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Processing constraints on word order choice in language production

Benjamin H. Fuller
Lehigh University

Fuller, Benjamin H.

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Benjamin H. Fuller

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Date

Laura Gonnerman
Assistant Professor, Department of Psychology
Advisor, Committee Chairperson

Committee Members:

Padraig O'Seaghdha
Associate Professor, Department of Psychology

Catherine Arrington
Assistant Professor, Department of Psychology

Diane Hyland
Professor, Department Chairperson

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Abstract

Recently emerging processing-based accounts of language production suggest that syntactic and lexical processing constraints simultaneously determine the organization of a to-be-produced utterance (Hawkins, 1994, 2004; Gibson, 2000). This thesis includes 3 experimental studies designed to explore a processing-based account of the nature of semantic, syntactic, and experiential processing constraints involved in language production.

Three production studies examined word-order preferences in verb-particle (V-P) constructions *(e.g., look up, level off)* because they can be produced with the particle adjacent to the verb or shifted to a position after the direct object noun phrase (NP). Studies 1 and 2 explored the effects of V-P dependency *(e.g., finish up* versus *chew out)* and NP lengths on word-order choice, duration of the direct object NP, and error rates. Study 3 explored the impact of recent experiences with adjacent or shifted structures on word-order choice and error rates.

Taken together, the results of these studies provide evidence that the processing constraints associated with the semantic dependency between a verb and particle as well as the syntactic constraints associated with NP length both influence speakers' word-order choices, and that these preferences reflect the relative efficiency of each word-order choice. The results also provide evidence for an effect of structural persistence on speakers' word order preferences that is argued to reflect the relative efficiency of using a recently processed sentence structure compared to a newly generated one. Finally, the studies indicate that these processing constraints influence performance characteristics including production durations and error rates.

Thus these studies provide additional evidence for the claim that word-order choice in language production is driven by an efficiency maximization goal that coordinates a number of simultaneously competing lexical-semantic, syntactic, and experiential processing constraints. Specifically, and in accord with processing-based accounts of language production, these studies indicate that, when producing verb-particle constructions, speakers will select the ordering that requires the least processing effort or affords the greatest efficiency. Finally, the studies presented here showcase a new methodological procedure for eliciting sentence productions and this procedural design constitutes an innovative and useful contribution to the exploration of language production processes.

Introduction

Traditional accounts of language processing have tended to prioritize either structural or lexical principles in their explanations of language processing mechanisms. Most such accounts have claimed that one or the other level of processing has a computational precedence that subsequently enables the second level of processing. Therefore, such accounts would predict that word order choices in language production are primarily determined by either a set syntactic framework that governs the organization of subsequently selected lexical content, or the choice of lexical content that, in turn, conveys preferences for specific syntactic forms. In contrast to such approaches that have exhibited a tendency to prioritize one or the other level of processing, I argue that word order choices emerge from the convergence of a variety of processing constraints deriving from not only lexical and syntactic properties, but recent experiential ones as well. Therefore, this thesis contains three experimental studies of English verb-particle (V-P) constructions (a well known grammatical construction with optional word order) designed to explore how specific lexical, syntactic, and experiential factors convergently determine word order preferences.

Accounts emphasizing the importance of structural principles have generally assumed that utterances are coordinated and organized by a discrete set of formal syntactic rules that are independent of and/or have operational precedence over other language-related processes (Gries, 1999, 2002). The importance of these abstract structural configurations has been argued for in both comprehension (Levy, 2006), and production (Bock, 1990) and is outlined in some detail by Garrett (1988). The principle idea behind basic renditions of the approach is that, following a message or meaning level of processing, language production involves a functional level of processing with syntactically specified word-form categories such as verb, noun, etc., which convey associated syntactic functions. Finally, following this level of processing, language production involves a positional level of processing wherein specific words and their phonological mapping are retrieved from the lexicon and assigned to places in a hierarchical structure.

Some strong positions among such syntactically oriented models of production hold that; syntactic organization is distinct from message formulation, that it is the level of processing responsible for mapping an event structure to a syntactic structure while preserving the relational correspondences between message elements, and, finally, that syntactic processing happens before and is independent of lexical retrieval. In other words, syntactic mechanisms are thought to be responsible for the organization of the structure of a message in the form of an abstract frame that, once completed, scaffolds the selection of particular lexical items that flesh out the semantics of a message (Garrett, 1988; Bock, 1990; Konopka and Bock, 2005).

Alternatively, evidence for the influence of lexical-semantic constraints has been provided by accounts that prioritize lexical processing, maintaining that word retrieval is the first step of sentence construction such that sentence structure is eventually derived from the syntactic specifications of the selected lexical items (Bock and Levelt, 1994, MacDonald, 1997). For example, Levelt inspired one line of research with his proposal of two-stages of word retrieval (Levelt et al., 1999; Cleland & Pickering, 2003). The idea is that the lemma level of representations, when activated, begins to specify the structure of the sentence being processed through linkages to associated syntactic forms. However, in contrast to the syntactically oriented positions, many of the lexically oriented positions hold that the lemma level is specified for and represents semantic information that is passed down from the conceptual level of representation. Then, only after the syntactic structure is specified, is the representation processed further to include phonological characteristics for overt production, but much of the semantic information has been passed down all the way from the conceptual level.

MacDonald's is another example of a lexically oriented position that contrasts with traditional accounts in an important way. She refrains from speculating about the specific nature of a lexical or 'lemma' level of representation and emphasizes our capacity to learn statistical regularities from linguistic input. She argues that people are sensitive to the probabilistic patterns of grammatical relationships between lexical items such that, over time, specific lexical items come to actively cue certain syntactic structures and that the semantic characteristics of individual lexical items can come to influence the ability to comprehend and produce correct syntactic features such as noun-verb agreement (MacDonald, Pearlmutter, & Seidenberg, 1994; Thornton & MacDonald, 2003). Thus, MacDonald's position is distinct from that of other lexically oriented accounts because it specifically acknowledges the important influence of prior experience on language processing.

Thus far it has been argued that most traditional accounts of language production emphasize the priority of either syntactic or lexical levels of processing. Furthermore, many such accounts (with the notable exceptions of MacDonald and Seidenberg and Bock) tend to downplay or ignore the important contributions of prior experience to language production tasks. In sharp contrast however, the performance-based accounts that will be discussed next, not only maintain that syntactic and lexical processing constraints interactively determine the nature of language production processes, but they also expressly acknowledge the important contributions of prior experience to production processing tasks.

The alternative to the formulations of most structurally or lexically oriented positions is an approach that maintains that word-order choices are determined by processing principles like the goal of maximizing processing efficiency, which is affected by the convergence of multiple constraints. Accounts such as Hawkins' *Minimize Domains* (MiD) and Gibson's *Dependency Locality Theory* (DLT) both predict that word-order choices reflect, not the application of some rule-like organizational scheme that processes one primary component thereby enabling the processing of a secondary component, but a pattern of preferences that represents the most efficient means of simultaneously satisfying multiple constraints in the mapping of a message's meaning to a grammatically organized sentence. The most significant advantage of performance-based accounts like those discussed below is that they offer the promise of a means of integrating important aspects of both structural and lexical processing principles and also admit the importance of recent experiential influences on sentence production.

Hawkins' MiD is a prominent example of one such performance-based account of the emergence of different grammars across languages. MiD posits that discrete grammatical structures entail both combinatorial and dependency relations contained within domains consisting of the "smallest sequence of elements and their associated syntactic and semantic properties that must be processed for the production and/or recognition of the combinatorial or dependency relation in question" (Lohse et al., 2004). MiD predicts that speakers of English and other head-initial languages will prefer sentence structures that minimize the size of these domains by making the relevant information available as early as possible.

Furthermore, under this view there are no innate or parameterized universals of word-order preferences but, rather, performance constraints that become conventionalized in the form of grammars to determine preferences for optimal and sub-optimal word orders (Hawkins, 1994, 2004). Such conventionalized grammatical preferences are not rigidly fixed (as a structurally oriented account would predict) but are subject to such incidental influences as specific lexical items or even competing syntactic constraints.

Hawkins is primarily concerned with language users' ability to organize sentences into phrasal domains that allow the recognition of conceptual and relational structures. He argues that the immediate constituents (IC's) of a phrase (*i.e.*, the minimal elements required to recognize what type of phrase one is dealing with) can be recognized before all the words in a given phrase are processed, cueing the comprehender to the syntactic and conceptual structure of a sentence. Thus, for example, in the most basic V-P constructions (without any extraneous processing constraints) MiD predicts that language users will prefer the shifted structure *The students will clear the floor off* over the alternative *The students will clear off the floor* because the former reduces the number of words needed to recognize all the IC's by allowing recognition of the final noun-phrase (NP) in only 5 words while the latter requires 6 words to be processed before the NP is recognized.

Hawkins' account is appealing for a number of reasons, most of which have to do with its generalizability. The principal of MiD is applicable in both comprehension and production tasks. Comprehenders will prefer to minimize domains because early recognition of IC's provides syntactic and conceptual structural information, freeing up processing capacity. Similarly, producers should also prefer to minimize domains because doing so reduces the complexity of the representation that must be maintained until it is produced. Evidence for this claim was provided by the V-P construction corpus analysis conducted by Lohse et al. (2004), which revealed that the same domain minimization goals underlie similar structural preferences in production as well as comprehension tasks.

Another important characteristic of the MiD is that it has the ability to account for a number of cross-linguistic differences in word-order preferences. Further, MiD proposes explanations of a variety of grammatical phenomena aside from the particle placement phenomena that are of interest here. Also, though the original formulation of the MiD theory was limited to syntactic domains and the immediacy of things like phrasal constituents, more recent versions have also addressed how the theory can incorporate semantic domains as well as how interactions between the two can impact domain minimization goals (Hawkins, 2004; Lohse, Hawkins, & Wasow, 2004).

Of particular relevance to the studies presented here, Lohse et al. (2004) specifically address the importance of semantic dependencies among sentence constituents in V-P constructions. They predict that, even when the most efficient form for syntactic processing is a shifted one, idiomatic relations like that between the verb and its particle in idiomatic V-P constructions *(e.g. throw up)* may drive speakers to prefer the adjacent construction because it allows immediate completion of the idiomatic expression whereas the shifted constructions necessitate a delay as the intervening NP is processed.

Another performance-based account that makes specific predictions about word-order preferences is Gibson's DLT. The DLT was designed to provide a single account of processing difficulty in sentences with either ambiguous (garden-path) or complex (center-embedded) constructions, and is a working-memory capacity-based account of sentence processing (Gibson, 2000). The basic idea behind the DLT is that, as a sentence is being parsed there are two computational processes that tap a singular working memory resource with a fixed capacity; Storage costs reflect the effort required to maintain a representation of the structure processed thus far, and Integration costs reflect the difficulty of integrating the next word into the existing structure. The cost of integrating a new word into a structure depends on the locality or distance between the structure elements such that the integration cost is supposed to correspond to the number of *discourse referents* (DR's)[1] that intervene between the beginning of the structure and the word being integrated.

The DLT is a comprehension-based account of language processing but it has been included it as well as several other comprehension based arguments in this discussion because it is likely that many of the same processing principles underlie both language comprehension and production. Support for this claim is provided by both Kempen (2000) and MacDonald (1994, 1997), who argue that language processing need not require the complex and independent series of processing modules dedicated to conceptual, grammatical, phonological, lexical, and even working-memory processing, as is advocated by standard cognitive architectural models, but that it can be achieved in a uniform (homogenous) connectionist architecture. Kempen specifically argues that the homogeneity of such an architecture would allow it to process a bi-directional flow of activity related to both input and output, allowing the singular architecture to carry out processing related to both encoding and decoding.

So, although Gibson is concerned with comprehenders, it is reasonable to expect that language producers also experience storage costs, but that these costs are associated with the structure that has not yet been produced. So, language producers likely experience an integration cost, similarly to comprehenders, that is associated with introducing new DR's into an unrelated, uncompleted dependency relation. For example, this interpretation of the DLT would predict that, with V-P constructions, speakers will

[1] Discourse Referents are taken to be any "Entity that has a spatiotemporal location so that it can later be referred to with an anaphoric expression, such as a pronoun for NP's, or tense on a verb for events". Thus, any number of structural elements ranging in size and complexity from entire phrases down to morphemic elements seem to constitute a DR.

increasingly prefer adjacent constructions over shifted ones as semantic constraints, such as V-P idiomaticity, and syntactic constraints, such as NP length, increase, because such constraints contribute to both integration and storage costs. For speakers intent on producing a shifted construction, inserting a noun phrase in the middle of the verb particle construction is associated with an integration cost and, the more idiomatic the V-P construction, the greater that integration cost will be. Additionally, the length of the NP contributes to the storage cost associated with maintaining a representation of the particle across the NP. Accordingly, the longer the NP, the greater the storage cost.

An additional benefit of Gibson's model is that it expressly acknowledges that a number of experiential factors influence the ease with which an element is processed for integration into a partially processed sentence. He notes pragmatic considerations, including the meaning and discourse relevance of the entity, whether or not an element is focused or new in a discourse, as well as the contextual plausibility of the resulting sentence, all of which are argued to affect the difficulty of processing and reflect a tapping of working memory resources.

Though there have been several lines of research into the kinds of experiential factors that influence language processing, most of this research has focused on pragmatic considerations. For example, Clark (1981, 1989, 2004) has written extensively on the pragmatics of communication, exploring the cooperative characteristics of communicative interactions and the mechanisms through which information and referential content are *grounded*. In general, the findings from this line of research have indicated that the more available or actively represented a given piece of information is, the more efficiently and easily it can be processed.

While it seems clear that a variety of informational characteristics of recent linguistic experiences can influence processing efficiency, such informational pragmatics are really beyond the scope of this paper's emphasis on lexical and syntactic processing principles. Therefore, the exploration of experiential effects on processing constraints will be limited to the well-known syntactic phenomenon, *structural persistence* (*i.e.* the tendency for speakers to produce sentences with the same structural organization as semantically unrelated preceding sentences). Though it is almost always manipulated as a means of exploring syntactic processing, structural persistence can also be thought of as an experiential effect that underlies the repetitive nature of speech in discourse. Furthermore, structural persistence is an ideal experiential factor to study because it has been shown to be reliably inducible in numerous studies through syntactic priming manipulations (Bock, 1986, 1990; Bock & Griffin, 2000; Potter & Lombardi, 1998; Smith & Wheeldon, 2001).

So, in addition to the semantically-based pragmatic factors that Gibson notes, syntactic persistence, or the repetition of syntactic form in discourse, is an experiential factor of discourse events that influences subsequent word-order choices. Smith and Wheeldon (2001) have provided some evidence for this claim and argue that the function of such syntactic persistence is to reduce processing costs. The basic idea is that speakers will reuse recently activated syntactic structures (that are represented in trace patterns of network activation) because it is more efficient to reactivate a residual pattern of activation than to generate a new one altogether. Therefore, this paper will explore the extent to which the working memory-based experiential benefits of structural persistence can systematically modulate the word-order preferences that emerge from the interactions of syntactic and semantic contributions to processing efficiency.

The experiments presented in this thesis were designed to explore the nature of processing constraints involved in language production. They are intended to demonstrate that performance-based accounts of sentence processing hold the promise of subsuming important principles from positions that have tended to prioritize either structural or lexical processing mechanisms, while incorporating the important influence of recent experiential factors on processing efficiency. Three studies of sentence production have been conducted that were designed to explore the convergences of a limited set of semantic, syntactic, and experiential factors on the structural organization of sentences being produced by a speaker. In accord with performance-based accounts, it is argued that, when producing an utterance with an optional word order, speakers will select the ordering that requires the least processing effort (Hawkins, 1994, 2004; Gibson, 2000). However, the studies presented here go beyond such general accounts by making explicit predictions about specific lexical, syntactic, and experiential factors and their contributions to the speaker's overall processing demands and resulting word-order preferences, production durations and error rates.

Verb-Particle Constructions

To begin, language production has been notoriously difficult to study, not least because of the difficulties involved in controlling both the input to and the output from the production system without overly or artificially constraining the processing mechanisms involved (Bock, 1990, 1996). Therefore, the experimental procedures employed in these studies were designed to elicit utterances containing optional word orders without overly constraining the production mechanisms involved. These studies explore the distinct and interactive effects of one syntactic and one lexical-semantic factor known to influence particle placement in V-P constructions.

V-P constructions afford particle placement options allowing both adjacent and shifted structures (*e.g. The seamstress will patch* up *the pants* or *The seamstress will patch the pants* up, respectively). These constructions are ideal to study because the particle placement option is subject to a number of factors including lexical-semantic, syntactic, and experiential considerations. For example, Gries (1999, 2002) points out that, while shifting is generally optional, there are several factors that affect when shifting can occur. Several of these factors are lexical or semantic in nature.

For example, it has been demonstrated that particle placement is affected by syntactic factors such as the length or complexity of the direct object NP (Gries, 1999, 2002; Hawkins, 2004). Shifted constructions are acceptable with short NPs, but become increasingly less acceptable as the number of words and/or embedded clauses in the NP increase. The importance of NP length to word order decisions in V-P constructions was noted by Stallings, MacDonald, and O'Seaghdha, (1998), and experimental evidence for the claim was provided by Hawkins (1994) and Wasow (1997) who demonstrated that the choice between adjacent and shifted V-P structures is strongly determined by NP length.

The critical syntactic factor being manipulated in these studies, NP Length, is known to influence word order preferences (Stallings, MacDonald & O'Seaghdha, 1998; Gonnerman & Hayes, 2005). Longer NPs are thought to increase processing demands and induce preferences for adjacent constructions because more information must be kept activated or processed before the complete V-P is processed. The NPs being used are adopted from the Gonnerman and Hayes (2005) study and consist of phrases that are two, three, or five words long. The advantage of using the same stimuli for this study is that, in doing so, the stage has been set for a direct comparison of the relative influence of the same semantic and syntactic factors on processing efficiency in both language comprehension and production.

Particle placement is also affected by semantic factors such as the idiomaticity[2]. of a particular particle construction, or the extent to which the verb and the particle depend on one another for their shared semantic content. Idiomaticity has been shown to moderate the choice between adjacent and shifted constructions such that idiomatic V-P pairs (*e.g. throw up* or *chew out)* are preferentially produced as adjacent constructions (Fraser, 1976; Gonnerman & Hayes, 2005; Konopka & Bock, 2005). Similarly, in a study of heavy-NP shift, Stallings, MacDonald, and O'Seaghdha (1998) provided evidence for a graded degree of "shifting disposition" amongst different verbs that is explained by the frequency with which each verb has previously been used in non-adjacent constructions.

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[2] This manipulation of V-P idiomaticity (Dependency) is not to be confused with idiomatic constructions *per se*. Idiomatic constructions such as *minding the clock* are argued to be stored in memory as a singular entity and are thus not easily separable. Our manipulation though, refers to the dependency relationships of the V-P constructions which have been shown to be dependent but separable (Lohse, et. al., 2004).

The critical semantic factor that is being manipulated in these studies is the dependency of the V-P pair. Dependency is known to influence particle placement preferences such that highly idiomatic V-P pairs (*e.g. throw up*) employ adjacent constructions more frequently than less idiomatic pairs (*e.g. patch up)* (Fraser, 1976; Gries, 1999, 2002; Gonnerman and Hayes, 2005). The distinction between what is meant by the terms idiomaticity and dependency is subtle, but deserves mention. Idiomaticity refers to the extent to which the meaning of a pair of words is distinct from the conjoined meanings of its elements. Alternatively, the dependency relationship refers to the extent to which the distinct meaning of the V-P pair depends on either the verb or the particle. For these studies, the manipulations and discussion are focused on the dependency relationship between the verb and particle, though most instances of high or low dependency ratings are likely comparable to idiomaticity ratings.

The particle position preference exists because shifted constructions of highly idiomatic V-P's increase processing demands on both storage and integration capacities as a representation of the verb must be maintained across the intervening NP before the particle is processed (Gibson, 2000). However, rather than imply a dichotomy between high and low dependency V-P pairs though, it should be pointed out there seems to be a graded degree of dependency relations in different V-P pairs.

So, for example the corpus study of Lohse, Hawkins, and Wasow (2004) illustrates that there is a graded pattern of dependency in phrasal verbs, not a simple dichotomy. Specifically, Lohse et al argue that, in addition to low dependency V-P pairs (*e.g. give away, beat up*) where there is no clear semantic relationship between the verb and particle and high dependency V-P pairs (*e.g. throw up, chew out*) where the unique particle choice has a much more obvious impact on the meaning of the verb in the V-P pair, there is also a range of V-P pairs with an intermediate level of dependency (*e.g. smell up, boil off*) where the particle seems to modify the meaning of the word without fundamentally changing it.

Additionally, the Gonnerman and Hayes' (2005) exploration of word-order preferences in language comprehension distributed V-P pairs across three levels of dependency in equal groupings of high, middle, and low levels of Dependency. Dependency ratings were reflected in both a similarity judgment and masked priming task in which participants either rated the semantic similarities of root verbs (*pull)* and associated V-P constructions (*pull off*) or demonstrated faster response times to target verbs when presented with masked primes of low Dependency V-P pair's (*e.g. finish up).* The results of these semantic similarity and masked priming tasks demonstrated a graded degree of V-P dependency ratings amongst these V-P pairs.

Importantly, Gonnerman and Hayes (2005) also found a main effect of Dependency on reading latencies in a self-paced reading task such that comprehenders showed faster reading times for adjacent constructions with highly Dependent V-P pairs and faster reading times for shifted constructions with increasingly less Dependent pairs. Accordingly, the V-P pairs used in these studies have been adopted from the Gonnerman and Hayes study. In the future, a comparison of the data from these two studies might enable a direct comparison of the impact of V-P dependency on word-order preferences in both sentence comprehension and production. Further, data from this comparison might be used to provide additional support for Kempen's (2000) claim that similar processing constraints underlie both comprehension and production by demonstrating that the semantic factor of dependency has a significant effect on word-order preferences as well as production durations and that these word-order preferences are evident in language production as well as comprehension tasks.

Finally, particle placement is also affected by experiential factors. Examples include the "informational status" of the V-P construction that is moderated by pragmatic considerations such as the apparent relevance, newness, or emphasis of the target structure (Chen, 1986; Gries, 1999, 2002). A more relevant example for the purposes of these studies is structural persistence effects that result from either naturalistic or experimentally induced structural priming, and which lead language producers to preferentially reproduce recently processed syntactic structures when presented with an optional word-order (Smith & Wheeldon, 2001; Bock, 1986, 1989; Bock and Griffin, 2000; Bock & Loebell, 1990; Lombardi and Potter, 1992; Potter & Lombardi, 1990, 1998). In short, because V-P constructions are subject to a wide array of influences, controlled studies of word order preferences in such sentences can reveal the relative influences of lexical, syntactic, and experiential contributions to sentence production loads.

<u>Study 1 (Sentence Repetition Task)</u>

This study was designed to explore semantic and syntactic contributions to word order preferences in sentences containing V-P constructions. In this study, participants read a sentence containing a V-P pair of high Dependency (*e.g. chew out*), middle

Dependency (*e.g. look up*), or low Dependency (*e.g. count off)* and a direct object NP of variable Length (2, 3 or 5 words) in either a particle-shifted or adjacent construction (*e.g. The man will look up the word* or *The man will look the word up).* Participants then performed a brief, unrelated distracter task, and finally reproduced the sentence from memory. Participants were expected to occasionally produce sentences with different word orders from the stimulus sentences, changing less optimal word-orders to those that maximize processing efficiency. This expectation was based on results from other studies that have used similar procedures to obtain evidence that people do not always have a verbatim recall for sentences (Potter & Lombardi, 1990; Lombardi & Potter, 1992; Bock, 1996; Konopka & Bock, 2005). These expected particle movements are argued to be mitigated, at least in part, by syntactic and lexical contributions to processing efficiency that will occasionally drive participants to produce adjacent constructions when they are trying to recall a shifted construction, or vice versa when the processing constraints make a shifted construction more efficient.

During each session an auditory recording was made of what participants produced. This allowed an analysis of particle Position as well as analyses of production durations and error rates in different parts of the utterance. Particle movements were expected when the to-be-recalled sentence had a less than optimal word order. Specifically, main effects of Dependency and NP Length were expected on the tendency to make particle movements to adjacent positions such that higher levels of Dependency or NP Length would both increase the tendency to move the particle to an adjacent position. Additionally, particle movements towards shifted positions were only expected with low levels of Dependency *and* NP Length.

Additionally, it was predicted that an analysis of the NP production durations would reveal that they might be good indicators of relative processing demands associated with different processing constraints. Specifically, the NP duration analysis was expected to demonstrate that an NP produced as part of a shifted construction would be produced faster than the same NP produced in an adjacent construction. The reasoning behind this hypothesis is that holding on to the particle across the NP syntactic domain would increase the overall processing demands, prompting speakers to accelerate production of the NP, allowing a quicker production of the particle and reduction of processing demands. An interaction between Dependency and particle Position was predicted such that Dependency would have a significant impact on production durations for shifted constructions. Specifically, among shifted constructions it was expected that sentences containing high Dependency V-Ps would be produced faster than sentences with either middle or low Dependency V-Ps, again, because speakers should accelerate the production of sentences with greater processing demands in an effort to reduce these loads faster.

Finally, it was also expected that varying the levels of both NP Length and Dependency would result in increases in specific error rates associated with the production of either the NP or the V-P pair. In particular, it was expected that increases in NP Length would increase the incidence of productions with NP length changes. It was also expected that a number of productions might be made where speakers omitted the particle, but it was expected that they would only be more likely to do so when the sentence contained a low Dependency V-P, a long NP Length, *and* a shifted construction. These error patterns were expected to confirm the predictions about the contributions of these factors to the overall processing demands and speakers' drive to compensate for inefficient constructions.

Method

Participants

94 Lehigh University undergraduates (53 males and 41 females) participated for course credit.

Materials

The materials for this study were drawn from those used by Gonnerman and Hayes (2005) in their study of processing constraints involved in language comprehension. The three independent variables manipulated across the set of target sentences in this study were V-P Dependency, the Length of the direct object NP, and the Structure of the V-P construction. These factors are described below. Each target sentence began with a two-word subject NP (*e.g. The woman, The principal)* that was controlled for frequency of occurrence (Kucera & Francis, 1967) across conditions.

Verb-particle Dependency. 78 unique V-P constructions, matched for frequency of occurrence, were used as the verb phrases in the target sentences. These 78 V-Ps were divided into 3 groups based on the semantic dependency relationship between the verb and particle: 26 high Dependency (*e.g. chew out)*, 26 middle Dependency (*e.g. look up*), and 26 low Dependency (*e.g. count off)*. Dependency was determined by a similarity judgment task and masked priming task conducted by Gonnerman and Hayes (2005). All of the verb phrases were presented in the future tense (*e.g.* The principal *will chew out...)* in order to avoid irregular conjugations.

Direct object NP Length. For each V-P construction, 3 direct object NPs varying in Length (short, medium, and long) were created. Short NPs consisted of 2 words (*e.g.* the class), medium consisted of 3 words (*e.g.* the disruptive class), and long NPs consisted of 5 words (*e.g.* the class of disruptive students). The direct object NPs were matched for the average frequency of all the words combined in the NP. All of the NPs used the definite article, *the*, as the determiner and NP type was consistent across conditions (*i.e.,* only common nouns were used).

Verb and particle Structure. Two versions of each sentence were created for each V-P construction and each NP Length; one with an adjacent structure where the verb and particle are in adjacent positions and one with a shifted structure where the particle is placed after the direct object NP.

Thus, for each of the 78 V-P constructions 6 sentences were created reflecting the three NP Length conditions (short = 2 words, medium = 3 words, and long = 5 words) and the two Structure conditions (adjacent vs. shifted) resulting in a total of 468 target sentences. (See Tables 1a and 1b for sample stimuli.) These 468 sentences were then divided into 6 lists of 78 sentences such that each list contained only one sentence form for each particle construction. Finally, these 6 lists were halved to reduce participant fatigue, resulting in 12 lists, balanced across the NP Length and Dependency conditions, each containing 39, or half, of the target V-P items.

To reduce the proportion of sentences containing V-P constructions, 78 filler sentences were also included. These fillers varied in length and syntactic type. Thus, each of the 12 lists contained 117 sentences, 39 of which were targets including a V-P construction.

Procedure

Participants were tested one at a time in a single session in a sound attenuated room. The experimental session was conducted on a Macintosh computer running Psyscope software (Cohen J.D., MacWhinney B., Flatt M., and Provost J., 1993). Participants were presented with a sentence for 5000 ms and were asked to read it silently to themselves after which the sentence disappeared from the screen and was followed by a 1000 ms delay with a blank screen. At the end of the delay participants performed a distracter task in which they were presented with 2 nouns on the screen and were instructed to press one of two buttons on a button-box to indicate whether the words were in alphabetical order or whether they needed to be switched. The distracter task was followed by another 1000 ms delay after which a prompt <repeat sentence> appeared on the center of the screen. The prompt remained on the screen for as long as 5000 ms or until the participant responded by speaking into a head-mounted microphone connected to the button box. At the end of each trial participants depressed a key on the button box to begin the next trial. The experimental session began with several practice items and lasted between 30 and 40 minutes.

Results

Data were collected from 94 participants. 27 participants were excluded from the analyses. Of these, 13 were excluded for non-compliance with task instructions, 7 were excluded because they were non-native speakers of English, and 7 were excluded because of technical failures resulting in missing data. Each of the remaining 67 participants (34 male, 33 female) provided data on 39, or one twelfth, of the 468 unique combinations of V-P pairs, NPs, and particle positions employed in this study.

The 2,652 responses were coded for specific error types that either occurred frequently or were of conceptual interest. A summary of these errors is provided in Table 1c and is described in the following. A total of 557 (21.0%) responses were eliminated in preparation for the particle movement and NP duration analyses. Of these, six (0.2%) were removed because of a stimulus flaw that was corrected partway through the study. An additional 127 (4.8%) were removed because of a complete failure to respond, and 31 (1.2%) more were removed because they were otherwise incomplete (*i.e.* incoherent utterances, partial responses). Furthermore, a series of responses were eliminated because speakers changed the content of the sentence through a lexical substitution. Thus, an additional 61 (2.3%) were removed because participants made a lexical substitution of the subject, 165 (6.2%) were removed because participants made a lexical substitution of the NP, and 26 (1.0%) were removed because participants made a lexical substitution in the V-P pair. Lexical substitutions in the NP were troublesome because of the impact on the NP production durations, and substitutions of the V-P pair were problematic because of the obvious impact on the dependency relation. Finally, 131 (4.9%) responses were removed because participants made an addition or omission in reproducing the NP (disrupting experimental control over the NP Length) and 10 (0.4%) responses were eliminated because participants omitted the particle. Particle omissions were a conceptually interesting error type because they were only expected to occur with the low Dependency V-P pairs where the particle contributes nothing to the meaning of the V-P pair. Changes to the NP length as well as incidences of particle omissions were subsequently explored and are discussed in the *error analysis* section of the results. This left a total 2,095 correct responses on which the primary analyses were conducted.

The dependent variables for this study were the number of utterances made with particle movements (in each direction), NP production duration times, and the number of each of the previously mentioned errors made in reproduced utterances. Of those utterances produced otherwise correctly, those utterances involving a particle movement were analyzed to determine which conditions contributed to preferential reorganizations of the utterance. Though it is true that particle movements constitute an error in terms of the task instructions, such movements were an expected occurrence and, as such, are treated as a dependent variable and not one of the previously described error types. Additionally, NP durations were analyzed as an indicator of overall processing load, and the error analysis was conducted to determine which conditions increase the processing load as measured by increases in the error rate.

Particle Movement Analyses

Of the 2,095 correct productions, only 48 involved a particle movement. Of these, 43 involved particle movements towards adjacent positions, while only 5 involved particle movements towards shifted positions. For each type of particle movement a 3

(NP Length) X 3 (Dependency) chi-square test of independence was used to determine expected frequencies of occurrence and to examine whether there were meaningful effects of NP Length or Dependency on the tendency to make particle movements in either direction. Data for the particle movement analyses are presented in Tables 1d (movement to shifted) and 1e (movement to adjacent).

For particle movements towards shifted positions, the differences across NP Length and Dependency conditions were not statistically significant, χ^2 (4, N = 5) = 3.75, *n.s.* This lack of significance was not surprising given the extremely low power (power < .19) available with only 5 responses. In fact, with only 5 responses across 9 cells it is doubtful that any patterns that might have been found in the data would even be descriptively meaningful.

For particle movements towards adjacent positions, the differences across NP Length and Dependency conditions were not statistically significant either, χ^2 (4, N = 43) = 4.35, *n.s.* Again, this lack of significance was not surprising given the low power (power < .36) available with only 43 responses. A power analysis based on a medium effect size indicates that the N would need to be increased by approximately 100 to achieve a power rating close to .8.

It must also be noted that these chi-square tests for independence really only speak to the presence of an interaction between Dependency and NP Length, they do not reveal the significance of the main effects of either variable. With the extremely low incidence of particle movements obtained in this Study, it is not really possible to determine whether or not the predicted main effects of NP Length or Dependency had a significant impact on particle movements.

A greater number of movements to adjacent positions were expected in sentences with long NPs and in sentences with high Dependency V-P pairs relative to sentences with short NPs and in sentences with low Dependency V-P pairs. The opposite pattern was also expected to hold with particle movements to shifted positions, such that a greater number of movements to shifted positions would have been observed in sentences with short NPs and in sentences with low Dependency V-Ps relative to sentences with long NPs and high Dependency V-Ps.

General speaking, the chi-square tests for independence of Dependency and NP Length on particle movements towards both shifted and adjacent positions were not particularly meaningful. No significant interactions were predicted, except for the case of the movements to shifted positions (where a dramatically higher number of movements to shifted positions were expected for sentences containing both long NP*s and* high Dependency V-Ps), but the incidence of such movements was so low as to prohibit any meaningful analyses of the data. In conclusion, it seems reasonable to suggest that the lack of meaningful patterns in the data is due to the insufficient number of responses, and suggest that an improvement on the current methodology is necessary to successfully explore the influences of these constraints on particle position preferences.

Duration Analysis

The NP from each target response was selected and its duration was measured using Sound Edit 16 software running on a Macintosh computer. The software presents the audio recording data in a soundwave format such that specific regions of the audio stream can be selected, pulled out, and mapped to a variable timescale, allowing precise measurement of duration times. Of the same 2095 correct productions, 75 additional individual trials were excluded because the length of the NP production duration was more than 2 standard deviations away from the mean for that NP Length condition, indicating a delay due to recall difficulty. This left 2024 trials for analysis. The average NP production duration in ms was entered into an analysis of variance with the factors NP Length (short, medium, and long), Dependency (low, middle, and high), and particle Position (adjacent or shifted). The means presented are based on analysis by participant. Data for the NP production durations are presented in Figures 1a and 1b.

The main effect of Length was significant, demonstrating longer NP production durations as the NP Length increased (short = 628 ms, medium = 1,037 ms, long = 1,501 ms), F_1 (2, 134) = 2493.66, $p < 0.001$, F_2 (2, 150) = 664.28, $p < 0.001$, though this indicates little more than the fact that longer phrases take longer to produce.

The main effect of Dependency also proved to be significant in the subject analysis, F_1 (2, 134) = 23.61, $p < 0.001$, indicating that NPs associated with high Dependency V-P pairs were produced faster (1,010 ms) than those associated with either middle (1,078 ms) or low (1,078 ms) Dependency pairs. The item analysis of the main effect of Dependency was not significant, F_2 (2, 75) = 1.04, *n.s.*, although the data pattern was as expected. Dependency was probably not significant in the item analysis because it becomes a between-item variable in the item analysis, thereby reducing the error degrees of freedom and power of the analysis. It should also be pointed out that the main effect of Dependency on NP duration is not very interesting from a conceptual standpoint because there was no expectation that Dependency would affect NP production durations for adjacent constructions because, in such sentences, the semantic domain is already closed before production of the NP begins. What was more interesting was the interaction between Dependency and particle Position that is discussed below.

Additionally, and as was originally hypothesized, the main effect of particle Position also proved to be significant, F_1 (1, 67) = 73.83, $p < 0.001$, F_2 (1, 75) = 73.69, $p < 0.001$, indicating faster NP production rates in sentences with shifted constructions (1,002 ms) than in sentences with adjacent constructions (1,109 ms). This effect supports the original hypothesis that NPs produced as part of a shifted construction will be produced faster than when they are produced in an adjacent construction. These speeded production rates reflect a drive to accelerate production of the NP to produce the particle as quickly as possible, thereby reducing the processing demand associated with the open semantic domain of the V-P pair.

In general, the results of this analysis support the hypothesis regarding NP production durations. Specifically, among accurately recalled productions, NPs produced as part of a shifted construction were produced faster than the same NP produced in an adjacent construction, and high Dependency V-P pairs enhanced this effect. This result was anticipated because participants were expected to accelerate the production of the NP in shifted constructions to enable them to produce the particle as quickly as possible, thereby reducing processing demands by closing the open semantic domain as soon as possible. The high Dependency pairs enhanced this effect because the semantic domain of such pairs entails higher processing demands. However, it should be noted that a phrase final lengthening effect (Ferreira, 1993) makes it difficult to discern whether the relatively longer NP durations in adjacent constructions are due to lower processing demands or a drawing out of the final phrase for prosodic contour.

Error Analyses

Data concerning trials on which participants made errors were also explored. The treatment of the error analyses is essentially descriptive because the incidence rates do not all provide suitably large enough power levels and, because the exploration of the error rates was based on the decision to conduct a post hoc exploration of the data. The distribution of specific types of errors was examined to explore which of the independent variable conditions (Dependency, Length, and Original Position) contributed to higher error rates associated with either the NP or the V-P pair. The errors that were explored included instances of NP length changes and instances of particle omissions. The distribution of those 158 (6.3%) instances where participants changed the length of the NP by omitting words (*e.g. the numbers he learned* instead of *the numbers that he learned)* was explored. Those 23 (0.9%) trials where participants omitted the particle from the sentence (*e.g. The child will count the even numbers)* were also explored. The distributions of these instances of different errors are presented in Tables 1f and 1g.

The distribution of incidences of NP length changes (Table 1f) was explored because it was expected that participants would be more likely to reduce the length of the NP in sentences with long NPs. It was expected that participants might omit words from the NP because doing so would reduce the processing load associated with these longer utterances. It was also expected that participants would be more likely to omit words from a long NP when it was part of a shifted structure because doing so would allow earlier production of the particle.

The distribution pattern revealed that participants were more likely to reduce the length of the NP as the NP Length increased. Thus, short sentences were the least likely to have a length change during production (6 total), medium sentences showed an increased tendency (45 total), and long sentences were the most likely to be produced with a reduction of the NP length (107 total). This length reduction may reflect a tendency to drop one or more words from the NP, shortening that portion of the sentence and reducing the overall processing load, or it may simply reflect the fact that longer NPs provided more opportunity for recall errors in the form of omissions.

The distribution also revealed that participants were slightly more likely to change the NP length when the sentence contained a shifted construction (88 total) than when the sentence contained an adjacent construction (70 total). This pattern of length change errors reflects a tendency to shorten the NP in shifted constructions, reducing the overall processing demand and allowing earlier production of the particle.

Finally, those instances where participants produced the sentence but omitted the particle from the V-P construction were also explored (Table 1g). It was expected that participants would be more likely to omit the particle from low Dependency V-P pairs because, in such cases, the particle contributes little or nothing to the meaning of the V-P construction and omitting the particle might benefit speakers by reducing the overall processing demands. It was also expected that speakers would be more likely to omit the particle from sentences containing long NPs and shifted constructions because such sentences should entail the highest processing demands associated with maintaining the particle across the duration of the NP.

The distribution of particle omissions did not reveal that this error was much more likely under any of the Dependency conditions, although there was a *slight* increase in particle omissions with each increase in the Dependency level (6 at low Dependency, 7 at middle Dependency, at 8 at high Dependency). The distribution also failed to reveal that particle omissions were more likely in either adjacent (11 total) or shifted constructions (10 total). The only pattern that seemed to emerge from this distribution was that particle omissions appeared to occur slightly more often in sentences with long NPs (6 with short NPs, 2 with medium NPs, and 13 with long NPs). This pattern makes sense because speakers should experience slightly more difficulty producing sentences with long NPs, and particle omissions might reflect a drive to reduce these larger processing demands. However, because of the extremely low incidence of particle omissions obtained in this study, it would be a mistake to draw any firm conclusions from the distribution of these errors.

Discussion

The pattern of results obtained in these analyses provides some support for the efficiency in processing based account of word order preferences that have been argued for. Though the incidence of particle movements was so low as to preclude any meaningful analyses, the NP duration and error analyses do support the predictions concerning the contributions of factors like the V-P Dependency rating and NP Length to the processing demands associated with a given production.

Specifically, the NP duration analysis revealed that speakers are likely to accelerate the production of NPs in sentences with both high Dependency V-P pairs and in sentences with a shifted construction. The analysis revealed that the NPs in shifted constructions are produced faster than those in adjacent constructions and that high Dependency V-P pairs enhanced this effect. A production based version of Gibson's DLT predicts an integration cost associated with introducing a new discourse referent (DR) into an unrelated, uncompleted dependency relation. The intervening NP in a shifted construction is one such example a discourse referent, and it serves to increase the processing load of sentences with shifted constructions. Additionally, the higher the dependency relation between the verb and particle, the greater the integration cost of the intervening NP will be, resulting in a drive to speed production times. This is taken as indirect evidence that, in general, shifted constructions entail greater processing demands and speakers try to accelerate the production of the NP to compensate for and reduce these processing demands as early as possible. This also appears to be good evidence that high dependency relations in V-P pairs contribute directly to such increases in processing demands. This effect supports the claim that such productions entail greater processing demands and that speakers will try to speed up the production of such sentences in an effort to reduce these demands as early as possible.

Additionally, the error analyses revealed that more errors are likely to occur in sentences with long NP Lengths and shifted constructions, indicating that such productions likely entail a greater processing demand. Finally, this study has highlighted some of the difficulties associated with collecting language production data in a controlled fashion and suggests that an improvement on the methodology needs to be made in order to collect enough data for a meaningful analysis of word order preferences.

Of specific concern regarding the number of particle movements is the fact that participants were provided with the sentences they were supposed to produce. The incidence of particle movements to shifted constructions was probably so much lower than expected because the relatively small processing benefits of generating a new, shifted structure were overwhelmed by the processing benefits associated with reusing the recently processed adjacent sentence structure. Alternatively, the costs to processing efficiency of producing a new, adjacent structure were often much less than those associated with producing a shifted structure containing large semantic and syntactic domains. That is likely why the incidence of particle movements to adjacent constructions (2.05% of all productions) was so much larger than that of particle movements to shifted positions (0.24% of all productions).

An important concern regarding the NP duration analysis involves the phrase final lengthening effect (Ferreira, 1993). This effect involves the lengthening of phrase final words during production to achieve a prosodic contour. The effect is of specific concern to the NP production duration analysis because it predicts a lengthening of the NP when it is produced at the end of a sentence, that is, when the particle is produced in an adjacent position. Therefore, despite the relative lengthening of the NP that was observed in adjacent constructions, it is not clear whether this was due to the phrase final lengthening effect or whether it was due to relatively lower processing demands, and a relative drawing out of the NP in adjacent constructions. So, future experimental designs will include a terminal clause to be produced at the end of every target sentence. The phrase final lengthening effect should occur within this terminal clause, thereby allowing me to determine if any NP lengthening is due to decreased processing loads associated with particle placement decisions.

This study did not adequately demonstrate the drive to organize produced sentences with the most efficient constructions allowed. However, it did demonstrate contributions of both Dependency and NP Length to the overall processing demands as was reflected by other performance characteristics like the NP production durations and error rates. What remained elusive was evidence supporting the prediction based on Hawkins' MiD, that speakers will find shifted constructions most efficient to process in the absence of large contributions to the processing demands from related semantic or syntactic domains. As was just mentioned, it seems reasonable that this effect was elusive specifically because the sentences had just been processed and the benefits of reusing a recently processed adjacent structure far outweighed the smaller benefits associated with producing a new, shifted structure. Therefore, the next study will be designed such that participants will be presented with the components of the sentence to be produced, without any organized structure. That way, the sentences being produced will be more natural productions and will be free from any influence of recent processing. Additionally, the target sentences in this study will include short terminal clauses to help eliminate the confounding factor of the previously mentioned phrase final lengthening effects to clarify the interpretation of any differences in NP duration across NPs in different constructions.

Study 2 (Picture Description Task)

The results of the first study were promising because they demonstrated a trend towards an increasing preference for adjacent structures with greater syntactic and semantic processing constraints as was predicted by the production-oriented interpretation of Gibson's DLT. However, the method of elicitation in Study 1 was overly restrictive due to the fact that participants were simply asked to provide a verbatim recall of recently processed sentences. As a result, the study was unable to provide evidence supporting the prediction, based on Hawkins MiD, that under the lowest processing loads, speakers should prefer a shifted construction. The reduction of processing load achieved through reusing a recently processed structure must have exceeded the nominal benefit that might have been achieved through generating a novel, shifted structure.

Syntactic priming has been shown to have a robust effect across a variety of structures and has been demonstrated to have an implicit effect on the on-line recreation of recently perceived sentences (Bock, 1986, 1989; Bock & Loebell, 1990; Lombardi & Potter, 1992; Potter & Lombardi, 1998). Therefore, the second study was specifically designed to induce participants to freely produce a limited set of utterances without any influence on word order choice from previous exposure. This procedural modification was expected to enable participants to produce sentences free from structural persistence effects, and it was expected to yield additional data supporting my Gibsonian predictions.

as well as evidence supporting the preference for shifted structures with low semantic and syntactic processing constraints that would be predicted by Hawkins' MiD (1994, 2004).

To this end, participants were shown a series of trials displayed on a computer screen, each of which included a picture portraying a moderately complex scene in which an actor was performing a clearly identifiable action (see Appendix). Other production studies have used picture cues to elicit sentences from participants (Bock, 1986; Bock & Griffin, 2000; Smith & Wheeldon, 2001; Wheeldon & Smith, 2003). However, the details of this elicitation procedure (outlined below) are considerably different than those of Wheeldon and Smith's procedures, which used visual cues to indicate simple relations between pictorial elements that then served as the content for the production of simple sentences. They also differ from those of Bock's procedures in which participants were asked to create a sentence describing a depicted scene using a few provided target words that corresponded to key elements of the scene. In this study though, participants were presented with text-based displays of sentence constituent words (displayed in a random order) needed to produce a sentence describing a relatively complex picture. Then, after viewing this presentation for several seconds, participants were asked to produce an utterance, using the constituents provided, to describe the scene depicted.

Crucially, there were two word order options possible. The structure of these utterances was analyzed with the expectation that they would reveal main effects of Dependency and NP Length on word order choice. Specifically, a higher percentage of shifted constructions were expected to be made in sentences containing both low Dependency V-Ps and short NP Lengths, and a lower percentage of shifted constructions were expected to be made in sentences with high Dependency V-Ps or long NP Lengths. It was also expected that NPs would be produced more quickly in shifted productions than when the same NP is produced as part of an adjacent production, and that higher levels of Dependency would also contribute to an acceleration of the NP production in shifted constructions. Finally, it was also expected that high Dependency pairs and long NP Lengths would contribute to increased error rates

Method

Participants

68 Lehigh University undergraduate students (roughly equal numbers of male and female participants) participated in this study for course credit. All participants were native speakers of American English.

Materials

The materials for this study consisted of a subset of the V-P constructions and associated sentence constituents used in the first study. A total of 90 stimuli (45 targets and 45 fillers) were chosen from the target V-P's and filler verbs from Study 1 that were easily visually depicted. From each level of the Dependency condition 15 target stimuli were drawn, resulting in a total of 45 target stimuli. These were sketched in black and white by a skilled artist. The additional information provided by the sentence constituents (described below) makes the images unambiguously interpretable. There were two important manipulations implemented across the target stimuli: V-P Dependency and the Length of the direct-object NP. Each of these factors is described below.

Verb-particle Dependency. The 45 target V-P pairs were chosen such that they were equally divided among three levels of Dependency. 15 were drawn from the set of high Dependency V-P pairs used in study 1 *(e.g. chew out)*, 15 were drawn from the set of middle Dependency V-P pairs *(e.g. look up),* and 15 were drawn from the set of low Dependency V-P pairs *(e.g. count off)*.

Direct object NP Length. For each of the 45 target V-P constructions, there were three NPs of varying Lengths (short, medium and long) drawn from the sentences used in Study 1. Short NPs consisted of 2 words (*the burglar)*, medium NPs consisted of 3 words (*the masked burglar),* and long NPs consisted of 5 words (*the burglar and his friend*). The resulting sentences were divided into separate lists, such that each V-P construction appeared once in each list, and equal numbers of short, medium, and long NPs appeared in each list. Thus, for example, List 1 included the target production *The man will head the burglar off,* List 2 included the sentence *The man will head the masked burglar off,* and List 3 included the target *The man will head the masked burglar and his friend off.* Finally, each of these three lists was presented in one of two randomized orderings, to control for any inadvertent ordering effects, resulting in a total of 6 different lists.

Sentence constituents. For each of the 45 target V-P pairs, the associated sentences (drawn from Study 1) were divided into 4 constituents including: 1) a subject; 2) an auxiliary plus verb; 3) a direct object NP and; 4) a particle (*e.g. The man / will head / the masked burglar / off*). These four sentence constituents were presented in the four corners of the display surrounding the picture. The position of these constituents was pseudo-randomized to avoid any priming that might occur if participants were to learn, for example, that the direct object NP always occurred in the upper right corner of the display.

Filler trials, which occurred in an equal ratio to target trials, were drawn from the set of filler verbs used in Study 1. Filler sentences were also divided into 4 sentence constituents including a subject, a verb, and an NP. Instead of a particle, the fourth constituent in the filler trials was a prepositional phrase, an adverb, or an adjective or adjectival phrase. As with the target trials, the sentence constituents for filler trials were displayed in the corners surrounding the appropriate picture. The same 45 filler trials were included in each of the 6 lists in a different random ordering, so that each list contained 90 picture production trials, half of which were targets and half of which were fillers.

Participants were also presented with a "frame" for the sentence they would be constructing that included the subject of the sentence and a final clause (*e.g.* "*The man*_______________*by himself.*"). The frame served to control those conditions where the subject and object of the VP were potentially interchangeable (*e.g. The masked burglar will head the man off.*) The final clause was included to control for any wrap-up effects, such as the slowing of production speed, which might otherwise have affected the measures of NP production duration in adjacent constructions.

Procedure

As in the first study, participants were tested one at a time in a single session in a sound attenuated room. The experimental session was conducted on a Macintosh computer running Psyscope software (Cohen J.D. et al., 1993). Participants were first presented with the subject of the sentence and a final clause such as "*The man* ________ ______ *by himself.*" This stimulus remained for 1500 ms to serve as a "frame" for the sentence participants would construct. Next, this screen was replaced and the participants were shown the picture of the scene with the sentence constituents placed in each corner of the display. Participants were given 5000 ms to look at the picture and read the sentence constituents, after which the constituents were removed and replaced by the original sentence "frame". At this point, participants produced aloud a sentence describing the depicted scene by using all of the constituents just read. Sound recordings were made of each session and were analyzed for particle placement choice, NP production duration, and errors. The experimental session began with several practice items and lasted between 30 and 40 minutes.

Results

Data from five of the 68 participants was excluded because of errors in one trial list that were detected and corrected part way through the experiment. An additional six participants were excluded because of errors with the recording device that resulted in a loss of data. This left a total of 57 participants who provided data on 45, or a third, of the 135 unique combinations of V-P pairs and NPs employed in this study.

The 2,565 sentences produced for this study were coded for specific error types that either occurred frequently or were of conceptual interest. A summary of these errors is provided in Table 2a and is described in the following. A total of 211 (8.5%) were removed because they contained one of the following types of errors. Of these, 22, (0.9%) were removed because of a failure to respond and 5 (0.2%) were eliminated because the response was otherwise incomplete (i.e. it was an incoherent utterance or only a partial response). An additional 22 (0.9%) were removed because a lexical substitution was made in the NP, and 26 (1.0%) were removed because a lexical substitution was made for either the verb or particle. An additional 96 (3.9%) were removed because participants added or omitted words in the NP, thereby changing its length. Finally, 40 (1.6%) of the responses were removed because the particle was omitted from the utterance. This left a total of 2,354 responses on which the Particle Position and NP duration analyses were conducted.

The dependent variables were the percentage of sentences produced with a shifted (non-adjacent) construction, NP production duration times, and the percentage of sentences produced with specific errors. Of those utterances produced correctly, particle placement was analyzed to determine which conditions led to preferences for either adjacent or shifted constructions. NP durations and error rates were also analyzed as indicators of processing difficulty.

Particle Position Analyses

Of the 2,354 correct productions, the percentage containing a shifted construction (503 items or 21.4% overall) were entered into an analysis of variance with the factors NP Length (short, medium, and long) and Dependency (low, middle, and high). The means presented are based on analysis by participant and data for the particle position analyses are presented in Figure 2a.

The main effect of NP Length was significant, F_1 (2, 112) = 14.86, $p < 0.01$, F_2 (2, 84) = 16.05, $p < 0.01$, indicating an increasing preference for shifted structures with shorter NPs (28% shifted) than with medium (19% shifted) or long NPs (16% shifted). The main effect of Dependency was also significant, F_1 (2, 112) = 22.65, $p < 0.01$, F_2 (2, 42) = 3.21, $p < 0.05$, indicating a greater preference for shifted constructions with low Dependency V-P pairs (28% shifted) than medium (20% shifted) or high (16% shifted) Dependency V-P pairs. The df within differ for the two item analyses because Dependency is treated as a between item variable in the item analyses. The interaction between NP Length and Dependency was not significant.

These results support the hypotheses that speakers will show a strong preference for adjacent constructions with long NP Length's and high Dependency V-P's, and that speakers will show a relative preference to produce shifted constructions in sentences containing short NP Length's and low Dependency V-P's. These different construction preferences under differential processing demands are consistent with drives to enhance processing efficiency by either, minimizing working memory loads associated with productions that involve high processing demands, or, in sentences with low processing demands, allowing the earliest possible release of all the sentence's ICs.

NP Duration Analyses

The NP from each target response was selected and its duration was measured using Sound Edit 16 software running on a Macintosh computer. An important difference between the NP duration analyses for Studies 1 and 2 involves the fact that the stimuli sentences in Study 2 included short terminal clauses that were included to help control for the influence of the phrase final lengthening effect (Ferreira, 1993), which, in the case of Study 1, made it difficult to discern whether the relatively longer NP durations in adjacent constructions were due to lower processing demands or a drawing out of the final phrase for prosodic contour. Of the 2,354 correct responses, an additional 139 were cut for the NP duration analyses because the length of their NP production was more than 2 standard deviations away from the mean production duration at each level of NP Length. This left 2,215 responses for the following analyses. The average NP production duration was entered into a 3 X 3 X 2 analysis of variance with the factors NP Length (short, medium, and long), Dependency (low, middle, and high), and particle Position (adjacent or shifted). The means presented are based on analysis by participant. Data for the NP duration analyses are presented in Figures 2b and 2c.

The main effect of NP Length was significant, F_1 (2, 110) = 1734.48, $p < 0.001$, F_2 (2, 42) = 471.91, $p < 0.001$, indicating little more than the fact that shorter NPs are produced faster than longer NPs (short = 593 ms, medium = 969 ms, and long = 1,376 ms).

The main effect of Dependency was also significant in the analysis by subject, F_1 (2, 110) = 16.25, $p < 0.001$, but not in the analysis by item, F_2 (2, 42) = .59, *n.s.* The item analysis reveals that, at least for the analysis of production durations, there was more variance among the items within each Dependency level then there was across the Dependency levels. This is not very surprising given that the variance of the production durations is subject to much more dramatic determiners like the overall length of the NP (either in words or syllables), so the variability between items is bound to be much higher than the variability across levels of Dependency. It should also be pointed out that the main effect of Dependency on NP duration is not as interesting from a conceptual standpoint, because there is no reason to expect that Dependency should have any effect on NP durations in adjacent constructions. What is more interesting and conceptually motivated is the analysis of the interaction between Dependency and particle Position that is discussed below.

The main effect of Position was also significant, F_1 (1, 55) = 24.72, $p < 0.001$, F_2 (1, 42) = 17.88, $p < 0.001$, indicating that sentences with shifted constructions were produced faster (946 ms) than sentences with adjacent constructions (1,013 ms). This finding supports the original hypothesis and demonstrates a drive to accelerate production of the NP to produce the particle as soon as possible in shifted constructions. This allows a reduction of the higher processing loads associated with maintaining the open semantic domain associated with a shifted V-P construction as soon as possible.

There was also a significant interaction between Dependency and Position, F (2, 110) = 4.25, $p < 0.02$, indicating that, while there are faster production times with both shifted constructions and sentences containing high Dependency V-P pairs, there is also an increasing impact of Position on production duration times at increasing levels of Dependency. So, while position did have an impact on production durations for low Dependency V-Ps, the position effect increased at mid Dependency V-Ps, and again for high Dependency V-Ps such that productions containing *both* high Dependency V-Ps and shifted constructions were produced the fastest (Figure 2d). Again, as was the case with Study 1, this indicates that speakers will accelerate the NP production most in sentences containing high Dependency V-Ps produced in a shifted construction. This acceleration reflects a drive to produce the particle in such sentences as soon as possible. Notably, the benefits to processing efficiency achieved by producing high Dependency V-P pairs in adjacent positions is reflected by production durations that are just as long as those associated with low Dependency pairs produced adjacently.

Error Analyses

Data concerning trials on which participants made errors were also examined. The distribution of two types of errors was examined to explore which conditions of V-P Dependency, NP Length, and particle Position contributed to higher error rates associated with the production of the NP and the V-P pair. Those 89 (3.6%) responses in which participants changed the length of the NP by omitting words (*e.g. The child will count off numbers* instead of *The child will count off the numbers)* were examined. These responses were coded as containing an NP length change. Those 40 (1.7%) responses where participants produced the verb but omitted the particle (*e.g. The child will count the numbers* instead of *The child will count off the numbers)* were also explored. These responses were coded as containing a particle omission. The distributions of these error types are presented in Tables 2b and 2c.

The distribution of NP length changes was explored (Table 2b) because it was expected that participants would be more likely to reduce the length of the NP in sentences with long NPs because doing so would reduce the processing demands associated with these longer utterances and because sentences with longer NPs afforded more opportunity to commit a recall error by omitting words that contributed little to the overall meaning of the sentence.

The distribution revealed that participants were more likely to change the length of the NP when it was long (73 total) than when it was short (0 total) or medium (16 total) in Length. The higher incidence of NP length changes among long NPs may reflect a drive to reduce the processing demands associated with these longer utterances or, alternatively, it may simply reflect the fact that, among longer NPs, there was greater opportunity to omit words without changing the meaning of the sentence.

It was also expected that participants would be more likely to omit words from a long NP when it was part of a shifted structure because doing so would allow earlier production of the particle. The distribution revealed that participants were actually more likely to change the length of the NP when it was part of an adjacent construction (70 total) than when it was part of a shifted construction (19 total). In contrast to the prediction that speakers would be more likely to drop words from the NP in shifted constructions to allow earlier production of the particle, the observed tendency to change the NP length more often in adjacent constructions suggests that, once the particle has been produced adjacently, speakers may be trying to finish production of the sentence as quickly as possible by omitting words that are not necessarily important to the meaning of the NP.

Additionally, the distribution of those instances where participants produced the sentence but omitted the particle from the V-P construction (Table 2c) was examined. It was expected that participants would be more likely to omit the particle from low

Dependency V-P pairs because the particle contributes little, if anything, to the meaning of these pairs, so omitting the particle could be expected to reduce the processing demands associated with these productions without affecting the meaning of the sentence.

The distribution showed that the largest number of particle omissions did occur with low Dependency V-P pairs (16 total) , an intermediate number of omissions occurred with the middle Dependency pairs (14 total), and that the fewest number of particle omissions occurred with high Dependency pairs (10 total). This pattern indicates that, as the contributions of the particle to the meaning of the V-P pair decreases, participants are more likely to omit the particle.

It was also expected that participants would be more likely to omit the particle from sentences containing long NPs than from sentences with either short or medium Length NPs. This expectation was held because sentences with longer NPs entail higher processing demands that might induce speakers to omit unnecessary words to lessen this load. Also, based on the pattern of NP length changes, it seemed likely that, as the Length of the sentences increased, speakers would be more likely to omit words, either because there were simply more words to remember, or because speakers drop words to reduce the processing demands associated with longer sentences. The distribution of particle omissions confirmed this expectation and revealed that speakers were, in fact, more likely to omit the particle from sentences with the longest NPs (27 total) than sentences with medium (8 total) or short NPs (5 total).

Discussion

Taken together, the results of these analyses support the hypothesis that speakers will choose word orders that maximize processing efficiency. The particle position analysis revealed that speakers will do this by producing adjacent constructions more frequently in sentences with high Dependency V-P pairs and long NP Lengths, and shifted constructions in sentences with low Dependency V-P pairs and short NP Lengths. As would be expected by the relatively small proportion of targets with both short NP Lengths and low Dependency V-Ps relative to those with higher levels of one or both variables, there was a general preference for adjacent constructions. However, a number of sentences were produced with shifted constructions. More importantly, there was a dramatic difference in the percent of productions using a shifted construction across those targets with high levels of both Dependency and NP Length versus those with low levels of both Dependency and NP Length. Under the highest levels of Dependency and NP Length, only 13% of the sentences produced contained a shifted construction. But, under the lowest levels of Dependency and NP Length, 35% of the sentences produced contained a shifted construction.

In contrast to Study 1, where it was argued that the relative benefits of choosing to produce a shifted construction in sentences with small semantic and syntactic domains were overwhelmed by the benefits associated with the structural persistence effects that lead speakers to produce structures similar to those that had just been processed, the results of the particle position analysis from this second study demonstrated a distinct willingness to produce shifted structures in sentences with small semantic and syntactic domains. These results support the original prediction, based on Hawkins' MiD (1994, 2004), that, in the absence of other contributions to processing demands (such as the long syntactic or semantic domains that would be associated with NP Length or Dependency), speakers will show an increased preference for shifted constructions. This preference exists because, by allowing the earliest release of the sentence's IC's without incurring much cost from the yet unproduced particle, shifted constructions are the most efficient structural organization for V-P's.

However, speakers were less likely to produce a shifted construction at increasing Dependency levels because the extension of the associated semantic domain across the NP would increase the overall processing demands, making an adjacent construction the more efficient choice. Similarly, speakers were less likely to produce a shifted construction as the NP Length increased because the maintenance of the V-P based semantic domain across increasingly long syntactic domains made adjacent constructions increasingly efficient.

Thus, this analysis also provided additional support for the hypothesis, as predicted by a production-based interpretation of Gibson's DLT (2000), that when the processing demands are higher due to increasing working memory loads associated with the syntactic and/or semantic domains, speakers will increasingly prefer adjacent structures because producing the particle as early as possible reduces the storage and integration costs of maintaining it across the production of the NP.

Additional analyses were conducted on NP production durations with the assumption that they might be good indicators of relative processing demands.

Interestingly, and in line with the original hypothesis, the duration analysis revealed that NPs produced as part of a shifted construction were produced faster than when the same NPs were produced as part of an adjacent construction. This reflects a drive to accelerate production of the NP in shifted constructions to reduce the heightened processing demands associated with the extended semantic domain in those shifted V-Ps by getting to the production of the particle as soon as possible. The NP duration analysis also confirmed the expectations that the NP would be produced faster in sentences with high Dependency V-P pairs, and that NPs will be produced fastest in those productions that involve *both* a high Dependency pair and a shifted construction. This pattern of results supports the expectation that speakers will try to ease the processing strain associated with less efficient sentences by accelerating the production of an intervening NP to allow earlier production (or release) of the particle. Furthermore, because of the inclusion of the short terminal clauses in the stimuli for this study, it seems likely that these effects are not due to a lengthening of the NP to achieve a prosodic contour but rather, that they reflect differences in processing efficiency in productions with different word orders.

Finally, the error analysis indicated that many of the errors that speakers make in producing sentences with V-P constructions may also serve to reduce the processing demands of a given production. So, for example, speakers had a greater tendency to omit words from longer NPs than shorter ones. This may reflect a drive to omit unnecessary words from more cumbersome sentences, or it may simply reflect greater opportunity to make omission errors in sentences with long NPs. A more telling error pattern was the one concerning particle omissions, which revealed that speakers were more likely to omit particles from sentences containing low Dependency V-P pairs and from sentences with long NP Lengths. This pattern indicates that speakers are most likely to omit a particle from a sentence when the particle either contributes little or nothing to the meaning of the sentence and thus represents an unnecessary contribution to the processing demands, or when the sentence contains a long NP so production of the particle (at least in shifted constructions) would entail an integration cost associated with the insertion of the NP and a storage cost associated with the maintenance of the particle across the duration of the entire NP.

The results of these analyses indicate that, when producing sentences with small syntactic and semantic domains associated with short NP Lengths and low Dependency V-Ps, speakers exhibited a preference for producing shifted constructions. Alternatively, when producing sentences with larger syntactic and semantic domains associated with long NP Lengths and high Dependency V-Ps, speakers preferentially produced adjacent constructions. This suggests that both the semantic domain associated with V-P Dependency and the syntactic domain associated with NP Length contribute to the relative efficiency of one construction versus another. Additionally, the difference in the pattern of results between Studies 1 and 2 indicates that the explanation of the lack of shifted structures found in Study 1 was likely correct. The benefits to processing efficiency associated with producing the target sentence exactly as it was presented, outweighed the benefits associated with producing a new, shifted construction, even in those conditions where the small syntactic and semantic contributions made the shifted construction the more efficient choice. This contrasting pattern of results across the two studies indicates that there is likely an effect of structural persistence on the relative processing efficiency associated with different sentence constructions. Therefore, the third and final study of this project will explore structural persistence effects directly.

Study 3 (Structurally Primed Picture Description Task)

Structural persistence is a frequently observed phenomenon in naturalistic discourse events that is easily induced in laboratory experiments through both initial phrasal similarities (Smith and Wheeldon, 2001; Wheeldon and Smith, 2003) as well as lexically-based conceptual similarities (Potter and Lombardi, 1990). However, much of the research that has employed manipulations of syntactic priming has done so not to explore the mechanisms or effects of structural persistence on processing efficiency, but rather to try to differentiate between structurally and lexically oriented accounts of sentence production processes (Bock & Loebell, 1990; Bock & Griffin, 2000; Smith & Wheeldon, 2003; Konopka & Bock, 2005). The idea has been that, if syntactic priming can be shown to exert its effect at an early, functional level of encoding, then it could be inferred that the lemma or lexico-syntactic level of processing carries the effect. If, on the other hand, the priming could be shown to occur somewhat later at a positional (structural) level of encoding, then it could be inferred that a purely syntactic level of processing carries the effect and is responsible for the structural organization of sentences being produced.

Moving beyond exploration of the level of encoding or representation at which structural persistence works, several experiments have actually sought to explain the mechanism behind the effects of this structural persistence phenomenon. The idea that reusing syntactic structures serves to reduce the speaker's processing effort has both theoretical and empirical grounding. This idea of reduced processing effort was first proposed by Levelt and Kelter (1982) and later by Bock (1986). More recent researchers such as Smith and Wheeldon (2001) and Potter and Lombardi (1998), have argued that structural persistence serves to reduce the processing effort required by the speaker. Direct evidence for this claim was provided by Smith and Wheeldon, whose on-line study of priming effects on processing speed indicated that syntactic priming served to reduce the processing effort required to generate new sentences, as measured by initiation times.

Additionally, Potter and Lombardi (1998) provided a more detailed explanation of why people have a tendency to reuse recently activated surface structures when the conceptual message of the to-be-produced utterance permits. Lombardi and Potter (1992) and Potter and Lombardi (1990, 1998) argue that there is no explicit memory for the surface syntactic structure of a perceived sentence. Rather, there is an explicit memory for a conceptual-level representation that can be thought of as motivating sentence formulation along standard production mechanisms. On this account, structural persistence results from the implicit memory trace of similar, recently processed structures. Potter and Lombardi argue that the coordination of the explicit conceptual memory and implicit structural trace can account for both short and longer-lasting structural persistence effects. This paper adopts this latter perspective and maintains that, while participants' target productions are constructed by normal production processes, these processes are subject to the transient influence of implicit traces of recently activated structures. Further, these implicit memory traces may contribute to relatively short-term benefits to processing efficiency but they do not indicate any longer-term learning.

This last point leads to a remaining consideration in the syntactic priming literature that requires some discussion before proceeding to the current study. That consideration is the question of how long-lasting the influence of structural persistence is. For example, Bock and Griffin (2000) report a robust priming effect of dative or transitive forms (both of which allow adjacent or shifted constructions of V-P pairs) that persisted across as many as 10 unrelated intervening filler stimuli. They interpret this persistence as evidence of implicit learning processes at work at the level of functional syntax. On the other hand, Wheeldon and Smith (2003) provide evidence from a positional or surface level NP priming study that failed to find any persistence of the priming effect beyond even one intervening filler item, leading them to argue that the effect derives from a residual activation that is subject to rapid decay, not implicit learning.

Following Wheeldon and Smith's (2003) explanation, the reason their results were so short-lived is because they were investigating a relatively late-occurring, positional level of processing involving simple or coordinate initial NP structures (*e.g.* "the eye moves up and the fish goes down" vs. "the eye and the fish move up"). In contrast, Bock and Griffin's (2000) evidence for long-lasting persistence of structural priming effects was based on a much earlier-occurring, functional level of structural processing involving transitive or passive constructions (*e.g.* "An ambulance is hitting a policeman" vs. "A policeman is being hit by an ambulance") and single or double object datives (*e.g.* "A boy is giving an apple to a teacher" or "A boy is giving a teacher an apple").

Both sets of constructions used by Bock and Griffin involve a structural decision that is thought to occur at an earlier, functional level of processing than the later, positional-level decision analyzed by Smith and Wheeldon. Therefore, Bock and Griffin found such a long-lived structural priming effect because the prime and production events influenced more levels of processing (*e.g.* functional, *and* positional) whereas Smith and Wheeldon's prime and production events only involved the final, positional, level of processing. Thus, Smith and Wheeldon argue that this difference in degree of processing influence should explain the observed differences in persistence of structural priming.

This paper proposes that syntactic priming does result from residual patterns of activation in implicit memory and argue that the differential decay rates noted in the literature are actually determined by the degree of priming influence on different levels of processing. A priming stimulus that influences an earlier stage of processing should have a more enduring impact that persists longer than a prime that influences a later stage of processing, because an influence at an early level of processing would affect subsequent processing stages, compounding the influence. The word-order choice involving particle placement for V-P pairs occurs at a later, positional level of processing so it was predicted that the effects of priming these structures should be relatively short-lived.

It was hypothesized that the processing benefits obtained through priming specific V-P constructions would have an impact on word-order choices in subsequent productions. It was also expected that the previously demonstrated semantic effects of

Dependency would continue influencing word order choices. Finally, it was hypothesized that, because the priming influences a later stage of processing, the processing benefits conferred through these structural persistence effects would diminish rapidly as the lag between prime and target production increased and the residual activation pattern corresponding to the primed structure decayed.

To test these hypotheses about the effects of priming Structure, priming Lag, and V-P Dependency on word-order choices, a third experiment was conducted in which participants were primed with a specified syntactic structure by presenting them with a priming sentence in a *Rapid Serial Visual Presentation* (RSVP) procedure and then asking them to immediately reproduce the sentence from memory. Target productions were elicited by asking participants to complete the picture-description task from Study 2. This procedural design offered a significant advantage over the production elicitation procedure used in Study 1 as well as that employed by Konopka and Bock's (2005) study of structural persistence. The studies reported by Konopka and Bock were designed to explore the relative priming ability of idiomatic versus non-idiomatic phrasal verbs and the results did not suggest any differences in the priming ability of the two types of phrasal verbs. However, a critical limitation of their methodology, as well as the methodology of Study 1, involved the fact that both prime *and* target sentences were presented in an RSVP procedure. This manner of presenting the target sentence effectively served to prime the participant twice, once with the initial priming stimulus, and again with the target stimulus. Additionally, it should be noted that, though Konopka and Bock's (2005) study found no evidence for an effect of the idiomaticity of a priming

V-P pair on syntactic priming, the priming stimuli in this study were limited to V-P pairs with only mid-level Dependency ratings.

By eliciting target productions by means of the picture production task employed in Study 2, participants were able to freely produce target sentences however they saw fit – not simply as they were recalled from memory. This eliminated any potential priming effects that might have ensued from processing the sentence for comprehension purposes, and ensured that any priming resulted only from the manipulation. Other priming studies have used picture stimuli to elicit productions, but none of them have presented both images of complex scenes and all the elements of the sentence to be produced (Bock, 1986; Smith & Wheeldon, 2001). However, the procedure employed here is, for the purposes of this study, an improvement over Smith and Wheeldon's as well as Bock's, because it allows the experimenter to specify all the content of the sentence instead of only a limited set of target words corresponding to key elements in the depicted scene.

The independent variables manipulated in this study included priming Structure (*i.e.* whether the prime sentence contained adjacent or shifted V-P constructions), priming Lag (*i.e.* whether 0 or 5 filler trials intervened between prime and target sentences), and Dependency (*i.e.* whether the target sentence contained a high Dependency V-P pair or a low Dependency V-P pair). The auditory recordings of produced target sentences were analyzed for word order choice as well as specific errors. Particle Positions were analyzed to determine whether priming Structure could have an additional effect on word order choices in addition to the semantic manipulation that Studies 1 and 2 have shown to impact word order preferences. Error rates were analyzed with the expectation that they would reveal similar effects of semantic and syntactic constraints as were revealed in Studies 1 and 2. NP durations from this study were not analyzed because there was no expectation that structural persistence would affect production rates to produce production duration effects different from those observed in Studies 1 and 2.

Patterns of particle Position choices under different combinations of the three independent variables were expected to reflect the most efficient word-order choice. Specifically, it was predicted that particle Position choices would be significantly influenced by priming Structures. From a processing standpoint, it should be more efficient to produce a target sentence with a recently processed syntactic structure than with an alternative structure that has not been recently processed. A main effect of Dependency was expected to demonstrate a greater tendency to produce shifted productions with low Dependency V-Ps and a lowered tendency to produce shifted constructions with high Dependency V-Ps. A main effect of priming Lag was also expected to indicate that the impact of this priming influence would be moderated by the length of the interval between the priming stimulus and the target stimulus such that, the longer the interval, the less the influence would be.

An interaction between Priming Structure and Priming Lag was also expected such that long Lags should be much more likely to reduce the effect of shifted priming Structures on word-order choices than adjacent priming Structures. This interaction was expected because, with adjacent priming structures, a relatively low percentage of shifted constructions was expected across both Lag conditions because of the general preference for adjacent constructions. With shifted priming structures though, some differential effects were expected across the two lag conditions. At short Lags a considerably large percentage of shifted constructions was expected because of the ongoing effect of the priming stimulus; however, with long lags, a comparably low percentage of productions was expected to contain shifted constructions because the effect of the priming stimulus was expected to dissipate over the long Lag so the particle position preferences were expected to become increasingly subject to the overall preference adjacent constructions. Again, these expected patterns of particle placement preferences should reflect the influence of structural priming on processing efficiency. There was no expectation that Dependency would significantly influence this interaction.

Method

Participants

72 Lehigh University undergraduate students (36 male and 36 female participants) participated in this study for course credit. All participants were native speakers of American English and received course credit for their participation.

Materials

This study combined the different tasks employed in the previous two studies and involved two distinct sets of materials. Participants read and reproduced sentences similar to those used in Study 1. These were referred to as reading sentences. Participants also performed the picture production task on a subset of the items used in Study 2. Participants read and reproduced a total of 255 reading sentences (48 were priming sentences for the target productions and 207 were filler sentences). They also performed 48 picture production trials (24 were target production trials and 24 were filler trials). In this study, 3 manipulations were implemented across the target production trials: V-P Dependency (high and low); priming Structure (adjacent or shifted); and prime-to-target Lag (short or long). Each of these is described below.

However, before proceeding to detailed descriptions of the manipulations and list construction, it must be acknowledged that a series of errors were committed during the actual implementation of the design for this study. What follows here is a description of the manipulations and how they were intended to be distributed within and across each trial list. During the actual implementation though, a series of mistakes resulted in the manipulations not being balanced within each trial. Details on how the manipulations were actually distributed are provided in the *Results* section, but the following is a description of how the lists were intended to be balanced.

V-P Dependency. 24 sets of picture production stimuli were drawn from the materials used in Study 2. Half, or 12, of these picture production stimuli were selected from the set of high Dependency V-P pairs. The other 12 were selected from the set of low Dependency V-P pairs. This resulted in a total of 24 V-P pairs divided into two equal groups of twelve on the basis of V-P Dependency. Additionally, each of the 24 V-P pairs used in a target production was matched with a long (5 word) NP Length (see image 2 in the Appendix).

Priming Structure. Each of the 24 production trials was preceded by the reading and reproduction of one of 48 different priming sentences. The priming sentences were drawn from Study 1 and entailed medium-level processing demands (*i.e.* with a mid-level V-P Dependency rating and a medium Length NP). Then, 24 priming sentences were chosen from Study 1 and each was presented in both particle adjacent and particle shifted constructions resulting in 48 different priming sentences. This allowed each of the 24 target production trials to be primed with either an adjacent V-P structure or a shifted V-P structure. This yielded a total of 48 different prime and target combinations. The priming sentences were divided into two lists, so that participants read each priming sentence only once, either in its adjacent form or in its shifted form.

Prime to target Lag. Each of the prime and target combinations were presented in two different prime-to-target lag conditions. Short lag conditions involved a priming sentence immediately followed by the target production trial, yielding a short lag period of 0. Long lag conditions included a prime-to-target lag of 5 filler sentences that had to be read and reproduced between the priming event and the target production, yielding a long lag period of 5. To reduce participant fatigue these 96 prime-lag-target combinations were divided into 4 lists such that each list contained a different version of a prime-lag-target combination for each of the 24 target productions.

In addition to the 24 prime and target pairs, each of the four lists also included 207 filler reading sentences that were semantically and syntactically unrelated to the priming sentences and the target productions. These sentences were mainly dative or passive constructions that varied in length from four to thirteen words and did not contain any verb particle constructions. These filler reading sentences consisted of a combination of newly created sentences as well as filler sentences drawn from Study 1. Some filler sentences did contain prepositions that were employed as particles in the target sentences, but the lists were constructed so that the same word was not used in two sentences separated by fewer than 10 intervening sentences. Sixty of the filler reading sentences were used to create the long Lag condition. That is, 12 of the prime and target pairings had a long lag period that was created with the inclusion of 5 filler reading sentences that intervened between the prime and target. Short Lag conditions did not have any intervening filler reading sentences.

Of the remaining filler reading sentences, 144 were used to separate each target production from the next priming event. There were 6 filler reading sentences after each target production. Additionally, a filler production trial was also used to separate each target production from the next priming sentence. Filler production trials were drawn from the list of filler stimuli used in Study 2 and were semantically and syntactically unrelated to the target productions or priming sentences. Following each target production, each of the 4 lists included 3 filler reading sentences, one filler production trial, and 3 more filler reading sentences.

The inclusion of these 7 filler items between each target production and the next priming event served several purposes. First, it helped to prevent participants from realizing that a prime (or a sentence with a particular kind of construction) always occurred immediately after a picture production task. Secondly, the combination of the two types of tasks helped maintain the illusion of a random order of presentation of the two different experiment components. Finally, the inclusion of the filler pictures prevented participants from realizing that every target picture included a V-P pair. Additionally, the first trial block in each list began with 3 of the remaining filler reading sentences to avoid beginning the experiment with a priming structure. Thus, each of the

4 lists included 255 reading sentences (48 are primes and 207 are fillers) and 48 picture production tasks (24 are target productions and 24 are filler productions).

Procedure

As in the previous studies, participants were tested one at a time in a single session in a sound attenuated room. For this study, participants completed the procedure using a PC computer running E-Prime software (Schneider, Eschman, and Zuccolotto, 2002). Participants were told that they would be performing two different kinds of tasks that would be presented "in a sort of random order". In the first kind of task participants were instructed to silently read a sentence one word at a time as the words flash by at a rate of one word every 250 ms. After reading the sentence in this RSVP procedure, participants were instructed to repeat the sentence aloud.

For the second kind of task, participants received the same instructions as they did in Study 2. First, they were presented with a sentence "frame" including the subject of the sentence and a final clause such as "*The principal* ________ *as usual.*" for 1500 ms. Next they were shown a picture of a scene with the sentence constituents placed in each corner of the display. Participants had 5000 ms to look at the picture and read the constituents, after which the constituents were removed and replaced with the original "frame". At this point, participants were instructed to produce a sentence describing the scene, using all of the constituents that had been presented. After producing a sentence, for either kind of task, participants were instructed to depress a keyboard key to begin the next trial. Digital audio recordings of the participants' responses were made for subsequent analyses.

For short and long lag conditions, the number and order of target and filler trials differed. The sequence for short lag items was as follows: Participants were presented with a priming sentence in an RSVP fashion that they read and then reproduced. Next, participants performed a target picture production task (described above). Finally, they responded to a series of 7 filler stimuli. They read and reproduced 3 filler reading sentences, completed 1 filler picture production task, and then read and reproduced 3 additional filler reading sentences. Then they began the next trial block with another priming reading sentence.

For long lag trials, participants again started with a priming reading sentence. In this kind of block though, participants read and reproduced 5 filler reading sentences before they were presented with the picture production task. Then, as with the first kind of trial block, participants were presented with 7 filler items, including 3 filler reading sentences, followed by one filler picture, and another 3 filler reading sentences before beginning the next trial block. Lists were randomly organized so there was no recognizable pattern of the trial blocks described here.

Sound recordings were made of each session using digital voice recorders and were analyzed for particle placement choice and errors. The experimental session began with several practice RSVP trials and one picture production trial. The experimental session was divided into two periods, each lasting between 15 and 20 minutes.

Results

Data was collected from 72 participants. Only one participant was excluded because of a technical failure resulting in missing data. Each of the remaining 71 participants (35 males, 36 females) provided data on 24, or one quarter, of the 96 unique combinations of V-P pair, priming Structure, and priming Lag employed in this study.

The sentences generated for this study were coded for specific error types that either occurred frequently or were of conceptual interest. A summary of these errors is provided in Table 3a and is described in the following. A total of 514 (30.2%) were eliminated for the analysis of particle placement choice. Of these errors, 223 (13.1%) trials were excluded because participants reproduced the particle from the priming sentence in a position other than how it was presented, effectively priming themselves incorrectly. Of these incorrect prime errors, 100 involved other errors and 123 were produced otherwise correctly. These incorrect prime events that were otherwise correct were subsequently analyzed to determine which factors were more likely to induce participants to produce this kind of error.

Additionally, of the targets that had been primed correctly 67 (3.9%) trials were coded as incomplete responses and were excluded because part, or all, of the sentence was omitted and not produced. Incomplete responses included subject omissions, entire NP omissions, particle omissions, and failures to respond. Another 44 trials (2.6%) were excluded because participants committed a lexical substitution of one of the words in the NP (*e.g. The child will count the* digits *off* instead of *The child will count the* numbers *off*). Additionally, 40 (2.5%) trials were excluded because participants made a lexical substitution of either the verb or particle (*e.g. The child will count* out *the numbers* instead of *The child will count off the numbers).* Finally, 141 (8.3%) trials were excluded because participants changed the length of the NP in the target sentence by omitting words (*e.g. The child will count off numbers).* This left a total of 1,189 trials that were analyzed for particle position choice.

The data were analyzed for word order choice as well as production errors. The dependent variables were particle Position choice (*i.e.* particle adjacent or shifted constructions) as well as the number and type of errors made in each production condition. However, before discussing the specific analyses that were conducted on this data, it must be acknowledged that a set of mistakes committed during the list construction process resulted in unevenly balanced lists. Specifically, Dependency was not balanced across the levels of Priming Structure within each list. Therefore, in one list, all the adjacent primes were paired with a low Dependency V-P, and the next list contained adjacent primes all paired with high Dependency V-Ps. This resulted in cells in the item matrix containing either 6 or 0 zero items instead of the planned 3. Additionally, Lag was not perfectly balanced across priming structure, resulting in a number of cells that should have had 6 items, actually containing 5, and some cells that would have had 0 items ended up with 1 item (Table 3b). However, because the items were balanced equally across the lists, an analysis of particle position could be conducted by item.

Particle Position Analyses

Although the unbalanced distribution of items within lists ruled out the potential for a straightforward subject analysis, the data could be analyzed by item because the items were distributed equally *across* the lists. So, of the 1,189 correctly produced trials, the percentage containing a shifted construction (209 items or 17.6% overall) were entered into an analysis of variance with the factors Dependency (low or high), priming Structure (adjacent or shifted) and priming Lag (short or long). The means presented are based on analysis by item and data for the particle position analyses are presented in Figures 3a and 3b.

The main effect of Dependency was not significant, $F_2(1, 22) = 1.86$, *n.s.*, but the pattern of the data does indicate that sentences containing low Dependency V-Ps were more likely to be produced with a shifted construction (22.7%) than were sentences containing high Dependency V-Ps (14.2%). This trend was likely not significant because the small df resulted in reduced power for the analysis.

The main effect of priming Structure was significant, $F_2(1, 22) = 8.44, p < 0.01$, indicating that sentences were more likely to be produced with a shifted construction if they had been primed with a shifted construction (20.9%) than if they had been primed with an adjacent construction (16.1%).

The main effect of priming Lag was not significant, $F_2(1, 22) = 2.39$, n.s., though the means do indicate a slight reduction in the effect of adjacent primes with 14.1% produced in a shifted position at the short Lag and 18% produced in a shifted position at the long Lag. No such reduction was observed with shifted primes (19% at short Lags and 22.7% at long Lags), and this leads to the conclusion that there was no effect of Lag. However, as will be explained later, it is believed that the percent of shifted productions was artificially suppressed by the use of long NPs. So, future versions of this experiment might expect to observe a significant Lag effect.

The Lag over Structure data also demonstrates that the expected interaction between priming Structure and priming Lag was not significant, $F_2(1, 22) = .002$, *n.s.* It was expected that the effect of priming Lag would be more pronounced following shifted priming Structures than adjacent priming Structures. This is because the shifted prime was expected to have a strong impact at short Lags, whereas at long Lags the priming effect was expected to have dissipated. In that case, the general preference for adjacent constructions was expected to determine particle Positions. Following adjacent priming Structures though, once the priming influence began to dissipate after the short Lag, the general preference for adjacent constructions was expected to result in a continued, albeit slightly reduced, preference for adjacent particle Positions. In contrast to these predictions though, the analysis results indicate that the only reduction in priming effect occurred for productions following an adjacent priming Structure. I conjecture that this pattern of results was obtained only because the Lag influence was artificially suppressed for the shifted priming Structures by the inclusion of a long NP in the target productions. The long NP may have overwhelmed the influence of the shifted prime and resulted in an unexpectedly low percentage of shifted constructions following shifted primes.

Error Analyses

Data concerning trials on which participants made errors were also examined with the expectation that they might reveal the influences of processing constraints and subsequent word order choices on other performance characteristics of sentence production. Those 141 (8.3%) trials where participants changed the length of the NP by omitting words (*e.g. The child will count off numbers* instead of *The child will count off* *the even numbers*) were explored. Specifically, the distribution of this error type across levels of Dependency and particle Position was explored to determine which levels of these conditions contributed to higher rates of such NP length changes. Those 123 (7.2%) trials where participants produced the priming sentence otherwise correctly, but incorrectly primed themselves by reproducing the priming sentence with the opposite structure of that with which it was presented (*e.g. The boy will throw up the warm and spoiled food* instead of *The boy will throw the warm and spoiled food up)* were also explored. Specifically, the distribution of this error type was examined across the levels of Priming Structure to determine which priming structure contributed to higher rates of incorrect priming errors.

The distribution of NP length changes (Table 3c) was explored because it was expected that participants would be more likely to reduce the length of the NP in productions with a shifted structure because doing so would allow earlier production of the particle. In contrast to what was predicted, the distribution revealed that participants were much more likely to reduce the length of the NP in sentences containing an adjacent construction (110 total) than in sentences containing a shifted construction (31 total). It is not immediately clear why speakers would be more likely to omit words from the NP in particle adjacent constructions, although one explanation might be that, by producing the particle adjacently, speakers have extended the time over which the NP components must be stored, increasing the associated storage costs and leading to higher incidence of NP omissions.

The distribution of incorrect priming errors was also explored because it was expected that participants would be more likely to incorrectly prime themselves by producing an adjacent construction when they had been given a shifted Priming Structure. The distribution pattern provided fairly dramatic confirmation of this prediction, and revealed that speakers were far more likely to incorrectly prime themselves when the original priming sentence contained a shifted prime (121 total) than when the original priming sentence contained an adjacent prime (2 total).

Discussion

Despite the fact that the data set was not structured as planned, the results of the item analyses were corroborated by some descriptive, subject-based analyses. Additionally, the results provide support for the more general of the hypotheses from this study, revealing the influence of priming Structure effects on word order choices in productions involving V-P pairs. The main effect of Dependency was not significant, though the data pattern indicated that speakers are more likely to produce a shifted construction with low Dependency V-Ps than with high Dependency pairs. There were not any significant findings regarding the effects of the Priming Lag on the effectiveness of the priming stimulus, but, because the effect of shifted primes was so much lower than expected after short Lags, a reasonable conclusion might be that the effect of the shifted prime was overwhelmed by the presence of the long NP. So, future versions of the experiment, changed to include a short NP, might expect to find a significant effect of Lag that would largely be driven by a reduction in the shifted priming effect after long Lags. Finally, the error analyses can be argued to show that certain kinds of frequently occurring errors may serve to compensate for inefficient constructions by reducing the overall processing demands of a given production.

The item-based particle position analysis revealed the significant effect of Priming Structure and the trend towards an effect of Dependency on word order choice, indicating that speakers were more likely to produce a sentence containing the same particle placement as the sentence with which they had been primed, but that they were also motivated to produce the particle in a shifted position when the V-P was of low Dependency.

Though these analyses are not conclusive, they do contribute additional support for the claim that the choice of construction used in sentence production is driven by a desire to maximize processing efficiency. As would be predicted by Smith and Wheeldon's (2001) and Potter and Lombardi's (1998) accounts of syntactic priming, this study demonstrated that speakers' particle position choices can be influenced by the presence of a syntactic priming stimulus because the recent processing of a given structure influences the relative processing demands associated with producing different structures in a subsequently produced sentence. Thus, this study has provided support for the claim that structural persistence can be thought of as a processing strategy that is adaptively deployed to increase processing efficiency by allowing speakers to reuse recently activated structures instead of constructing sentence structures anew for each utterance that is produced.

The particle position analyses also indicated that speakers do not blindly follow the example of a priming structure, but that they are only more likely to do so when it serves to enhance processing efficiency. Of particular relevance is the lower than expected percentage of sentences produced with a shifted construction following a shifted priming structure. This unexpectedly low incidence of shifted productions, despite the influence of a shifted priming structure, indicates that participants *were* willing to produce a different structure, and were most likely to do so because the alternative structure proved to be more efficient given the long NP Length. In accord with the predictions based on Gibson's DLT (2000) and Hawkins' MiD (1994, 2004), this is because the most efficient structure for the majority of target sentences in this study was an adjacent construction, largely because of the long NPs.

For example, those sentences with high Dependency V-P's were still produced more efficiently as part of an adjacent construction, despite the influence of the prime. Even more important though, is the observation that a large number of the low Dependency V-P's were more efficiently produced in adjacent constructions, despite the benefit of a shifted prime. This preference for adjacent constructions presumably reflects the long NP that was paired with each V-P construction. In hindsight, this choice of NP Length was a design flaw because it contributed to a larger syntactic domain, further increasing the baseline preference for adjacent constructions. During the design process it was thought that this might be necessary because, without knowledge of the baseline preference for adjacent constructions, it was expected that the effect of the priming stimulus might be so strong that some other processing constraint might be necessary to drive at least some constructions towards adjacent positions following a shifted prime. Future versions of this experiment would benefit from pairing the V-P targets with short

NPs because this would help to reduce the overall preference for adjacent constructions, providing a clearer picture of the main effects of priming Structure and priming Lag on word-order choices.

The results of the particle position analyses did not reveal any significant main effect of priming Lag on overall particle position choice, though it seems plausible that this was because any effect that might have obtained following shifted priming structures was washed out by the inclusion of long NPs in the target sentences.

However, the results did suggest a trend in the direction of an interaction between priming Structure and priming Lag, such that the effects of only adjacent priming events began to dissipate over long Lags. This is not the pattern of effects that was expected, specifically because the shifted priming effect was expected to decay over long Lags more than the adjacent priming effect. Again though, it is likely that a decay in the shifted priming effect was not observed over long Lags specifically because the inclusion of the long NP dramatically increased the preference for adjacent constructions, thereby reducing the number of sentences that were produced with shifted constructions over short Lags, precluding the possibility of a dramatic reduction over long Lags.

So, while a clear picture of the interactive effects of priming Structure and priming Lag was precluded by the unexpectedly low percentage of shifted constructions produced following a shifted prime, future versions of the experiment, changed to include both short NP Lengths and better control of items within the lists, may demonstrate that, consistent with Wheeldon and Smith (2003), the syntactic priming manipulated in this study involved a late-occurring, positional level of processing that results in a relatively short-lived priming effect. Additionally, future versions of this experiment would benefit from an analysis of NP production durations, as was conducted in Studies 1 and 2. Such an analysis could provide additional support for the claim that these processing constraints affect other performance characteristics of language production aside from word-order choice.

General Discussion

Taken together, the results of these three studies support the performance-based account of word order preferences that have been argued for and they have provided support for the claim that word order preferences are determined by an efficiency maximization goal that drives speakers to produce sentences whose structures entail the lowest processing costs (Hawkins, 1994, 2004; Gibson, 2000).

The studies described here have provided varying degrees of support for the claim that particle placement preferences emerge from the convergence of multiple factors that affect the processing load associated with each sentence production. Specifically, Study 1 indicated the need for a new methodological procedure for eliciting sentence productions, and it highlighted the experiential contributions that seemed to have affected particle placement choices. Additionally, Study 2 demonstrated the effects of semantic constraints such as V-P Dependency levels and lexical constraints such as direct-object NP Length, while Study 3 provided limited support for the claim that experiential effects like structural persistence also influence word-order choices.

Furthermore, both Studies 1 and 2 demonstrated that the production rate of the NP's in sentences containing V-Ps is influenced by factors like particle position and V-P

Dependency levels, which are argued to affect overall processing demands. Finally, the error analyses conducted in all three studies suggested that some of the more frequently occurring production errors may serve a functional purpose by increasing the efficiency with which a given sentence is produced or, at the very least, compensating for inefficiently organized constructions.

Both Hawkins' MiD (Lohse et al. 2004) and a production-based interpretation of Gibson's DLT (2000) predict that speakers should have a general preference for adjacent constructions in productions containing anything but short NP Lengths and low Dependency V-Ps. The MiD predicts that, in sentences with even moderate Dependency levels in the V-P pair, the adjacent construction will be more efficient because it allows the immediate completion of the semantic domain associated with the V-P. Additionally, the DLT predicts that there are storage and integration costs associated with producing an NP before completing the V-P pair that serve to make the adjacent construction more efficient.

Studies 1 and 2 supported this predicted preference for adjacent constructions, as reflected by the higher incidence of particle movements to adjacent constructions in Study 1, and the particle position analysis of Study 2. Additionally, and in line with the predictions of both Hawkins' MiD and Gibson's DLT, the results of Study 2 demonstrated that this general preference for adjacent constructions over shifted ones was most pronounced under conditions with high Dependency V-P pairs and long NP Lengths. Thus, these studies were able to show that increases in semantic and syntactic processing constraints induce a preference for adjacent constructions of V-P pairs because such constructions lessen elevated processing demands by allowing the particle to be produced earlier. This benefits the speaker because such adjacent constructions allow speakers to avoid the storage and integration costs that would be incurred by producing the NP before the particle. Additionally, in the case of high Dependency pairs and long NP Lengths, adjacent constructions allow immediate completion of the V-P pair rather than an extension of it across the NP.

At the same time, the results from studies 2 and 3 also support the predictions about when speakers' will benefit from producing a shifted construction. These predictions were also based on Hawkins' MiD (1994), but they held that, under conditions of low V-P Dependency and short NP Length, speakers should prefer shifted constructions over adjacent ones because the low semantic domain of low Dependency V-Ps and the low syntactic domain of short NP Lengths are not enough to drive a preference for an adjacent construction. Additionally, the shifted constructions allow the earliest production (or release) of the sentence's ICs. The incidence of particle movements (especially to shifted positions) was too low in Study 1 to allow a meaningful interpretation of the data, but the results of Study 2 indicated that speakers were more likely to make shifted particle constructions in sentences involving low Dependency V-Ps as well as in sentences with shorter NP Lengths. Additionally, the particle position analyses of Study 3 indicated that, despite the effects of structural persistence on particle placement choices, speakers who made a shifted construction despite having received an adjacent prime were more likely to have done so if the sentence contained a low Dependency V-P.

In addition to the semantic effects of V-P Dependency and the syntactic effects of NP Length on word-order choices demonstrated in Study 2, Study 3 has provided limited support for the important impact of such recent experiential effects as structural persistence on word-order choices. The particle position analysis indicated that speakers' word-order choices were influenced by the particle construction employed in a priming sentence. The observed trend indicated that the processing loads of produced sentences are influenced by experiential factors such as structural persistence effects because, as predicted by both Smith and Wheeldon (2001) and Potter and Lombardi (1990, 1998), it becomes more efficient for the language production system to reuse a recently processed syntactic structure then to generate a new one, even in many cases where, other things being equal, the primed structure is not the most efficient construction.

The particle position analysis from Study 3 did not reveal the influence of a significant latency or Lag effect that reduces the impact of a priming event, however, it is expected that future versions of this experiment (including target stimuli containing short NPs) will reveal a significant Lag effect that becomes more pronounced following shifted priming Structures. A comparison of the means from this study suggests that the impact of adjacent primes is reduced after a lag period, and it seems reasonable to expect that, if the impact of the shifted prime had not been muted by the long NP length, then there likely would have been an effect of a lag period on the influence of shifted priming events as well. Future versions of this experiment could hope to conclusively demonstrate that the effects of a structural prime begin to dissipate within a few intervening sentences, providing support for the claim that structural priming influences a late-occurring, positional-level of encoding, resulting in relatively short-lived priming effects (Wheeldon and Smith, 2003).

These three studies have indicated that, if productions can be elicited properly, analyses of particle position preferences are sensitive to a convergence of semantic, syntactic, and experiential processing constraints that collectively contribute to the relative efficiency associated with producing sentences with different word-order choices. Notably though, these studies also indicated that, in addition to the influence that these processing constraints exert on word order choices, these constraints also influence other production-based performance characteristics including both the production rate of sentence constituents as well as different patterns of error rates.

For example, the NP duration analyses from Studies 1 and 2 have provided support for another prediction, based on the performance-oriented theories of Gibson (2000) and Hawkins (1994, 2004), that the effects of both semantic dependency relationships and word order choices on the processing demands of a given sentence will be reflected in the production durations of certain sentence constituents. The production duration analyses indicated that processing demands do affect the production rate and provide support for the prediction that speakers will accelerate the production of NPs in sentences with higher processing demands in an effort to compensate for and reduce the elevated load as quickly as possible.

The duration analyses confirmed the expectation that NPs produced as part of a shifted construction would be produced faster then the same NP produced as part of an adjacent construction, and this reflects a drive to close the open semantic domain created by the shifted construction as quickly as possible. The duration analyses also confirmed the prediction that higher V-P Dependency levels would also lead to accelerated NP production rates. These findings support the prediction that, in productions with increased processing demands, speakers should want to reduce these demands as quickly as possible. By accelerating production of the NP in shifted constructions, speakers allow themselves a speedier release of the particle and subsequent closure of the open semantic domain.

Worthy of specific mention is the finding that NPs associated with high Dependency V-P pairs and spoken in a shifted construction are produced the most quickly, indicating that participants may be trying to compensate for inefficient constructions by accelerating the production to reduce the higher processing demands as quickly as possible. This finding confirms the results of the Gonnerman and Hayes (2005) comprehension study and further demonstrates that both Dependency and particle positions contribute to the efficiency of a given production. However, as a point of contrast, the Gonnerman and Hayes study of comprehension demonstrated that increased processing demands resulted in extended reading times, whereas the production tasks employed by this study demonstrated that less efficient constructions actually lead speakers to accelerate production rates. It seems reasonable to conclude that this acceleration of the NP production rate allows speakers to finish the NP sooner, enabling faster closure of the open semantic domain through the production of the particle and to speculate that this acceleration may reflect a production system strategy to compensate for an inefficient word-order choice.

Finally, another point worth mentioning is the observation that certain of the error patterns that were explored may be explained as a strategy for reducing the processing demands of a given production. So, for example, it seems self-evident that increases in NP Length would contribute to increased processing demands. Unfortunately, however, it is not reasonable to conclude that the increased incidence of NP omissions in sentences with long NPs is actually a reflection of this increased processing demand and a subsequent drive to reduce the increased load by omitting unnecessary words, specifically because an equally likely explanation might simply be that the increased rate of NP omissions in longer NPs merely reflects the increased opportunity for error with long NPs.

It was also predicted that speakers would be more likely to omit words from the NP when it was part of a sentence with a shifted construction. The expectation was that speakers would want to drop unnecessary words to allow the earliest production of the shifted particle and subsequent closure of the open semantic domain. However, the results of the error distributions indicated that speakers were actually more likely to drop words from the NP when it was part of an adjacent construction. It is not immediately clear why speakers would be more likely to drop words from the NP in sentences with adjacent constructions, but it seems possible that, once the semantic domain has been closed by producing the particle and the final IC has been produced, subjects may be demonstrating a sort of cognitive laziness in their willingness to omit words from the sentence once all the critical syntactic pieces have been produced. Alternatively, it could be that by producing the particle in an adjacent construction, participants have extended the time over which they must maintain all the words in the NP, and this heightened storage demand may result in an increased tendency to omit words from the NP.

However, a more persuasive example of how certain errors may serve to enhance processing efficiency is revealed in the distribution of particle omissions from Study 2. This distribution revealed that particle omissions were more likely to occur in sentences whose V-Ps had low Dependency levels and whose NPs were of the longest Length. This finding suggests that particles are most likely to be omitted from sentences where the particle makes little or no contribution to the meaning of the V-P pair, but where there are substantial storage costs associated with maintaining the particle across the duration of a long NP. In such instances where the particle adds nothing to the meaning of the sentence, it seems likely that the "error" in which participants omit the particle altogether, may actually reflect a strategy to reduce the storage and integration costs associated with holding on to the particle for production in a shifted position.

To be fair, because the error rates were not of primary interest for these studies, only those errors that were expected to be conceptually interesting were explored. Therefore, the only errors that have been discussed here are those which were expected to reflect contributions to processing efficiency. There were a number of other error types (*e.g. lexical substitutions* and *complete omissions or incompletes*) that were not of conceptual interest and were not explored. In short, this discussion is not meant to suggest that all, or even most, production errors reflect a drive to enhance processing efficiency. It is clear that some errors (complete omissions or incompletes) reflect a breakdown of either the memory or the production system, and that others (lexical substitutions) reflect the fact that speakers do not always have verbatim recall for a sentence (Potter & Lombardi, 1990; Lombardi & Potter, 1992; Bock, 1996; Konopka & Bock, 2005). However, it is not unreasonable to suspect that some of the errors that were observed do serve a purpose by eliminating unnecessary contributions to processing demands. A study specifically designed to explore this hypothesis might either simply collect more data to increase the overall error count, or it might manipulate the stimuli to elicit a higher error rate.

Taken together, the results from these three studies provide some encouraging, albeit limited, evidence for the claim that semantic, syntactic, and experiential factors collectively contribute to the processing demands associated with a given sentence production. Specifically, the studies indicated that the Dependency level of a V-P construction, the Length of an associated NP, and the influence of a prior production involving a shifted or adjacent particle, all influence the determination of what the word-order will be for a given sentence production. So, word-order choices reflect the sentence structure that entails the lowest demands resulting from the convergence of semantic, syntactic, and experiential constraints.

These studies also provided evidence that these same processing constraints also affect other performance characteristics associated with sentence production, including both production and error rates. Specifically, the studies revealed that speakers will accelerate production rates in sentences with greater processing demands in an effort to reduce these demands as quickly as possible. Finally, the studies also suggested that some of the errors that occur in sentence productions may also reflect a drive to enhance processing efficiency by omitting unnecessary words from sentence productions. Future studies employing this new sentence generation procedure may benefit from exploring different kinds of constructions that afford optional word orders, exploring the production durations of similarly affected sentence constituents, and/or exploring ways to induce higher error rates in different parts of the sentence.

Table 1a: Sample stimuli for adjacent Constructions, demonstrating the specific Dependency of each V-P pair, and how each V-P pair is paired with three different NP Lengths.

DEP	LENGTH	Adjacent Stimulus Sentences			
High	Short	The principal will	chew	out	the class.
High	Medium	The principal will	chew	out	the disruptive class.
High	Long	The principal will	chew	out	the class of disruptive students.
Mid	Short	The man will	look	up	the word.
Mid	Medium	The man will	look	up	the unusual word.
Mid	Long	The man will	look	up	the origin of the word.
Low	Short	The child will	count	off	the numbers.
Low	Medium	The child will	count	off	the even numbers.
Low	Long	The child will	count	off	the numbers that he learned.

Table 1b: Sample stimuli for shifted Constructions, demonstrating that each particular V-P and NP Length pairing are used to create both adjacent and shifted constructions.

DEP	LENGTH	Shifted Stimulus Sentence			
High	Short	The principal will	chew	the class	out.
High	Medium	The principal will	chew	the disruptive class	out.
High	Long	The principal will	chew	the class of disruptive students	out.
Mid	Short	The man will	look	the word	up.
Mid	Medium	The man will	look	the unusual word	up.
Mid	Long	The man will	look	the origin of the word	up.
Low	Short	The child will	count	the numbers	off.
Low	Medium	The child will	count	the even numbers	off.
Low	Long	The child will	count	the numbers that he learned	off.

Table 1c: Study 1 - Error types and incidence rates. Items produced with these errors were removed from the position and duration analyses. NP length changes and particle omissions were subsequently explored.

Error Type	Count	Percent of Total Responses
Stimulus Flaw	6	0.2%
No Response	127	4.8%
Otherwise Incomplete	31	1.2%
Lexical Substitution of Subject	61	2.3%
Lexical Substitution of NP	165	6.2%
Lexical Substitution of V-P	26	1.0%
NP Length Change	131	4.9%
Particle Omission	10	0.4%
Totals	557	21.0%

Table 1d: Study 1 - Expected vs. observed frequencies of particle movements to shifted positions across levels of NP Length and Dependency. The differences were not significant, likely because of the extremely low incidence of movements to shifted positions.

Length	Short		Medium		Long	
	(expected)	(observed)	(expected)	(observed)	(expected)	(observed)
Dependency						
Low	0.8	1	0.8	0	0.4	1
Middle	0.8	1	0.8	1	0.4	0
High	0.4	0	0.4	1	0.2	0

Table 1e: Study 1- Expected vs. observed frequencies of particle movements to adjacent positions across levels of NP Length and Dependency. These differences were not significant either, despite the higher incidence of movements.

Length	Short		Medium		Long	
	(expected)	(observed)	(expected)	(observed)	(expected)	(observed)
Dependency						
Low	4.8	6	5.6	7	5.6	3
Middle	2.7	2	3.1	4	3.1	3
High	5.5	5	6.3	4	6.3	9

Table 1f: Study 1 - Distribution of NP length changes across Dependency, Length, and Position, demonstrating an increased tendency for length change errors with longer NPs and in shifted constructions.

	Adjacent			Shifted		
Dependency	Short	Medium	Long	Short	Medium	Long
Low	1	6	19	0	8	21
Middle	1	10	13	1	8	24
High	2	7	11	1	6	19

Table 1g: Study 1 - Distribution of particle omissions across Dependency, Length, and Position, demonstrating a slight increase in particle omissions with increases in Dependency level and a slightly more meaningful increase in particle omissions in productions with long NPs relative to short NPs.

	Adjacent			Shifted		
Dependency	Short	Medium	Long	Short	Medium	Long
Low	1	1	2	0	1	1
Middle	1	0	1	2	0	3
High	2	0	3	0	0	3

Table 2a: Study 2 - Error types and incidence rates. Items produced with these errors were removed from the position and duration analyses. NP length changes and particle omissions were subsequently explored.

Error Type	Count	Percent of Total Responses
No Response	22	0.9%
Otherwise Incomplete	5	0.2%
Lexical Substitution of the NP	22	0.9%
Lexical Substitution of the V-P	26	1.0%
NP Length Change	96	3.9%
Particle Omission	40	1.6%
Totals	211	8.5%

Table 2b: Study 2 - Distribution of NP length changes across Dependency, Length, and Position, demonstrating an increased likelihood of NP Length change errors in sentences with long NPs, and a higher incidence of such errors in adjacent constructions relative to shifted ones.

	Adjacent			Shifted		
Dependency	Short	Medium	Long	Short	Medium	Long
Low	0	2	20	0	3	5
Middle	0	4	21	0	2	6
High	0	4	19	0	1	2

Table 2c: Study 2 - Distribution of particle omissions across Dependency and Length, demonstrating an increasing likelihood of particle omission errors in sentences with lower Dependency V-Ps and longer NPs.

Dependency	Short	Medium	Long
Low	1	3	12
Middle	3	4	7
High	1	1	8

Table 3a: Study 3 - Error types and incidence rates. Items produced with these errors were removed from the position and duration analyses. Incorrect Primes and NP Length change errors were subsequently explored.

Error Type	Count	Percent of Total Responses
Incorrect Primes	223	13.1%
Incomplete Response	67	3.9%
Lexical Substitution of NP	44	2.6%
Lexical Substitution of V-P	40	2.5%
NP Length Change	141	8.3%
Totals	514	30.2%

Table 3b: Study 3 - Those conditions where subjects were presented with either 5 or 6 items (presented by list for the sake of brevity and clarity), showing the percentage of items produced with a shifted construction in each condition.

Priming Structure:	Adjacent				Shifted			
Priming Lag:	Short		Long		Short		Long	
Dep:	Low	High	Low	High	Low	High	Low	High
List 1	13.9	--	33.3	--	--	9.7	--	19.2
List 2	--	2.8	--	12.8	19.0	--	26.5	--
List 3	25	--	18.0	--	--	29.2	--	20.7
List 4	--	8.8	--	9.8	27	--	20.6	--
List 5	15.4	--	22.7	--	--	7.9	--	17.9
List 6	--	8.5	--	9.1	23.7	--	15.4	--
List 7	14.8	--	19.4	--	--	21.4	--	14.7
List 8	--	16.2	--	19.4	42.3	--	40	--
Average	17.3	9.1	23.4	12.8	23.4	17.1	25.6	18.1

Table 3c: Study 3 - Distribution of NP length changes across Dependency and particle Position, demonstrating an increased likelihood for NP length change errors with adjacent constructions.

Dependency	Adjacent	Shifted
Low	70	19
High	40	12

Figure 1a:

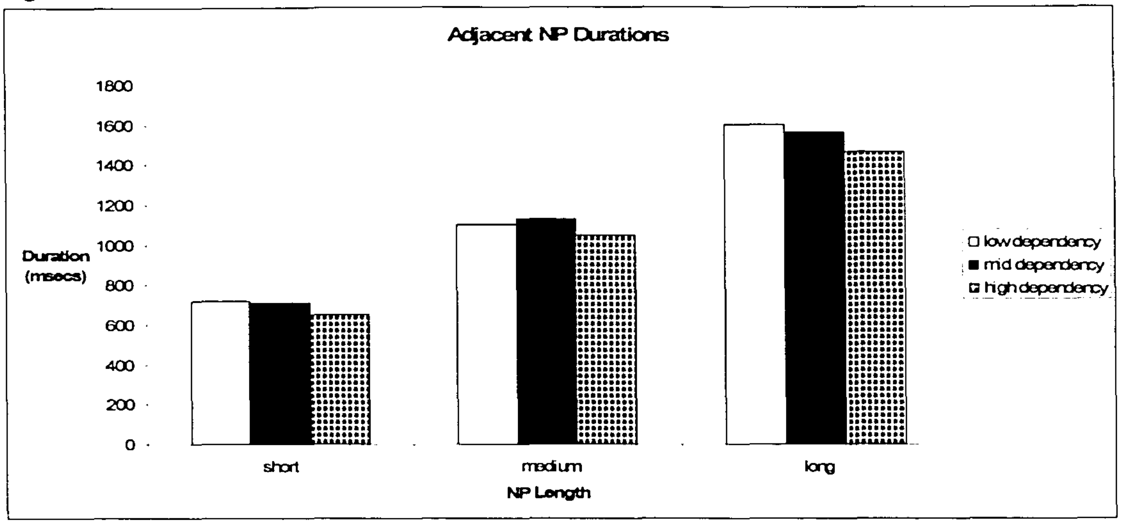

Figure 1b:

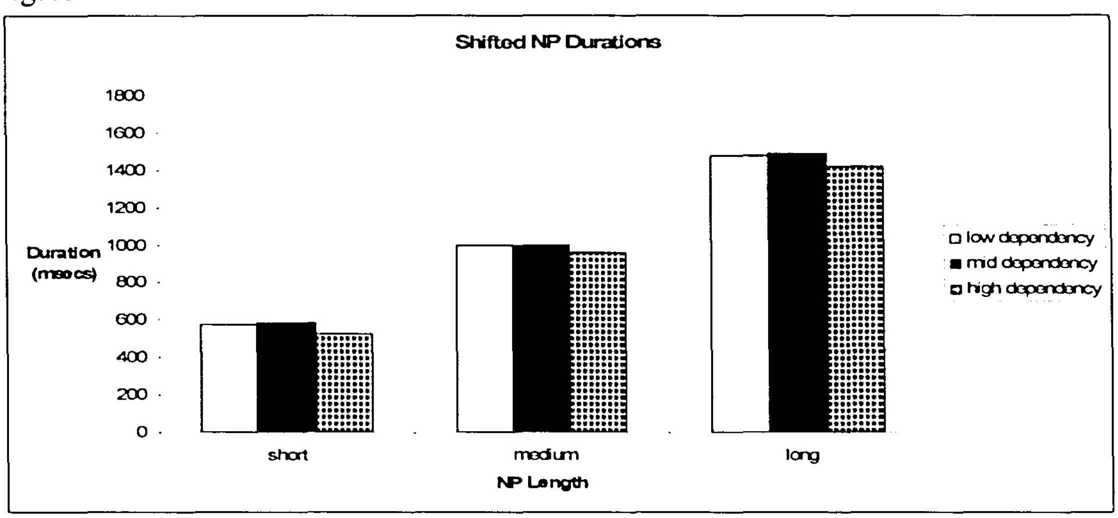

Figure 1a: Study 1 - Average NP duration in adjacent constructions, demonstrating the inverse effects of increased levels of NP Length and Dependency on production duration.

Figure 1b: Study 1 - Average NP duration in shifted constructions, demonstrating the inverse effects of increased levels NP Length and Dependency on production duration. Comparison with Figure 1a also demonstrates the effect of particle Position on production duration, showing faster productions in shifted constructions.

Figure 2a:

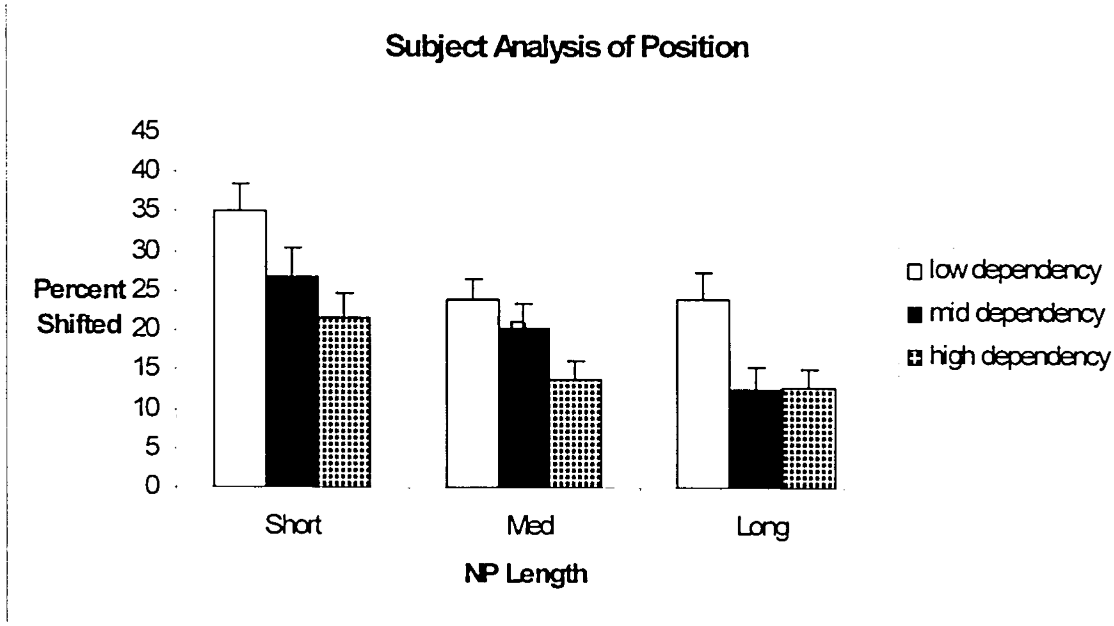

Figure 2a: Study 2 - Percent of sentences produced with a shifted construction, demonstrating the increased preference for shifted constructions with shorter NP Lengths and lower levels of V-P Dependency.

Figure 2b:

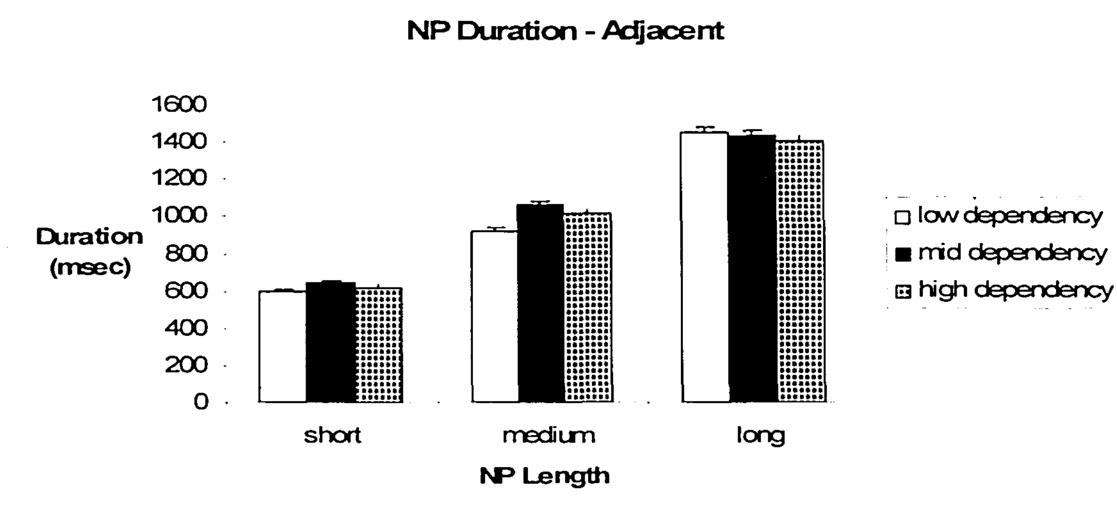

Figure 2c:

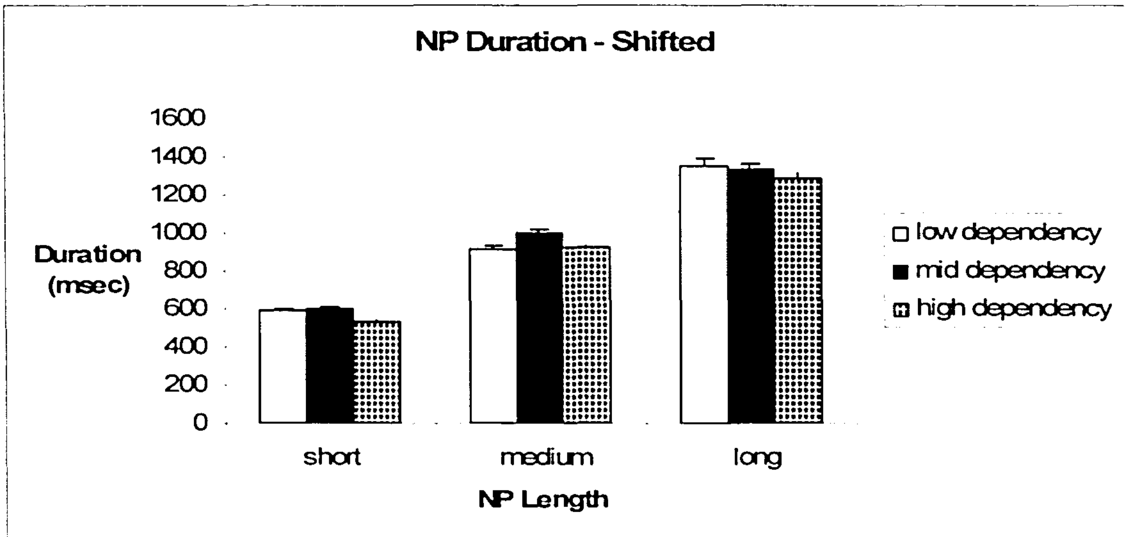

Figure 2b: Study 2 - Average NP duration in adjacent constructions, demonstrating the inverse effects of increased levels of NP Length and Dependency on production duration.

Figure 2c: Study 2 - Average NP duration in shifted constructions, demonstrating the inverse effects of increased levels of NP Length and Dependency on production duration. Comparison with Figure 2b also demonstrates the effect of particle Position on production duration, showing faster productions in shifted constructions.

Figure 2d:

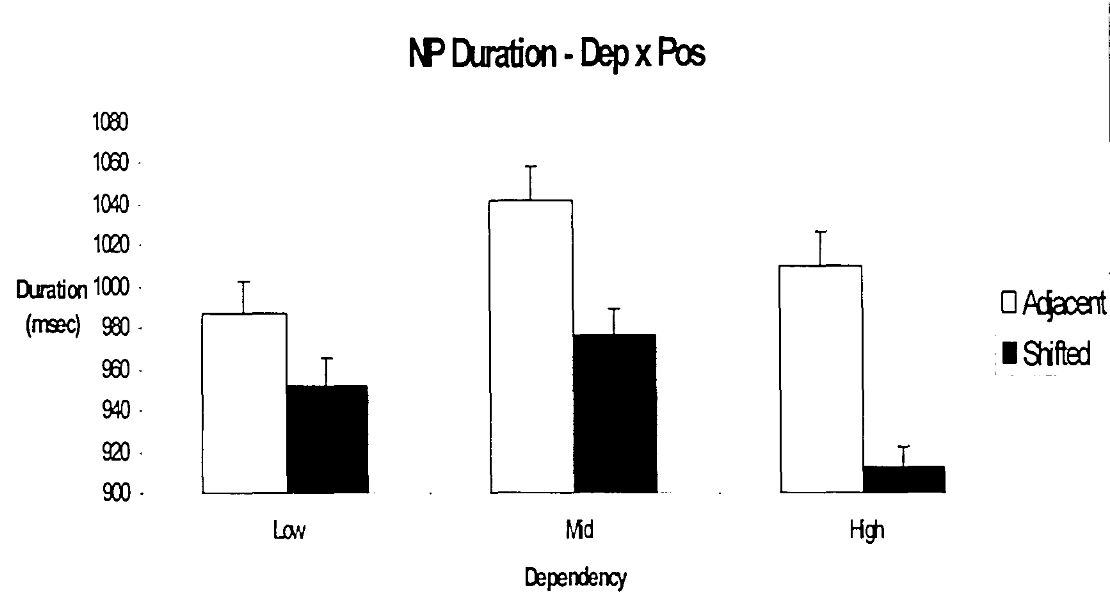

Figure 2d: Study 2 - Average NP duration across levels of Dependency and particle position, demonstrating the significant interaction between Dependency and Position on NP durations, with the shortest durations occurring in sentences with both high Dependency V-Ps and shifted constructions.

Figure 3a:

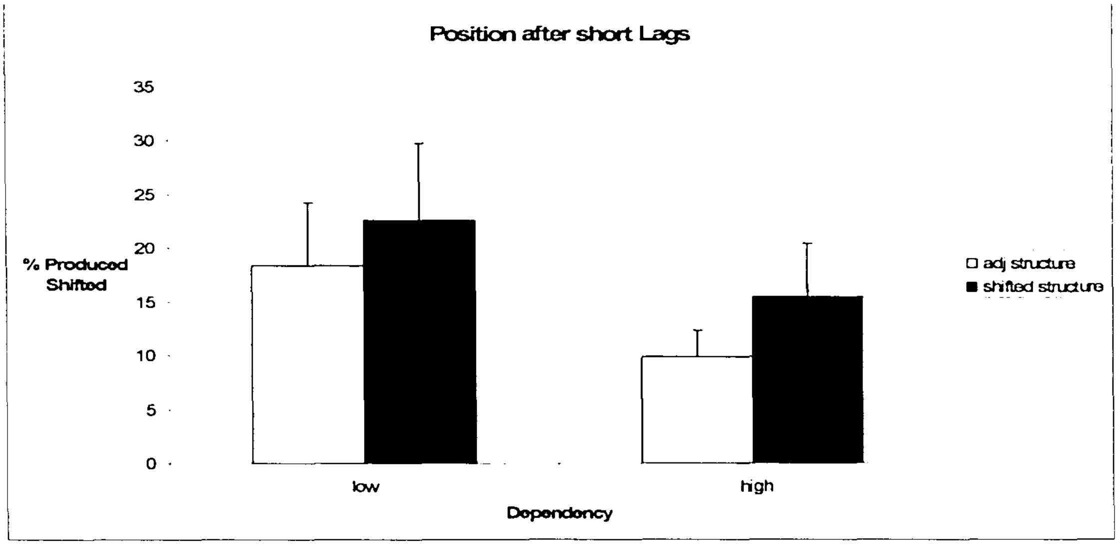

Figure 3b:

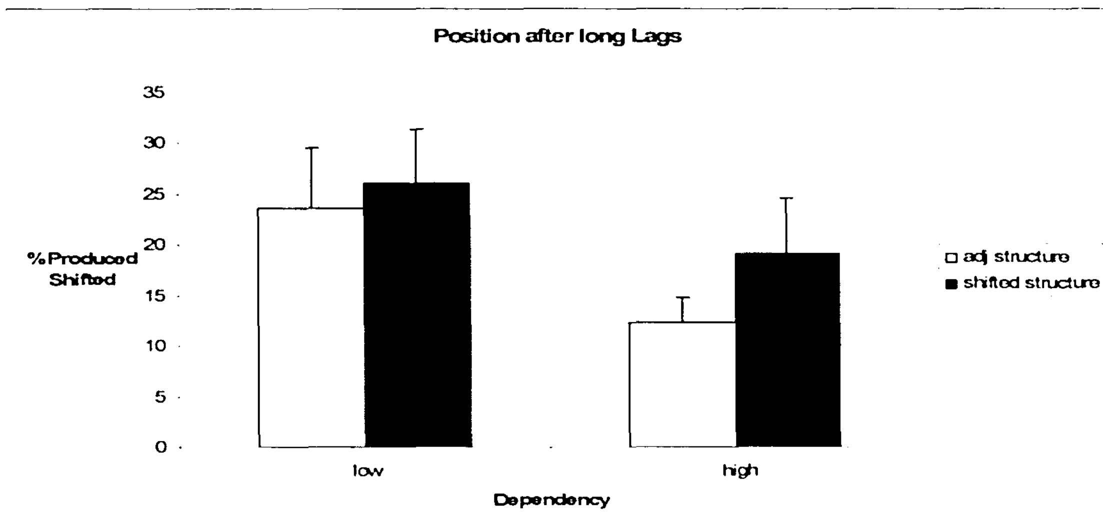

Figure 3a: Study 3 - Percent of target sentences produced with a shifted construction after a short Lag, demonstrating the significant effect of priming Structure on particle position.

Figure 3b: Study 3 - Percent of target sentences produced with a shifted construction after a long Lag, demonstrating the significant effect of priming Structure on particle position.

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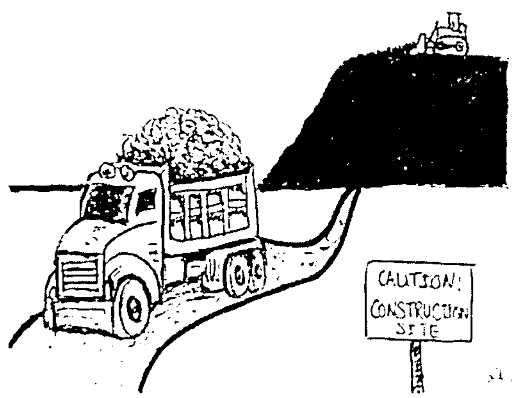
Appendix: Examples of Target Picture Stimuli

Image 1:

the hill off



The workers will level

Image 2:

up will patch

the old moth eaten pants the seamstress

Image 1: level off

Image 2: patch up

Curriculum Vitae

Benjamin H. Fuller

Contact Information

Office Address:

Department of Psychology

17 Memorial Dr. East

Bethlehem, PA 18015

bhf204@lehigh.edu

Home Address:

4805 Lanark Rd

Center Valley, PA 18034

trog1680@yahoo.com

Education

Institution	Major Field	Degree	Year
Lehigh University	Cognitive Psychology	M.S.	May, 2007 (expected)
Trinity College	Psychology/ Philosophy	BS	2003

Honors and Awards

2003 Faculty Honors, Trinity College

Psi Chi, National Psychology Honor Society

Research Experience

2004-present **Lab Manager/Research Assistant,** Language Acquisition & Processing Lab, Lehigh University, Psychology Dept.

Tasks: Designed, conducted, and collected data for multiple research projects. Managed databases for these experiments including data coding, data entry, and analysis procedures. Recruited, trained, scheduled, and compensated student assistants for lab work. Organized and coordinated participant recruitment campaigns involving mother-infant pairs and retired alumni.

2002 **Lab Assistant,** Marcus Lab, UCONN, Neuroscience Dept.

Tasks: Managed animal facility, and scheduled animal weight maintenance. Assisted in data collection and analysis. Acquired skills in micro-drive construction for experimentation with hippocampal and amygdalar involvement in emotional learning with rats.

Teaching Experience

2002 **Teaching Assistant,** Trinity College, Dept. of Psychology,

Course: Psychobiology

Tasks: Assisted in class preparation, organization, and grading.

Fall, 2004, Spring, 2007 — **Teaching Assistant**, Lehigh University, Dept. of Psychology
Course: Mind and Brain
Tasks: Administered and evaluated course examinations, lead review sessions.

Spring, 2004 — **Teaching Assistant**, Lehigh University, Dept. of Psychology
Course: Statistics
Tasks: Administered and evaluated course examinations, lead review sessions. Lead computer lab teaching SPSS statistical software.

Fall, 2006 — **Teaching Assistant**, Lehigh University, Dept. of Psychology
Course: Cognitive Psychology
Tasks: Administered and evaluated course examinations, lead review sessions. Taught the course to one student individually.

Academic Service

Spring, 2005- Fall, 2006 — **Graduate Assistant**, Lehigh University, Dept. of Psychology
Tasks: Provided hardware and software support for student and faculty computers and experimental facilities. Configured and operated software and hardware used for scoring automated response forms used for testing in all

university departments. Managed the department's experimental participant pool involving over 1200 participant hours per semester.

Spring, 2005- **Colloquium Coordinator,** Lehigh University, Dept. of Psychology

Fall, 2006 Tasks: Provided hardware support for presentation speakers. Prepared inviting refreshment buffets.

END OF TITLE