering of the selected words. These two systems generally process information independently; however, the message system is able to influence the ordering of elements by the sequencing system, allowing for the influence of lexical items on the syntactic structure selected, as was the case with the serial incremental model.

The recurrent feature of this network allows it to receive input, (cword¹), make predictions regarding the output (‘word’) and compare the predicted and actual outputs in order to adjust strength of the connections between pairs of nodes in the model. This is an important attribute for the model to be able to account for syntactic acquisition.

Through a process of constantly monitoring the previously produced word (cword), combined with learned knowledge of legal syntactic combinations (e.g., a noun follows a determiner) and the event semantics of the current message (e.g., which noun has a higher activation level), the model is able to provide a step-by-step description of the process of sentence production. In the generation of a sentence (e.g., The ball was thrown by the girl),

¹ Note: the c- prefix refers to the fact that a word has been comprehended by the system (Chang et al., 2006). In production the cword represents the previously produced word in an utterance, which is required in order to track the sentence being produced.
Figure 2. A connectionist model of syntactic production (Chang et al., 2006).
the cword receives the previously uttered word (e.g., ‘The’), which is then processed by both the meaning and sequencing systems. In the meaning system, the lexical semantics (‘what’ components) of the previous and intended words are linked to the appropriate thematic roles (‘where’ components, e.g., ‘girl’ – agent; ‘ball’ – theme) within the meaning system. These roles, or ‘event semantics’, are assigned a numerical value which represents a level of activation and are subsequently sent to the ‘hidden’ layer of the sequencing system where they become activated. Here, the most prominent concept, or the unit with the highest event semantics level, is more likely to be selected first by the sequencing system. In the case of the given sentence, the event semantics for ‘ball’ would have received a higher level of activation compared to ‘girl’, which would have led to its production in the subject role of the output sentence. The sequencing system receives only event semantics and not the individual concepts from the meaning system.

In the sequencing system meanwhile, the compression units (compress, ccompress) have as a role to parse the syntactic information of activated event semantics by word class for the hidden layer, to ensure syntactic rather than linear processing. Working with the event semantics and the legal syntactic rules, the sequencing system is able to order the words in the sentence. Each selected word is fed back to the system for determination of the subsequent word.

While this model allows for alternations between syntactic forms, such as active and passive, it is not specified how values are assigned to the event semantics. Presumably this model would allow for the influence of similar factors (animacy, concreteness, etc.), as were
described in Bock and Levelt (1994) and that these influences on activation levels are experienced over time and learned by the meaning and sequencing systems.

Both of the models described allow for the influence of lexical characteristics and other factors on syntactic production. They are however somewhat underspecified on this point. The serial incremental model (Bock & Levelt, 1994) allows for prominence, and indeed some of the influencing factors are mentioned. Beyond the idea of conceptual accessibility however, the mechanism in the model that causes the ‘prominent’ lexical item to be selected is not detailed. The model by Chang et al. (2006) on the other hand describes the prominent unit as having a higher activation level, which leads to its selection ahead of other units. What this model fails to specify is the manner in which prominence is achieved. We will now examine evidence from the psycholinguistic literature and then evaluate the models’ ability to explain that evidence.

EVIDENCE FROM THE PSYCHOLINGUISTIC LITERATURE

From the descriptions of the sentence production models above, it may be reasoned that factors that can influence word selection (and therefore grammatical role assignment) can also influence sentence production. Certain factors, such as prototypicality (Onishi, Murphy & Bock, 2008), word length, and prosody (McDonald, Bock & Kelly, 1993) have been found to influence word order within a phrasal boundary only, (e.g., the order of the underlined nouns in the sentence, “Nancy made some pants and a scarf out of denim”). Other factors such as verb type, animacy, and the phonological and semantic characteristics of words have been observed to influence the syntactic structure produced (e.g., through the ordering of the underlined nouns in the sentence, “The window was broken by the rock”);
Bock, 1986, 1987; Ferreira & Firato, 2002). It should be noted that there are other factors that may influence the selection of a particular syntactic form at the discourse (e.g., topicalization) or sentence level (e.g., syntactic priming), however for the purposes of this study we will focus on word level factors that influence sentence production.

Effects of Verb Type and Noun Animacy in Sentence Production Studies

In a series of experiments, Altmann and Kemper (2006) asked 59 older adults (mean age 76 years) and 51 younger adults (mean age 20 years) to produce a sentence that would include three written words, presented one above the other on a screen. The first and third words were nouns and the second one was a verb. Among the many questions investigated in this study, Altmann and Kemper sought to examine the influence of verb type and animacy on the type of sentence structure produced. To that end, these two factors were manipulated across item presentation. The authors made use of the active/passive alternation in this study. These two syntactic forms differ primarily in the grammatical role assigned to the agent and patient nouns in the sentence. As an example, in the sentence, “The bee chased the elephant”, ‘bee’ is the agent noun, or the ‘do-er’ of the action and ‘elephant’ is the patient noun, or the receiver of the action. In an active sentence, the agent noun is assigned to the subject role, and in a passive sentence, the patient noun is assigned to the subject role of the sentence.

In each of the four experiments in the study, the participants were presented with a different verb type. The first verb type, utilized in the experiment as a baseline verb type, was a transitive verb (e.g., stirred), which requires agent and patient or theme arguments. The second verb type was a theme-experiencer verb (e.g., bored), which requires an animate object in an active sentence, (e.g., The book bored the student), but places no constraints on
the subject noun. The third verb type used was an irregular past participle of a transitive verb (e.g., shaken). This verb type requires either a passive sentence (e.g., The juice was shaken by the butler), or a perfective verb (e.g., The butler had shaken the juice), which the authors claimed requires additional metalinguistic processing, relative to the baseline transitive verbs. Finally, the authors presented experiencer-theme verbs (e.g., adored), which require animate subjects that can experience the psychological state of the verb (e.g., The author adored the poem). Animacy of the nouns was controlled by alternating the position of the animate and inanimate nouns between the top and bottom positions on the screen. By combining these two variables, the authors were able to investigate whether one or both influenced the production of active and passive sentences.

While Altmann and Kemper (2006) presented their stimuli to both older and younger adults, in this section we will focus on the responses of the younger adults. (The data from the older adults will be presented in a subsequent section.) The authors found that younger adults were more likely to produce a passive sentence when provided with an irregular past participle (e.g., shaken) or a theme-experiencer verb (e.g., bored) compared to when presented with a simple transitive (e.g., stirred) or an experiencer-theme verb (e.g., adored). They also found that younger adults produced an increased number of passive sentences when the inanimate noun was presented first for transitive, irregular past participle and experiencer-theme verbs. In the case of theme-experiencer verbs (e.g., bored), the younger adults produced an increased number of passive sentences when presented with the animate noun rather than the inanimate noun in first position. This is understandable given that the animate noun is the theme for this verb type, so an animacy effect would require a passive sentence. The effects of animacy were greater for younger adults compared to older adults.
The results from this study demonstrate that verb type and relative noun animacy can cause an increase or decrease in the likelihood of a passive sentence being produced. At a more basic level, this study provides evidence that the active-passive alternation can be influenced by inherent characteristics of target words.

Effects of Semantic and Phonological Relatedness in Reaction Time Studies

The influence of semantic and phonological information on word and sentence production is particularly interesting, given the potentially conflicting results that have been presented in the literature. These results will be presented in the following two sections.

Using a picture-word interference task, numerous studies have investigated the influence of semantic and phonologic distractors on the reaction time to utterance onset for word and sentence production (e.g., Costa & Caramazza, 2002; Glaser & Düngehoff, 1984; Meyer, 1996; Meyer & Schriefers, 1991; Schriefers, Meyer, Levelt, 1990). The methodology consisted of presenting both a picture to be named or described and an auditory distractor word which was related or unrelated to the target picture. The distractor word was presented either auditorily or in written form (Costa & Caramazza, 2002; Glaser & Düngehoff, 1984; Meyer, 1996).

A key feature of these studies is the manipulation of stimulus onset asynchrony (SOA). SOA refers to the timing between two stimuli; in this case, it is the timing between presentation of the auditory distractor and the picture to be named. An SOA of 0 ms means that the distractor and target picture are presented simultaneously. A negative SOA (e.g., -150 ms) indicates that the distractor was presented prior to the target picture, and a positive SOA (e.g., 150 ms) indicates that the distractor word was presented after the target picture. It
is the manipulation of SOA that permits the observation of the time course of word processing. At the word level, studies have generally found that when a categorically related\textsuperscript{2} semantic distractor word (e.g., wasp) was presented just prior to (e.g., SOA= -150 ms) or simultaneously with (SOA=0 ms) the target picture (e.g. BEE), a delay in response time is observed relative to the presentation of an unrelated distractor (e.g., desk; Glaser & Dungelhoff, 1984; Meyer & Schriefers, 1991)\textsuperscript{3}. Conversely, at positive SOAs (including 0 ms), the presentation of a phonologically related distractor word (e.g., beet) has been found to lead to shorter response times to target production relative to the presentation of an unrelated distractor (e.g., desk; Costa, & Caramazza, 2002).

It is hypothesized that these delays and facilitations of response time indicate the timing of semantic and phonological processing in lexical production respectively (Roelofs 1992, 1997). It has been proposed that when a semantically related distractor (e.g., wasp) is presented prior to picture presentation (BEE), the lemma of the distractor word is being processed while activation of the target word begins. At the moment that the lemma of the target BEE is activated, the distractor word lemma remains activated. As a result, an interference exists between the activation levels of the two related lemmas, causing a delay in the selection of the target noun. This interference is not observed at earlier SOAs (e.g -400 ms, Glaser & Düngelhoff, 1984), presumably because the distractor word’s lemma is no longer being processed 400 ms later when the target lemma is activated. Semantic interference is also absent at positive SOAs (e.g., 150 ms) (Schriefers et al., 1991), again, presumably because the timing of the activation of the two lemmas does not coincide.

\textsuperscript{2} A categorical relationship denotes one in which words belong to the same semantic category (e.g., ‘lion’, ‘cougar’).

\textsuperscript{3} Note: an effect of facilitation has been consistently observed with associatively-related semantic distractors (Glaser & Dungelhoff, 1984; Alario, Segui & Ferrand, 2000). Unless otherwise stated, in the current study the term ‘semantically related’ will refer to categorically related distractors.
The facilitation observed with phonological distractors is thought to occur due to the shared phonemes in the distractor word and the target. If the phonemes required for a target noun have already been activated by a related distractor word, the target word should be produced with less delay. Phonological facilitation is generally observed at later SOAs than semantic interference, presumably because the phonological aspect of a word is processed after the semantics of a word (Levelt, Roelofs, & Meyer, 1999; Schriefers, Meyer, & Levelt, 1990, although see Damian & Martin, 1999 and Jescheniak & Schriefers, 2001 for a different viewpoint).

Reaction time studies have also investigated the effects of semantic and phonological distractors at the phrase (Costa & Caramazza, 2002; Meyer, 1996) and sentence level ((Meyer, 1996; Schnur, Costa & Caramazza, 2006) and have found that the same effects of semantic interference and phonological facilitation are observed, with one exception. In Meyer’s (1996) study the goal was to investigate the extent of utterance encoding prior to utterance onset, by using these documented effects of semantic interference and phonological facilitation. In two experiments, participants were presented with a picture with two objects and were either asked to produce a pre-determined noun phrase of the form, ‘the X and the Y’, or were asked to produce a sentence of the form, ‘The X is next to the Y’, in both cases beginning with the object on the left side of the picture. The auditory distractor that was presented was a patch of noise, an unrelated word, a phonologically related word, or a semantically related word. Meyer found that semantic distractors to either of the target nouns led to slower reaction times than the unrelated distractors, suggesting an interference effect for both of the nouns. The exception to the other findings was observed with the phonological distractors. It was found that the presentation of a phonological distractor led to

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4 Note that these are translations of the original Dutch sentences.
faster reaction times to utterance onset compared to unrelated distractors, suggesting an
effect of phonological facilitation, but only for the first noun of the utterance. No effect of
facilitation was observed with the second noun in the utterance. These results suggest that
prior to utterance onset, the extent of semantic processing is greater than that of phonological
processing.

Effects of Semantic and Phonological Relatedness in Studies of Sentence Type

In other investigations of the effects of phonological and semantic information on
language production, the opposite effects of semantic facilitation and phonological
interference have been observed, in this case as measured by the type of sentence produced
(Bock, 1986, 1987). Also using a form of picture-word interference task, Bock (1986)
investigated the relationship between auditorily-presented words and sentence production. In
these studies, participants were presented with experimental and filler auditory distractor
words and experimental and filler pictures. Participants were required to repeat each
distractor word and describe each picture. After each repetition and each description,
participants were required to indicate whether or not they recognized the item and they then
received feedback on their decision. Words and pictures were pseudo-randomly ordered
although the experimental distractor words were presented immediately prior to the related
experimental picture, which represented a transitive action (e.g., a rock breaking a window).
The distractors were related to the target nouns in the sentence (e.g., rock, window),
semantically (e.g., boulder, door) or phonologically (e.g., lock, limbo). Two sentence types
were commonly used to describe the pictures: an active sentence (e.g., The rock broke the
window) and a passive sentence (e.g., The window was broken by the rock). This study
sought to determine whether the related distractors would influence the syntactic structure
produced (an active or a passive sentence) by influencing the availability of the related noun in the sentence. For example, if the word *rock* becomes more ‘available’ after the presentation of a related word (e.g., boulder, lock), its production could be facilitated which could result in it being produced prior to *window*, resulting in the active sentence “The *rock* broke the window”. If the presence of a distractor word interferes with ‘rock’ and makes it less available, the passive sentence, “The window was broken by the *rock*” should result. In Bock’s (1986) study, an effect of facilitation was found with semantically related distractors (e.g., boulder), meaning that the target word was more likely to be produced in the subject position compared to the object position (“The *rock* broke the window”). In that study no effect was found with distractors related by word final phonological similarity (e.g., target: ‘rock’; distractor word: ‘lock’). In her 1987 article, Bock modified the phonological relationship and found an effect of interference with distractors that were related phonologically by word initial phonological patterns. In this case, the target noun was more likely to be produced in the object position compared to the subject position (e.g., distractor: ‘wrong’; sentence: “The window was broken by the *rock*”).

Using a different methodology, Ferreira and Firato (2002) found an effect of semantic interference, as measured by syntactic production. In their task, Ferreira and Firato required participants to repeat a given sentence containing an optional complementizer, such as, “The author, the poet, and the biographer recognized (that) the writer was boring”. The sentences were presented to the participants both with and without the optional complementizer. The authors found that when the target noun phrase in the relative clause (e.g., ‘the writer’) was semantically related to the noun phrase in the main clause, (e.g., ‘The author, the poet, and the biographer’), a participant was more likely to include the optional complementizer ‘that’
in his/her response. This was in comparison to a sentence in which the noun phrase in the embedded clause was unrelated to the noun phrase in the main clause (e.g., ‘The author, the poet, and the biographer recognized (that) the golfer was boring’). The authors argued that the semantic relatedness between noun phrases caused a production delay of the embedded noun phrase which resulted in the inclusion of the complementizer ‘that’ in order to provide extra time for the delay.

Summary of the Effects of Semantic and Phonological Distractors.

While the tasks in Meyer’s (1996) and Bock’s (1986, 1987) studies are similar in that the participants heard an auditory distractor word and then were required to describe a picture, the different types of studies reported seemingly opposing results regarding the effects of semantic and phonological distractors. Meyer’s study found effects of semantic interference and phonological facilitation, as measured by reaction time to utterance onset, and Bock’s studies found effects of semantic facilitation and phonological interference, as measured by the position of the target noun in the sentence. It is not clear if and how these interference and facilitation effects would co-occur if the two methodologies were combined. Is it possible to have interference in terms of reaction time, and simultaneously show facilitation in terms of word order, or vice versa? In such a situation do “interference” and “facilitation” properly describe the effects?

The seemingly opposing effects observed in Bock’s (1986; 1987) and Meyer’s (1996) studies could potentially be accounted for by methodological differences, including differences in the tasks used, different measurement of facilitation and interference, and the manipulation of SOA. In Bock’s (1986, 1987) studies, participants were required to generate
an unconstrained sentence in response to seeing a picture. In Meyer’s (1996) study, the syntactic structure was dictated. Importantly, these two types of studies also measured the effects of interference and facilitation differently. In the sentence generation studies (Bock, 1986, 1987), it was the position of the primed word that represented whether interference or facilitation had occurred. For example, as the target words tended to be produced in the subject position more often than in the object position with semantic distractors, it was concluded that the semantic cues caused a facilitating effect. Production of a related noun in the object position more often than in the subject position of the sentence led to a conclusion of an interference effect, as was the case with the phonological distractors. In Meyer’s (1996) study, interference and facilitation were measured in terms of reaction time to utterance onset relative to reaction times with unrelated distractors as a baseline condition. As the target phrases and sentences tended to be produced with a longer delay with a semantic distractor compared to an unrelated distractor, it was concluded that semantic distractors caused an interference effect. Shorter response times were generally observed with phonological distractors compared to trials with unrelated distractors, leading to the conclusion that phonological distractors caused a facilitating effect.

The other difference between these studies was the use of SOA. In Meyer’s (1996) study SOA was manipulated. In the studies by Bock (1986, 1987) SOA was not manipulated, however it was estimated by the author that the timing between repetition of the distractor and the presentation of the target picture was approximately 2 seconds (SOA = -2000 ms). Given the hypothesis proposed by Meyer and her colleagues that SOAs of -150 ms and 150 ms represent the time course of encoding of semantic and phonological information
respectively, it is unclear what process was being observed in Bock’s studies at the very early
SOA of -2000 ms.

An additional complexity is added by the result of semantic interference found in
Ferreira and Firato’s (2002) study. In this study, Ferreira and Firato measured their effects by
the type of sentence structure produced, similarly to the studies by Bock (1986, 1987).
However, in their results they found an effect of semantic interference, which is the opposite
effect as found by Bock (1986) but the same effect found by Meyer (1996).

CAN SENTENCE PRODUCTION MODELS ACCOUNT FOR THE DATA?

Let us now return to the models of sentence production (e.g., Bock & Levelt, 1994;
Chang et al., 2006) to examine how well they can predict the experimental results reviewed
above. Very briefly, both of the models of sentence production allow for lexical information
to influence syntactic production. Chang et al.’s (2006) connectionist model achieves this
interaction through the sequencing system’s selection of the lexical item with the highest
‘event semantics’ (or activation level). Because of this, if a distractor word were able to
increase or decrease the event semantics of a noun, then that would influence the item
selected by the sequencing system. In Bock and Levelt’s (1994) serial incremental model, the
selection of lexical items occurs prior to, but at the same processing level as the assignment
of grammatical role, allowing for characteristics of the lexical item to influence the selected
syntactic structure, as would be the case in a sentence level picture-word interference task.
While both of these models are able to account for the experimental results, it is clear that
they are both underspecified regarding the details of semantic and phonological processing.
Now that we have reviewed influences on typical syntactic production in adults, we will address the question of syntactic production in older adults. There is less evidence available regarding syntactic production in aging, relative to that for young adults. In general, syntactic production is thought to decline in older adults, but how exactly does it differ from that of younger adults? What are the postulated causes of these changes? Does lexical information, such as semantic or phonological relatedness influence syntactic production in the same way or does that change in older adults?

**LANGUAGE PRODUCTION IN OLDER ADULTS**

As with other skills, language production changes over a person’s lifetime, including through adulthood. While the evidence is equivocal, most studies of language production in healthy aging suggest that the language production of older adults contains more hesitations (Bortfeld, Bloom, Schober, & Brennan, 2001; Cooper, 1990; Le Dorze & Bedard, 1998; Schmitter-Edgecombe, Vesneski, & Jones 2000; Spieler & Griffin, 2006), more errors (Albert, Heller, & Milberg, 1988; Au, Joung, Nicholas, Obler, Kaas & Albert, 1995; Barresi, Nicholas, Connor, Obler & Albert, 2000; Hodgson & Ellis, 1998; Le Dorze & Durocher, 1992; Maylor, 1995; Nicholas, Obler, Albert & Goodglass, 1985), and is generally slower than that of younger adults (Bowles, 1994; Feyereisen, Demaeght & Samson, 1998; Hodgson & Ellis, 1998; Kemper, Herman & Lian, 2003; Maylor, 1995; Mitchell, 1989; Spieler & Griffin, 2006; Thomas, Fozard & Waugh, 1977, but see Altmann & Kemper, 2006 and Mortensen, Meyer & Humphreys, 2008). These changes, which tend to emerge during a person’s mid-70s (Nicholas et al, 1985; Kemper, Thompson & Marquis, 2001), have been observed in production at both the word and sentence levels. It should be noted that the
literature on language production in older adults consists of more studies on production at the single-word compared to the sentence level. Findings from studies of production at the single-word level will be presented in the current review as they pertain to factors that are also important to production at the sentence level.

Naming in Older Adults

Much of the interest in language in aging has revolved around naming abilities, both at the discourse and the single-word level. The results of discourse studies suggest that the language production of older adults is less dense than that of younger adults, as measured by the number of propositions per unit of speech (Mackenzie, 2000; Kemper & Sumner, 2001). However the type/token ratio, or the lexical diversity of the productions of older adults may be greater (Kemper & Sumner, 2001).

Word Production Tasks

Word level tasks, such as picture naming and naming to definition provide a manner of investigating naming difficulties in older adults. While early evidence implicated an impairment in accessing the phonological level in lexical retrieval, newer evidence suggests that naming difficulties in older adults may also be due in part to impairments in the representations at both the phonological and semantic levels.

Evidence from tip of the tongue (TOT) studies with older adults suggests that naming difficulties are due to an impairment in accessing the phonological level from the semantic level. A TOT state is one in which a person is able to access semantic and syntactic information of a word, and perhaps some information regarding the form of the word, but is unable to access the full phonological form of the word (Brown & McNeill, 1966; Burke,
MacKay, Worthley & Wade, 1991; Vigliocco, Vinson, Martin & Garrett, 1999). A common methodology used to induce a TOT state requires participants to name a low frequency word when given a definition. Looking across the results of younger and older adults, it has generally been found that older adults perform better on a naming task than younger adults but that when there is a naming difficulty, older adults are more often in a TOT state than are younger adults (Brown & Nix, 1996; Burke et al., 1991; Heine, Ober & Shenaut, 1999; Rastle & Burke, 1996). Studies have also demonstrated that a phonological cue can most often resolve the naming difficulty for participants, including older adults (James & Burke, 2000; Rastle & Burke, 1996). Combined, these results suggest that for older adults the semantic and phonological representations of the word are likely intact, but that access to the phonological representation may be degraded to some extent.

Results from studies using other methodologies suggest that there may even be some degradation at the level of semantic and phonological representations. Hodgson and Ellis (1998) asked younger (ages 22-33) and older adults (ages 71-86) to name 230 black and white pictures. The pictures were characterized by the following predictor variables: age of acquisition, word length, name agreement, visual complexity, object familiarity, imageability, and word frequency. The participants were not under any time pressure, but their responses were measured for accuracy and the time taken to respond (as measured by number correct within 5 second increments, up to 15 seconds). In comparing the responses, the authors found that the older adults were less accurate in their productions than the younger adults (91.1% vs. 96% respectively) and slower in responding. The authors then performed a multiple regression analysis on the responses of the older adults and determined that name agreement, age of acquisition and name length negatively influenced the older
adults’ naming accuracy. Given that age of acquisition and word length are lexical characteristics that are considered to be encoded at the level of the phonological representation and that name agreement is considered a feature of the semantic representation, the authors concluded that there is likely some degradation of both semantic and phonological representations.

Additional studies (Albert et al., 1988; Au et al., 1995; Barresi, Nicholas, Tabor Connor, Obler and Albert, 2000) have demonstrated that a high proportion of the errors by older adults are semantic in nature, further implicating an impairment at the level of semantic representations. Barresi et al. (2000) conducted a longitudinal study investigating the naming abilities of 39 older adults divided into three groups (mean ages at the time of the first testing: 55, 66 and 73 years) by presenting a naming task approximately every three years over a time period of approximately 7 years. They were curious to see if semantic and phonemic cues helped when participants produced errors. Additionally, they sought to investigate whether or not the pattern of errors and success with cueing were consistent across sessions. For example, if a participant was unsuccessful after a cue on the first attempt, but successful with that same item at a later testing time (with or without the cue), then that would be taken as evidence by the authors that the semantic representation was intact, but that there was an access problem. Consistent errors on a lexical item was hypothesized by the authors to suggest probable degradation of the semantic representation. The authors found that all three groups showed both inconsistent and consistent error patterns, suggesting a combination of access and semantic degradation problems. However, the oldest group of adults showed significantly more errors than the two younger groups, and
notably, significantly more consistent error patterns, suggesting an increase in semantic degradation.

*Picture-Word Interference Tasks*

Another source of information regarding word production in aging comes from studies using the picture-word interference paradigm. In this type of task, older and younger adults seem to show a similar response pattern overall. Bowles (1994) presented associatively related distractor words (e.g., ‘tuna’, target: ‘sandwich’) and unrelated distractors (e.g., ‘dog’, target: ‘table’) in a picture naming task. In her results, she found that older adults (aged 65-83) responded with longer response delays overall than young adults (aged 18-33), but that both older and younger adults showed a facilitation effect of associatively related distractors, in that response times were faster when preceded by a related distractor than an unrelated distractor. This finding in the productions of older adults is consistent with results of associatively related distractors in the psycholinguistic literature (e.g., Alario, Segui, & Ferrand, 2000). Importantly, there was no interaction between age and prime type (related vs. unrelated), suggesting that semantic processing was similar in both age groups. Bowles found also that the first SOA (of approximately 100 ms) at which effects of the semantic distractors were observed was similar for both groups. In a second experiment, she observed effects of associatively related distractors also at later SOAs (approximately 350 ms SOA vs. 200 ms SOA) for the older adults (aged 65-88) compared to the young adults (aged 18-32). These results were taken as evidence that semantic processing occurred similarly for both groups, but lasted longer for the older adults. Bowles suggested

5 A key component to her study was the manipulation of item presentation duration for each participant, according to the individual’s visual processing speed. Because different participants required different processing times for visual stimuli, the SOAs varied across participants.
that this extended level of activation by the older adults was due to a difficulty in inhibiting the distractor, as per the Inhibition Deficit hypothesis proposed by Hasher and her colleagues (e.g., Lustig, Hasher & Zacks, 2007).

Using different methodologies, additional studies have conducted similar experiments with categorically related distractors (e.g., ‘bee’ and ‘wasp’) and have generally found that both younger and older adults showed semantic interference (Taylor and Burke, 2002; Tree & Hirsh, 2003; Wilshire, Keall, Stuart & O’Donnell, 2007), a finding that is consistent with previous studies of language production in younger adults involving categorically related distractors (e.g., Glaser & Düngelhoff, 1984). Replication of the results of these studies involving categorical distractors may be warranted because of methodological differences or weaknesses in these studies that could detract from consistency with the reported results in the productions of younger adults (e.g., Schriefers et al., 1990). For example, in Tree and Hirsh’s study, they used written distractor words rather than auditory distractors. The study by Wilshire et al., whose focus was naming in people with aphasia, included a sample size of 12 older adults, thus limiting generalization. Finally the results in the study by Taylor and Burke (2002) may be limited by the fact that the post hoc analysis of interactions involved running repeated measures ANOVA analyses on subsets of the data in order to find subsequent interactions that were then analyzed using planned comparisons.

The effect of phonological distractors on the productions of older adults has also been examined with the picture-word interference methodology. In addition to the experiment mentioned above, Taylor and Burke (2002) investigated the effect of phonological distractors and found similar results for both younger and older adults. In their study, facilitation effects were found for both younger and older adults when phonologically related distractors were
presented at a positive SOA (150 ms). Again, older adults showed a slower overall reaction time.

In a more recent study, Mortensen et al. (2008) performed two experiments using phonological distractors. The first experiment used a similar design to that of Taylor and Burke, and indeed they found the same pattern of results. In an effort to examine in more detail how the two groups might differ in a production task, the authors increased the difficulty of the task by requiring participants to name three simultaneously-presented pictures. In this second experiment, the left-most picture was related phonologically or unrelated to the distractor word. The authors found once again that there was a facilitating effect of phonological distractors for both groups in terms of production latency. However, there was no difference in the naming latencies of the older and younger adults in this more complex task. The younger adults were slower in this task than the first one, but the older adults produced a similar naming latency across tasks. The authors speculated that this difference may have been caused by a different approach by the two groups, due to the change in the duration of the picture presentation across the two tasks (1500 ms vs. 4000 ms). In both of the experiments participants were required to respond as quickly and accurately as possible, but the younger adults may have used the extra time provided in Experiment 2 to reduce their error production, unlike the older adults. In addition to the response time data, the authors found that in Experiment 2 the older adults made significantly more errors than the younger adults, which was not the case in Experiment 1. Mortensen et al. proposed that the two groups may have been differently influenced by a speed-accuracy trade-off.

While picture naming tasks reveal difficulties at both the semantic and phonological levels for older adults, picture-word interference tasks reveal a similar pattern of processing
of semantic and phonological information in younger and older adults, with the exception that the older adults are slower in overall production. One important difference between the two paradigms is that effects were measured by errors in the naming tasks and by reaction times in the picture-word interference task. For this reason, one cannot unequivocally declare that processing at the semantic and phonological levels is intact based on the evidence that older adults performed similarly to younger adults in the picture-word interference task. Error analyses of the performance of older adults on a picture-word interference task were generally not performed in these studies, perhaps because of the low error rates. Mortensen et al.’s (2008) suggestion of a speed-accuracy trade off in the results of the older adults indicates that the picture-word interference results might be consistent with those of picture naming, namely that older adults have more difficulty with these tasks, despite the fact that processing generally proceeds in a similar manner.

Sentence Production in Older Adults

Relative to research into sentence production in younger adults, the literature regarding sentence production in older adults is still quite limited. Nevertheless, both observational and experimental studies have noted a decrease in a) propositional content (Kemper, Marquis & Thompson, 2001), b) syntactic complexity (Kemper Thompson, et al., 2001; Kynette & Kemper, 1986; Kemper, Herman & Lian, 2003), c) speed of production (Kemper, Herman & Lian, 2003; Spieler & Griffin, 2006) and d) correct verb use (Kemper et al., 2003, Kynette & Kemper, 1986). Investigators have also begun to investigate external

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6 As an example, Wilshire et al. (2007) reported only 22 errors by their 12 older adult participants, out of a total of 3600 trials.
and internal factors that influence sentence production in aging, such as animacy and directionality of stimuli (Altmann & Kemper, 2006).

Sentence complexity

In a cross-sectional study, Kynette and Kemper (1986) analyzed the spontaneous speech of adults between the ages of 50 and 90. They found that adults aged 50-69 produced a greater variety of simple structures (including sentences with copulas and auxiliaries and object relative clauses). Similarly, adults in their 50s used more complex syntactic structures than the older age groups. They also observed a progressive loss in accuracy of the use of verbs and syntactic structures. These results were observed in the context of equivalent performances between older and younger adults in dysfluencies, mean length of utterance (MLU) and type-token ratio.

Evidence from longitudinal studies suggests a similar pattern. As part of the ‘nun study’ Kemper, Greiner, Marquis, Prenovost, and Mitzner (2001) analyzed written autobiographical language samples across a span of 60 years. In this study, the written language samples were collected from the nuns at the mean ages of 22, 47, 75 and 83 years. In the data of the 139 adults who did not meet the criteria for dementia, the authors found a gradual decline in grammatical (and propositional) complexity across the lifespan. In another study, Kemper, Thompson et al. (2001) analyzed spoken language samples derived from responses to autobiographical questions. They collected these samples from 30 older adults originally aged 65-75, across a span of 7-15 years. They found that over time the older adults produced utterances that were less complex in both propositional and syntactic complexity, with a marked change occurring in the mid- to late-70s. In these two studies, the authors used
composite measures of grammatical and propositional complexity (e.g., D-level and P-density respectively), therefore the exact syntactic forms used by the participants are not specified. From the descriptions, a D-level score generally increases with embedding and left- rather than right-branching structures.

A similar pattern emerged in 2 experiments by Kemper, Herman & Lian (2003). In the first experiment older and younger participants (ages 70-80 and 18-28 respectively) were presented with two to four content words and asked to use them in a sentence (e.g., ‘pianist’, ‘canyon’ and ‘rope’). The authors found that both older and younger adults produced grammatical utterances with no hesitations or repairs in the production of simple sentences (when two or three words were presented). When participants were required to incorporate four words however, the older adults made more errors than the younger adults and their utterances were shorter and less complex. While it could be argued that the difficulties of the older adults were due to increased propositional complexity, similar findings were observed in the second experiment in which participants were required to incorporate verbs of varying complexity into a sentence. In this case, verb complexity was defined by an increased number of arguments, or the requirement of a phrasal complement (e.g., The pianist suggested that he hike through the canyon). Using the same methodology as in the first experiment, Kemper et al. found that older adults produced more errors and their sentences were less complex when required to use complex verbs (e.g., ‘suggested’). These same participants performed as well as the younger adults when required to use simpler verbs, such as intransitive (e.g., ‘laughed’) or transitive verbs (e.g., ‘examined’). The results from the two experiments suggest the presence of a syntactic difficulty. In both experiments the responses of the older adults were slower than those of the younger adults.
In a related experiment, Kemper, Herman and Liu (2004) asked 39 older adults (mean age 73 years) and 34 younger adults (mean age 19 years) to produce sentences beginning with memorized sentence stems (e.g., Right branching stem: “George thought that…”; Left-branching stem: “That Joan stole…”) which differed in the complexity required for completion. The authors found that overall the productions of the younger adults were longer than those of the older adults. Additionally they found that the responses of the younger adults were more complex than those of the older adults when required to use the less complex right-branching form, but became more similar only when the more complex left-branching form was required. The authors argued that a ceiling effect existed in the older adults’ productions and that they were limited in their ability to produce both syntactic forms.

Influences on Syntactic Complexity

Why would syntactic production differ in older adults? We have seen that older adults have difficulty producing more complex utterances. Is this due to an inherent change in the language production abilities of older adults or is it due to a different strategy (whether conscious or otherwise) used by older adults? To examine this question, we will return to the series of experiments by Altmann and Kemper (2006), previously presented in the section on syntactic production in younger adults. In this study they presented 59 older adults (mean age 76 years) and 51 younger adults (mean age 20 years) with three written words presented one above the other on a screen. The participants were asked to produce a sentence that would include the three written words. The first and third words were nouns and the middle word was a verb. Within the sentences the level of animacy and the ordering of the agent and patient nouns were manipulated so that the authors could investigate whether the preference
for the more animate noun in subject position or the preference for active sentences would be more dominant. Additionally, they sought to compare the syntactic structures across verb type to determine its effects if any. All of the effects were also compared between the age groups. Overall the authors found no main effect of age on reaction time to utterance onset. What they did find was that the younger adults tended to produce sentences with the more animate noun in subject position, suggesting an effect of animacy. Older adults on the other hand were more likely to produce the sentence based on the presented order of the nouns. Altmann and Kemper argued that in order to successfully complete the task, the older adults made use of the environmental cues compared to the younger adults who may have surveyed all of the stimuli and then relied on animacy to determine their syntactic constructions. This idea is consistent with the proposal by Craik and colleagues who suggest that the cognitive performance of older adults can be improved to the level of that by younger adults with proper environmental support (e.g., Craik, 1986). Another finding of the study was that neither group of participants showed an overall preference for active sentences, producing passive sentences according to their preferred strategy (e.g., animacy, use of environmental cues). What this study suggests is that even with relatively simple syntactic structures such as active and passive sentences (they contain no right- or left-branching), older and younger adults were differentially influenced by environmental and lexical factors as they attempted to complete the task as quickly as possible.

Summary of Language Production Findings in Older Adults

The quantity of studies of language production in aging is limited relative to the quantity of studies of language production in younger adults, but the findings thus far have
been relatively consistent. In general, studies of word production have shown that older adults are less accurate in their productions (Hodgson & Ellis, 1998) and produce fewer propositions per unit of speech (Kemper & Sumner, 2001; Mackenzie, 2000), but at the same time they may show increased lexical diversity (Kemper & Sumner, 2001). Earlier evidence tended to suggest that errors in word production were due to errors in accessing the phonological level (e.g., Brown & McNeil, 1966), but more recent evidence suggests that there may also be impairments at the levels of semantic and phonological representation (e.g., Barresi et al., 2000; Hodgson & Ellis, 1998). Finally, results of studies using the picture-word interference paradigm suggest that older adults process semantic and phonological information at the word level in a similar manner to younger adults, albeit more slowly (e.g., Bowles, 1994; Mortensen et al., 2008; Taylor & Burke, 2002).

Differences between the language production of older and younger adults have also been observed at the sentence level. Overall, studies have reported a decrease in the variety and complexity of syntactic structures produced (e.g., Kemper, Greiner et al., 2001; Kynette & Kemper, 1986), a decrease in the accuracy of syntactic production (e.g., Kemper et al., 2003) and a decreased speed of production. In certain sentence production tasks, studies have found no difference in the syntactic productions of older and younger adults, notably in cases in which the complexity of the syntactic structures could be classified as less complex, such as the difference between active and passive sentences (Altmann & Kemper, 2006), or sentences created from two to three provided content words, compared to a condition involving four provided content words (Kemper et al., 2003). Finally, it has been hypothesized that differentiated performance between the two groups may be due in part to the use of different ‘strategies’ by older and younger adults. As an example, Altmann and
Kemper (2006) argued that older adults utilized the given word order to create their sentences in a timelier manner, while younger adults scanned all of the stimuli prior to producing their utterances.

STATEMENT OF THE PROBLEM AND RATIONALE FOR THE CURRENT STUDY

Based on the results of previous studies, the full nature of the influence of semantic and phonological distractors on sentence production in younger adults remains unclear. Related to this issue is the question of whether it is possible to reconcile the seemingly opposing effects of semantic interference and phonological facilitation observed in reaction time studies (e.g., Glaser & Dungelhoff, 1984; Meyer, 1996) with the effects of semantic facilitation and phonological interference observed in studies measuring the position of the primed target word (Bock, 1986, 1987). While these studies shared a similar methodology but found different results, the study by Ferreira and Firato (2002) presents additional complexity to the issue. This study measured the type of sentence produced similarly to Bock’s studies, but found a result of semantic interference, similar to Meyer’s study.

Another important question in the literature relates to the relationship of lexical retrieval and syntactic production in older adults. There are numerous studies that report a change in syntactic production in older adults compared to younger adults, but the cause of these changes remains unclear. As well, many studies have demonstrated differences in lexical retrieval between older and younger adults (e.g., Mackenzie, 2000; Kemper & Sumner, 2001). If, as the literature suggests, lexical retrieval and syntactic production are in fact related (Bock, 1986, 1987; Ferreira & Firato, 2002), then does this relationship change
through the process of aging and could that be one cause for the change in syntactic production in aging?

The current study was designed to investigate aspects of the relationship between lexical retrieval and syntactic production and to determine whether this relationship changes with aging. Two experiments were carried out. The first experiment examined the effect of phonological and semantic distractors on the syntactic productions of younger adults at three different SOAs. Based on results in the first experiment, the second experiment examined the effect of semantic distractors on syntactic production in both younger and older adults at a single SOA. In both experiments the reaction time to utterance onset and the type of sentence produced were measured and analyzed.

Experiment 1 investigated the relationship between lexical retrieval and syntactic production in younger adults by presenting participants with pictures to be described along with auditory distractor words that were either related or unrelated to elements of the picture. The pictures presented scenes involving common nouns depicting actions that could easily be described using active or passive transitive sentences. As in previous studies, distractor words were related either semantically or phonologically to one of the two nouns in the picture. Unrelated distractors were also presented in order to serve as a baseline condition to the two forms of related distractors. Based on previous studies in the literature, the stimuli were presented using three different SOAs. The design of this experiment allowed for measurement of both reaction time to utterance onset and the type of sentence produced. Detailed predictions regarding the effects of semantic and phonological distractors on the productions of younger adults are presented in Chapter 2.
Based on the results of Experiment 1, Experiment 2 compared the relationship between lexical retrieval and syntactic production in younger and older adults. The task in Experiment 2 was the same as that in Experiment 1, with some differences in methodology. Overall the design of Experiment 2 was simplified from that in Experiment 1 to include only semantic and unrelated distractors and the SOA of -150 ms. Details regarding the predictions in Experiment 2 are presented in Chapter 3.
Experiment One - Lexical Influence on syntactic production in younger adults

BACKGROUND

Experiment 1 was designed with the purpose of examining the influence of lexical level information (notably semantic and phonological characteristics) on syntactic production. Unlike previous studies addressing this issue, both reaction time to utterance onset and the syntactic form of the utterance were measured in the same task.

As evidenced by the review of the literature, the type of sentence produced can be influenced by different lexical characteristics, such as noun animacy, verb type (Altmann & Kemper, 2006) and semantic and phonological characteristics of lexical items (Bock, 1986, 1987; Ferreira & Firato, 2002). Using a sentence production task, Bock (1986) found semantic facilitation, in that semantically related distractor words resulted in the target noun being more often produced in the subject rather than the object position of the sentence. In a second study she found an effect of phonological interference (Bock, 1987) in which phonologically related distractor words resulted in the target noun being produced more often in the object rather than the subject position of the sentence. In both cases, the lexical-level characteristics of the distractor words were able to influence the syntactic form produced.

The results of these studies stand in contrast to the results of picture-word interference tasks. In these studies, the effects of semantic and phonological distractors on word or phrase or sentence level productions were measured by reaction time to utterance onset (Costa & Caramazza, 2002; Glaser & Dungelhoff, 1984; Meyer, 1996; Meyer & Schriefers, 1991). These studies found that, relative to a baseline condition of an unrelated distractor, the presentation of a semantic distractor resulted in interference (a delayed
response time), while the presentation of a phonological distractor resulted in facilitation (a faster response time). An important aspect of these studies was the manipulation of the timing between the presentation of the picture and distractor word, or stimulus onset asynchrony (SOA). SOA is thought to reveal the time course of semantic and phonological processing. Effects of semantic influence have been observed at SOAs of -150 ms and 0 ms (Glaser & Dungelhoff, 1984; Meyer, 1996) and effects of phonological distractors have been observed at SOAs of closer to 150 ms (Costa & Caramazza, 2002; Glaser & Dungelhoff, 1984; Meyer, 1996; Meyer & Schriefers, 1991).

The current study was designed to combine the two methodologies in a sentence production task. In the literature to date, the studies measuring the type of sentence produced have required participants to generate novel sentences in response to a picture presentation, but have not recorded the timing of utterance onset. Reaction time studies have required participants to produce either a word level utterance (e.g., Glaser & Dungelhoff, 1984), a phrase (Costa & Caramazza, 2002; Meyer, 1996), or a sentence whose syntactic form is predetermined (Meyer, 1996; Schnur et al., 2006). Reaction time studies have not yet measured response times in a task in which participants were required to generate an unconstrained syntactic form.

In the current task participants were required to view a picture of a scene that could be easily described by an active or a passive transitive sentence. In addition to seeing the picture, participants heard a distractor word. The distractor word in the experiment was presented at SOAs of -1000 ms, -150 ms and 150 ms. The first SOA was selected based on the estimated SOA in Bock’s (1986, 1987) studies, with a modification for the lack of a repetition of the distractor word in the current study, but which was present in Bock’s
studies. The latter two SOAs were selected as representative of SOAs in which semantic interference and phonological facilitation respectively, were observed in previous reaction time studies (e.g., Meyer, 1996). Three types of distractor words for each target noun (e.g., ‘bee’) were included in the study: semantic (‘wasp’), phonological (‘beet’) and unrelated (‘suds’). The unrelated distractor was designed for use as a baseline condition relative to the two related distractor types.

Predictions for the Effects of Semantic Distractors

Because the models of sentence production reviewed both allow for the influence of lexical factors on syntactic production but are underspecified regarding further details of such an interaction, the predictions for the experiments in this study were based on the results in the literature. The following predictions were made for semantic distractors in Experiment 1: it was predicted that there would be an effect of semantic interference at the SOA of -150 ms, as measured by increased reaction times to the production of a sentence relative to the production of a sentence with unrelated distractors. In terms of sentence production, it was predicted that we would replicate Bock’s (1986) result of semantic facilitation at the SOA of -1000 ms, in which the target noun in the sentence that was semantically related to the distractor word would more likely be produced in the subject position of the sentence compared to a target noun primed with an unrelated distractor. Specifically, it was predicted that a) an agent primed with a semantic distractor would lead to a greater proportion of active sentences relative to an agent primed with an unrelated distractor; b) that a patient noun primed with a semantic distractor would lead to a smaller proportion of active sentences (i.e., a greater proportion of passive sentences) relative to a patient noun primed with an unrelated
distractor; and c) that a greater proportion of active sentences would be produced when the agent noun rather than the patient noun was primed with a semantic distractor.

Predictions for the Effects of Phonological Distractors

The predictions for the effects of phonological distractors were similarly made: in terms of the reaction time measurements, it was predicted that phonological distractors would result in an effect of facilitation, or a faster reaction time to the production of a sentence relative to the response time to sentence production with an unrelated distractor, at the SOA of 150 ms. In terms of the predictions for the proportion of active sentences produced, it was predicted, based on previous findings in the literature, that the presence of phonological distractors would result in an effect of phonological interference at the SOA of -1000 ms. Specifically we predicted a) that an agent primed with a phonological distractor would lead to a smaller proportion of active sentences (i.e., a greater proportion of passive sentences) relative to an agent primed with an unrelated distractor; b) that a patient noun primed with a phonological distractor would lead to a greater proportion of active sentences relative to a patient noun primed with an unrelated distractor; and c) that a smaller proportion of active sentences (i.e., a greater proportion of passive sentences) would be produced when the agent noun rather than the patient noun was primed with a phonological distractor.

METHOD

Participants

Sixty-one undergraduate students (40 women, 21 men) participated in the experiment. For inclusion in the study, participants were required to be native English speakers (i.e.,
English was the primary language spoken in the home, and/or they were educated in an English primary school) and have no history of speech, language, hearing or cognitive disorders, as determined through a brief questionnaire of background information. Fifty-two participants completed the testing. Of the nine participants who did not complete the testing, five participants stopped coming without further explanation, one participant revealed a history of stuttering, one participant reported not being a native English speaker and one participant was discharged after repeatedly falling asleep during the first session. Finally, through a clerical error, one participant was given the wrong presentation lists and, as such his data were not analyzable. Of those who completed testing, 32 participants cited minor vision problems, however these were corrected with glasses or contact lenses. The mean age of the participants was 21.8 years (SD 2.1 years). The mean years of education was 15.4 years (SD: 2.8 years). Thirty-four of the participants were female and 18 were male. Forty of the participants were right handed, ten were left-handed, and two did not indicate their handedness. Participants were recruited through flyers posted throughout the university.

Stimuli

Pictures

The stimuli consisted of 72 black and white line drawings. Of these, 36 were experimental pictures devised to elicit transitive sentences (e.g., a bee chasing an elephant), which could be described using an active sentence structure (e.g., “The bee chased the elephant”) or a passive sentence structure (e.g., “The elephant was chased by the bee”). See an example picture in Figure 3. The difference between these two sentence structures is the grammatical role of the agent and patient nouns. As previously described, the agent of a sentence is the one who does the action (e.g., the bee does the chasing), and the patient (or
theme) of a sentence, is the one (or thing) who receives the action (e.g., the elephant receives the chasing).

Figure 3. An example picture in the sentence production task.

In an active sentence, the agent is the subject of the sentence and the patient is the object of the sentence, but in a passive sentence the order is reversed and the agent is in the object position of the sentence, while the patient is in the subject position. In the set of stimuli in the current experiment, each picture, or target sentence was designed around the agent and patient nouns. Of the 36 experimental pictures, twelve contained two inanimate objects as nouns (e.g., chair, hat), twelve of the sentences contained two human animate nouns (e.g., acrobat, caveman) and twelve of the sentences contained two animal animate nouns (e.g., bee, elephant). The full set of sentences is provided in Appendix A, and the corresponding pictures are provided in Appendix B. The degree of animacy was controlled within sentences (e.g., inanimate, human animate, or animal animate) to control against the bias in which more
animate nouns are more likely to be produced in the subject position (Bock, Loebell and Morey, 1992).

Presented among the experimental pictures were 36 filler pictures, which were designed to elicit syntactic structures other than transitive sentences (e.g., intransitive: “The teenager shaved.”, and dative: “The football player threw the helmet to his teammate.”) in order to avoid a syntactic priming effect in the study (Bock & Loebell, 1990). Nouns within each filler sentence were not necessarily from the same animacy category. For example, in the filler sentence, "The bride gave the groom a camera", camera is an inanimate object but bride and groom are human animates. Different sets of nouns were used in the filler pictures and the experimental pictures. Experimental pictures were presented once during each session, but filler pictures were presented twice, resulting in a total of 108 pictures that were presented to each participant in a session.

The nouns within each experimental picture were matched for frequency to minimize the likelihood that frequency could influence the order in which the nouns would be produced in the sentence. The average noun frequency was 28.5 per million for the agent nouns; and 29.1 per million for the patient/theme nouns (Francis & Kucera, 1982), [t(70) = 0.16, p<0.87]. Across all of the sentences (including filler sentences), noun frequency was maintained below 100 per million, with the exception of horse (frequency count of 203) and dog (frequency count of 147), which were kept within the same experimental sentence.

*Auditory Distractor Words*

Each target noun (e.g., ‘bee’) in the experimental pictures was paired with three distractor words: a semantically related distractor (e.g., ‘wasp’), a phonologically related distractor (e.g., ‘beet’) and an unrelated distractor (e.g., ‘suds’). The full set of distractors is
presented with the target sentences in Appendix A. The criteria for selecting semantically related distractors were as follows. Distractors were categorically related to the target noun and were selected from synonyms, or if synonymy was not possible, a closely related noun from the same semantic category (e.g., cow – bull) was selected. Semantic distractors shared a categorical relationship with their target word for two reasons. First, La Heij, Dirkx, and Kramer (1990) provided evidence that associatively related words (e.g., tuna and sandwich) produce a facilitating effect in a picture-word interference production task (in terms of reaction time) and that categorically related words (e.g., mop and broom) produce an interference effect in the same production task. To avoid the possibility that these effects would cancel each other out, only one relationship (i.e., categorical) was used in this study. Secondly, the use of a categorical relationship in this study maximized the similarity of our materials to those used by Meyer (1996).

To control for the degree of semantic relatedness between the target noun and their related distractor words, a list of possible semantically related distractors was compiled in a relatedness questionnaire. The questionnaire was given to 22 participants; 12 younger adults (9 women, 3 men) between the ages of 18 and 35, and 10 older adults (7 women, 3 men) between the ages of 49 and 67. The mean age of the younger adults was 26.5 (SD = 5.0) and their mean number of years of education was 18 (SD = 2.5). The mean age of the older adults was 58.5 (SD = 6.8) and their mean number of years of education was 18.8 (SD = 1.7). These two age groups were selected to mirror the age groups of the participants to be used in the two experiments in the current investigation. Participants were asked to “rate (on a scale of one to seven) how related each word” was to its target word. Based on the results of the questionnaires, the most highly rated semantic distractor was selected for inclusion in this
study, but only if it was also given an average rating of at least 5.0, by both the younger adult and the older adult groups. There was no overt phonological relationship between target nouns and their semantic distractors (e.g., they did not rhyme, nor did they share phonemes in the first syllable). The number of syllables and the stress pattern were not controlled for.

The criteria for selection of phonologically related distractors were taken from the strictest guidelines provided by the studies upon which the current investigation was based (Bock, 1986, 1987; Meyer, 1996). The distractor and the target word in the sentence shared:

1) the same word-initial consonant or consonant cluster (e.g., clock - clot),
2) the same vowel in the word-initial syllable (e.g., mouse – mouth),
3) the same number of syllables and stress pattern (e.g., elephant – elegant)

Where possible they shared:

4) the same vowel in the stressed syllable (e.g., conductor – conduction),
5) the same consonants in the coda of the word-final syllable (e.g., waitress – weightless).

There was no semantic relationship between the target nouns and their phonological distractors.

Within a sentence the distractors for one target noun were unrelated phonologically and semantically to the other target noun. There was no difference in the frequency of the phonological distractors and the semantic distractors across the sentence groups (inanimate nouns: t(46) = -0.303, p>0.7; human animate nouns: t(46) = -0.459, p>0.6; animal animate nouns: t(46) = -1.192, p>0.2). The frequency count of the semantic and phonological distractors was controlled as carefully as possible within each sentence. The frequency count
for all distractors was less than 100 per million (Francis & Kucera, 1982), with the exception of *mouth* (frequency count of 113), the phonologically related distractor word for *mouse*.

The unrelated distractors were unrelated to both nouns in the sentence. In order to have the same number of unrelated distractors as there were phonological and semantic distractors, there were two unrelated distractors for each sentence (one for each of the two target nouns). The unrelated distractors were selected from the group of related distractors, but were paired with target nouns for which there was no phonological or semantic relationship. Unrelated distractors were also paired with target nouns sharing the same thematic role as the target noun to which the distractor was related. For example, if a distractor was used as a semantic distractor to an agent noun, then it would act as an unrelated distractor to an agent noun. An equal number of the semantically related and phonologically related distractors was used as unrelated distractors. Distractors were also used for the filler sentences. These distractor words were also selected from the pool of related distractors. They were unrelated semantically and phonologically to the target nouns in the selected filler sentence. All of the distractor words were recorded by the same male speaker, using WavePad Sound Editor, version 3.05 (NCH Software, 2007).

**SOA**

The auditory distractor words and picture stimuli were paired with three different stimulus onset asynchronies, or SOAs (-1000 ms, -150 ms, and +150 ms). These SOAs were chosen based on the studies by Bock (1986, 1987) and Meyer (1996). While SOA was not controlled in Bock’s studies and was reportedly quite variable, she estimated that the average SOA was approximately -2000 ms. This SOA is estimated to represent the timing between the repetition of the distractor word and the presentation of the picture. As mentioned earlier,
in Bock’s studies after hearing the distractor word but before seeing the picture participants were required to repeat the distractor word, judge if they recognized it, and then receive feedback on their decision. These three steps were not included in the current investigation in an attempt to render the current methodology more similar to more typical reaction time studies. It was estimated that with the removal of the recognition and feedback components, an SOA of -1000 ms would be roughly equivalent to the SOA of -2000 ms estimated in Bock (1986).

Organization of Picture-word Pairs

Experimental and filler pictures were pseudo-randomly ordered, with the condition that not more than two experimental pictures could be presented sequentially and that the same filler picture was not presented twice in a row. The 36 experimental pictures were presented once to each participant in a session and only one SOA was presented per session, resulting in three sessions. Across all participants, the pictures were counterbalanced, crossing SOA, distractor type and thematic role. This resulted in each distractor type by thematic role combination (e.g., semantically related distractor to the agent noun, phonologically related distractor to the patient noun) being presented six times in each of the three sessions. This presentation design allowed for a tripling of the exposure to the various combinations and permitted the blocked presentation of each SOA. In all, there were 18 presentation lists, six for each SOA. Participants were assigned to one list at each SOA by random assignment. Order of SOA presentation (-1000 ms, -150 ms, 150 ms) was counterbalanced across participants.
The pictures were black and white line drawings of the actions. The agent of the sentence was on the right side of the picture in half of the pictures and on the left side of the picture in the other half.

Procedure

Participants took part in three sessions, and were paid $10 per session at the end of their participation. Each session lasted approximately 45 minutes. There was a familiarization and an experimental phase in each session.

Familiarization Phase

The familiarization phase had two main goals. The first goal was to prime the production of passive sentence structures (to counteract the inherent bias against the production of passive sentences in English; Bates & Devescovi, 1989). The second goal was to promote the likelihood that the participants would accurately produce the target noun in their sentences so that the selected semantic and phonological distractors would maintain their maximal effect. The familiarization phase was composed of three tasks. In the first task, participants were presented with a series of 20 colour photographs depicting transitive actions (e.g., a cashier slapping a woman). For each picture, participants were required to look at the picture and think of a sentence that they could use to describe the picture, without saying it out loud. Participants were asked to then read aloud a written sentence describing the picture (in the active or passive form), which appeared below the picture after six seconds. Half of the written sentences were in active form and half were in passive form.
In the second task, participants were presented with 28 pictures of target nouns from the experimental stimuli that were potentially ambiguous (e.g., a participant might say ‘chipmunk’ upon seeing the picture of a *squirrel*). The target name was written below each picture. Participants were simply required to attend to the stimuli presented on the screen. In the third task, participants were presented with the pictures of all the target nouns from the experimental phase and were asked to name them. Incorrectly named pictures were subsequently presented in paper form to the participant with the correct word. Participants were not required to repeat the correct word out loud. Data from the familiarization phase were not recorded or analyzed. The familiarization phase took approximately 10 to 15 minutes.

**Experimental Phase**

The experimental phase consisted of a sentence generation task, which was presented to the participants as a memory task. While they were not told overtly that it was a memory task, the participants were told that they would be asked to indicate whether or not they had already seen each picture after its presentation. The reason for the deception was to draw their attention away from their sentence productions. Participants were told that they would see a series of pictures, and hear some words. Their task was to describe each picture as quickly and accurately as possible. They were also told that following the picture presentation, they would be asked if they had seen the picture before (within the session), to which they would respond either yes or no. Because filler pictures were shown twice, a ‘yes’ answer was correct after the second presentation of the filler pictures and a ‘no’ answer was correct after presentation of the experimental pictures and after the first presentation of the
filler pictures. There were three practice picture-word pairs, which contained stimuli not included in the main set of picture-word pairs.

Picture and distractor word presentation were synchronized using E-Prime software (Psychological Software Tools, 2002). Both the participant and the examiner wore headphones through which the distractor words were presented. Participants were allowed to increase or decrease the volume of the sound presentation. The pictures were presented in the centre of a computer screen for 9 seconds. Prior to the appearance of a picture, a prompt (+) appeared on the screen to indicate that the next picture would soon appear. The examiner controlled the onset of each picture-word trial after the prompt. The recording of response delays was accomplished via E-Prime software (Psychological Software Tools, 2002). The actual recording of the sentence productions was accomplished using a SONY digital recorder. Responses to the memory questions were not retained. At the end of the third session participants were debriefed regarding the purpose of the study, including the reason for the deception regarding the memory portion of the task.

RESULTS

Scoring: Exclusionary Criteria

The criteria outlined in Bock (1986, 1987) and Meyer (1996)’s studies to determine which sentences could be included in the analyses were used. In addition to being grammatical, an utterance had to have a successfully recorded reaction time for inclusion in the analyses. Additional exclusionary criteria fell into one of three categories: a) Utterances were excluded from the analyses if the participants failed to produce one or both of the target nouns in the sentence. Included in this group were missing or substituted target words and
repetitions of the distractor word. The use of compound words was accepted (e.g., ‘alarm clock’ was acceptable in place of ‘clock’); b) Utterances were also excluded if a participant produced a hesitation, either verbal (e.g., ‘um’) or non-verbal (e.g., laugh), rendering an invalid measure of reaction time; c) Finally, utterances were excluded when the validity of the reaction time data was suspect (for example, due to a technical error with the computer or microphone, or the presence of external noise).

In addition to being grammatical and following the above guidelines for exclusion, sentences had to be transitive sentences in either the active or passive form. Because the stimuli were counterbalanced in the experimental design, only an analysis by participants was conducted (Clark, 1973; Raaijmakers, 2003, Raaijmakers, Schrijnemakers & Gremmen, 1999). In this experiment we were able to investigate the influence of semantically and phonologically related distractor words on syntactic form (relative to the baseline condition of unrelated distractors).

Following Altmann and Kemper (2006), a participant’s data were removed from the analysis if greater than two thirds of the utterances in a given condition were excluded. In this experiment there were 18 conditions, created by crossing SOA (-1000 ms, -150 ms, 150 ms), distractor type (semantic, phonological and unrelated) and thematic role of primed word (agent and patient). For each condition there were six trials. Thus, if more than 4 trials were excluded in a single condition for a given individual, that participant’s entire set of data was removed. This resulted in the exclusion of the data of nine participants from the analysis. The final data set was based on the data of 43 participants. Of this data set, 351 utterances (7.6% of the total data) were excluded from analysis due to the fact that they were not transitive active or passive sentences. An additional 383 utterances (8.2% of the total data) were
excluded from analysis for the reasons just detailed (e.g., equipment malfunctions). The data were analyzed according to both reaction time to utterance onset as well as the proportion of active sentences produced.

Data Set Consisting of Active and Passive Sentences

Results of Reaction Time Analysis

In order to test the predictions regarding the reaction time data, the reaction time to utterance onset was collected for each trial. Condition means for each participant were then calculated. Outliers, defined as values beyond +/- 2 standard deviations of the individual’s condition means were replaced with that value. The condition means were then entered into a 3x3x2 analysis of variance, crossing SOA (-1000 ms, -150 ms, 150 ms), distractor type (semantic, phonological, unrelated) and thematic role of the primed noun (agent, patient). Post hoc testing was accomplished using Tukey’s HSD. For all analyses, differences were considered significant with a p-value less than 0.05. Effect size was calculated using eta squared (η²).

The mean reaction times to utterance onset per condition were calculated. The data are presented in Table 1. Only the main effect of SOA was significant\(^7\) [F(2, 84)=10.04, p<0.001], with a very large\(^8\) effect size (η² =0.14). Comparison of the three SOAs revealed faster reaction times to pictures presented at an SOA of -1000 ms (1692 ms), compared to those presented at both the SOA of -150 ms (1872 ms) and 150 ms (2012 ms). There was no difference between the reaction times at the SOAs of -150 ms and 150 ms. There was a trend

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\(^7\) A full list of the p-values from both experiments, including non-significant ones, is included in Appendix C.

\(^8\) Cohen (1988)
towards a 3-way interaction between SOA, distractor type and thematic role of the primed noun \( F(3.4, 140.6)=2.219, p<0.082 \). 

<table>
<thead>
<tr>
<th>Distractor type</th>
<th>Role of primed noun</th>
<th>SOA -1000 ms</th>
<th>SOA -150 ms</th>
<th>SOA +150 ms</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agent</td>
<td>Patient</td>
<td>Agent</td>
<td>Patient</td>
<td>Agent</td>
</tr>
<tr>
<td>Semantic</td>
<td>1676</td>
<td>(555)</td>
<td>1947</td>
<td>(561)</td>
<td>2015</td>
</tr>
<tr>
<td></td>
<td>1738</td>
<td>(590)</td>
<td>1866</td>
<td>(423)</td>
<td>2046</td>
</tr>
<tr>
<td>Phonological</td>
<td>1737</td>
<td>(581)</td>
<td>1863</td>
<td>(500)</td>
<td>1958</td>
</tr>
<tr>
<td></td>
<td>1700</td>
<td>(566)</td>
<td>1913</td>
<td>(516)</td>
<td>2007</td>
</tr>
<tr>
<td>Unrelated</td>
<td>1727</td>
<td>(543)</td>
<td>1830</td>
<td>(462)</td>
<td>2003</td>
</tr>
<tr>
<td></td>
<td>1683</td>
<td>(539)</td>
<td>1927</td>
<td>(539)</td>
<td>2007</td>
</tr>
<tr>
<td>Mean</td>
<td>1713</td>
<td>1707</td>
<td>1880</td>
<td>1902</td>
<td>1992</td>
</tr>
</tbody>
</table>

Note. Values enclosed in parentheses represent Standard Deviation.

Table 1. Mean reaction time (ms) for data including only active and passive sentences, by distractor type and role of primed word for each stimulus onset asynchrony (SOA).

Results of Sentence Type Analysis

In order to test the predictions regarding the sentence type data, each utterance was scored for the presence of an active sentence. The data were analyzed using the General Estimating Equations (GEE) approach. The GEE method was selected for its ability to analyze non-normally distributed data (in this case binomial data) with multiple observations for each individual (Burton, Gurrin & Sly, 1998). The benefit of GEE is that it is able to account for the correlation of outcomes within an individual. An exchangeable correlation structure was used with the assumption that each observation for an individual is equally correlated with every other observation by that same individual (Burton et al., 1998). In the analysis of

\(^9\) In this case the Greenhouse-Geisser values were used due to a violation of the assumption of sphericity, resulting in a modification of the degrees of freedom (Leech, Barrett, & Morgan, 2004).
sentence type the independent variables were SOA, distractor type and role of primed word and the dependent variable was the presence of an active sentence (yes or no). Pairwise comparisons were performed to determine the significance of contrasts in main effects and interactions. Differences were considered significant with a p-value less than 0.05. Because the data are binomial in nature, effect sizes were calculated using an odds ratio.

The proportions of active sentences per condition are presented in Table 2. The analysis revealed a main effect of thematic role of the primed word ($Z = 34.9, p<0.000$) with an odds ratio of 1.81, in which a larger proportion of active sentences was produced when the agent noun was primed (.96) compared to when the patient noun was primed (.93). The odds ratio suggests that the odds that an active sentence will be produced when an agent noun is primed are 1.81 times greater than when a patient noun is primed. There was also a trend of distractor type ($Z = 5.7, p<0.057$), in the direction of fewer active sentences being produced with the presentation of a phonological distractor (.94) compared to an unrelated distractor (.96).

Data Set Consisting of all Grammatical Sentences

Due to a lack of definitive results in the above data, a second data set containing all grammatical sentences was analyzed as an exploratory analysis. It was observed in the first data set that 7.6% of all trials were lost due to the fact that the utterances were not of the transitive active or passive sentence form. The purpose of analyzing this data set was to determine whether the semantic and phonological distractors had any effect on utterance production, without the constraint of considering syntactic form. In this second data set, reaction time was similarly used as a dependent variable. However, instead of measuring the
proportion of transitive active sentences produced as in the previous data set, we simply
analyzed the position of the primed target noun in the sentence. A higher proportion of
semantically- or phonologically-primed nouns in the subject position (relative to a noun
primed with an unrelated distractor) would indicate a facilitation effect, and the opposite
interference effect would be inferred from a higher proportion of semantically- or
phonologically-primed nouns in the object position.

<table>
<thead>
<tr>
<th>Distractor type</th>
<th>SOA -1000 ms</th>
<th>Role of primed noun</th>
<th>SOA -150 ms</th>
<th>SOA +150 ms</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agent Patient</td>
<td>Agent Patient</td>
<td>Agent Patient</td>
<td>Agent Patient</td>
<td></td>
</tr>
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<td>Semantic</td>
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<td>.97 (0.01) .93 (0.02)</td>
<td>.98 (0.01) .93 (0.02)</td>
<td>.95 (0.01)</td>
<td></td>
</tr>
<tr>
<td>Phonological</td>
<td>.94 (0.02) .92 (0.02)</td>
<td>.93 (0.02) .92 (0.02)</td>
<td>.98 (0.01) .92 (0.03)</td>
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<td></td>
</tr>
<tr>
<td>Unrelated</td>
<td>.94 (0.02) .95 (0.01)</td>
<td>.97 (0.01) .94 (0.02)</td>
<td>.96 (0.01) .95 (0.02)</td>
<td>.96 (0.01)</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>.95 (0.01) .92 (0.02)</td>
<td>.96 (0.01) .93 (0.02)</td>
<td>.97 (0.01) .93 (0.02)</td>
<td>0.942</td>
<td></td>
</tr>
</tbody>
</table>

Note. Values enclosed in parentheses represent Standard Error.

Table 2. Proportion of active sentences produced (SE) by distractor type and role of primed
word for each stimulus onset asynchrony (SOA).

For this data set we predicted again that in the reaction time analysis a longer
response time would occur when a semantic distractor was presented compared to when an
unrelated distractor was presented. In terms of phonological distractors, it was predicted that
there would be a shorter response time when a phonological distractor was presented
compared to when an unrelated distractor was presented. These effects were
predicted at the SOAs of -150 ms and 150 ms, respectively. In the analysis of the position of the primed target noun, consistent with the prediction in the previous data set, we expected that at the SOA of -1000 ms a semantically-primed target noun would be produced in the subject position of the sentence more often than an unrelated-primed target noun. In terms of phonological distractors, we predicted an effect of phonological interference, in which the phonologically-primed target word would be produced more often in the object position of the sentence compared to a trial in which an unrelated primed target noun was presented.

Results of Reaction Time Analysis

The analysis of reaction time data was performed in the same way as in the previous data set. The condition means were entered into a 3x3x2 repeated measures analysis of variance, crossing SOA, distractor type and thematic role.

<table>
<thead>
<tr>
<th>Distractor type</th>
<th>SOA</th>
<th>Role of primed noun</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1000 ms</td>
<td>-150 ms</td>
<td>+150 ms</td>
</tr>
<tr>
<td></td>
<td>Agent</td>
<td>Patient</td>
<td>Agent</td>
</tr>
<tr>
<td>Semantic</td>
<td>1700</td>
<td>1733</td>
<td>1974</td>
</tr>
<tr>
<td></td>
<td>(566)</td>
<td>(591)</td>
<td>(571)</td>
</tr>
<tr>
<td>Phonological</td>
<td>1717</td>
<td>1676</td>
<td>1870</td>
</tr>
<tr>
<td></td>
<td>(547)</td>
<td>(555)</td>
<td>(516)</td>
</tr>
<tr>
<td>Unrelated</td>
<td>1737</td>
<td>1687</td>
<td>1836</td>
</tr>
<tr>
<td></td>
<td>(579)</td>
<td>(533)</td>
<td>(485)</td>
</tr>
<tr>
<td>Mean</td>
<td>1718</td>
<td>1698</td>
<td>1893</td>
</tr>
</tbody>
</table>

Note. Values enclosed in parentheses represent Standard Deviation.

Table 3. Mean reaction time (ms) for data set containing all grammatical utterances, by distractor type and role of primed word for each stimulus onset asynchrony (SOA).
The mean reaction times per condition are presented in Table 3. As in the previous analysis, only the main effect of SOA was significant [F(2, 84)=11.00, p<0.001], with a very large\(^\text{10}\) effect size (\(\eta^2 = 0.15\)). A comparison of the three SOAs revealed faster reaction times to pictures presented at an SOA of -1000 ms (1709 ms), compared to pictures presented at both the SOA of -150 ms (1895 ms delay) and 150 ms (2019 ms). There was no difference between the reaction times at the SOAs of -150 ms and 150 ms. There was also a trend of a 3-way interaction between SOA, distractor type and role of the primed noun [F(4, 168)=2.014, p<0.095].

<table>
<thead>
<tr>
<th>Distractor type</th>
<th>SOA</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1000 ms</td>
<td>-150 ms</td>
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<tr>
<td>Semantic</td>
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<td>.52 (.01)</td>
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<td>Phonological</td>
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<td>.51 (.01)</td>
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<tr>
<td>Unrelated</td>
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<td>.50 (.01)</td>
</tr>
<tr>
<td>Mean</td>
<td>.52 (.01)</td>
<td>.51 (.01)</td>
</tr>
</tbody>
</table>

Note. Values enclosed in parentheses represent Standard Error.

Table 4. Proportion of primed words in subject position for data set containing all grammatical sentences, by distractor type for each stimulus onset asynchrony (SOA).

Results of Position of Primed Word Analysis

The proportions of primed target words per condition are presented in Table 4. Because we were only interested in the position of the individual primed noun and not the alternation in sentence type, the thematic role of the primed word was not relevant and as

\(^{10}\) Cohen (1988)
such it was not included as an independent variable in the analysis. In this analysis the independent variables were SOA and distractor type and the dependent variable was whether the primed target word was in the subject position or not. From the GEE analysis, there was a main effect of distractor type ($Z = 7.2$, $p< 0.027$; odds ratio $= 1.13$), with the target noun produced in the subject position more often when a semantic distractor was presented (.53) compared to when an unrelated distractor was presented (.50). The odds ratio of 1.13 suggests that the odds of a target noun being produced in the subject position of a sentence with a semantic distractor are 1.13 times greater than the odds of it occurring with an unrelated distractor. No other outcome was significant.

DISCUSSION

In this experiment participants were required to describe a picture using a full sentence while hearing a distractor word which appeared either before or after the presentation of the picture. The purpose of Experiment 1 was to investigate the influence of phonological and semantic distractor words on the sentence productions of younger adults. The unique aspects of this experiment included the use of three different SOAs in an unconstrained sentence generation task, as well as the concurrent measurement of both reaction time and sentence structure together in a study of sentence production. Previously the study of reaction times and sentence structure productions have been segregated. Predictions for the current study were based on results in the literature.

Overall, the results of this experiment did not provide a clear picture of the effect of lexical level characteristics on sentence production. No effect of the semantic and phonological distractors on the response times of the participants was observed, contrary to
our predictions. This null result was observed in the data set comprised of active and passive sentences as well as in the data set containing all of the grammatical sentences. Although there was a main effect of SOA in the reaction time analyses (of both data sets), this finding was only minimally relevant to the purposes of the study. This effect revealed quicker response times with an SOA of -1000 ms, compared to both the SOAs of -150 ms and 150 ms. Because it is a main effect, it therefore provides information regarding the combined effect of the processing of semantic, phonological and unrelated distractors. As such it likely reveals information regarding the interference effect of processing of lexical information in general, rather than the effects of the semantic and phonological distractors relative to the baseline condition of unrelated distractors. Because this effect provides no information regarding the influence of semantic or phonological distractors, it yields little relevant information to the current study.

In the sentence type analysis (of the data set containing only active and passive sentences), there was a main effect of thematic role and a marginally significant effect of distractor type. Both of these results are somewhat difficult to account for in terms of the predictions of the study. In terms of the main effect of thematic role, it was observed that more active sentences were produced when the agent noun was primed compared to when the patient noun was primed. Because this effect of thematic role was independent of distractor type, it means that regardless of the relationship between the distractor word and the target noun, when the patient noun was primed it resulted in the less preferred passive form more often than when an agent noun was primed, suggesting an overall effect of facilitation. It is not clear why this differentiation should occur given that it is independent of distractor type and because the agent and patient nouns were matched on linguistic characteristics and
differed only in their thematic role relative to the verb. Had there been a co-occurring significant interaction between thematic role and distractor type, in which there was no difference between the proportion of active sentences when the agent or patient were primed with an unrelated distractor, then this main effect could have been explained. In such a case, it could have been argued that the combined semantic and phonological distractors caused a facilitating effect, resulting in the primed word occurring more often in the subject position (meaning more active sentences when the agent was primed and more passive sentences when the patient was primed), and the unrelated distractors would have a zero net effect on the proportional differences of active and passive sentences. However, no interaction was observed, implying that for the observed effect of thematic role all three distractor types caused a facilitating effect; this is difficult to account for, especially in regards to the unrelated distractors.

A second result that is difficult to explain is the marginally significant trend of distractor type in which fewer active sentences were produced with the presentation of a phonological distractor compared to an unrelated distractor. The finding seems to imply a co-occurring effect of phonological facilitation and phonological interference. To explain why this is, we must look at the relationship between agent and patient nouns and the structure of active and passive sentences. If the priming of an agent noun leads to fewer active sentences, it means that the agent noun was interfered with in its production and produced in the object position of the sentence. However for the priming of a patient noun to result in fewer active sentences it means that the patient noun is facilitated, such that it is produced in the subject role of the sentence. This means that to attain this effect, the phonological distractor would
have to create both a facilitation and an interference effect in the same task, which would appear to be unlikely.

The main finding of the experiment emerged in the data set containing all grammatical sentences. In this data set there was a main effect of distractor type in the analysis of the position of the primed target noun, indicating an effect of semantic facilitation, wherein the semantically-primed noun was more likely to be produced in the subject position compared to an unrelated-primed noun. Interestingly, this effect was observed across all three SOAs (-1000 ms, -150 ms, 150 ms), rather than only at the predicted SOA of -1000 ms. Apart from the similarity of effect across SOAs, this result supports our prediction of semantic facilitation. The same effect of semantic facilitation however, was not observed in the sentence type analysis (i.e., the data set containing only active and passive sentences). This limitation suggests that the semantic distractors did have an effect on the production, but they did not necessarily influence the sentence structure produced in the predicted manner. The reason it is possible to make this distinction is because the result was observed in the data set that was not limited to transitive active and passive sentences and measured only by the position of the target noun, rather than by the type of sentence produced. It is possible therefore that the effect of semantic facilitation was observed in the production of a sentence such as, “The sailor was bathing and the conductor was conducting” with the distractor word ‘mariner’. In this sentence the distractor word may have had the effect of causing the semantically related target word to be produced in the subject position, but the sentence was not in the expected transitive form (e.g., “The conductor bathed the sailor”, or “The sailor was bathed by the conductor”).
How Do the Results Fit With the Models of Syntactic Production?

Because a null result cannot provide support for or against a model, the effect of semantic facilitation observed in the analysis of the position of the primed word (but not in the sentence type analysis) and the lack of relevant effects found in other analyses cannot provide support for or against the models of sentence production. More will be discussed on this topic in the General Discussion.

The effect of thematic role and the marginally significant effect of distractor type that were observed in the sentence type analysis did demonstrate an influence of lexical level information on syntactic production, which would support the hypothesis of the syntactic models which permit such an interaction. This support for the models however is complicated by the fact that the effects are difficult to explain logically.

Overall the results of this experiment were somewhat equivocal regarding the effects of semantic and phonological distractors on syntactic production. In the reaction time analyses there were no relevant significant effects of the distractors. In the analysis of the position of the primed word there was an effect of semantic facilitation, however it was not mirrored in the analysis of sentence type.

It is possible that this lack of results could be an accurate reflection of what occurs in an unconstrained sentence generation task, such as this one. However, it is also possible that effects were not observed because of the nature of the design of the current experiment. The number of variables investigated concurrently, namely SOA and distractor type, may have been ambitious and may have masked real results. There may have been two adverse effects of the inclusion of the large number of conditions created by the independent variables investigated. First is that the participants may have been distracted, either consciously or
unconsciously by the multitude of conditions presented. Secondly, it is possible that the additional complexity of a 3x3x2 statistical analysis resulted in the loss of effects and/or interactions that might otherwise have been significant in a less complicated design. It is also possible that we did not observe effects of semantic or phonological distractors in the sentence type analysis that Bock (1986, 1987) observed, due to the fact that the task in the current experiment did not require the repetition of the distractor word, as was the case in Bock’s experiments. The additional processing of the distractor word may have strengthened its influence on the syntactic structure in Bock’s studies.

To investigate further the lexical influence on syntactic production, it was proposed that the design of the current experiment be simplified in order to focus on the effects of the semantic distractors that were hinted at in the analysis of the position of the primed word. As well, because the effects of SOA were independent of distractor type, it was proposed that only one SOA be studied in the follow-up experiment. Finally, to investigate syntactic production in older adults, it was proposed that the simplified methodology be attempted with both younger and older adults.
Experiment Two - Lexical influence of semantic distractors on syntactic production in younger and older adults

BACKGROUND

Experiment 2 was designed with two purposes. The first was to continue the investigation of lexical influence on syntactic production. The second goal was to extend this investigation to the older adult population.

Because of the equivocal results in Experiment 1 and the possibility that methodological issues may have confounded the results, we simplified the original design in Experiment 2. In this experiment we investigated only the influence of semantic distractors relative to the baseline condition of unrelated distractors and only the SOA of -150 ms was included in the design.

Semantic rather than phonological distractors were chosen for two reasons. The first was that the results from Experiment 1 suggested a stronger pattern of facilitation with semantic distractors compared to phonological distractors. While there was no effect of semantic distractors in the sentence type analysis (i.e., active vs. passive) in Experiment 1, semantic distractors did show an effect of facilitation in the analysis of the position of the primed word, suggesting that with a simplified design we might observe effects of semantic distractors on the production of active versus passive sentences.

The second reason for investigating semantic distractors rather than phonological distractors was derived from the review of the literature. It is the case that both phonological and semantic distractors (or priming words) have been extensively studied in the literature with opposing outcomes, through the analysis of reaction time (e.g., Costa & Caramazza, 2002; Glaser & Düngelhoff, 1984; Meyer, 1996; Meyer & Schriefers, 1991; Schriefers,
Meyer, Levelt, 1990) and syntactic form produced (Bock, 1986, 1987). Additionally, in a study investigating the effects of semantic relatedness, Ferreira and Firato (2002) found an effect of semantic interference in contrast to the effect of semantic facilitation found by Bock (1986), despite the fact that effects were measured in terms of the syntactic form produced in both studies. The various conflicting results in the literature provide a compelling reason to further investigate the effects of semantic distractors on syntactic production.

The SOA of -150 ms was selected for Experiment 2 for various reasons. Firstly, the factor of SOA was not found to be discriminating in Experiment 1; there was no interaction with distractor type, meaning that at each SOA the same effect of distractors was found. In light of this and the fact that the SOA of -150 ms has been used in previous studies involving semantic distractors (e.g., Glaser & Dungelhoff, 1984; Meyer, 1996), the SOA of -150 ms was chosen for the present study. There is some concern regarding the selection of an SOA for a sentence production task based on the results from a word level task, as the amount and timing of processing required for the word versus the sentence level of production may differ. Because of this, it is possible that the use of the same SOA could result in missing effects at the sentence level that might otherwise have been detected. However, it was felt that it was important to maintain a connection to previous results in the literature so the SOA of -150 ms was chosen.

The second goal of this experiment, that of investigating the effects of semantic distractors on sentence production in older adults was undertaken in an effort to further the study of this area. Investigations of sentence production in older adults are still quite limited in number and have focused primarily on the changes that occur in aging. Results to date
suggest a decreased complexity of syntactic production (Kynette & Kemper, 1986; Kemper, Thompson, et al. 2001; Kemper, Greiner, et al., 2001), increased difficulty with more syntactically complex productions (Kemper et al., 2003; Kemper et al., 2004) and increased errors in syntactic productions with more complex verbs (Kemper et al., 2003). The current investigation examined the influence of a lexical-level characteristic on syntactic production in aging, in an attempt to investigate changes in syntactic production between younger and older adults. We examined this question using an experimental task designed to elicit active and passive sentences. In an attempt to keep the production task as natural as possible we placed as few constraints as possible on the production of the utterance.

Specifically we asked, if there is a difference in the syntactic production of older adults compared to younger adults, is it reflected in a difference in the proportion of active vs. passive sentences produced between the groups? Do the groups differ in their response times? Do the groups vary in the type and quantity of errors produced?

Predictions for the Performance of Younger Adults

As presented in Experiment 1, an effect of semantic interference was predicted in the reaction time analysis, reflected in longer reaction times to production of a sentence in the presence of a semantic distractor compared to the reaction times to production of a sentence with an unrelated distractor. In terms of the type of sentence produced, it was predicted that we would observe a result of semantic facilitation, in which the target noun (e.g., ‘bee’) in the sentence that was semantically related to the distractor word (e.g., ‘wasp’) would more likely be produced in the subject position of the sentence compared to a target noun primed with an unrelated distractor (e.g., ‘suds’). In specific terms, we expected 1) that an agent
primed with a semantic distractor would lead to a greater proportion of active sentences relative to an agent primed with an unrelated distractor; b) that a patient noun primed with a semantic distractor would lead to a smaller proportion of active sentences (i.e., a greater proportion of passive sentences) relative to a patient noun primed with an unrelated distractor; and c) that a greater proportion of active sentences would be produced when the agent noun rather than the patient noun was primed with a semantic distractor.

For consistency with the analyses of Experiment 1, a second data set comprised of all the grammatical sentences produced was analyzed. Once again, the same general predictions held for the two data sets. For this second data set we predicted a longer response time when a semantic distractor was presented compared to when an unrelated distractor was presented. In the analysis of the position of the primed word, it was predicted that a semantically-primed target word would be produced more often in the subject position of the sentence, relative to the production involving a target noun primed with an unrelated distractor.

Predictions Regarding the Comparison of Performance by Younger and Older Adults

Our predictions for the results of the comparison between the performance of older and younger adults were also based on the previous findings in the literature. Specifically, we predicted that the presence of semantic distractors would cause older adults to produce an increased error rate and an increased delay in response time relative to younger adults. Because transitive active and passive sentences consist only of a matrix clause and therefore could be classified as relatively simpler syntactic forms (Kemper et al., 2003; Kemper, Thompson et al., 2001; Kynette & Kemper, 1986), the relative complexity of the two forms should not be a factor in the comparison of the productions of the two age groups. However,
we predicted a similar result to that found in Altmann and Kemper’s (2006) study, in which the younger and older adults responded differently due to the environmental cues in the study. In that study, the younger adults were primarily influenced by noun animacy and verb type and the older adults were primarily influenced by the order of noun presentation. In the current study, it was predicted that the older adults would be more influenced than the younger adults by the left to right ordering of the patient then agent nouns in all of the pictures. The result of this is a prediction of an increased susceptibility to beginning their utterances with the left-sided patient nouns in the presence of the semantically related distractor words, which should result in an increased production of passive sentences for the older adults compared to the younger adults.

METHOD

Participants

Younger Adults

Eighty-three undergraduate students (59 women, 24 men) participated in the experiment. For inclusion in the study, participants were required to be native English speakers (i.e., English was the primary language spoken in the home, and/or they were educated in an English primary school) and have no history of speech, language, hearing or cognitive disorders, as determined through a brief questionnaire of background information. Seventy-one participants completed the testing. Of the 12 participants who did not complete the testing, five participants revealed a history of cognitive, linguistic or developmental hearing disorder and seven participants reported not being native English speakers. The
remaining 71 participants fit the above criteria. A number of participants cited minor vision problems, however these were corrected with glasses or contact lenses. The mean age of the participants was 22.9 years (SD 4.5 years). The mean years of education was 16.3 years (SD: 3.0 years). Fifty-three of the participants were female and 18 were male. Fifty-eight of the participants were right handed, ten were left-handed, two participants were ambidextrous and one participant did not indicate his handedness. Participants were recruited through flyers posted throughout the university and by word of mouth referrals.

**Older Adults**

Fifty-six adults (39 women, 17 men), between the ages of 65 and 92 participated in the experiment. For inclusion in the study, participants were required to be native English speakers (i.e., English was the primary language spoken in the home, and/or they were educated in an English primary school) and have no history of speech, language, cognitive or developmental hearing disorders, as determined through a brief questionnaire of background information and a screening of their hearing during the testing procedure. Based on demographic information, the data from five participants were removed from the analyses. Two of the participants revealed a history of cognitive or linguistic disorder (e.g., stuttering) and two participants reported not being native English speakers. The data from another participant were removed as the participant arrived at the testing session after the consumption of alcohol. A number of participants cited a history of vision problems, including cataracts, however these were corrected with surgery, glasses, or contact lenses. Several participants reported a late onset decline in their hearing ability, and some of these
participants wore hearing aids. These participants were requested to wear their hearing aids during the testing session.

In addition to self-report as described above, a hearing screening and the Mini-mental State Examination (MMSE: Folstein, Folstein & McHugh, 1975) were administered in order to rule out hearing and cognitive problems in the older adults. The screening of their hearing was conducted at 40dB HL for the frequencies of 500 Hz, 1000 Hz, and 2000 Hz in each ear (Ventry & Weinstein, 1983). The data of participants who were unable to hear two or more frequencies at 40dB were not included in the analysis. Similarly, the data of participants with a score of less than 26/30 on the MMSE (Kim & Caine, 2002) were not included in the analysis. Across the two screening tasks, the data from only two participants were excluded from analysis due to a failing score on the hearing screening. The remaining 49 participants fit the above criteria.

The mean age of the remaining 49 participants was 74.6 years (SD 5.1 years). The mean years of education was 17.2 years (SD: 2.8 years). Thirty-five of the participants were female and 14 were male. Forty of the participants were right handed, six were left-handed, two were ambidextrous and one did not indicate her handedness. Participants were recruited through flyers posted throughout the university community and by word of mouth.

Stimuli

Pictures

The same 72 pictures used in Experiment 1 were used in Experiment, including the 36 experimental pictures depicting a transitive action and 36 filler pictures (see pictures in Appendix B). A modification made to the materials of this experiment was that of the
positioning in the picture of the agent and patient nouns. In Experiment 1, agent and patient nouns were placed an equal number of times on the right and left sides of the pictures. In this experiment, however, the patient noun was positioned on the left side of all of the pictures. This change was made in an attempt to obtain an increase over the small proportion of passive sentences that had been produced by the participants in Experiment 1. It was hypothesized that by putting the patient noun on the left side of the page, an English speaker’s left-right bias (Abed, 1991) might lead to an increase in the proportion of passive sentences produced. The pictures were the same black and white line drawings used in Experiment 1 and they were altered simply by using the ‘flip horizontal’ command in the Windows Paint program.

*Auditory Distractor Words*

The same distractor words were used from Experiment 1, with the exception that each target noun in the experimental pictures was paired with only two distractors: a semantically related distractor and an unrelated distractor. Phonologically related distractor words were not used in this experiment. When crossed with the second independent variable of thematic role of the primed noun (agent, patient), there were four conditions in the experiment, with 9 items per condition. The auditory distractors were presented in the same pre-recorded male voice across all items, at an SOA of -150 ms. The full set of sentences and distractors for Experiment 2 is presented in Appendix D.

*Organization of Picture-word Pairs*

Experimental and filler pictures were pseudo-randomly ordered, as in Experiment 1, with the condition that not more than two experimental pictures were presented sequentially.
and that the same filler picture was not presented twice in a row. The two within-subject independent variables in this study were: distractor type (semantically related or unrelated), and thematic role (whether the agent or patient was primed by the distractor). The 36 experimental pictures were presented once to each participant and the filler pictures were presented twice. Across all participants, the pictures were counterbalanced, crossing distractor type and thematic role. This resulted in each of the four combinations of distractor type by thematic role (e.g., semantically related distractor to the agent noun, unrelated distractor to the agent noun) being presented nine times in a session. There were four different lists of 108 items, and participants were randomly assigned to one of the four lists.

Procedure for Younger Adults

Young adult participants took part in one 45 minute session and were paid $10 for their participation. The procedure during the session was the same as that in Experiment 1, including the presentation of the familiarization and experimental tasks. Participants were debriefed at the end of the session regarding the aims of the experiment, and the deception regarding the memory task.

Procedure for Older Adults

Additional tasks were included in the testing of the older adult participants that were not used with the younger adults. In addition to the sentence production task and the screening tasks mentioned in the participant description, the older adults participated in a word level picture-word interference task. The order of presentation of the word and sentence level tasks was counterbalanced across participants. Combining all the tasks, the older adults
participated in one session, lasting approximately 1 ¼ hours. They were paid $15 for their participation.

**Word level task**

Because we aimed to investigate the effects of semantically related distractors on sentence production in older adults, it was important to first confirm the effect of categorically related semantic distractors on word level production in the older adult population (Taylor and Burke, 2002; Tree & Hirsh, 2003; Wilshire et al., 2007). For this reason, the older adults were presented with a word level picture-word interference task in addition to the sentence level task that was presented to the younger adults. There were two components to this portion of the testing, a familiarization task and the experimental task.

**Stimuli**

*Pictures.* The stimuli for this task consisted of 22 black and white line drawings, each depicting a common noun. These pictures were different from the pictured nouns from the sentence production task. Twenty-one of these pictures were taken from Snodgrass and Vanderwart (1980). The remaining line drawing (taxi) was obtained from Google images. The pictures were presented in the centre of a computer screen.

*Auditory distractor words.* Each target noun was paired with a semantically related and an unrelated distractor word, as in the sentence level task. Within the session, a participant saw all 22 pictures, half of which were paired with a related distractor word, and half were paired with an unrelated distractor word. The degree of semantic relatedness between the distractor word and the target noun was determined as part of the relatedness questionnaire given to younger and older adults described in the Methods section of
Experiment 1. Again, the most highly rated semantic distractor was selected only if it was given an average rating of at least 5.0 on a 7 point scale, in the ratings of both younger and older adults. There was no overt phonological relationship between the paired distractor word and target noun. Unrelated distractor words were selected from the set of distractor words in the sentence level task. The auditory distractor words for this task were recorded by a different male speaker, in a similar manner to the recording of the distractor words for the sentence task.

**SOA.** The SOA of -150 ms, which was used in the sentence level task, was used in the word level task.

**Organization of picture-word pairs.** Two presentation lists were created from the set of 22 pictures. In the first list, half of the pictures were paired with a semantically related distractor word, and the other half were paired with an unrelated distractor word. In the second list, this pattern was reversed. Participants were randomly assigned to one of the two presentation lists. The full list of target nouns and their distractors is presented in Appendix E and the corresponding pictures are presented in Appendix F.

*Procedure*

Testing consisted of a familiarization task and an experimental task. In the familiarization task, participants were presented with the 22 pictures and asked to name them. There was no time constraint. Incorrectly named pictures were presented again to the participants in paper form with the desired target noun.

In the experimental task, participants were told that they would see a series of pictures and hear some words, and asked to name the picture as quickly and accurately as possible. There was no memory component to this task. There were three practice picture-
word pairs, which contained stimuli not included in the set of 22 pictures and distractor words.

As in the sentence task, picture and distractor word presentation were synchronized using E-Prime software (Psychological Software Tools, 2002). Both the participant and the examiner wore headphones through which the distractor words were presented. Participants were allowed to increase or decrease the volume of the sound presentation. The pictures were presented in the centre of a computer screen until the participant responded. At this point, the examiner pressed a key to remove the picture from the screen. Prior to the appearance of each picture, a prompt (+) appeared on the screen to indicate that the next picture would soon appear. The examiner controlled the presentation of the picture after the prompt. The recording of response delays was accomplished via E-Prime software (Psychological Software Tools, 2002). The actual recording of the participants’ productions was accomplished using a SONY digital recorder. The ordering of the word and sentence level components to this experiment was counterbalanced across participants.

RESULTS

Picture-word Interference Task (Older Adults Only)

Utterances were scored in the word level task using the same exclusionary criteria as were used in the sentence level task. Excluded utterances fell into one of three categories: a) Utterances were excluded from the analyses if the participants failed to produce the correct target noun. Included in this group were missing or substituted target words and repetitions of the distractor word. The use of compound words was accepted (e.g., ‘alarm clock’ was acceptable in place of ‘clock’); b) Utterances were also excluded if a participant produced a
hesitation, either verbal (e.g., ‘um’) or non-verbal (e.g., laugh), rendering an invalid measure of reaction time; c) Finally, utterances were excluded when the validity of the reaction time data was suspect (for example, due to a technical error with the computer or microphone, or the presence of external noise).

Mean reaction times from acceptable trials of the picture-word interference task were collected for the older adults for each condition (semantically related, unrelated) and submitted to a paired t-test (two-tailed).

The t-test revealed a significant difference between the reaction times to the semantically related and unrelated distractors \([t(34) = 2.051, p<0.048]\). The mean reaction time to utterance onset in the semantically related condition (1081 ms) was longer than the mean reaction time to utterance onset in the unrelated condition (1030 ms).

Sentence Production Task

The data and analyses in this experiment differed from that in Experiment 1 by the addition of the between-subjects independent variable of group. Additionally the within-subjects variable of SOA was not included and the distractor type independent variable had only two levels (semantically related and unrelated). The data were organized into the same two data sets as in Experiment 1. The primary analyses were run with the data set containing only active and passive forms of transitive sentences. Within this data set there were two dependent measures: reaction time to utterance onset (ms) and the proportion of active sentences produced. The second data set consisted of all the grammatical sentences produced and was analyzed according to reaction time to utterance onset (ms) and the proportion of utterances with the primed word in the subject position. Because the stimuli were
counterbalanced in the experimental design, only an analysis by participants was conducted (Clark, 1973; Raaijmakers, 2003, Raaijmakers, Schrijnemakers & Gremmen, 1999).

Utterances were scored using the same criteria as in Experiment 1. Again, following the same procedure as Altmann and Kemper (2006), a participant’s data were removed from the analysis if greater than two thirds of the utterances in a given condition were excluded. For each participant in this experiment there were four conditions, created by crossing distractor type (semantic and unrelated) and thematic role of the primed target noun (agent and patient). In each condition there were nine trials, thus if more than six trials in a condition were excluded that participant’s entire set of data was excluded from the analyses. In this experiment, the data from 3 of the remaining 71 younger adults and 11 of the remaining 49 older adults were excluded from the analysis for this reason. The data from three additional older adults were excluded from the analysis as the reaction times were not recorded due to an equipment malfunction. This resulted in the data of 68 younger adults and 35 older adults being included in the analyses.

**Error Analysis**

Of the data from the productions of the younger adults included in the analysis, a mean of 3 utterances per participant (8% of the total data) was excluded due to the fact that they were not produced as transitive active or passive sentences. In the data of the older adult participants a mean of 3.5 utterances per participant (10% of the total data) was excluded for this reason. The mean number of errors produced by each of the two groups is presented in Table 5. The total number of errors, as well as the means of specific error types produced by the younger and older adults, (not including equipment malfunctions or external interruptions) were analyzed in independent samples t-tests (two-tailed). The analysis
revealed a significant difference in the total number of errors between the younger adult (mean: 3.6 errors, or 10% of the data) and older adult groups (mean: 10.5 errors, or 29% of the data) in a corpus of 36 items \([t(45) = -9.723, p<0.001]\).  

<table>
<thead>
<tr>
<th>Group</th>
<th>Distractor nouns produced in place of target</th>
<th>All other types of missing or substituted target nouns</th>
<th>Verbal and nonverbal hesitations</th>
<th>Utterance mis-starts</th>
<th>All errors by participants (excludes nonhuman faults)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger adults</td>
<td>1.0</td>
<td>1.8</td>
<td>0.4</td>
<td>0.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Older adults</td>
<td>1.9*</td>
<td>4.5***</td>
<td>3.6**</td>
<td>0.5</td>
<td>10.5***</td>
</tr>
<tr>
<td>Mean</td>
<td>1.5</td>
<td>3.2</td>
<td>2.0</td>
<td>0.4</td>
<td>7</td>
</tr>
</tbody>
</table>

* Difference significant \((p<0.05, \text{two-tailed})\); **\((p<0.01)\); ***\((p<0.001)\)

Table 5. Mean number of errors by type and participant group.

Across the specific categories of errors, independent samples \(t\)-tests (two-tailed) revealed that compared to the younger adults, the older adults produced more verbal and nonverbal hesitations \([t(37) = -2.899, \ p<0.006]\), they omitted or substituted the target noun(s) more often \([t(47) = -6.592, \ p<0.001]\), and they repeated the distractor word more often \([t(50) = -2.316, \ p<0.025]\). The two groups were equal in the mean number of mis-starts (e.g., utterances in which the participant began the utterance and then self-corrected), \([t(101) = -1.177, \ p<0.242]\).

**Data Set Consisting of Active and Passive Sentences**

**Results of Reaction Time Analysis**

As in Experiment 1 reaction time data were collected for each trial. Condition means for each participant were then calculated. Outliers, defined as values beyond +/- 2 standard

\(^{11}\) Note: equality of variances was not assumed.
deviations of the individual’s condition means were replaced with that value. The mean reaction times per condition are presented in Table 6.

<table>
<thead>
<tr>
<th>Distractor type</th>
<th>Role of primed noun</th>
<th>Younger adults</th>
<th>Older adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agent</td>
<td>Patient</td>
<td>Agent</td>
</tr>
<tr>
<td>Semantic</td>
<td>2190 (526)</td>
<td>2207 (566)</td>
<td>2305 (677)</td>
</tr>
<tr>
<td>Unrelated</td>
<td>2194 (596)</td>
<td>2118 (557)</td>
<td>2236 (666)</td>
</tr>
<tr>
<td>Mean</td>
<td>2192</td>
<td>2163</td>
<td>2271</td>
</tr>
</tbody>
</table>

Note. Values enclosed in parentheses represent Standard Deviation.

Table 6. Mean reaction time (ms) of data set containing active and passive sentences only, by distractor type and role of primed word for each participant group.

The condition means were entered into a 2x2x2 mixed analysis of variance, crossing group (younger adults and older adults), distractor type (semantic and unrelated) and thematic role of the primed noun (agent and patient). The analysis of reaction times revealed no significant effects or interactions.

Results of Sentence Type Analysis

As in Experiment 1, each utterance was scored to indicate if it was an active sentence. Differences in performance in the various conditions were evaluated using the General Estimating Equations (GEE) approach with an exchangeable correlation structure. Pairwise comparisons were performed to determine the significance of contrasts in main effects and interactions. Differences were considered significant with a p-value less than 0.05. Because
the data are binomial in nature, effect sizes were calculated using an odds ratio. The
independent variables in this experiment were group, distractor type and thematic role of
primed word and the dependent variable was presence of active sentence. The proportions of
active sentences per condition are presented in Table 7.

<table>
<thead>
<tr>
<th>Group</th>
<th>Role of primed noun</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Younger adults</td>
</tr>
<tr>
<td>Distractor type</td>
<td>Agent</td>
</tr>
<tr>
<td>Semantic</td>
<td>.97 (.01)</td>
</tr>
<tr>
<td>Unrelated</td>
<td>.95 (.01)</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>.96 (.01)</td>
</tr>
</tbody>
</table>

Note. Values enclosed in parentheses represent Standard Error

Table 7. Proportion of active sentences produced by distractor type and role of primed word for each participant group.

The analysis revealed a main effect of thematic role ($Z = 6.6$, $p < 0.01$), in which a
larger proportion of active sentences was produced when the agent noun was primed (.96)
compared to when the patient noun was primed (.94). The odds ratio for this comparison is
1.53, suggesting that the odds of an active sentence being produced when the agent noun is
primed is 1.53 times greater than the odds of an active sentence being produced when the
patient noun is primed. The interaction between distractor type and thematic role was also
significant ($Z = 19.1$, $p < 0.000$). Investigation of the interaction revealed significant
differences 1) between the proportion of active sentences produced with semantically-primed
agent nouns (.97) compared to semantically-primed patient nouns (.89), with an odds ratio of
3.54, and 2) between the unrelated-primed patient nouns (.96) and the semantically-primed
patient nouns (.89), with an odds ratio of 2.51. In each of these cases, the odds ratio suggests that it is much more likely that an active sentence would be produced in the first compared to the second condition. There was no difference between the proportion of active sentences produced with a semantically-primed agent noun (.97) compared to an unrelated-primed agent noun (.94), nor was there a difference between the proportion of active sentences produced when either agent (.94) or patient nouns (.96) were primed with an unrelated distractor (see Figure 4). There were no effects or interactions involving the group variable.

*Data Set Consisting of All Grammatical Sentences*

For consistency with the methodology in Experiment 1, analyses of a second data set comprised of all grammatical sentences were conducted in this experiment. The purpose of this second data set was to determine whether the semantic distractors had any effect on utterance production, without the constraint of investigating only active and passive sentences. In this second data set reaction time was similarly used as a dependent variable. Once again, an effect of interference was inferred if the response time was longer with a related distractor word compared to a trial with an unrelated distractor word. Facilitation was inferred if the response time was shorter with a related distractor word compared to a trial with an unrelated distractor word. Instead of measuring the proportion of transitive active sentences produced, we looked simply at the position of the primed target noun in the sentence. A higher proportion of semantically primed nouns in the subject position (relative to nouns primed with an unrelated distractor) would indicate a facilitation effect, and the opposite pattern (i.e., a higher proportion of semantically primed nouns in the object position
Figure 4. Proportion of active sentences produced by distractor type and thematic role of primed noun.
relative to the proportion of nouns in the object position with an unrelated distractor) would indicate an interference effect.

Results of Reaction Time Analysis

The analysis of reaction time data was performed in the same way as with the previous data set. The condition means were entered into a 2x2x2 mixed analysis of variance, crossing group, distractor type and thematic role. The mean reaction times per condition are presented in Table 8. The analysis of reaction times revealed no significant effects or interactions.

<table>
<thead>
<tr>
<th>Distractor type</th>
<th>Role of primed noun</th>
<th>Group</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Younger adults</td>
<td>Older adults</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Agent</td>
<td>Patient</td>
<td>Agent</td>
<td>Patient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semantic</td>
<td>2189 (522)</td>
<td>2243 (587)</td>
<td>2325 (694)</td>
<td>2340 (694)</td>
<td>2274</td>
<td></td>
</tr>
<tr>
<td>Unrelated</td>
<td>2231 (607)</td>
<td>2160 (554)</td>
<td>2270 (672)</td>
<td>2267 (618)</td>
<td>2232</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2210</td>
<td>2202</td>
<td>2298</td>
<td>2304</td>
<td>2253</td>
<td></td>
</tr>
</tbody>
</table>

Note. Values enclosed in parentheses represent Standard Deviation.

Table 8. Mean reaction time (ms) for data set containing all grammatical sentences, by distractor type and role of primed word for each participant group.

Results of Position of Primed Word Analysis

In this analysis, each utterance was scored to indicate if the primed target word was in the subject role of the sentence. These data were entered into an analysis using GEE, with an exchangeable correlation structure. Because the thematic role of the primed target noun was
not relevant in the analysis of the position of the primed word, only the independent variables of group and distractor type were analyzed. The dependent variable was the presence of the primed word in subject position (yes or no). The proportion of primed target words in subject position per condition are presented in Table 9.

There was a significant effect of distractor type ($Z = 17.4$, $p<0.000$; odds ratio: 1.22), with the semantically-primed target nouns appearing in the subject position (.55) more often than the unrelated-primed target nouns (.50). As in the analysis of sentence type, there were no effects or interactions involving group.

<table>
<thead>
<tr>
<th>Distractor type</th>
<th>Younger adults</th>
<th>Older adults</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantic</td>
<td>.54 (.01)</td>
<td>.56 (.02)</td>
<td>.55 (.01)</td>
</tr>
<tr>
<td>Unrelated</td>
<td>.50 (.01)</td>
<td>.49 (.02)</td>
<td>.50 (.01)</td>
</tr>
<tr>
<td>Mean</td>
<td>.52 (.01)</td>
<td>.53 (.01)</td>
<td>0.523</td>
</tr>
</tbody>
</table>

Note. Values enclosed in parentheses represent Standard Error.

Table 9. Proportion of primed words in subject position by distractor type for each participant group.

**DISCUSSION**

The first step in this experiment involved the investigation of the effects of semantic distractors in a picture-word interference task at the word level. This task was presented to the older adults with the aim of investigating whether this population processes semantic information in a similar manner to younger adults. This task was performed because of the limited number of studies in the literature investigating the effects of categorically related
distractor words on production (Taylor and Burke, 2002; Tree & Hirsh, 2003; Wilshire et al., 2007). In the current experiment it was found that the older adults showed an effect of semantic interference at the word level with categorically related distractors, consistent with reports of the productions of younger adults in the literature (e.g., Schriefers et al., 1990). Because there is no data from the younger adults for this task, we were unable to compare the reaction times statistically; however, it seems likely that the older adults were slower in single word production with a semantic distractor (1081ms) compared to production by younger adults in a similar task (e.g., 668 ms, Schriefers et al., 1990, Experiment 2).

The next step in this experiment was to investigate the influence of semantic distractors on the sentence level productions of the two populations in order to further the investigation of the effect of lexical level information on syntactic production, and to investigate the effect of lexical level information on syntactic production in older adults. In the sentence level task both the older and younger adults were required to describe a picture using a full sentence, while a distractor word that was semantically related or unrelated was presented 150 ms prior to the picture presentation.

The results of this portion of the experiment provided some more definitive results compared to Experiment 1. Overall the results revealed that semantic distractors were able to influence the type of syntactic structure produced through a facilitating effect in terms of the proportion of active sentences produced by the older and younger adults. This finding was observed primarily through the interaction of distractor type and thematic role in the sentence type analysis. Semantic facilitation was observed in the comparison between the semantically-primed agent noun and the semantically-primed patient noun, as well as in the comparison between the semantically-primed patient noun and the unrelated-primed patient
noun. Contrary to our prediction, no difference was observed between the proportion of active sentences produced with a semantically related distractor to the agent noun compared with an unrelated distractor to the agent noun. However, it is possible that the lack of this result could be due to a ceiling effect, as both proportions were close to 1.0. Additionally, no difference was observed between the proportions of active sentences produced with agent or patient nouns primed with an unrelated distractor. The effect of semantic facilitation was also supported by the analysis of the position of the primed word. Contrary to our predictions, but consistent with the results in Experiment 1, the semantic distractors did not appear to influence response times for either group. Also contrary to our predictions, no differences were observed between the performances of the older and younger adults, apart from the increase in the number of errors produced by older adults.

Comparing to results in the literature, the effect of semantic facilitation on the type of sentence produced (and in the order of words produced) replicates the effect found by Bock (1986), but with a modified methodology including the use of unrelated distractors as the baseline condition and without the repetition of the distractor word as in Bock’s study. This finding serves to strengthen the suggestion that lexical level characteristics do influence syntactic production. In addition, the fact that we were able to replicate Bock’s result with semantic distractors without the use of distractor repetition, which did not occur in Experiment 1, suggests that the omission of distractor word repetition may not be a factor in the lack of results with phonological distractors in Experiment 1.

The fact that we did not find a difference between response times for the older and younger adults is inconsistent with many results in the literature which found slower responding in older adults (Bowles, 1994; Feyereisen et al., 1998; Hodgson & Ellis, 1998;
Kemper et al., 2003; Maylor, 1995; Mitchell, 1989; Spieler & Griffin, 2006; Thomas et al., 1977). It is however consistent with the results found in Altmann and Kemper (2006), who also investigated the production of active and passive sentences. The current results, in addition to the results of Altmann and Kemper’s study, appear to confirm some scoring schemes used in the literature (Cheung & Kemper, 1992; Rosenberg & Abbeduto, 1987) that would classify both active and passive sentences as less complex syntactic forms, due primarily to the fact that they do not contain embedded clauses. The decreased complexity of active and passive forms used in the current experiment could provide an explanation for the failure to find a difference in reaction times in older and younger adults. However, the fact that the older and younger adults were similarly influenced in their syntactic production by the semantic distractors is inconsistent with the results found in Altmann and Kemper’s (2006) study, perhaps due to the nature of the stimuli. More will be discussed regarding this difference in the General Discussion.

Consistent with studies in the literature (Albert, et al., 1988; Au, et al., 1995; Barresi, et al., 2000; Hodgson & Ellis, 1998; Le Dorze & Durocher, 1992; Maylor, 1995; Nicholas, et al, 1985), it was found that the older adults produced more errors than the younger adults. Across the breakdown of errors, the greater production of hesitations, and target noun errors by older adults reflects the previous findings of the literature at both word and sentence level production (Albert et al., 1988; Au, Joung et al., 1995; Barresi et al., 2000; Hodgson & Ellis, 1998; Kemper et al., 2003; Le Dorze & Durocher, 1992; Maylor, 1995; Mortensen et al., 2008; Nicholas et al., 1985).

As an interesting comparison with the results in Experiment 1, there was once again a main effect of thematic role, in which a larger proportion of active sentences was produced
when the agent noun was primed compared to when the patient noun was primed. While this result was difficult to explain in Experiment 1, in this experiment this main effect was qualified by the interaction between distractor type and thematic role. Given that there was no difference between the proportions of active sentences produced when the agent or patient nouns were primed with unrelated distractors, the main effect of thematic role can be interpreted essentially as an effect between the agent and patient nouns primed with a semantic distractor, and hence be an indication of semantic facilitation.

How Do the Data Fit With the Psycholinguistic Models?

The results of the current experiment support the prediction of the sentence production models which predict that sentence type can be influenced by lexical characteristics. However the lack of specification of the models regarding the specific involvement of lexical level information, such as semantic characteristics, diminishes their predictive capacity. A full discussion of the fit of the data with the production models will be presented in the General Discussion.
General Discussion

The design of the current study permitted the investigation of two primary goals. The first was to investigate the effect of semantically and phonologically related distractors on typical sentence production, in an effort to investigate the influence of lexical characteristics on syntactic production. A sub goal was to investigate these effects by concurrently analyzing the type of sentence produced and the response times of production. These two approaches have not been previously combined in the sentence production literature; studies have tended to analyze language production data according to one approach or the other, but not both.

The second main goal of the current study was to compare the sentence production of older adults to that of younger adults to uncover reasons as to why changes in syntactic production occur in aging. As in the analysis of younger adults, this was achieved through concurrent analyses of syntactic structure and response times. Results pertaining to the younger adults will be discussed first, followed by the comparison between the results for the younger and older adults.

YOUNGER ADULTS

Effects of Semantic Distractors on Syntactic Structure

The main finding observed in Experiment 2 and to some extent in Experiment 1 was that the type of sentence produced (and the position of the primed target noun in the sentence) was influenced by the presence of semantically related information, in this case a semantically related distractor word. Specifically the semantic distractor had a facilitating
effect on the target word in the production of a sentence. This was evident in two patterns of production produced by the participants in the study: a) A semantically-primed patient noun led to an increase in the production of passive sentences, compared to an unrelated primed patient noun; and b) a semantically-primed agent noun resulted in the production of more active sentences compared to a semantically-primed patient noun. It should be noted that contrary to our predictions no difference was observed in the proportion of active sentences produced between a semantically-primed agent noun and an unrelated-primed agent noun. It is possible that this null result was due to a ceiling effect in the proportion of active sentences produced. Importantly, the first two patterns suggest that the semantically primed noun was facilitated to the subject position in the sentence. Notably, these effects influenced the syntactic structure produced. A similar finding was observed in the analysis of the set of all grammatical sentences, in which it was found that a semantically primed word was more likely to be in the subject position of the sentence compared to a target word primed with an unrelated distractor.

These two results replicate the semantic facilitation in Bock’s (1986) study, in which she also found that a semantically primed word was more likely to be in the subject position rather than the object position of a transitive sentence. However, the results of the current study strengthen Bock’s finding by the fact that the current methodology differed from that of Bock’s study in three ways.

First, in the current study the effect of semantic distractors was demonstrated relative to the presence of unrelated distractors, rather than in a comparison between primed nouns that were produced in subject position versus primed nouns that were produced in object position. By using a baseline condition with unrelated distractors, the strength of the
conclusion is augmented and the results become more comparable to other investigations in the psycholinguistic literature (e.g., Glaser & Dungelhoff, 1984; Meyer, 1996).

In a second modification, the current study did not include a repetition of the distractor noun suggesting that, at least for the processing of semantic information, the process of repetition was not required in order for the characteristics of the distractor word to influence the related target noun in the sentence. Finally, the sentence type results from the current study were observed through a controlled SOA of -150 ms, compared to the longer SOA of -2000 ms estimated in Bock’s study. Additionally, the other reported effect of semantic facilitation in the current study, observed in the word ordering analysis of Experiment 1, was observed across the range of SOAs from -1000 ms to 150 ms. This wide range of SOAs at which an effect of semantic distractors on the type of sentence produced was evident is in contrast to the narrow window of SOAs at which the effect of semantic interference in reaction time studies has been observed (e.g., Glaser & Dungelhoff, 1984; Meyer, 1996; Schriefers, et al., 1990). This difference will be discussed further. Overall the result of semantic facilitation supports our predictions, with the exception that this effect was observed at all SOAs, rather than only at the predicted SOA of -1000 ms.

It could be charged that while the effects of semantic distractors are statistically significant, they may not be practically meaningful. However, as an example, the difference in proportion of active sentences produced between the semantically primed agent noun and the semantically primed patient noun is .07. This difference in proportion is similar to that in other studies in the literature that have investigated the production of active and passive sentences. Using what could be argued as a more directive methodology, but still measuring the proportion of active and passive sentences produced, Altmann and Kemper (2006) found
a difference of .13. Additionally, the odds ratios of 2.5 and 3.5 for the comparisons within the interaction between distractor type and thematic role (in Experiment 2) suggest that semantic distractors do exert an important influence on sentence production.

No Effects of Semantic Distractors on Reaction Time to Utterance Onset

Unlike studies investigating the effect of semantic distractors at the word level (e.g., Cutting & Ferreira, 1999), or those with constrained syntactic structures (Meyer, 1996), no effect of semantic distractors on the reaction time to generation of the sentences was observed in the current study. At the word level, it has been proposed that a semantic distractor causes a delay in production because of competition between the distractor and target noun lemmas before the target noun is correctly selected. It is possible that we did not see an effect of reaction time at the sentence level in the current study because of an increased variability in reaction time. In Meyer’s task, the difference in reaction time between the semantic and unrelated distractor conditions was approximately 30-40 ms, with a standard error of approximately 25. In the current experiments the difference between distractor conditions was still approximately 30-40 ms, but the standard error was approximately 60-70. It is possible that this higher variability in the current experiment has masked differences that were significant in a word level task.

Why should the variability be greater in a sentence task compared to that of a standard picture-word interference word level task? It could be due to the added complexity of a sentence generation task compared to Meyer’s (1996) sentence task, which was more of a picture identification task given that the syntactic form was provided for the participants. With the increased complexity in a sentence generation task, it is possible that participants
approached this task differently than a word level task in regards to the speed-accuracy trade-off.

It is also possible that we did not observe a reaction time effect because of the SOAs chosen for use in this study. It has been argued that an SOA such as -150 ms reveals the time course of semantic processing in word (Meyer & Schriefers, 1991) and constrained syntactic productions (Meyer, 1996). Due to the increased processing required by the sentence generation task in the current experiment in comparison to word level experiments it could be hypothesized that semantic processing would only appear at a later time (i.e., a larger positive SOA than what was presented in the current study).

No Effects of Phonological Distractors on Sentence Production

Contrary to the findings in Bock’s (1987) study and the reaction time studies reviewed (e.g., Meyer, 1996; Meyer & Schriefers, 1991), no interpretable effects of the phonological distractors were observed, either in the sentence type (word order) analyses, or in the reaction time analyses. This comment should be qualified by acknowledging that beyond the testing in Experiment 1, which was possibly hindered by a complex design as previously discussed, there was no further investigation of the effect of phonological distractors in the current study. This is relevant, as no effects of semantic distractors on sentence production were observed in Experiment 1, but they were observed with the simplified design of Experiment 2.

Assuming that a different methodology would have resulted in the same findings, one possibility for the lack of results is that although we followed the guidelines for selection of target-distractor word pairs, as set out by Bock (1987) and Meyer (1996), there may have been a flaw in the materials used in the current study. It may have been that the phonological
similarity between the target nouns and related distractors was not as strong or consistent across the word pairings in the current study as in other studies in the literature. This is an unanswered question, as the relatedness between target noun and phonological distractors, although carefully controlled, was not tested with rater opinions, as was the relatedness between target noun and semantic distractors.

Another possible reason for the failure to find effects of phonological distractors in the current study could be the omission of the repetition component in Bock’s (1987) study. In that study, participants were required to repeat the distractor word prior to seeing the picture. In the current study, this portion of the task was eliminated in order to keep the task as similar to the task in Meyer’s (1996) reaction time study. One argument against this omission accounting for the lack of effects with phonological distractors, is that an effect of semantic distractors was observed without the inclusion of distractor repetition in Experiment 2.

However, it is possible that the repetition component of the task would influence semantic and phonological relatedness differently. It could be imagined that the omission or inclusion of the repetition component of the task could result in different outcomes if we assumed separate input and output phonological pathways. The existence of separate phonological input and output pathways is supported by studies of pure word deafness, a type of aphasia in which people with intact hearing are able to understand orthographic input, but not spoken input while being able to produce the same spoken output (e.g., Franklin, Turner, & Morris, 1994). If we imagine a single phonological system, then it is plausible that the phonemes from a phonologically related distractor word (e.g., ‘beet’: /b/ /i/ /t/) would be activated and therefore accessible to the production system when required for the utterance of
a related target noun (e.g., ‘bee’: /b/ /i/). If there are separate input and output phonological systems, then the phonemes in the input, but not the output phonological system would be activated upon hearing the distractor word. The phonemes in the output phonological system (that would be used for production of the target noun) would only be activated by the distractor word as it is repeated. After such a repetition, the phonemes of the distractor word could then be shared by the phonologically related target noun from the picture, which would result in a faster response time.

If the phonological systems are indeed separate, and the distractor word is not repeated, then the phonemes activated by the auditory distractor word (e.g., /b/ /i/ /t/) would not be accessible to the phonemes required for the target word (e.g., ‘bee’), and as such, no facilitation would be observed. Evidence against the hypothesis of separate input and output phonological lexicons is the fact that an effect of phonological distractors has been observed in reaction time studies that did not include repetition of auditory distractors (e.g., Glaser & Dungelhoff, 1984; Meyer, 1996). Although further study is required, this finding suggests that the phonemes heard in the distractor word are accessible to the phonemes of the target word, and therefore that the phonological input and output coincide, either through a shared lexicon or otherwise.

Returning to the null results of phonological distractors in the measurement of sentence type, it is possible that the analyses in the current study accurately represented the fact that the phonological distractors do not cause a change in sentence type or word order. Such a result would lend support to Bock and Levelt’s (1994) hypothesis which suggests that information flows only from the semantic to the phonological level and not the reverse.
Future study of phonological distractors with a simplified design similar to that of Experiment 2 could provide some insight into these questions.

Similar to the lack of reaction time results with semantic distractors, it is possible that we observed no effects of phonological distractors as measured by reaction time due to the increased variability in the data that was mentioned earlier. It is also possible that effects of phonological distractors do exist in reaction time data, but were not revealed by the design of the study. One possible reason for this could be that a larger positive SOA was needed. As previously mentioned, it has been postulated that an SOA such as +150 ms reveals the time course of phonological processing in word (Meyer & Schriefers, 1991) and phrase or constrained sentence production (Meyer, 1996). Due to the increased complexity of the sentence generation task used in the current experiment compared to other experiments, it could be hypothesized that phonological processing would not appear until a later SOA than what was tested in the current study.

Another possible reason why we may not have observed reaction time effects in the analysis of phonological distractors relates to one of the findings in Meyer (1996). In her study she found that an effect of phonological facilitation was observed only for the first noun in a phrase or a sentence containing two noun phrases (e.g., The fork is next to the tent). Her conclusion was that only a portion of an utterance is encoded phonologically prior to utterance onset. In the sentence production task in the current study, which is arguably more complex than the task in Meyer’s study, it could be that very little of the utterance produced is encoded phonologically prior to utterance onset, such that we would not observe any effects of phonological distractors for the two nouns (e.g., The bee chased the elephant).
The Combination of Sentence Type and Reaction Time Results

One of the issues we attempted to investigate was the concurrent collection of sentence type (or word order) and reaction time data within the same task. This is an important step in the field as it can help to bring together two long-standing forms of evidence that have generally been analyzed independently.

By investigating the two concurrently, we were provided with the opportunity to investigate aspects of both the nature and the time course of sentence production. For example, a review of the studies presented in the Introduction suggested potentially conflicting results (e.g., semantic interference in the reaction time studies but semantic facilitation in sentence type studies). Combining the measurement of the two data sets concurrently had the potential to provide us with a clarification of such opposing effects, as was attempted in the current study.

Concurrent measurement of the two types of data also had the potential to provide a bridge between performances by different populations in order to provide a more complete explanation of results and patterns of performance. For example, if one were comparing the productions of older adults and participants with aphasia in a word level picture-word interference task, one might not expect to see the same level of reliability in the reaction time results of participants with aphasia as may have been observed in older adults. However, a comparable effect in the data of the people with aphasia may appear in an error type analysis, which could permit a comparison across groups. Because we might not expect to see enough errors by older adults in such a task, a comparison between the groups might not otherwise have been possible without an overlap of data sets.
In the current study we did not observe co-occurring reaction time and sentence type effects in the production of a sentence in the presence of a semantic or phonological distractor. As mentioned previously, this may be an accurate depiction of what occurs in sentence production, or it may indicate a failure of the experimental design to detect an actual co-occurrence. Based on the results of the current study these two possibilities cannot be adjudicated. The fact that the lack of co-occurrence was observed in two experiments across two different populations could lend credence to the former interpretation, however it cannot be determined within the limits of this study. Despite this equivocal result, the combination of the two methodologies does permit some discussion regarding issues raised in the literature.

What Does SOA Reveal?

One question that was raised in the Introduction relates to the processes of facilitation and interference observed across the very different SOAs reported in the sentence type and reaction time studies. The sentence type effects Bock (1986, 1987) observed were found at an estimated SOA of -2000 ms, while the effects observed in reaction time studies were commonly found between the much smaller SOAs of -150 ms to 150 ms. As mentioned previously, it has been proposed that small SOAs, such as -150 ms and +150 ms reveal the time course of semantic and phonological processing respectively in lexical retrieval (e.g., Meyer, 1996; Roelofs, 1992, 1997). Studies have also demonstrated that reaction time effects of semantic and phonological distractors are not observed earlier than -400 ms (Dungelhoff & Glaser, 1984; etc.).
The question remains, what process is revealed by the effects of semantic and phonological distractors at the SOA of -2000 ms in Bock’s (1986, 1987) studies, as well as the effect of semantic facilitation observed at the SOA of -150 ms in Experiment 2? In the first experiment of the current study, it was found that an effect of semantic facilitation was independent of SOA, meaning that it was observed across very different SOAs (-1000 ms, -150 ms and 150 ms). This implies that within the process represented by this word order effect, the semantic representation of a lexical item is capable of being maintained across a relatively long time span, especially in comparison to the reaction time effects observed across the much smaller range of SOAs. It follows that the results of Experiments 1 and 2 combined with the results of Bock’s studies likely represent different types of facilitation and interference effects compared to those found in the reaction time studies with small SOAs. To investigate this idea further, we shall consider the notion of ‘availability’.

‘Availability’

The term ‘availability’ has seemingly been used in a contradictory manner across studies in the literature. In word production studies in which effects have been measured by reaction time to utterance onset (Costa & Caramazza, 2002; Glaser & Düngelhoff, 1984; Meyer, 1996; Meyer & Schriefers, 1991; Schriefers, et al., 1990), it was generally found that semantic distractors caused a delay in production, while phonological distractors caused a faster response. It was interpreted that the target word was made more or less available for production by the presence of a phonological or semantic distractor respectively, and that change in availability led to the decrease or increase in reaction time.
The studies investigating sentence type found the opposite effects of semantic facilitation and phonological interference, this time determined by the type of sentence produced and/or by the position of the primed word (Bock 1986, 1987). These studies also proposed that the semantic or phonological distractors (or prime words as they were referred to in these studies) influenced the availability of the lexical items, which then resulted in the effects observed at the syntactic level. In this case, it was argued that semantic distractors increased and phonological distractors decreased a lexical item’s availability.

On the surface, it appears as though it is being claimed that semantic and phonological distractors each result in both an increase and a decrease in a target word’s availability, which would seem impossible. However, it is possible that each statement is accurate but simply in need of clarification.

In the presentation of reaction time results it has been claimed that semantic distractors result in the decreased availability of a target word as evidenced by a delay in reaction time to utterance onset and that phonological distractors increase availability, as evidenced by a shorter reaction time (e.g., Meyer, 1996). An important qualifier relates to the default or comparison state. In these reaction time studies the effects were being compared to the reaction time to production with an unrelated distractor. Availability then for these studies refers to the time required to retrieve a lexical item with a semantically or phonologically related distractor, relative to the time required to retrieve that same lexical item in the presence of an unrelated distractor. It should be noted that relative to no distractor, even an unrelated distractor decreases the ‘availability’ of a lexical item by this definition because of the additional processing time required with the presence of a distractor word (Meyer, 1996). In the case of the reaction time studies we could refer to this as an
increased or decreased availability in the process of lexical retrieval, which differs from the effect we will now address.

In the presentation of sentence type results (Bock, 1986, 1987), it was proposed that semantic distractors increased the availability of a lexical item while phonological distractors decreased its availability, the opposite pattern to that reported in reaction time studies. In these sentence type studies, facilitation and interference were determined by the position of the primed target noun in the sentence relative to a second noun within the same clause (or sentence).

There were two relevant findings in the current study to address the difference between these two effects. The first was that an effect of semantic facilitation as measured by the type of sentence structure produced was observed at the SOA of -150 ms in Experiment 2. This is in contrast to the much longer SOA of -2000 ms found by Bock (1986), which implies that the retention of the semantic information in this process lasts for a much longer time, compared to the range of retention of semantic information in the process highlighted by the SOAs commonly used in reaction time studies. Secondly, it was found in Experiment 1 that any effect of a semantic distractor word, as measured by the position of the primed target noun, was independent of SOA. These two results combined suggest that the sentence type (or word ordering) effect is independent of effects observed at the shorter SOAs of reaction time studies, meaning that the effects observed in reaction time studies compared to word order studies are distinct from each other. The effects of interference and facilitation at the sentence level could be viewed as a syntactic availability of retrieved lexical items that is related to the assignment of one target noun over another to the subject role (e.g., Bock & Levelt, 1994), or prominence of an item (Chang et al., 2006), while the effects of facilitation
and interference observed in reaction time studies could be viewed as being related to the retrieval of lexical items per se. One potential flaw in this type of syntactically-based explanation comes from the evidence that Bock found an effect of phonological interference when participants were required only to name two items on a page in whatever order, which suggests that a syntactic form is not necessarily required. Although two-word production is not modeled specifically, it could be hypothesized that some level of prominence is assigned for any multi-word production.

The results found in Ferreira & Firato’s (2002) study present an interesting puzzle, but one that is compatible with the above distinction between lexical and syntactic level availabilities. In a production task in which participants were required to repeat a sentence with an embedded clause (e.g., “The author, the poet, and the biographer recognized (that) the writer was boring”) Ferreira and Firato found that the optional complementizer ‘that’ tended to be included more often at the beginning of an embedded clause when the noun phrase in the clause was related to the noun phrase in the matrix clause, compared to when there was no semantic relationship. The authors argued that the optional complementizer ‘that’ was included in order to provide the speaker with additional time prior to producing the embedded noun phrase. The additional time was likely required due to the delay caused by the semantic relatedness of the two noun phrases. Although the result demonstrated a change in syntactic structure, similarly to the effect in Bock’s studies (see the original article for a justification of why it is a syntactic change), the ‘availability’ of the semantically related word is meant in comparison to the process of retrieving that same word in an unrelated context, similarly to the lexical retrieval in reaction time studies. Indeed, Ferreira and Firato spoke of the speed of retrieval of the related word. Contrary to Bock’s results, the retrieval of
the related word is not being compared to the retrieval of another word competing for the same grammatical role in that clause or sentence (of which there is none). Ultimately, it appears as though the idea of a word’s ‘availability’ was appropriately used in all of the studies mentioned, but when considered together, additional qualifications or characterizations may be required in order to maintain consistency of the terminology.

How Do the Results Fit with Psycholinguistic Models of Production?

*Sentence Production Models*

At this point in the development of sentence production models, it is not expected that they would be able to account for all specific experimental results relating to sentence production. With this limitation in mind, we can evaluate the sentence production models to the extent that they are able to correctly predict the experimental results. Additional information gathered from experimental studies such as the current one can ultimately assist in the refinement of current models.

The main result from the current experiments relating to the production of younger adults, namely that semantic distractors influenced the syntactic structure produced but showed no effects on reaction time, fits with both of the presented models of sentence production. The serial incremental model (Bock & Levelt, 1994) proposed that external factors could influence sentence production at the level of functional processing, and indeed it was observed that the presence of a semantic distractor influenced the syntactic form produced. Although not explicitly stated in the model, one mechanism that could cause this alternation in sentence type is an increased activation level of the primed noun relative to the unprimed noun in the sentence, resulting in it being produced as the subject of the sentence. This explanation would be consistent with the results of the current study.
The dual path model (Chang et al., 2006) proposed that an increased activation level of a particular concept unit or noun in an utterance would give it prominence, which in turn would cause it to be produced prior to a less activated concept unit. This idea of prominence could account for the alternation between active and passive sentence structures that was observed in the current study. What this model is lacking is a description of the factors that can influence the level of prominence assigned to a thematic role, or event semantics. The results of this study could be used to enhance this step of the model by contributing information regarding influencing factors.

**Word Production Models**

While the sentence production models were supported by the evidence from the current study, they remain underspecified regarding the processing of lexical level information during sentence production. For this reason, we will review current models of lexical production for a more detailed look at the processing of lexical information.

**Spreading Activation Model**

The first model to be presented is a spreading activation model by Dell and his colleagues, as depicted in Figure 5 (Dell, Schwartz, Martin, Saffran & Gagnon, 1997; Foygel & Dell, 2000). This model of word production has been developed based on errors in normal and impaired language production. According to this model, when a word is activated, its activation will spread to related nodes at other levels. For example, if a picture of a bee is presented for naming, the nodes at the conceptual level that are related to ‘bee’, such as ‘insect’ and ‘stings’ will be activated along with ‘bee’. These nodes will spread activation back to the lexical-semantic node ‘bee’, providing it with an even higher level of activation. The node ‘bee’ will spread activation down to the related phonological nodes, such as /b/ and
These nodes will then feed activation back to the ‘bee’ node, which will in turn, strengthen its activation level. At the same time that this is occurring, related nodes at the lexical-semantic level will also be activated.

Figure 5. Spreading activation model of word production (Dell et al., 1997; Foygel & Dell, 2000).

For example, when the relevant conceptual nodes to ‘bee’ are activated, they will spread activation to other nodes at the lexical-semantic level that are related to ‘bee’, such as ‘wasp’. This is because other words share semantic attributes with bee. Therefore when the node ‘stings’ is activated, both ‘bee’ and ‘wasp’ will receive activation, and they will both send activation down to the phonological level. From the phonological level, the activated phonemes will feed information back to phonologically related words at the lexical-semantic level.
level. Because of this spreading activation, the target word, ‘bee’ and semantically and phonologically related words will be activated at the lexical-semantic level, and the most highly activated word will be produced. Generally this will be the target word, but in some cases, errors will occur. A final feature that must be mentioned is ‘decay’. Nodes do not stay activated permanently; over time activation levels decay back to resting levels. This feature prevents the system from constantly producing the same word.

Figure 6. Serial Incremental model of word production (Levelt, Roelofs, & Meyer, 1999).

**Serial Incremental Model of Word Production**

The second model to be presented is a serial incremental model, as depicted in Figure 6 (Levelt, Roelofs, & Meyer, 1999). This model also has conceptual, semantic, and phonological levels. A primary difference is that this model features top-down processing, meaning that activation spreads only from upper to lower levels. This means that the
phonological level cannot influence the semantic level as it can in the previous model. If a picture of a bee is presented to be named, the relevant conceptual node will be activated, (which will spread activation to the related conceptual nodes, such as ‘wasp’). The activation from these nodes will spread to the semantic level which will activate both nodes, or lemmas, at this level (‘bee’ and ‘wasp’). Only the most activated node at this level will spread activation to the phonological level, which will activate the relevant phonemes for production.

As mentioned, the sentence production models reviewed above permit the influence of lexical items on syntactic production. The word production models however would make different predictions regarding the influences of semantic and phonological characteristics of words on a sentence generation task, such as in the current study. We will need to extend the reach of these models to the sentence level in order to attempt to account for the results of the current study.

*The Sentence Production Task and the Models of Word Production*

We will begin by explaining the steps involved in a sentence level picture-word interference task, as could be described by lexical production models, using as an example a target picture of a bee chasing an elephant with a semantic (e.g., ‘wasp’; ‘elephant’) or phonological (e.g., ‘beet’; ‘elegant’) distractor. It should be noted that in the current study interference and facilitation were relative to a condition involving the presentation of an unrelated distractor (e.g., ‘suds’; ‘aquafit’).

The spreading activation model of word production (Figure 5) will need to be further extended as this model was not designed to explain reaction time effects. With that in mind, suppose that in the example picture a person heard the distractor word ‘wasp’. Upon hearing
the word, activation would spread from the lexical-semantic level to the relevant nodes at both the conceptual and phonological levels. From these levels, activation would spread back to the lexical-semantic ‘wasp’ node, as well as to conceptually and phonologically related words (likely including the target noun ‘bee’, as well as other related words, such as ‘hornet’, ‘wash’ and ‘walk’). As such, when the target picture of a bee chasing an elephant is presented, the lexical-semantic nodes of both ‘bee’ and ‘elephant’ would receive activation, which would lead to the spreading of activation and the strengthening of the activation levels of these target words and their related nodes. Because of the initial activation received due to the distractor word ‘wasp’, the node for ‘bee’ should have more activation than the lexical-semantic node for ‘elephant’. Because of this higher activation level, ‘bee’ should be produced prior to ‘elephant’ in the sentence, in an effect of facilitation due to the semantically related distractor word.

In the same circumstance (note that no mention is being made regarding the order of the effects), this model could be extended to explain the reaction time effects with a semantic distractor. As described, both the nodes for ‘wasp’ and ‘bee’ would have high activation levels, which would mean that there would be a competition between the two for selection. This competition could result in a delay of production that could be represented by a longer reaction time compared to an unrelated distractor. This model would, therefore, predict that semantic distractors would lead to facilitation in a sentence-type analysis and interference in a reaction time analysis.

If a phonologically related distractor (i.e., ‘beet’) were presented, then the activation level at the lexical-semantic node ‘beet’ would spread to both conceptually and phonologically related nodes, which would include words containing the same phonemes
(likely including the target ‘bee’). With the presentation of the picture of the bee chasing the elephant, ‘bee’ would accumulate some activation on its own. This combined level of activation for ‘bee’ should result in the selection of ‘bee’ prior to ‘elephant’ (facilitation), due to its relatively higher activation level.

In terms of the response time for the production of ‘bee’ with a phonological distractor, the prediction is less clear. There should also be competition between ‘beet’ and ‘bee’ at the lexical-semantic level, which could conceivably translate into slower reaction times. However, this interference may or may not be offset by a facilitation in terms of production time as a result of the relevant phonemes (e.g., /b/, /i/) already being activated from hearing the related distractor word (e.g., ‘beet’). As such, the predictions for this model would therefore be that a phonologically related distractor would result in facilitation in an analysis of sentence type data but the effect as measured by the reaction time data is unclear given that the relative contributions of the interference at the lexical-semantic level and the facilitation at the phonological level are not quantifiable at this point.

Comparing these predictions with results from the literature relating to the type of sentence produced, Bock’s (1986) result of semantic facilitation is consistent with the prediction of the spreading activation model. However, Bock (1987) found phonological interference, rather than the effect of phonological facilitation predicted by this model. Examining next the predictions of this model relative to results of reaction time analyses in the literature, the prediction of semantic interference in reaction time data has been demonstrated at the word level (e.g., Meyer & Schriefers, 1991) and in constrained syntactic productions (e.g., Costa & Caramazza, 2002; Meyer, 1996). Given the lack of clarity regarding the predictions for phonological distractors, the results of phonological facilitation
reported in the literature (e.g., Glaser & Dungelhoff, 1984; Meyer, 1996) cannot be used to adjudicate the model’s predictive ability.

Turning to the serial incremental model (see Figure 6) using the same example, suppose that a person heard the distractor word ‘wasp’. Upon hearing this distractor, its lemma node WASP would be activated, which would spread activation to the relevant node at the conceptual level. This would lead to the activation of semantically related conceptual nodes (which in this case could include the node of the target noun ‘bee’). The activated conceptual nodes would then spread activation to the relevant nodes at the lemma level. In the current example, the lemma nodes ‘wasp’ and ‘bee’ would be highly activated. Upon presentation of the target picture, the conceptual nodes of the target words (‘bee’ and ‘elephant’) would be activated, which would spread activation to related conceptual nodes (which in this case would likely include the node ‘wasp’). This activation would spread to the lemma level, which would result in the nodes ‘wasp’, ‘bee’ and ‘elephant’ (and others such as ‘mammoth’) receiving high activation. Two things should happen at this point. The first is that in terms of the picture description task in which the two target nouns must be produced, ‘bee’ should have a higher activation level compared to ‘elephant’ (because the additional activation it received from ‘wasp’), so it should be the first of the two target nouns selected, in an effect of facilitation.

The second thing that should happen relates to the response time to utterance onset. Given the high activation levels of both ‘wasp’ and ‘bee’ (because they have each contributed to the activation level of the other), there should be a competition between the two, resulting in an interference, or reaction time delay in utterance onset. The predictions of this model would, therefore, be that a semantically related distractor word would result in an
effect of semantic facilitation in terms of the type of sentence produced and an interference
effect in a reaction time analysis.

Upon presentation of a phonologically related distractor (e.g., ‘beet’), its lemma node
would be activated. This would lead to the activation of its conceptual nodes and
semantically related conceptual nodes (e.g., ‘turnip’). Activation would spread from these
conceptual nodes to the related lemma nodes, which are unrelated to the target nouns (e.g,
‘bee’, ‘elephant’), meaning that the activation level of the target nouns would not be affected.
Upon presentation of the target picture, only then would the activation level of the conceptual
nodes for ‘bee’ and ‘elephant’ and semantically related words be enhanced. Activation would
then spread to related nodes at the lemma level. At this point, ‘beet’, ‘bee’ and ‘elephant’
would all have high activation levels, gained from the input sources. However, because these
words are unrelated semantically, they would not have contributed activation to each other.
Therefore when selecting between ‘bee’ and ‘elephant’ at the sentence level, these lemmas
should have similar activation levels, suggesting that a factor other than distractor relatedness
would influence the order of lemma selection. This implies that a phonological distractor
should have no influence on the word order effects.

Turning now to the potential effects of phonological distractors on reaction time data,
given that ‘beet’ and ‘bee’ would not have contributed activation to each other at the
conceptual level there should be no more competition between these two lemmas than what
would occur with any unrelated distractor. However, the production of ‘bee’ should
ultimately take less time with a phonologically related distractor word than with an unrelated
distractor word, because the phonemes shared between it and ‘beet’ would have a higher
activation already, such that less time would be required to activate them to produce ‘bee’.
The serial incremental model would therefore predict no effect of phonological distractors in an analysis of sentence type data, but would predict an effect of phonological facilitation in an analysis of reaction time data.

Relating to the type of sentence produced, the predictions of this model are consistent with Bock’s (1986) result of semantic facilitation. However, in her 1987 paper Bock found an effect of phonological interference in contrast to the prediction by this model that there should be no effect of phonological distractors. Examining the effects reported for reaction time data in the literature, it can be concluded that the model accurately predicts the reported effects of semantic interference and phonological facilitation found at the single word level and in constrained syntactic production (e.g., Glaser & Dungalhoff, 1984; Meyer, 1996).

It is apparent that the models of word production provide us with a better framework from which to discuss the specific effects of phonological and semantic information. However, it must be remembered that as models of word production they were not designed to explain sentence level production and in the case of the spreading activation model, it was also not designed to account for reaction time effects. In comparison with the results in the literature, both models appear to be capable of accounting for effects due to a semantic distractor (with some modification to the spreading activation model), however, they are less successful in accounting for effects of a phonological distractor.

*Can the Word Production Models Account for the Findings of the Current Experiment?*

Turning now to the results from the current experiment, it appears that the results of the current study provide less support for the word production models than for the models of syntactic production. Examining first the sentence type results, we find some differentiation
in the models’ predictive success. Both the spreading activation model and the serial incremental model predicted that semantic distractors would cause a facilitating effect, which was indeed observed. It is less clear how the results of phonological distractors should be viewed however, as phonological distractors were only used in Experiment 1. The null results found in that experiment may have been due to methodological considerations, as mentioned previously, or they may indeed reflect the reality of sentence production in the presence of phonological distractors. In any case, the spreading activation model predicted a facilitating effect of phonological distractors and the serial incremental model predicted no effect.

Considering the predictions of reaction time results, the spreading activation model predicts semantic interference but makes no clear prediction for phonological distractors, and the serial incremental model predicts semantic interference and phonological facilitation. In the actual experimental results, no effects were seen in the reaction time measures. This result supports neither word production model, however the lack of a result cannot be used as evidence against a model. The possibility of this being an accurate or inaccurate result was discussed in the previous section, and future study of phonological distractors in a similar paradigm would be appropriate to investigate this result and the fit of the models further.

Overall the sentence production models successfully predicted the sentence type results, although their lack of specification diminishes their utility. It should also be noted that they made no prediction regarding the effect of distractors on the reaction times in production. The word production models were less successful at predicting the results. The lack of fit of the results with the predictions of the word production models could suggest
that predictions designed for the lexical level may not be applicable to language production in a sentence generation task.

OLDER ADULTS

Similar Findings

A second major goal of the current study was to compare the sentence productions of older and younger adults. Interestingly, the results pertaining to the influence of semantic distractors on the sentence productions of older adults were quite similar to those of the younger adults, in that the sentence productions of the older adults were also influenced by the semantic distractors. Specifically, the alternation between the production of active and passive sentences was influenced by the presentation of semantic distractors which caused the target noun to be produced in the subject position of the sentence more often than when an unrelated distractor was presented. However, no effect of semantic distractors on the reaction time to utterance onset was observed for either participant group.

Under direct comparison, no effect of age was observed between the older and younger adults regarding the proportion of active sentences produced, the proportion of primed words in subject position, and the reaction time to utterance onset. The one difference observed between the data sets was in error rate. The older adults produced significantly more errors and hesitations in their sentence productions compared to the younger adults.

It should be noted that in a task administered only to the older adults, this group showed an effect of semantic interference as measured by reaction time in the one-word task, which is the same pattern as that demonstrated by younger adults (e.g., Glaser & Dangelhoff,
1984; Roelofs, 1992). Although a direct comparison across groups was not possible for this task due to the lack of word level reaction time data with younger adults, the mean reaction time for the older adults with a semantic distractor appears to be much longer than that typical of younger adults reported by Schriefers et al. (1990). This suggests that the older adults may take longer to initiate single-word utterances, which is consistent with previous word level studies of aging (e.g., Bowles, 1994; Feyereisen, Demaeght & Samson, 1998; Hodgson & Ellis, 1998; Maylor, 1995; Thomas, Fozard & Waugh, 1977).

How Do the Data of the Older Adults Fit with Previous Results in the Literature?

Syntactic Complexity

As mentioned, no group difference was observed in the production of active and passive sentences. This pattern of results between older and younger adults has been observed in previous studies. Kemper, Herman and Lian (2003) demonstrated that when older adults were required to produce a sentence when provided with two to three content words, they performed similarly to the younger adults. It was only when they were required to produce a sentence using 4 or more given content words that the older adults showed decreased accuracy. Considering these two conditions, active and passive sentences could be considered similar to the three-word utterances because they contain an agent, a patient and a verb. Longitudinal studies have found a decrease in the accuracy of production of more complex syntactic structures by older adults relative to younger adults, but that difference was not evident for simpler syntactic structures (Kemper, Greiner et al., 2001; Kemper, Thompson, et al., 2001). If it is the case that both active and passive sentences are considered to be less complex syntactic structures, then the results of the current study could be consistent with these results found in the literature.
Relative Proportion of Active and Passive Sentences

Altmann & Kemper (2006), on the other hand, specifically elicited the alternation between active and passive sentences and found that the older and younger adults differed in their relative proportion of active vs. passive sentences. They proposed that the two groups followed different strategies that were influenced by lexical and environmental characteristics or cues (e.g., animacy, verb type and word order presentation). Although their results seem inconsistent with those of the current study, it remains possible that the behaviour of the older adults in the current study is compatible with that of the older adults in their study, but that among other factors, the environmental cues in the current study (e.g., distractor words) may not have been as dominant or constraining as those in Altmann and Kemper’s study. There are two cues in particular in the current experiment that could have had such an influence but seemingly did not.

The first such cue that the groups appeared to use in a similar manner was that of the left to right order of the depicted target nouns. This is in comparison to the top to bottom presentation of target nouns in Altmann & Kemper’s (2006) study which the older adults followed by beginning their sentences with the ‘top’ noun more often than the younger adults did. In Experiment 2 of the current study, all of the patient nouns (e.g., ‘the elephant’ in a scene of a bee chasing an elephant) were depicted on the left side of the page. If the older adults had been more susceptible to this environmental cue than the younger adults, they would have begun more sentences with the patient noun, thus producing a higher proportion of passive sentences. The fact that the left-sided position of the patients nouns in the current study had no effect but that the top to bottom presentation of the written words used by Altmann and Kemper did have an effect may have to do with the nature of the presented
cues. In that study the stimuli were written words, which effectively force the participant to produce the individual words (either internally or aloud) in the given order at some point in the process of sentence generation. Altmann and Kemper argued that the older adults likely used the given order to achieve the speed requirement of the task. The authors argued that younger adults on the other hand were less influenced by the given order, but rather viewed the stimuli more globally, a result that is supported by eye-tracking results (e.g., Griffin & Spieler, 2006). In the current study, the stimuli were presented pictorially rather than in written form, which likely did not offer the older adults a quicker strategy than following the general preference for active sentences. Therefore the left-right cue in the current experiment may have been a less obvious or less useful cue relative to the presentation of the written words in Altmann & Kemper’s study, causing less differentiation between the two groups.

It is also possible that the main ‘environmental cue’ in the current study, namely the presentation of auditory distractors, did not offer the older adults a ‘better solution’ to the task that otherwise might have differentiated their performance from that of the younger adults. The distractor words were designed to influence the syntactic productions of the participants by influencing the activation of related lemmas, or semantic representations of lexical items. In contrast, Altmann and Kemper (2006) presented their participants with the target words in written form which were to be produced to form a grammatical sentence. It is likely that the cues in the current study were once again much less constraining or useful in the production of the target words compared to the cues provided in Altmann and Kemper’s study and it is this difference in salience that may have been another factor for the difference in results between the two studies. This is not to say that older adults were not influenced by the distractor words, but rather that it was not a strong enough cue to provide them with an
advantage in completing the task, so they would have used it in a similar manner to the younger adults.

Because of the similarity in responses between the older and younger adults, the current study does not permit us to determine whether the language skills of older adults were changing due to a decrease in language abilities or due to a change in strategy. These results do inform us regarding language skills that are maintained across age groups, namely that older and younger adults are similarly influenced by the presence of related lexical items in the course of the production of active and passive sentences.

**Reaction Time**

In the current study, no difference in the reaction times to utterance onset was observed between the two age groups. This result is consistent with the findings of Altmann and Kemper (2006), in which they investigated the production of active and passive sentences, and Mortensen et al.’s (2008) second task which involved the production of multi-word productions. It differs however from results of other studies, in which the response times of the older adults were longer than those of younger adults (Bowles, 1994; Feyereisen et al., 1998; Hodgson & Ellis, 1998; Kemper et al., 2003; Maylor, 1995; Mitchell, 1989; Spieler & Griffin, 2006; Thomas et al., 1977). For the most part it appears as though older adults were slower in responding in word tasks, but not in sentence level tasks, except in the case of the sentence production task presented by Kemper et al. in which older adults showed a longer response time compared to that of the younger adults. Altmann and Kemper (2006) and Mortensen et al. (2008) hypothesized that the older and younger adults approached their tasks with a different strategy than the younger adults, which reduced any difference in response time. It is possible that the syntactic complexity of the task in Kemper et al.’s study
was sufficiently high, such that the older adults were not able to use a strategy that would reduce their reaction times to the level of those of the younger adults. Consistent with this hypothesis, it should be noted that in the current study the older adults showed what appears to be a longer delay in response time in the word level picture word interference task, compared to the reaction times of younger adults in a similar task\textsuperscript{12}, despite showing the same pattern of semantic interference with the semantic distractors.

Errors

It is difficult to attribute a direct cause to the increase in errors by the older adults. Overall, the older adults produced approximately three times more errors than the younger adults. One factor in their increased error rate appeared to be due to some form of interference, as the older adults repeated the distractor word in place of the target noun 2.6 times more often than younger adults. Another significant portion of the errors produced by the older adults consisted of sentences with one or both of the target nouns missing (excluding the repetitions of the distractor word). The older adults produced almost 2.5 times as many of this type of error as the younger adults. Given that all participants were trained on the target nouns prior to running the sentence production task and given that studies have demonstrated that older adults may have a greater vocabulary (Kemper & Sumner, 2001), it is unlikely that this was due to decreased vocabulary skills. This could again have been due to interference at the lemma level. Finally, the older adults produced more than seven times the number of verbal hesitations (e.g., ‘um’) compared to the younger adults, which is a result consistently found in the literature (Mortensen et al., 2008).

\textsuperscript{12} Note that a statistical analysis for this question was not possible due to the lack of data for younger adults in the current experiment.
The two groups were similar in their production of sentence mis-starts in which they began the sentence with one of the target nouns and then restarted the sentence with the other target noun in the subject role. It is possible that this was done in order to restart their utterance in the active voice, which was preferred by participants in both age groups.

Theories of Cognitive and Linguistic Aging

What can theories of cognitive and linguistic aging tell us about the current results? In general, theories of cognitive and linguistic aging must be able to account for a great variety of results observed in language abilities in aging. This includes both a decrease in performance (e.g., Barresi et al., 2000; Hodgson & Ellis, 1998; Kemper et al., 2003), and in some cases, superior performance (e.g., Kim et al., 2007). Theories that propose a global deficit, encompassing an impairment in or slowing of cognitive processes, such as the general slowing theory (Salthouse, 1996) are less successful at explaining better performance by older adults (e.g., Kim et al., 2007). Theories proposing specific sources of disruption of cognitive performance in older adults (e.g., Inhibition Deficit Hypothesis – IDH, e.g., Lustig et al., 2007; Transmission Deficit Hypothesis – TDH, e.g., Burke, MacKay, Worthley, & Wade, 1991; Mackay & Burke, 1990; Taylor & Burke, 2002) may be better able to explain the variety of experimental results.

Inhibition Deficit Hypothesis

According to the Inhibition Deficit Hypothesis (IDH), the difficulties that older adults have in cognitive performance, including language production, are due to a decreased ability to inhibit non-relevant information. The authors of this hypothesis propose three forms of this
deficit (see Lustig et al., 2007 for a review). The first is a difficulty inhibiting access to attentional resources to irrelevant information. The second deficit involves an inability to delete non-relevant information. The third deficit is a difficulty in restraining a strong but incorrect response (May & Hasher, 1998). It is important to note that what Hasher, Zacks and their colleagues call inhibition is not the lateral inhibition mechanism of connectionist models, which is an automatic and subconscious process. Rather their interpretation of inhibition relates to the allocation of attention through working memory resources (Zacks & Hasher, 1997). This is an important point, as most current models of word production do not contain the construct of inhibition (e.g., Dell, et al., 1997; Foygel & Dell, 2000; Levelt, et al., 1999). The construct of inhibition proposed by Hasher, Zacks and their colleagues is more consistent with an increase or decrease in the activation levels of target and irrelevant lexical items in word production models, due to the level of attention provided to a stimulus.

The deficits described by Hasher, Zacks and colleagues have been used to explain delays in responding (Carlson, Hasher, Connelly, & Zacks, 1995, Gerard, Zacks, Hasher & Radvansky, 1991) as well as decreased response accuracy (Butler, Zacks, & Henderson, 1996). Following the IDH however, Hasher, Zacks and colleagues have noted that these deficits can also lead to superior performance, compared to younger adults. For example, Kim et al. (2007) presented older and younger participants with a reading task, in which they were asked to read a passage out loud while ignoring interspersed distracting words. In the subsequent task, participants were asked to produce a word that would relate three otherwise unrelated words (e.g., Falling, Actor, Dust: answer: ‘star’; Remote Associates Test, Mednick, 1962). In the design of the experiment, some of the previously distracting words from the reading task served as answers in the Remote Associates Test. In the first task, the authors
found that the older adults responded more slowly when distracting words were presented compared to the younger adults, presumably due to an inability to ignore distracting information. In the second task however, they found that the older adults were able to use those distracting words from the previous task to achieve a greater accuracy than the younger adults in the Remote Associates Test. Thus their impairment in inhibiting and deleting non-relevant information led to more successful responding.

Based on this hypothesis what should we expect of the performance of older adults in the sentence level picture-word interference task from the current study? This hypothesis would predict that with a semantic distractor, older adults would exhibit an increased response delay and possible decreased accuracy, due to an inability to inhibit the distractor lemma. Within the context of this hypothesis, the case of a phonological distractor in this paradigm is more difficult to predict. Once again, there should be a delay, as a participant would have difficulty inhibiting the distractor word, but it is unclear whether or not, or to what extent, that delay would offset the facilitation observed in younger adults. It is also unclear what this hypothesis would predict regarding the word order of the two target nouns.

*Transmission Deficit Hypothesis*

The general slowing theory (Salthouse, 1996) suggests that the speed of cognitive processing slows, which results in impaired performance, due to an inability to complete a task within the limited amount of time allocated for a given process. A related theory, which was developed to specifically address language in aging, proposes that difficulties in language production arise from a decrease in the connection strength of links between semantic and phonological nodes within the framework of a connectionist model.
Transmission deficit hypothesis – TDH, Burke et al., 1991; Mackay & Burke, 1990; Taylor & Burke, 2002). This hypothesis is often presented within Node Structure theory (NST - MacKay, 1987; Taylor & Burke, 2002). For our purposes, the general structure and connections of NST are relatively similar to those of other connectionist models of word production (e.g., Dell et al., 1997; Foygel & Dell, 2000).

This hypothesis proposes that in aging, the connection strength between nodes is weakened, which reduces the amount of priming transmitted between the semantic and phonological levels. Further, it is proposed that in the presence of weakened connections, language skills are differentially impaired due to redundancies built into the architecture of NST (and other models of word production). Specifically, this hypothesis proposes that production will be more impaired than comprehension, and that the phonological level is more susceptible to damage than the semantic level. This is possible in part due to the fact that priming spreads between nodes, and through summation ultimately leads to activation of a node, which is an all-or-none event. In unimpaired comprehension, as information is passed from multiple phonological nodes (e.g., ‘d’, ‘o’, ‘g’), each of those nodes will spread priming to the lexical node at the semantic level (e.g., ‘dog’). When the amount of priming crosses a certain threshold level, then activation of the lexical item occurs and comprehension is achieved. This hypothesis proposes that in aging, there may be an impairment in one or more of those connections, such that less priming may be transmitted between nodes along the impaired connection. What saves activation of the semantic node in comprehension however, is the summation of priming that occurs from the individual phonological nodes. Therefore, even though less priming may be transmitted from an individual phonological node (e.g., ‘d’),
priming from the other nodes (e.g., ‘o’, ‘g’) can compensate, thereby activating the target semantic node.

However, in production there is not the availability of summation from different nodes. In the case of unimpaired production, priming from a semantic node (e.g., ‘dog’) spreads to the individual phonological nodes (e.g., ‘d’, ‘o’, ‘g’) that become activated when the threshold level for each is achieved. When an impairment occurs in the same connections as above but processing spreads from the semantic to the phonological level, the affected phonological node(s) will not be activated, as priming cannot reach the threshold level. In this case, another node cannot contribute priming, and an incorrect word will be produced. It is for this reason of redundancy that this hypothesis predicts that production and the phonological level are more susceptible when there are impaired connections than are comprehension and the semantic level. This also suggests that a naming impairment is more likely to be due to an impairment at the phonological rather than the semantic level.

In a word level picture-word interference task, this hypothesis predicts increased levels of semantic interference in aging, as an auditory distractor noun (e.g., ‘wasp’: target word: ‘bee’) would receive increased priming due to the larger network of nouns with shared features (e.g., James & Burke, 2000). This should result in an increased reaction time and more errors. This hypothesis however predicts no age differences with phonological priming because the same type of network does not exist at the phonological level. Similar to younger adults, older adults should be helped by having the target phonological nodes already at higher activation levels due to the distractor word.

This hypothesis attempts to explain word level phenomena and, as such, makes no predictions regarding the sentence level. Therefore, to predict production in a sentence level
picture word distractor task, we would extend the effects determined at the word level. As such, we would predict increased semantic interference and phonological facilitation as measured in reaction time and decreased accuracy of target word production. This model would predict no age changes in the word order results, as the two target nouns should be similarly affected.

*Do the Findings Support the Models of Cognitive and Linguistic Aging?*

Both the Inhibition Deficit Hypothesis (IDH - e.g., Lustig et al., 2007) and the Transmission Deficit Hypothesis (TDH - Burke et al., 1991; Mackay & Burke, 1990; Taylor & Burke, 2002) predict similar results: an increased delay of response and a possible decrease in accuracy in the productions of older adults compared to the productions of younger adults. Where the models differ is in the proposed cause of the differences between the groups. The IDH proposes that the changes in the older adults are the result of an inability to inhibit the distractor word. The TDH on the other hand predicts a decrease in accuracy and speed because of the weakened links from the semantic representation to the individual phonological nodes. Neither of these hypotheses can model sentence type effects. The IDH, given that it is a cognitive model, is not able to explain different aspects of language production in specific ways and, therefore, is not capable of explaining the relative positioning of one target word over another. The TDH is designed specifically to explain language production, but only at the single-word level. As such, it is also unable to predict the relative positioning of one target word over another.

Reviewing the results, no difference in reaction time to utterance onset was observed between the two groups, but the older adults did show a decreased level of accuracy in their
responses. The nature of some of the errors could be attributed to a decreased ability to inhibit an activated lexical item (e.g., the distractor word) giving support to the IDH. The TDH’s rationale seems to fit the error data more completely because it allows for production errors that are not necessarily directly related to distracting related stimuli (e.g., missing or substituted errors vs. erroneous production of distractor word).

LIMITATIONS OF THE CURRENT STUDY

There are some limitations to the study which restrict the conclusions that can be drawn and the generalization to everyday language performance that can be made. Because of the large scope of the current study, it was not possible to investigate in depth the question of SOA and the lack of observed reaction time effects. As mentioned previously, it is quite possible that reaction time effects might have been observed with larger positive SOAs. In the current study we used three SOAs, with 150 ms being the only positive SOA. In all cases, no reaction time effects were observed. In word level studies reported in the literature, the SOA of 150 ms has revealed reaction time effects of phonological facilitation (e.g., Dungelhoff & Glaser, 1984; Roelofs, 1997). Because in the current study participants were required to generate novel sentences which would likely require more processing time compared to the production of a single word, larger positive SOAs may have revealed reaction time effects for both semantic and phonological distractors. Such an investigation would have required additional experiments, and would have led the study in a different direction. However, the benefit of such an investigation would have been a firmer conclusion, and possibly even a different one regarding the co-occurrence of reaction time and sentence type effects in sentence production.
Similarly, because of the scope of the current study, it was not possible to continue the investigation of the effects of phonological distractors, as was done for semantic distractors. Information regarding the effects of phonological distractors would certainly be useful for models of production, and could have practical uses as well (e.g., see discussion regarding cueing in aphasia, in next section).

A second limitation of the current study involved the high error rate, which was evident in both populations, but especially in the data of the older adults. The errors in this study ranged from non-verbal noises prior to the utterance (e.g., lip smacking) to ungrammatical sentences or missing target nouns. This rate of lost data is not necessarily unusual, especially in studies of sentence production. Bock (1986, 1987) reported an overall loss of 31% of the data. In the current study, the loss of 15-18% does not include the errors produced by the participants whose data were removed entirely from the analysis due to their high error rate. Nonetheless, the loss of these data reduces the generalizability of the conclusions. For example, our sample may not be as representative of the population of younger and older adults given that there were some participants whose entire data set was lost.

It should be noted that the loss of language data due to errors is an often reported problem. One way of minimizing this problem is by creating a task that reduces the possible errors. In the current study, the participants were fairly unconstrained in their sentence production. Altmann and Kemper (2006) attempted to maximize the production of their target lexical items by providing the written target words as part of the task. They acknowledged in their article the downside of this approach, which is that the task can
become less natural, and therefore the results may be less generalizable to normal language production.

The nature of the stimuli themselves may have also hampered the results. Transitive verbs and the active/passive alternation were selected for use in this study primarily to maintain a similarity to Bock’s methodology. However, the drawback to using transitive verbs with the active/passive alternation relates to the infrequent use of the passive voice by English speakers. It was found that active sentences were produced at least 89% of the time across the different conditions of the present study. Because of the imbalance between the production of active and passive sentences, this means that the distractors had to produce a strong effect to overcome the bias against passive sentence production. As a result, some effects of distractors may not have been observed due to this choice of verb.

It should be noted that there are transitive verbs for which the bias against the passive voice is not quite as strong. Altmann and Kemper (2006) presented four different types of transitive verbs with varying degrees of frequency for active or passive sentences, including those used in the current study. A different type of transitive verb, a theme-experiencer verb (e.g., bore, amuse), which requires an animate noun in the object position of an active sentence is often produced using the passive voice (e.g., ‘The student was bored by the book’ vs. ‘The book bored the student’). The use of such verbs may have allowed for a reduction in the bias against passive sentences. However, their use in the current study was not possible due to the difficulty in depicting a scene involving this class of verbs.

Despite its drawbacks, the active/passive alternation is useful in the measurement of reaction time to utterance onset because the critical decision point occurs at the first noun phrase. Generally the purpose of reaction time measurements is to determine the amount of
information encoded prior to utterance onset. In the current study we aimed to determine how the related distractors influenced both the type of sentence produced and the time taken to plan that utterance before it is started. The value of observing active and passive sentences compared to dative and double object dative sentences, for example, lies in the fact that the critical noun phrase is in the subject position of the sentence for active and passive sentences. Once the subject has been produced in an active or passive sentence, the type of sentence is clear. In a dative sentence the critical noun phrase occurs after the verb. This means that when an active or passive sentence has been started we can determine the type of sentence, and the reaction time to utterance onset should reflect the influence of the distractor word on the sentence type. With the dative and double object dative alternation, it is possible that a participant could begin their utterance (which would provide a reaction time), but hesitate mid-sentence prior to the critical noun phrase, suggesting possible continued planning of the sentence type. This situation would lead to the reaction time being less informative, and interpretation of any hesitations would be required.

Finally, in the current study, the results of the older adults and the comparisons with those of the younger adults may have been affected by the range of ages of the older adults as presented. In the current study the older adults ranged in age from 65 to 92 years. In some studies of language, healthy adults in this age group are subdivided into smaller age ranges (often 60 to 74 and 75 to 90) for the detection of subtle differences in older adults as they age (e.g., Kemper, 1992; White & Abrams, 2002). The inclusion of a similar division of older adults into smaller age groups, along with additional recruitment, may have yielded more specific findings of language production in older adults.
IMPLICATIONS FOR FUTURE RESEARCH

Phonological Distractors at the Sentence Level

The current study focused primarily on the investigation of the effects of semantic distractors on sentence production. To achieve a more complete understanding of the influence of lexical level effects on syntactic production, an important direction to follow would be the continued investigation of the effects of phonological distractors on syntactic production which would be possible using a similar design. The influence of phonological relatedness could be especially interesting, given the different predictions made by the two prominent word production models, based on the presence or absence of feedback from the phonological level (e.g., Foygel & Dell, 2000 and Levelt et al., 1999 respectively).

SOA

Another direction that would be possible, which follows directly from the limitations of the study, would be the investigation of SOA in order to provide a stronger conclusion regarding the effects of semantic and phonological distractors as well as additional insight into the co-occurrence between reaction time and word order effects in language production. Such a study could involve the same design as that in Experiment 2, but with larger positive SOAs. One could adopt the SOAs used in the word production experiments (e.g., Glaser & Dungalhoff, 1984), which range up to 400 ms (at which point no effects of semantic or phonological distractors are found), or, given the hypothesis regarding the additional processing required in a sentence production task, one could investigate even larger positive SOAs. It is not known how a large positive SOA would influence sentence type effects, however following upon the result in Experiment 1 of sentence type effects being independent of SOA, it might not be a concern.
Clinical Considerations

With reference to the study of aphasiology, there are two direct lines of research that follow from the current study. The first such line of study relates to the use of cueing. Cueing has been extensively studied in the aphasiology literature and a large proportion of treatments for word-finding impairments in the literature make use of semantic and/or phonological cues to aid in the correct production of a target word (e.g., Best, Herbert, Hickin, Osborne, & Howard, 2002; Boyle, 2004; Boyle & Coelho, 1995; Conley & Coelho, 2003; Leonard, Rochon, & Laird, 2008; Miceli, Amitrano, Capasso, & Caramazza, 1996; Raymer, Thompson, Jacobs, & LeGrand, 1993; Wambaugh, 2003; Wambaugh, Cameron, Kalnyak-Fliszar, Nessler, & Wright, 2004). However, with the knowledge that a semantically related word causes a delay in production at the word level in non-brain injured adults (both older and younger), we could investigate from a different perspective the effects of a semantically related word on the production of a target word. For example, if such a delay existed for a person with aphasia, would that impair their ability to ultimately retrieve the word, or would the semantic cue still be useful, but simply cause a delay in production? Similarly, with the knowledge that a semantically related word can facilitate the production of a target word in a sentence, such that it is more likely to be produced in the subject position of a sentence, could semantic cueing be useful in the treatment of syntactic disorders, by facilitating certain sentence forms? As an example, a clinician may be more successful eliciting a passive sentence with a semantic cue to the patient noun. Factors such as the nature of the anomia or agrammatism, or a difficulty with inhibition in individual participants with aphasia would need to be explored and controlled in experiments of this nature.
Finally, the results of the current study suggest that the relatedness of lexical items can influence a person’s sentence production. Specifically, upon hearing a word that is semantically related to a noun in a person’s upcoming utterance (as can happen in conversation) that person’s syntactic structure may be altered such that the related word is produced in the subject position of the sentence. What is relevant to aphasiology is that information at the lexical level can influence syntactic production. Almost every person with aphasia suffers from some form of anomia, or word finding difficulties (Goodglass & Wingfield, 1997). Additionally many people with nonfluent aphasia have agrammatism, or a difficulty producing syntax (Davis, 2000; Thompson, 2001). If, according to the results of the current study, lexical retrieval and syntactic production are related, then to what extent could anomia and agrammatism be related disorders? The findings of studies investigating this question to date are equivocal (e.g., Berndt et al, 1997; Faroqi-Shah & Thompson, 2003; Marshall, Pring & Chiat, 1998). The methodology in the current study could provide another manner with which to investigate this question. Implications of these findings may be useful theoretically and in the development of treatments for anomia and agrammatism.

CONCLUSION

In conclusion, sentence production is a complex operation which is generally effortless and efficient. The current study demonstrated that this process can be influenced by information contained at the lexical level, notably the semantic characteristics of a word. It was also shown that this lexical influence on syntactic production occurs similarly in both younger and older adults. This result suggests that while some aspects of language production may change with aging, others may not. Given the importance of language
production and communication in general, continued research regarding the process of sentence production in speakers with or without an impairment will be both necessary and important.
REFERENCES


Appendix A - Experimental and filler sentences, including semantic, phonological and unrelated distractor words (Sentence production task, Experiment 1).

Inanimate sentences with their semantic, phonological and unrelated distractor words

The fan blew away the stamp. The stamp was blown away by the fan.  
(air conditioner, fang, wasp)  (postage, stand, Cajun)

The needle popped the bubble. The bubble was popped by the needle. 
(pin, needy, snare)  (suds, bundle, highness)

The fork pierced the glove. The glove was pierced by the fork. 
(spoon, fort, tighter)  (mitten, glug, shed)

The bus smashed the toilet. The toilet was smashed by the bus. 
(subway, buzz, hare)  (lavatory, toiling, umpire)

The chair flattened the hat. The hat was flattened by the chair. 
(seat, chain, liar)  (cap, hack, jester)

The shoe flattened the flower. The flower was flattened by the shoe. 
(boot, shoot, tabby)  (blossom, flounder, schemer)

The clock smashed the glasses. The glasses were smashed by the clock. 
(watch, clot, hoard)  (spectacles, gladness, hilly)

The hammer smashed the kettle. The kettle was smashed by the hammer. 
(drill, hamper, ape)  (teapot, kennel, mariner)

The piano flattened the suitcase. The suitcase was flattened by the piano. 
(keyboard, piazza, coyote)  (luggage, sucrose, clergy)

The arrow pierced the tire. The tire was pierced by the arrow. 
(spear, error, zero)  (wheel, tile, kink)

The tornado destroyed the castle. The castle was destroyed by the tornado. 
(cyclone, torpedo, pick)  (palace, cancel, father)

The scissors ruined the purse. The purse was ruined by the scissors. 
(shears, sisters, loon)  (handbag, perch, wrangler)
Animate (human) sentences with their semantic, phonological and unrelated distractor words

The acrobat punched the caveman. The caveman was punched by the acrobat.
(gymnast, aquafit, fang) (Neanderthal, Cajun, elegant)

The scientist washed the queen. The queen was washed by the scientist.
(researcher, silencer, pin) (highness, queer, poultry)

The waitress poked the referee. The referee was poked by the waitress.
(server, weightless, subway) (umpire, repartee, sheet)

The nun splashed the chef. The chef was splashed by the nun.
(sister, numb, fort) (cook, shed, moot)

The butler poked the hippie. The hippie was poked by the butler.
(servant, butter, shoot) (flower child, hilly, grizzly)

The boxer dropped the clown. The clown was dropped by the boxer.
(prize-fighter, bother, seat) (jester, cloud, hen)

The magician punched the skier. The skier was punched by the magician.
(illusionist, malicious, hamper) (alpinist, schemer, puppy)

The nurse kicked the priest. The priest was kicked by the nurse.
(RN, nerds, watch) (clergy, preen, count)

The baby splashed the king. The king was splashed by the baby.
(infant, bailey, piazza) (monarch, kink, chipmunk)

The conductor washed the sailor. The sailor was washed by the conductor.
(musician, conduction, spear) (mariner, saviour, turmoil)

The pilot kicked the farmer. The farmer was kicked by the pilot.
(aviator, pirate, shears) (cultivator, father, rat)

The painter dropped the cowboy. The cowboy was dropped by the painter.
(decorator, painless, torpedo) (wrangler, coward, fraud)
Animate (animal) sentences with their semantic, phonological and unrelated distractor words

The bee chased the elephant. The elephant was chased by the bee.
(wasp, beet, aquafit) (mammoth, elegant, suds)

The snake kissed the bird. The bird was kissed by the snake.
(viper, snare, researcher) (poultry, burrs, postage)

The tiger pushed the moose. The moose was pushed by the tiger.
(leopard, tighter, sister) (elk, moot, glug)

The rabbit scratched the sheep. The sheep was scratched by the rabbit.
(hare, rapid, weightless) (lamb, sheet, toiling)

The cat chased the bear. The bear was chased by the cat.
(tabby, cap, servant) (grizzly, bend, flounder)

The lion pushed the chicken. The chicken was pushed by the lion.
(cougar, liar, bother) (hen, chipping, cap)

The horse pulled the dog. The dog was pulled by the horse.
(pony, hoard, nerds) (puppy, dock, teapot)

The monkey scratched the cow. The cow was scratched by the monkey.
(ape, Monday, illusionist) (bull, count, gladness)

The wolf hugged the turtle. The turtle was hugged by the wolf.
(coyote, wool, bailey) (crocodile, turmoil, luggage)

The zebra pulled the squirrel. The squirrel was pulled by the zebra.
(horse, zero, musician) (chipmunk, squirm, tile)

The duck hugged the frog. The frog was hugged by the duck.
(loon, dug, pirate) (toad, fraud, cancel)

The pig kissed the mouse. The mouse was kissed by the pig.
(hog, pick, decorator) (rat, mouth, handbag)
Filler sentences (and unrelated distractors):

The teenager shaved. (keyboard, chipping)
The convict danced. (hog, wheel)
The ballerina cried. (spoon, dock)
The baton twirler tripped. (pony, toad)
The astronaut sang. (drill, blossom)
The singer laughed. (wool, elk)
The bride gave the groom a camera. (silencer, hack)
The policeman fed the fireman a sandwich. (cougar, palace)
The football player threw the helmet to his teammate. (leopard, kennel)
The grandmother gave her granddaughter a present. (beet, sucrose)
The judge opened the safe with a key. (painless, lamb)
The mailman gave a package to the soldier. (rapid, cultivator)

The ant was bleeding. (chain, bundle)
The ostrich ran. (clot, flower child)
The seal barked. (aviator, mitten)
The camel drank. (RN, burrs)
The koala bear scratched. (air conditioner, saviour)
The kangaroo hopped. (butter, repartee)
The butterfly flew into the cage. (server, mammoth)
The giraffe slept in the tall grass. (sisters, queer)
The beaver sat on the chair. (prize-fighter, monarch)
The shark swam in the ocean. (buzz, preen)
The dolphin played with the toy. (malicious, coward)
The goat ate in the cave. (error, alpinist)

The snowman melted. (horse, perch)
The helicopter landed. (gymnast, squirmly)
The chandelier swung. (cap, Neanderthal)
The kite fell in the puddle. (viper, mouth)
The umbrella blew away. (conduction, cook)
The candle was burning. (Monday, stand)
The guitar string was broken. (dug, cloud)
The cover of the magazine was ripped. (needy, crocodile)
The tap was dripping. (cyclone, bend)
The phone was ringing. (numb, spectacles)
The moon rose over the mountains. (boot, lavatory)
The tower collapsed. (infant, bull)
Appendix B - Experimental and filler pictures for Experiments 1 and 2.

Experimental Pictures (Note that in Experiment 2, the pictures were modified such that the patient noun was always presented on the left side of the picture (not shown here)).
Appendix C - P-values from Experiments 1 and 2.

Experiment 1

Sentence type analysis:

main effect of soa: (Z = 4.01, p<0.14),
main effect of distractor type (Z = 5.71, p<0.06),
main effect of thematic role (Z = 34.94, p<0.001),

soa x distractor type (Z = 4.54, p<0.34),
soa x thematic role (Z = 3.21, p<0.20),
distractor type x thematic role (Z = 3.26, p<0.20),

soa x distractor type x thematic role (Z = 4.31, p<0.37),

RT analysis (active and passive sentences)

main effect of soa: F(2, 84)=10.04, p<0.001
main effect of distractor type: F(2, 84)=0.46, p<0.63
main effect of thematic role: F(1, 42)=0.65, p<0.43

soa x distractor type: F(4, 168)=0.37, p<0.83
soa x thematic role: F(2, 84)=0.43, p<0.65
distractor type x thematic role: F(2, 84)=0.16, p<0.86

soa x distractor type x thematic role: F(4, 168)=2.22, p<0.07

Position of primed word:

main effect of soa: (Z =1.02, p<0.60),
main effect of distractor type (Z = 3.33, p<0.19),
main effect of thematic role (Z = 1535.75, p<0.001),

soa x distractor type (Z = 3.19, p<0.53),
soa x thematic role (Z = 5.02, p<0.08),
distractor type x thematic role (Z = 0.92, p<0.63),

soa x distractor type x thematic role (Z = 3.67, p<0.45),

RT (all grammatical sentences)

main effect of soa: F(2, 84)=11.00, p<0.001
main effect of distractor type: F(2, 84)=1.26, p<0.29
main effect of thematic role: F(1, 42)=0.04, p<0.84

soa x distractor type: F(4, 168)=0.23, p<0.92
soa x thematic role: F(2, 84)=0.67, p<0.52
distractor type x thematic role: F(2, 84)=0.81, p<0.45

soa x distractor type x thematic role: F(4, 168)=2.01, p<0.095

**Experiment 2**

**Word-level task:**

Distractor type: t(34) = 2.051, p<0.048

**Error analysis:**

all errors: t(45) = -9.723, p<0.001
verbal and nonverbal hesitations t(37) = -2.899, p<0.006,
omission/substitution of target noun: t(47) = -6.592, p<0.001,
repetiton of distractor word: t(50) = -2.316, p<0.025
mistarts: t(60) = -1.114, p<0.270

**Sentence type analysis:**

main effect of group: (Z = 0.36, p<0.55),
main effect of distractor type (Z = 1.0, p<0.32),
main effect of thematic role (Z = 6.6, p<0.01),

group x distractor type (Z = 0.72, p<0.40),
group x thematic role (Z = 0.70, p<0.40),
distractor type x thematic role (Z = 19.1, p<0.001),

group x distractor type x thematic role (Z = 2.40, p<0.12),

**RT analysis (active and passive sentences)**

main effect of group: F(1, 101)=0.94, p<0.34
main effect of distractor type: F(1, 101)=2.24, p<0.14
main effect of thematic role: F(1, 101)=0.002, p<0.97

group x distractor type: F(1, 101)=0.01, p<0.91
group x thematic role: F(1, 101)=0.66, p<0.42
distractor type x thematic role: F(1, 101)=0.19, p<0.66
group x distractor type x thematic role: F(1, 101)=1.20, p<0.28

Position of primed word:

main effect of group: (Z = 0.10, p<0.75),
main effect of distractor type (Z = 18.4, p<0.00),
main effect of thematic role (Z = 614.66, p<0.00),
group x distractor type (Z = 1.76, p<0.18),
group x thematic role (Z = 0.01, p<0.91),
distractor type x thematic role (Z = 0.57, p<0.45),
group x distractor type x thematic role (Z = 1.10, p<0.29),

RT analysis (all grammatical sentences)

main effect of group: F(1, 101)=0.69, p<0.41
main effect of distractor type: F(1, 101)=1.90, p<0.17
main effect of thematic role: F(1, 101)=0.002, p<0.97

group x distractor type: F(1, 101)=0.49, p<0.49

group x thematic role: F(1, 101)=0.05, p<0.83
distractor type x thematic role: F(1, 101)=1.44, p<0.23

group x distractor type x thematic role: F(1, 101)=0.80, p<0.37
Appendix D - Experimental and filler sentences, including semantic and unrelated distractor words (Sentence production task, Experiment 2).

Inanimate sentences with their semantic and unrelated distractor words

The fan blew away the stamp. The stamp was blown away by the fan. (air conditioner, wasp) (postage, Cajun)

The needle popped the bubble. The bubble was popped by the needle. (pin, snare) (suds, highness)

The fork pierced the glove. The glove was pierced by the fork. (spoon, tighter) (mitten, shed)

The bus smashed the toilet. The toilet was smashed by the bus. (subway, hare) (lavatory, umpire)

The chair flattened the hat. The hat was flattened by the chair. (seat, liar) (cap, jester)

The shoe flattened the flower. The flower was flattened by the shoe. (boot, tabby) (blossom, schemer)

The clock smashed the glasses. The glasses were smashed by the clock. (watch, hoard) (spectacles, hilly)

The hammer smashed the kettle. The kettle was smashed by the hammer. (drill, ape) (teapot, mariner)

The piano flattened the suitcase. The suitcase was flattened by the piano. (keyboard, coyote) (luggage, clergy)

The arrow pierced the tire. The tire was pierced by the arrow. (spear, zero) (wheel, kink)

The tornado destroyed the castle. The castle was destroyed by the tornado. (cyclone, pick) (palace, father)

The scissors ruined the purse. The purse was ruined by the scissors. (shears, loon) (handbag, wrangler)
Animate (human) sentences with their semantic and unrelated distractor words

The acrobat punched the caveman. The caveman was punched by the acrobat.
(gymnast, fang) (Neanderthal, elegant)

The scientist washed the queen. The queen was washed by the scientist.
(researcher, pin) (highness, poultry)

The waitress poked the referee. The referee was poked by the waitress.
(server, subway) (umpire, sheet)

The nun splashed the chef. The chef was splashed by the nun.
(sister, fort) (cook, moot)

The butler poked the hippie. The hippie was poked by the butler.
(servant, shoot) (flower child, grizzly)

The boxer dropped the clown. The clown was dropped by the boxer.
(prize-fighter, seat) (jester, hen)

The magician punched the skier. The skier was punched by the magician.
(illusionist, hamper) (alpinist, puppy)

The nurse kicked the priest. The priest was kicked by the nurse.
(RN, watch) (clergy, count)

The baby splashed the king. The king was splashed by the baby.
(infant, piazza) (monarch, chipmunk)

The conductor washed the sailor. The sailor was washed by the conductor.
(musician, spear) (mariner, turmoil)

The pilot kicked the farmer. The farmer was kicked by the pilot.
(aviator, shears) (cultivator, rat)

The painter dropped the cowboy. The cowboy was dropped by the painter.
(decorator, torpedo) (wrangler, fraud)
Animate (animal) sentences with their semantic and unrelated distractor words

The bee chased the elephant. The elephant was chased by the bee.
   (wasp, aquafit)       (mammoth, suds)

The snake kissed the bird. The bird was kissed by the snake.
   (viper, researcher)   (poultry, postage)

The tiger pushed the moose. The moose was pushed by the tiger.
   (leopard, sister)    (elk, glug)

The rabbit scratched the sheep. The sheep was scratched by the rabbit.
   (hare, weightless)   (lamb, toiling)

The cat chased the bear. The bear was chased by the cat.
   (tabby, servant)     (grizzly, flounder)

The lion pushed the chicken. The chicken was pushed by the lion.
   (cougar, bother)     (hen, cap)

The horse pulled the dog. The dog was pulled by the horse.
   (pony, nerds)        (puppy, teapot)

The monkey scratched the cow. The cow was scratched by the monkey.
   (ape, illusionist)   (bull, gladness)

The wolf hugged the turtle. The turtle was hugged by the wolf.
   (coyote, bailey)     (crocodile, luggage)

The zebra pulled the squirrel. The squirrel was pulled by the zebra.
   (horse, musician)    (chipmunk, tile)

The duck hugged the frog. The frog was hugged by the duck.
   (loon, pirate)       (toad, cancel)

The pig kissed the mouse. The mouse was kissed by the pig.
   (hog, decorator)     (rat, handbag)
Filler sentences (and unrelated distractors):

The teenager shaved. (keyboard, chipping)
The convict danced. (hog, wheel)
The ballerina cried. (spoon, dock)
The baton twirler tripped. (pony, toad)
The astronaut sang. (drill, blossom)
The singer laughed. (wool, elk)
The bride gave the groom a camera. (silencer, hack)
The policeman fed the fireman a sandwich. (cougar, palace)
The football player threw the helmet to his teammate. (leopard, kennel)
The grandmother gave her granddaughter a present. (beet, sucrose)
The judge opened the safe with a key. (painless, lamb)
The mailman gave a package to the soldier. (rapid, cultivator)

The ant was bleeding. (chain, bundle)
The ostrich ran. (clot, flower child)
The seal barked. (aviator, mitten)
The camel drank. (RN, burrs)
The koala bear scratched. (air conditioner, saviour)
The kangaroo hopped. (butter, repartee)
The butterfly flew into the cage. (server, mammoth)
The giraffe slept in the tall grass. (sisters, queer)
The beaver sat on the chair. (prize-fighter, monarch)
The shark swam in the ocean. (buzz, preen)
The dolphin played with the toy. (malicious, coward)
The goat ate in the cave. (error, alpinist)

The snowman melted. (horse, perch)
The helicopter landed. (gymnast, squirm)
The chandelier swung. (cap, Neanderthal)
The kite fell in the puddle. (viper, mouth)
The umbrella blew away. (conduction, cook)
The candle was burning. (Monday, stand)
The guitar string was broken. (dug, cloud)
The cover of the magazine was ripped. (needy, crocodile)
The tap was dripping. (cyclone, bend)
The phone was ringing. (numb, spectacles)
The moon rose over the mountains. (boot, lavatory)
The sword shone in the sun. (infant, bull)
Appendix E - Experimental words, including semantic and unrelated distractor words (word level task, Experiment 2).

Target nouns (semantic distractor, unrelated distractor)

Apple (pear, stand)
Bicycle (two-wheeler, tile)
Boat (ship, flower child)
Bridge (moat, cultivator)
Broom (mop, handbag)
Camera (photograph, mouth)
Desk (table, mitten)
Gate (door, burrs)
Guitar (violin, monarch)
Kangaroo (wallaby, bundle)
Key (lock, pirate)
Lamp (chandelier, queer)
Magazine (book, saviour)
Pants (slacks, kennel)
Pillow (bed, coward)
Rake (hoe, fraud)
Taxi (bus, perch)
Train (metro, squirmy)
Tree (bush, fang)
Trumpet (cornet, preen)
Whistle (noise-maker, cloud)
Window (glass, lamb)
Appendix F - Picture stimuli for the word level task, Experiment 2.

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