EXPLORING THE COGNITIVE UNDERPINNINGS OF THE CORRESPONDENCE BETWEEN VERB MEANING AND SYNTAX

by

Eunkyung Yi

September 1, 2016

A dissertation submitted to the
Faculty of the Graduate School of
the University at Buffalo, State University of New York
in partial fulfillment of the requirements for the
degree of

Doctor of Philosophy

Department of Linguistics

To Kwon Hwan

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to Jean-Pierre Koenig who has advised me for all those years with incredible enthusiasm and patience. Since my second year when we began regular meetings, I have greatly benefited from his knowledge and insight as well as from his attitude as a linguist and scientist. Now I would like to say, as did his former students, that he is the kind of advisor any doctoral student would wish for. My graduate study would have never finished without his academic, administrative, and sometimes, even emotional support. I also want to extend him a special thank-you for his willingness to discuss my projects late at night over FaceTime when we were working in different time zones.

I would also like to thank my other committee members, Gail Mauner and Douglas Roland, for their invaluable input from the very early stage of my graduate studies and for their suggestions and comments on this thesis. I would especially like to thank Gail for providing me with invaluable lab experience and Doug for his kind and tireless help on my corpus work.

Special thanks go to Hongoak Yun who, as my first roommate, helped me survive in my early years at UB and has since been a good friend and colleague. My sincere appreciation also goes to my parents, Kil-Jae Lee and Myungok Kim, and parents-in-law, Seongkoo Ko and Sunhee Kim, who have been extremely supportive of my graduate work and have been waiting for its completion with so much patience. I am also deeply indebted to my Master's advisor, Eun-Jung Yoo, at Seoul National

University for her continued mentoring and warm encouragement throughout all my years in the graduate programs in Seoul and Buffalo.

Lastly, none of this would have ever been possible without help, support, and understanding of my husband, Kwon Hwan Ko. I am immensely grateful to him for always being there.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This dissertation explores the cognitive underpinnings of the linguistic observation that there is a strong correspondence between the meanings of verbs and the syntactic contexts in which they occur. Building on the assumption that this correspondence is due to the fact that speakers' prior experience with linguistic structures affects their subsequent behavior (*priming*), I propose the Verb Anchor hypothesis that holds that experience with a sentence leads to a cognitive association between the sentence's verb and the syntactic frame the sentence instantiates and that when this association is strong, the verb serves as an 'anchor' of the frame. I predict that high semantic similarity between verbs leads to an increase in the likelihood of speakers' choosing the same syntactic frame across sentences. More precisely, the more semantically similar a verb is to the anchor, the more likely speakers are to choose the same frame as the frame associated with the anchor. I examine the Verb Anchor Hypothesis in two related but separate contexts of use. First, four syntactic priming experiments investigate whether an anchor formed via speakers' immediate sentence experience (the *recent* anchor of a frame) affects syntactic frame selection in subsequent sentence production. Second, two sets of corpus analyses investigate whether an anchor that results from repeated experience of association between verb and syntactic frame (the *typical* anchor of a frame) influences the syntactic realization of verbs that are semantically similar to the anchor and have similar syntactic options. Overall, the studies this thesis report on support the Verb Anchor hypothesis and provide a partial

answer to the question *why* verbs with similar meanings tend to occur in similar syntactic contexts. They thus contribute to answering the ultimate question of why grammars of language are the way they are.

CHAPTER 1 Introduction

1.1 The Correspondence Between *Verb Meaning* and *Syntax*

Linguists have investigated the relationship between meaning and syntactic structure for several decades. Since the 1960's, the influence of semantics on syntax has been studied in a more rigorous and systematic way (Katz & Fodor, 1963; Fillmore, 1968; Gruber, 1965; G. Lakoff, 1965; R. Lakoff, 1968; McCawley, 1968). Much research has been devoted not only to understanding the nature of the relationship but also to developing mechanisms that can best explain them. Particularly since Gruber (1965) and Fillmore (1968), it has been acknowledged that the syntax of lexical items is to a great extent determined by and predicted from their meaning. This correspondence manifests itself most evidently in the relationship between verb meaning and verb syntax.

Verb meaning is relational in that it specifies *semantic arguments* required for any event the verb can be used to describe, or expressions that complete the meaning of a predicate (e.g., who did what to whom). Although not all semantic arguments are necessarily realized as *syntactic dependents*, or phrases co-occurring with the verb in a sentence (some semantic arguments are implicit), the semantic arguments of a verb are in many languages realized syntactically in one way or another. This is why verb meaning is a crucial determinant of the structure of a sentence, or its *syntactic frame*. These relationships are illustrated in the examples in (1.1).

(1.1) a. Jen gave her assistant a signed letter.

award, *grant*, *give*, *hand*, *lend*, *offer*, *pass, promise*, *toss*,…

b. Jen kept the man from entering the meeting room.

bar, *discourage*, *keep*, *prevent*, *prohibit*, *stop*,…

c. Jen hit at the door.

beat, *chip*, *hit*, *kick*, *poke, strike*, *slap*, *punch*,…

The syntactic frame of the sentence *Jen gave her assistant a signed letter* in (1.1a) can be schematized as [NP_{agt} VERB NP_{rec} NP_{thm}]. Many different verbs such as *give*, *lend*, *hand*, *promise*, *toss* and so on can participate in this frame. Previous studies suggest that the meaning component 'caused possession' is shared across verbs that participate in this frame. The meaning 'caused possession' requires at least three semantic arguments, namely, an agent, a recipient, and a theme, which are encoded by the three NPs in this frame, respectively. The syntactic frame underlying *Jen kept the man from entering the*

meeting room in (1.1b) can be schematized as [NP_{agt} VERB NP_{pat} *from*-PP]. The meaning of 'prevention' shared across verbs like *bar*, *prohibit*, *discourage* and so on is assumed to be associated with this syntactic frame. Likewise, the syntactic frame underlying *Jen hit at the door* in (1.1c) can be schematized as [NP_{agt} VERB *at*-PP_{pat}] and verbs like *beat*, *chip*, *kick*, etc. can participate in the frame, which share the meaning of '(potential) forceful contact.' The examples in (1.1) illustrate the claim that a component of a verb's meaning can play a significant role in determining the verb's syntactic context and, as a result, verbs that share that semantic component or verbs that are semantically similar in this respect can occur in the same syntactic frame. This relationship can be referred to as the CORRESPONDENCE BETWEEN VERB MEANING AND SYNTAX.

The correspondence between verb meaning and syntax has been extensively studied in theoretical linguistics under the rubric of *linking theories* (Green, 1974; Grimshaw, 1990; Goldberg, 1995, 2006; Koenig & Davis, 2001, 2006; Levin, 1993; Pinker, 1989). There are at least two ways of explaining the relationships between verb meanings and syntactic frames. Some researchers view syntactic frames as being directly associated with particular meanings (Goldberg 1995; Ramchand, 2008, for example). They argue that only verbs whose meanings are compatible with the meaning of the frame can occur in that frame. Others view the meanings as being derived from lexical rules that map a set of verb meanings onto another set of meanings (Pinker, 1989, among others). The output of these lexical rules is what then licenses particular verbs to occur in the same syntactic frame, which is a more lexically-driven explanation of the phenomena than the former approach. Either way, however, the primary goal in this line of research

is generally to find the components of verb meaning that are most relevant for syntactic purposes (see Grimshaw, 1990).

Previous studies have further shown that the syntactic behavior of verbs may differ "crucially and in regular ways," depending on very *subtle* similarities and differences in their meanings (Green, 1974, p. 10). Four verbs and three different frames in (1.2) illustrate this point.

(1.2) a. Bill hit at the dog. (Pinker, 1989, pp. 104-106)

*Nancy touched at the cat.

*Jerry broke at the bread.

Mary cut at the bread.

b. Miriam hit the dog on the leg.

Terry touched Mavis on the ear.

*Jim broke Tom on the leg.

Sam cut Brian on the arm.

c. *That wall hits easily.

*This wire touches easily.

This glass breaks easily.

This bread cuts easily.

The verbs *touch*, *break*, and *cut* are to some degree semantically similar to the verb *hit*, shown in (1.1c). They all involve the meaning of an agent acting on a patient and can occur in the transitive frame where the subject and the object encode the agent and

patient arguments, respectively (e.g., Jen *hit*/*touched*/*broke*/*cut* it). However, these verbs differ as to whether they can also occur in the other three types of syntactic frames illustrated in (1.2a-c). First, the verbs *touch* and *break* do not occur in the frame in (1.2a) unlike *hit* and *cut*, as they do not inherently involve the meaning of 'caused motion.' In other words, only the verbs whose meanings include both the notion of 'contact' and the notion of 'caused motion' can occur in this frame. But *touch* and *break* are further distinguished from each other by their occurrence in the syntactic frame illustrated in (1.2b), where *touch* can, but *break* cannot, occur in the frame. This is because the meaning of *break* does not inherently require the notion of 'contact,' as is evidenced by its use in the intransitive frame (e.g., The window *broke*/**hit*/**touched*/**cut*). Finally, *break* and *cut*, but not *hit* and *touch*, can occur in the syntactic frame illustrated in (1.2c). The meanings of *break* and *cut* include the notion of 'change of state' while the meanings of *hit* and *touch* do not. This semantic difference is also observed in the behavior of their deverbal nouns. Namely, *a break* and *a cut* both refer to the resultant state of the change while *a hit* and *a touch* lead to no such interpretation. To summarize, research in verb semantics has shown that the correspondence between verb meaning and syntax is not coincidental but has complex but regular semantic foundations.

The phenomena illustrated above lead us to the hypothesis that semantically similar verbs tend to exhibit similar syntactic behavior. Moreover, the correspondences seem to be a logical solution to the problem that there are, in general, much fewer syntactic frames than verb meanings in languages. When one needs to map 4,000 distinct verbs or even more different verb senses to 50 or so different frames, there needs to be a way of making the mappings between verb meanings and frames organized and

consistent. In this context, the correspondence between meaning components and syntactic frames seems to be a "reasonable" system speakers can depend on. It should be noted, however, that, although the correspondences illustrated with (1.1) and (1.2) look like a natural consequence of the problem at hand, it is not always and not necessarily the case, as illustrated in (1.3).

(1.3) a. NP_{agt} VERB [implicit patient] (e.g., Jen ate all day.)

bake, *drink*, *dust*, *eat*, *fish*, *read*, *sing*, *wash*, *write*,…

b. *THERE* VERB NP_{subj} (e.g., There developed a problem.)

appear, *spread*, *climb*, *develop*, *grow*, *amble*, *pass*, *stand*,…

c. PP_{loc} VERB NP_{subj} (e.g., In the cabin lives the man.)

jump, *rise*, *awake*, *sing*, *lean*, *live*, *wander*, *emerge*,…

There are syntactic frames or syntactic configurations that have little basis in verb meaning. In contrast to the verbs discussed above, verbs that instantiate each of the three syntactic frames in (1.3a-c) hardly share any semantic similarity. Verbs within each group of verbs, e.g., *bake* and *fish* in (1.3a), are semantically as diverse as verbs across the groups, e.g., *bake* in (1.3a) and *jump* in (1.3c), as opposed to what was the case in (1.1). The compatibility of the verbs and the syntactic frames in (1.3) seems to be determined primarily by factors other than verb meanings, at least not by the component of verb meaning that has much to do with the verb's semantic arguments. For example, verbs that exemplify the intransitive frame in (1.3a), where the patient argument is implicit, share little semantic similarity. Whether a verb can occur in this frame is related to how

predictable the patient argument of the verb is (Resnik, 1993). Namely, in the eating event, anything edible will be predicted to be eaten, in the fishing event, fish will be what is intended to be fished, and so on. Similarly, so-called *there*-insertion, illustrated in (1.3b), and locative inversion, illustrated in (1.3c), are, roughly speaking, allowed for any verbs that can involve appearance or existence, no matter what particular semantic arguments they encode (Levin, 1993). These examples in (1.3) suggest that the correspondence between verb meaning and syntax illustrated in (1.1) and (1.2) above is not an a priori necessity but a phenomenon that requires an explanation.

My thesis aims to investigate the COGNITIVE UNDERPINNINGS of the "quite regular" correspondence between verb meaning and syntax. The meticulous analysis of linguistic data, introduced above, allows us to posit abstract rules and constraints that model linguistic structures. However, one of the biggest challenges in the study of language is the attempt to ultimately explain the fact that everyone learns and uses a language with no special training in language or linguistics. Not knowing how to draw parsed trees of a sentence does not impede speakers' ability to produce grammatical sentences fluently. Likewise, being unable to consciously extract a semantic component related to a certain syntactic frame does not mean that people cannot unconsciously "know" the correspondence between meaning and syntactic form and use this knowledge when they speak. The theoretical contribution of linguistic theories may in fact diverge from its psychological reality, as already pointed out in Kiparsky (1968).

> Suppose that someone succeeds in writing a grammar which correctly enumerates the sentences of a language and assigns them the right structural descriptions. Such a *grammar* would ipso facto correctly represent the *substance* of a fluent speaker's knowledge of this language. But it would not necessarily represent the form of this

> knowledge in the sense of actually corresponding to *the system of rules which is internalized by the speaker* and constitutes part of what enables him to produce and understand arbitrary utterances in the language. (p. 171, italics added)

The abilities people naturally exploit when learning and using language should have much to do with the 'substance' or actual form of the rules. The study of what Kiparsky calls 'grammar' and 'the system of rules which is internalized by the speaker' must complement each other. By combining both perspectives, we may be able to find clues as to *why* grammars have to be the way they are. In Section 1.2, I introduce my hypothesis about the mechanisms speakers resort to when they choose a syntactic frame for a verb when producing a sentence, which, I argue in this thesis, is what accounts for the correspondence between verb meaning and syntax in language.

1.2 The Verb Anchor Hypothesis

I propose that one of the cognitive phenomena called *priming* underlies the correspondence between verb meaning and syntax. Priming refers to the fact that exposure to certain stimuli influences our response to subsequent stimuli. Importantly, research has shown that, if preceded by similar stimuli, the processing of subsequent stimuli is usually facilitated. Research on language processing has shown that speakers' responses to linguistic items are modulated by their prior linguistic experience. In what follows, I discuss both the effect of one-time and short-term priming of a linguistic pattern and the relatively constant effect resulting from frequent association of a verb and a syntactic frame, which can be seen as involving priming in a broader and slightly more indirect way.

It is widely acknowledged in the literature that experience with each linguistic item or the frequency with which it is experienced plays an important role in speakers' constructing and using linguistic representations. This is often called the exemplar view or usage-based view of language in the linguistics literature in that actual uses of language are considered crucial factors that modulate language and linguistic structures (Langacker, 1987; Kemmer & Barlow, 2000; Bybee, 2006, 2013, cf. the competence-grammar view, Chomsky, 1965). There is a huge amount of literature in language processing, acquisition, diachronic change of language as well as in linguistic typology that provides support for this exemplar view. For example, the processing of a linguistic item can be facilitated by prior experience with the same or similar items, even by experience with the single prior occurrence of an item in an experimental setting.

Repeated experience with, or frequent occurrences of, an item in natural language use was also shown to affect online sentence processing (Trueswell, 1996). Early language learning has been shown to depend more on the uses of frequent linguistic items than on abstract generalizations (Tomasello, 1992, 2003). Historical studies have also shown that the frequency of use is a major determinant of diachronic changes in phonology, morphology, semantics and syntax (Bybee, 2007; Krug, 2000). Hawkins (1994, 2011) has also suggested, based on within- and across-language variations, that language processing and use can, to a large extent, explain typological patterns and that grammar can be viewed as "conventionalizations of the patterns and preferences … in the performance of language" (2011, p. 206).

Following this empirical evidence, I assume in this thesis that each and every use of a particular linguistic unit, more specifically experience with a sentence, can affect subsequent sentence production (i.e., local priming effects) and repeated experience of a particular unit may bias the way speakers formulate a sentence (i.e., global priming effects). For my purposes, the most important aspect of language experience, or the most relevant kind of priming stimuli, is the co-occurrence between a verb and a syntactic frame. A sentence exemplifies a particular syntactic frame and consists of lexical items chosen to convey the intended meaning. As discussed in the previous section, the verb in the sentence is the key lexical item which determines, in large measure, the syntactic frame being exemplified in the sentence (e.g., because verbs are the syntactic head of the sentence, Pollard & Sag, 1994). Upon processing a sentence, speakers associate the verb meaning with the syntactic frame it occurs in. For example, experience with a sentence like *Jen gave her assistant a signed letter* (=1.1a) leads to an association between the

meaning of *give* and the syntactic frame [NP_{agt} VERB NP_{rec} NP_{thm}]. There are different views about the process through which the association between a verb meaning and a syntactic frame develops from experience with sentence tokens. For example, some may argue that the sentence serves as a linguistic exemplar of the association as by processing the sentence native speakers experience the co-occurrence of the verb and the frame (constructionists' view, e.g., Goldberg, 1995). Others may argue that the verb itself includes in its representation a syntactic frame and its associated meaning (lexicalists' view, e.g., Koenig & Davis, 2006). The choice between these two views makes no difference for my purpose. What is crucial here is that the verb is a lexical item one can actually experience and that it is associated somehow with a syntactic frame via its occurrence in a sentence.

There may also be various ways of formalizing the cognitive process involved in verb-and-syntactic-frame associations. For example, it may be interpreted as assigning a semantic category the verb meaning denotes to the syntactic category represented by the given syntactic frame, i.e., the verb is categorized as a member of the group of verbs that participate in that syntactic frame (Rosch, 1978, for example). The facilitatory effect of prior experience with this association that I will be concerned with may also be viewed as a result of a kind of analogy, i.e., structural-mapping is facilitated if there is high relational similarity between the verb meaning and the frame in the prior sentence and those in the later sentence (Gentner, 1983, for example). In this thesis, however, I make minimal theoretical assumptions about the cognitive processes involved other than priming and focus on the changes in the linguistic representations that each use (i.e., an individual instance of priming) as well as frequent uses of a verb and a sentence (i.e., a

cumulative effect of repeated priming) may lead to. I assume linguistic units or items are individually represented in the mind and connected to each other, analogous to Roelofs's (1992, 1993) model which consists of a network of nodes and allows for spreading activation. Note that I use this localist-type of model for expository purposes only. The phenomena I discuss in this thesis can be equally well modeled using distributed and feature-based models (e.g., Seidenberg & McClelland, 1989; see Chapter 4 for more discussion).

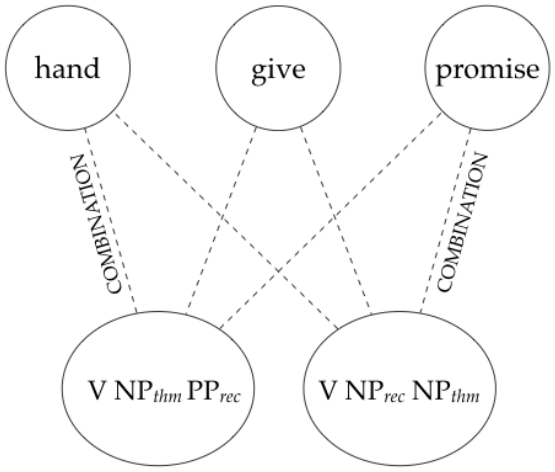


Figure 1.1 Pickering and Branigan's (1998) model of representations

As to the representations of verbs, syntactic frames, and their combinations, I make two key assumptions, illustrated in Figure 1.1. Firstly, following Pickering and Branigan's (1998), individual verb lemma nodes are directly linked with the nodes of syntactic frames or combinatorial nodes with which those verbs can occur in sentences (indicated by the dotted lines). For example, *give*, *hand*, and *promise* are linked with both the [NP$_{agt}$ VERB NP$_{thm}$ PP$_{rec}$] and [NP$_{agt}$ VERB NP$_{rec}$ NP$_{thm}$] nodes, indicating that these

verbs can occur with either frame. Note that verb nodes have no relationships with each other in Pickering and Branigan's proposal.

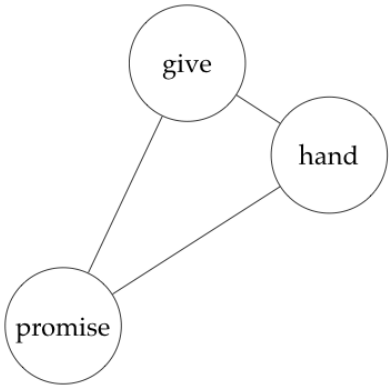


Figure 1.2 Illustration of a semantic network of verb lemma nodes

Another important assumption I make is that verbs or verb meanings are connected to each other and also that the activation of a particular verb spreads to other verbs to the degree to which they are semantically similar to each other, illustrated in Figure 1.2. For expository purposes, I put the verbs *give* and *hand*, for example, closer to each other than *give* and *promise* or *hand* and *promise*, to indicate higher semantic similarity between *give* and *hand* than between these other verb pairs (i.e., "the amount of activation arriving at a node is a negative function of network distance," Roelofs, 1993, p. 64). Network-type models usually assume that the activation of each unit (node) spreads to others through links connecting them. Researchers in semantic processing have shown that activation of a particular meaning spreads to other meanings (Collins & Loftus, 1975). Importantly, more of the activation goes to similar or related meanings than to dissimilar meanings, as demonstrated by semantic priming experiments (e.g., the

processing of a word is usually facilitated if preceded by a semantically similar word, McRae & Boisvert, 1998).

As to the changes in the network that are triggered by our experiences, I simply assume that experience with a sentence co-activates the representations of the verb and the syntactic frame exemplified by the sentence and that the weight of the association link between them changes as a result of that experience, i.e., updated. It is this constantly updated weighted link that ensures that encountering a verb activates both its meaning and syntactic properties at the lemma stratum (Levelt, 1989; Roelofs, 1992). For example, upon experiencing the sentence *Jen gave her assistant a signed letter* (=1.1a), the association between the verb lemma node *give* and the syntactic frame [NP_{agt} VERB NP_{rec} NP_{thm}] is strengthened (this strengthening of the association is indicated by a line with circled ends in the following figures).

Based on these assumptions, I hypothesize that syntactic frame selection is modulated by the *interplay* between the prior association of a verb and a syntactic frame and the activation of a verb's associated semantic network upon retrieval of its meaning, illustrated in Figure 1.3, such that the activation of a verb lemma's combinatorial node (corresponding to the sentence's syntactic frame that occurs as a result of producing or comprehending a sentence) influences the syntactic realization of other verb meanings in the semantic network.

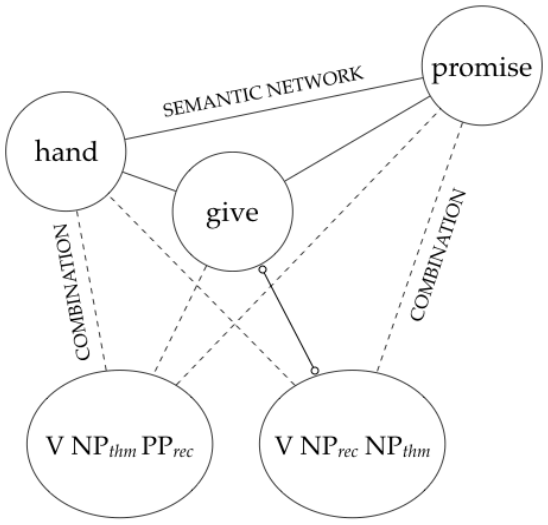


Figure 1.3 Illustration of the mechanism behind the Verb Anchor hypothesis

For example, the strong activation of [NP$_{agt}$ VERB NP$_{rec}$ NP$_{thm}$] associated with the verb *give* (e.g., by experiencing the sentence *Jen gave her assistant a signed letter*) is more likely to influence the choice of syntactic frame for *hand* than for *promise,* as *hand* is more semantically similar to *give* than *promise* is to *give*. This is because when trying to choose a frame for *hand*, *give* will be more strongly activated than when trying to choose one for *promise*, as the higher similarity between *hand* and *give* means more features of *give* are activated. The strong association between *give* and the ditransitive frame, [NP$_{agt}$ VERB NP$_{rec}$ NP$_{thm}$], in turn will increase the activation of the frame above its base activation, increasing the likelihood the ditransitive frame is chosen. In other words, given the association between *give* and the frame [NP$_{agt}$ VERB NP$_{rec}$ NP$_{thm}$], I predict that the verb *hand*, which is highly semantically similar to *give*, is more likely to occur in the ditransitive frame than the verb *promise*. Speakers are affected more by the prior co-occurrence between *give* and the frame [NP$_{agt}$ VERB NP$_{rec}$ NP$_{thm}$] when they are to select a

frame for the verb *hand* than when they are to select a frame for the verb *promise*. I will label the verb associated with a particular syntactic frame via sentence experience as an ANCHOR for that frame to which other verbs are compared with respect to semantic similarity. In short, I hypothesize that the semantic similarity to an anchor verb of a syntactic frame modulates the likelihood of other verbs occurring in the same frame as the anchor, which I will call the VERB ANCHOR HYPOTHESIS throughout this thesis. Note that I do not argue that a verb's semantic similarity to the anchor is the sole determinant of the choice of syntactic frames. Multiple other factors have been shown to influence online syntactic frame selection or the ability of a verb to occur in a particular frame (e.g., morphophonological, pragmatic, contextual, etc.) and I will discuss some of these factors in Chapter 3.

I investigate in this thesis two separate (but related) ways of a verb acquiring an 'anchor' status, i.e., via immediate sentence experience or via repeated experience with the association of a verb and a frame. So, my Verb Anchor hypothesis encompasses two subhypotheses that can be tested independently. As noted above, it is known that recent experience with a linguistic item makes this item more accessible and exerts an immediate influence on the processing of subsequent sentences. It is also known that repeated and frequent experience with a particular linguistic item has profound effects on language use and structures. The former is often considered a relatively short-term effect while the latter is a long-term learning effect.

As illustrated in Figure 1.4, recent experience with a sentence makes the verb and its underlying frame co-activated, and also makes the association link between them stronger and highly accessible (indicated by the line and empty circles at the ends). If the

Verb Anchor hypothesis is correct, this recently experienced verb is predicted to serve as an anchor of its associated frame and we can expect that in subsequent sentence production speakers are more likely to use the same syntactic frame with verbs that are semantically similar to the anchor than with verbs that are semantically dissimilar from the anchor. This will be referred to as the *Recent* Verb Anchor hypothesis.

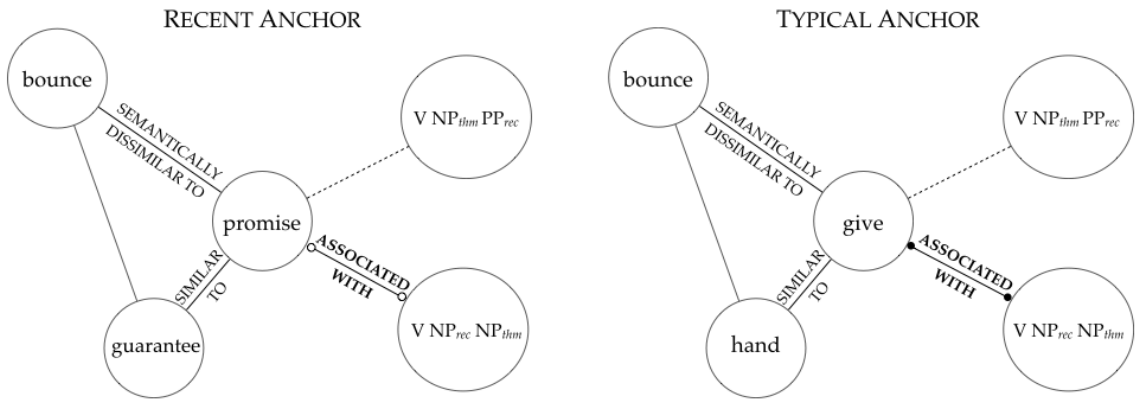


Figure 1.4 Illustration of the mechanisms behind *recent* and *typical* anchors

In addition, if one experiences a number of sentences that instantiate a particular syntactic frame with a particular verb, the association between this verb and the frame is expected to be strengthened, as the association is learned over an extended period of time via frequent use (indicated by the line with filled circles at the ends). If frequent enough to be representative of the syntactic frame, a verb can thus become a typical anchor of that syntactic frame. The strong association between the typical anchor and the syntactic frame becomes relevant when trying to produce a sentence with a verb semantically similar to the anchor, as that verb will activate, via shared semantic

features, the anchor and raise the activation of the frame above its base activation. While a recent anchor is expected to exert an instant and local influence on subsequent syntactic frame selection, the typical anchor of a syntactic frame is expected to have a constant and global effect on syntactic behavior of other semantically similar verbs. If the Verb Anchor hypothesis is correct, high semantic similarity to the typical anchor of a syntactic frame is predicted to increase the likelihood of other verbs occurring in the same frame. The more semantically similar a verb is to the typical anchor, the more likely it is to occur in the frame with which the anchor is strongly associated. I will refer to this correlation as the *Typical* Verb Anchor hypothesis in this thesis.

In the following two subsections, I introduce the Recent and Typical Verb Anchor hypotheses in more detail, respectively, and also outline the designs of the empirical investigations whereby I test each of these subhypotheses. If these hypotheses are confirmed, it would suggest that the immediate effect of local priming and the global effect of repeated priming underlie speakers' tendency to use the same syntactic frame for semantically similar verbs, which I will argue constitutes the cognitive underpinning of the linguistic correspondence between verb meaning and syntax that I introduced in Section 1.1.

1.2.1 Subhypothesis #1: the effect of *recent* verb anchors

Much research in sentence processing has shown that recent verb experience can modulate the comprehension and production of a subsequent sentence. For example, Trueswell and Kim (1998) showed that very brief prior exposure to a verb which is

biased towards a particular syntactic structure significantly modulates syntactic ambiguity resolution in sentence comprehension (i.e., fast priming). Melinger and Dobel (2005) also showed that prior exposure to a verb that only allows a particular syntactic frame facilitates speakers' use of that syntactic frame in subsequent sentence production. A large body of syntactic priming studies has also shown that recent experience with a particular syntactic frame facilitates the use of the same frame in subsequent sentence production (Bock, 1986; Bock & Loebell, 1990; Pickering & Branigan, 1998; Potter & Lombardi, 1998, to name a few). In a nutshell, these studies have shown that recent experience of a verb or a syntactic frame plays an important role in choosing or interpreting the syntactic structure of a subsequent sentence.

The Verb Anchor Hypothesis fits well with these results: Through sentence production and comprehension, speakers experience the mutual association between a verb and a syntactic frame, as processing the sentence co-activates the mental representation of both the verb and the syntactic frame as well as the link between them. Some portion of the activation of the verb and frame nodes is assumed to spread along the links. In this context, I hypothesize that the activation of the syntactic frame influences other verbs via verbs' semantic network to the degree to which they are semantically similar to the *recent* anchor verb, i.e., the verb co-activated with the frame from the recent use of the sentence. I labeled this mechanism as the Recent Verb Anchor hypothesis.

The Recent Verb Anchor hypothesis holds that verbs that are semantically similar to the recent anchor are affected more by the activation of its associated syntactic frame than verbs that are semantically dissimilar to the anchor. In addition, verbs that are

affected more by the activation of the frame node can be more strongly associated with that frame than verbs that are affected less by the activation of the frame. Thus, this hypothesis predicts that if asked to produce a sentence with a verb that is either semantically similar or dissimilar to the recent anchor of a syntactic frame, speakers are more likely to use the same frame for verbs semantically similar to the recent anchor than for verbs semantically dissimilar to the anchor.

The Recent Verb Anchor hypothesis can be investigated using the syntactic priming paradigm. As alluded to above, much research in syntactic priming has probed the effect of previous experience with a particular syntactic frame on subsequent sentence processing. Recent experience with a sentence was shown to facilitate the reuse of the same frame in the production of a subsequent sentence (Bock, 1986, among others) and also facilitate the comprehension of a subsequent sentence (Arai et al., 2007). Using this paradigm, we can let participants experience a sentence in which a particular (anchor) verb occurs in a particular syntactic frame and see whether this recent experience modulates the choice of syntactic frame when they produce a subsequent sentence. More specifically, we can manipulate semantic similarity between the anchor verb in the prior or *prime* sentence and the verb in the following or *target* sentence using the syntactic priming paradigm. The Recent Verb Anchor hypothesis will be confirmed if the tendency of reusing the same frame increases as target verbs are semantically more similar to the anchor verb experienced in the production of prime sentences.

In Chapter 2, I report four syntactic priming experiments where I manipulate semantic similarity between prime (i.e., anchor) and target verbs. For example, the two prime sentences shown in (1.4) contain verbs that differ in their semantic similarity to

the verb in the target sentence. When the target sentence includes a verb like *promise*, the main verb is highly semantically similar to the target verb in one prime condition, i.e., *guarantee* in (1.4a), while the main verb in the other prime condition is dissimilar to the target verb, i.e., *bounce* in (1.4b).

(1.4) Target: *promise* (The director promised a large part to the actress / The director promised the actress a large part)

Prime: (a) *guarantee* (The CEO guaranteed all employees a bonus)

(b) *bounce* (The ball boy bounced the player a new ball)

The Recent Verb Anchor hypothesis predicts that speakers are more likely to choose to produce the target verb *promise* in the same syntactic frame as primes (i.e., reuse the syntactic frame of the prime sentence) when they have experienced the prime's syntactic frame together with a highly semantically similar verb like *guarantee* in (1.4a) than when they have experienced it with a dissimilar verb like *bounce* in (1.4b). In other words, speakers are more likely to produce *The director promised the actress a large part* (rather than *The director promised a large part to the actress*) when they have previously experienced *The CEO guaranteed all employees a bonus* than when they have experienced *The ball boy bounced the player a new ball*. Note that both prime types exemplify the same syntactic frame (i.e., NP_{agt} VERB NP_{rec} NP_{thm}) but the verbs (*guarantee* and *bounce*) differ in their semantic similarity to the target verb (*promise*). I will present these syntactic priming experiments in Chapter 2.

1.2.2 Subhypothesis #2: the effect of *typical* verb anchors

Zipf (1935, 1949) showed that word frequency is highly skewed in natural language use: Some words occur very frequently while many others occur much more rarely. This skewed frequency distribution has been shown to influence many facets of language processing (Diessel, 2007, for a review). For example, much research in sentence processing has shown that speakers are sensitive to words' frequency biases and automatically make use of frequency information when processing a sentence online (Trueswell, 1996, for example).

For present purposes, the most important property of words' biased frequency distributions is the fact that the occurrence of verbs with specific syntactic frames is highly skewed. Only a small number of verbs occur very frequently in a particular syntactic frame; most other verbs occur in that syntactic frame much less often. A single verb may even account for the 'lions' share' of the occurrences of a particular syntactic frame (Goldberg et al., 2004; Gropen et al., 1989). In the context of my Verb Anchor hypothesis, the frequent occurrence of a verb in a particular frame means speakers' frequent experience with the same association pattern between this verb and the syntactic frame. Frequent co-occurrences or co-activations of a verb and a syntactic frame are expected to strengthen their association and this association can be "learned" over repeated use (or priming) of a verb and a particular frame (Reitter et al., 2011). I therefore expect a highly frequent verb to become a typical anchor verb of the syntactic frame and have a constant and global influence on speakers' syntactic frame selection, irrespective of recent experience. In other words, I hypothesize that speakers choose the

same syntactic frame for verbs that are semantically similar to the typical anchor verb, if such a frequent verb exists. I labeled this hypothesis the Typical Verb Anchor hypothesis.

The motivation behind the Typical Verb Anchor hypothesis is the assumption that high frequency of occurrence of a verb in a syntactic frame leads to a strong cognitive association between that verb and that frame in the same way that a highly frequent exemplar of a category is strongly associated with the category (see Hintzman, 1986; Komatsu, 1992; Medin & Schaffer, 1978; Medin, 1989; Nosofsky, 1988, for reviews). Research on categorization shows that the more similar a stimulus is to that most frequent member of a category, the more likely it is to be considered a member of the same category. Several previous studies support the assumption that the relationship between a verb and a syntactic frame is qualitatively analogous to the relationship between an exemplar and a category. First, syntactic frames are not explicitly taught but are abstracted from repeated exposure to sentences with various verbs in the same way that natural categories are extracted from exemplars (Goldberg et al., 2007; Tomasello, 1992). Second, verbs, and more generally words, are organized by similarities in the mind as category exemplars are. Similarity is known to significantly modulate the organization of category exemplars. McRae and Boisvert (1998), for example, showed that words are also shown to be mentally organized by similarity, as they are primed to the degree to which two words are semantically similar to each other. Third, the use of syntactic frames often display typicality effects. For example, speakers tend to think of the most typical verb when asked to name a verb that can occur in a particular syntactic frame. If asked to provide an example verb that would fit the string 'A man ___ a kid a toy,' people are most likely to come up with the verb *give* (Goldberg, 1995). Importantly,

this typicality effect seems to be a consequence of highly skewed verb frequencies for each syntactic frame. These similarities suggest that syntactic frames and verbs can be conceived of, respectively, as abstract (syntactic) categories (e.g., schemas) and exemplars that exemplify abstract syntactic categories in actual linguistic experience.

The effect of the typical anchor of a syntactic frame results from experience with a number of sentences over a relatively extended period of time, as opposed to the effect of recent anchors discussed previously. The effect itself is not triggered by any single stimulus but is the long-term effect of a skewed frequency distribution. Thus the best way to test the frequency effect predicted by the Typical Verb Anchor hypothesis is to investigate a large amount of language use and examine whether natural language use exhibits the patterns predicted by the hypothesis, namely whether verbs' semantic similarity to the typical anchor of a syntactic frame influences the use of that same syntactic frame. In Chapter 3, I investigate the Typical Verb Anchor hypothesis through analyses of large-scale corpora.

As a final note, it should be kept in mind that I do not assume that the effects of recent and frequent verb anchors are mutually exclusive in natural language use. They may occur concurrently or independently of each other. For present purposes, it should suffice to test whether each effect is at play in syntactic frame selection when speakers construct a sentence.

1.3 Organization of the Thesis

In Section 1.1, I introduced a well-known linguistic phenomenon, the correspondence between verb meaning and sentential form, and provided a brief introduction to theoretical treatments of this problem. In Section 1.2, I proposed my hypothesis on some cognitive mechanisms which may give rise to the correspondences. I suggested that priming is the mechanism behind the linguistic phenomena. Namely, prior experience with a sentence modulates speakers' subsequent sentence processing. I assume the mechanism in sentence processing ultimately influences the way speakers construct language and linguistic structures. For my purposes, the most relevant aspect of the experience with a sentence is the co-occurrence between the verb and the syntactic frame in the sentence, which leads to a cognitive association between them. I hypothesized, first, that the verb that exemplifies a syntactic frame in a sentence becomes a semantic anchor of that syntactic frame and, second, that semantic similarity to that anchor of the syntactic frame modulates the likelihood of other verbs occurring in the same frame, which I labeled the Verb Anchor hypothesis.

I then made two subhypotheses. First, given the fact that speakers are significantly influenced by recent sentence experience, I predict that speakers tend to reuse the same syntactic frame if a given verb is semantically similar to the verb in the previous sentence, i.e., a recent anchor. Second, given the fact that high frequency of occurrence leads to typicality in cognition, I further hypothesized that a highly frequent verb in a certain sentential form becomes typical of and even identified with that abstract syntactic frame and predicted that speakers tend to use that syntactic frame for

verbs more often when they are semantically similar to the highly frequent verb, i.e., a typical anchor. In short, I predicted the effect of verb anchors operates both under the influence of recent sentence experience and in the context of verbs' frequency biases.

The following two chapters will be dedicated to testing these two subhypotheses. Chapter 2 investigates the effect of recent sentence experience on sentence production processes using the syntactic priming paradigm. I will report four syntactic priming experiments where verb similarity between prime and target sentences are manipulated. Chapter 3 investigates the effect of frequent verbs typical of abstract syntactic frames, analyzing large-scale corpus data. I will report the methods for data collection and the results of statistical modeling on the dataset. In both experimental and corpus-based studies, I used two sets of verbs that are known to participate in the so-called dative and locative alternations, respectively. The dative alternation refers to the contrast between *She gave me a book* and *She gave a book to me*; the locative alternation refers to the contrast between *I sprayed the dough with some oil* and *I sprayed some oil on the dough*.[1]

Chapter 4 will review current models of sentence production processes and explore whether and how present findings can be accommodated in these models. Chapter 5 summarizes the results of this thesis and discusses future research. Appendices include experimental materials from Chapter 2 and the statistic details of the corpus studies from Chapter 3.

[1] An early report of the studies discussed in Chapters 2 and 3 can be found in Yi and Koenig (to appear).

CHAPTER 2 The Effect of Recent Verb Experience on Syntactic Frame Selection

2.1 The *Recent* Verb Anchor Hypothesis

Assuming that sentence experience gives rise to a cognitive association between its verb and the syntactic frame the sentence exemplifies, the Verb Anchor hypothesis, outlined in Chapter 1, proposes that a verb can become an anchor of a syntactic frame as a key lexical item in constructing sentences and hypothesizes that semantic similarity to an anchor verb modulates the likelihood of other verbs occurring in the same frame. More specifically, verbs semantically similar to the anchor are more likely to occur in the anchor's frame than verbs that are not semantically similar to the anchor. I suggest this cognitive mechanism gives rise to speakers' tendency to choose the same or similar

syntactic frame(s) for semantically similar verbs, and ultimately influences the grammar of language. Namely, I argue that the mechanism proposed by the Verb Anchor hypothesis is the cognitive underpinnings of the correspondence between verb meanings and sentential forms that have been widely observed in language.

In this chapter, I attempt to verify one of the corollaries of the Verb Anchor hypothesis, namely the effect of *recent* verb anchors. Previous research in sentence production has shown that speakers are immediately affected by the exposure to a single linguistic stimulus. In other words, recent experience modulates upcoming language processing. In particular, Bock (1986) demonstrated that after producing a sentence in a particular syntactic form, speakers are more likely to use the same syntactic structure in their subsequent sentence production, even when an alternative syntactic option is available for use. This effect, commonly referred to as *syntactic priming*, has been attested despite the absence of lexical and semantic overlap between adjacent sentences, so it often serves as significant empirical evidence for the existence of abstract syntactic structures or syntactic categories in the human mind. In a nutshell, syntactic priming demonstrates that recent experience with a single sentence can lead to a change in our way of formulating a subsequent sentence. In this context, what I labeled the Recent Verb Anchor hypothesis predicts that speakers are more likely to reuse the same syntactic frame for a verb that is semantically similar to the recently experienced anchor than for a verb that is not or less semantically similar to the anchor verb.

As illustrated in Figure 2.1, if one has experienced a sentence like *The man promised employees a bonus*, I assume it leads to co-activation of the verb lemma *promise*

and the syntactic frame [NP_{agt} V NP_{rec} NP_{thm}]. The lexical-syntactic association is represented by a connecting line with circled ends in the diagram.

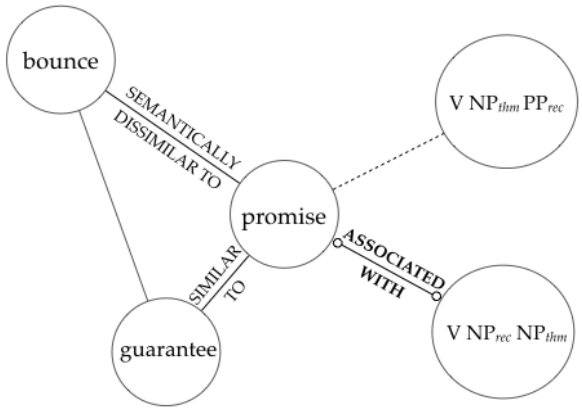


Figure 2.1 Association between a recent verb anchor and a syntactic frame

As detailed in Section 1.2 in Chapter 1, I also assume that verb lemmas are connected to the degree to which they are semantically similar to each other, based on the research on semantic priming (McRae & Boisvert, 1998), and the activation of one node influences others through these links (Collins & Loftus, 1975). Activation of a particular verb is expected to affect semantically similar verbs more than dissimilar verbs. For expository purposes, in Figure 2.1, I put the verbs *promise* and *guarantee* closer to each other than the verbs *promise* and *bounce* to illustrate higher semantic similarity between *promise* and *guarantee* than between *promise* and *bounce*. In this setting, I hypothesize that the activation of the syntactic node [NP_{agt} V NP_{rec} NP_{thm}] associated with the verb *promise* is more likely to influence the choice of syntactic frame for *guarantee* than for *bounce,* as *guarantee* is more semantically similar to *promise* than *bounce* is to *promise* (Roelofs, 1992, 1993). As a result, the verb *guarantee* is more easily associated

with the same [NP_{agt} V NP_{rec} NP_{thm}] node than the verb *bounce* is, if they are to be used in subsequent sentence production.

The syntactic priming paradigm can be a useful tool for testing the Recent Verb Anchor hypothesis. In this experimental paradigm, participants experience a sentence stimulus first (*prime*) and then are asked to produce another sentence (*target*). Experimenters can manipulate certain aspects of the prime sentence for their purposes and determine whether the manipulations affect the target sentence production in the predicted way. In this setting, the Recent Verb Anchor hypothesis can be tested by manipulating semantic similarity between verbs in prime and target sentences. I illustrate the logic step by step: Through producing a prime sentence (i.e., priming), participants experience the association of a particular verb and a syntactic frame. Participants are then asked to produce a target sentence, given another verb. By examining the target sentences they produce, we can determine whether semantic similarity between the verb in the prime and the verb to be used in the target modulates their choice of syntactic frame. If the recent experience of the verb anchor has the predicted effect, we can find an increased tendency for speakers to choose the syntactic frame the anchor is associated with in producing target sentences when target verbs are semantically similar to the prime verb (i.e., anchor). In other words, I expect to observe stronger priming effects when prime and target verbs are highly semantically similar than when prime and target verbs are semantically dissimilar.

The remainder of this chapter reports four syntactic priming experiments where I manipulated semantic similarity between prime and target verbs. As a preliminary, Section 2.2 first provides an overview of syntactic priming and the methodologies used

in this line of research. Section 2.3 introduces two argument alternations that I used to test speakers' syntactic frame selection, the so-called dative and locative alternations. The dative alternation refers to the contrast between *She gave me a book* and *She gave a book to me*; the locative alternation refers to the contrast between *I sprayed the dough with some oil* and *I sprayed some oil on the dough*. Four syntactic priming experiments are reported. Section 2.4 first reports two experiments where syntactic priming is measured by syntactic shifts from the preferred to the dispreferred frame between alternate frames of each alternation (i.e., syntactic shifts in targets towards the relatively infrequent syntactic variant in each alternation). Section 2.5 reports two other experiments where syntactic priming is measured by relatively easy syntactic shifts in targets from the dispreferred to the preferred frame in each alternation. The prime and target structures tested in Section 2.5 are a mirror-image of those tested in Section 2.4. Section 2.6 reports meta-analyses of all four experiments. Section 2.7 discusses the overall implications of the four experiments and concludes this chapter.

2.2 Syntactic Priming as a Methodology

2.2.1 A brief overview

Since Bock's seminal work (1986), syntactic priming has served as robust behavioral evidence for the theoretical claim that abstract syntactic structures are represented in the human mind independently of other linguistic components. In her experiments, participants were first asked to read a sentence out loud and then asked to describe a picture intended to prompt participants to produce a sentence either in the same syntactic structure as the prime sentence or in alternative structures. The results of these experiments showed that speakers tend to reuse the structure of the prime sentence in producing the target sentence. This effect has since been called syntactic priming in that the abstract syntactic structure seems primed by processing the first sentence and remains available for reuse until the moment its subsequent target sentence is formulated.

Syntactic priming is particularly well-attested in language production, for example when producing two subsequent sentences. More recent studies report that syntactic priming also occurs when going from production to comprehension (Bock et al., 2007) as well as from comprehension to comprehension (Arai et al., 2007). Syntactic priming effects have been replicated using various syntactic frames, the dative alternation (Bock, 1986), the active-passive alternation (Bock & Griffin, 2000), the locative alternation (Chang et al., 2003), pre- and post-nominal modification (Cleland & Pickering, 2003), the verb-particle alternation (Konopka & Bock, 2009), and so on.

Syntactic priming effects were found in many languages other than English such as German, Dutch, Korean, and Japanese, to name a few.

Earlier syntactic priming research emphasized that syntactic priming occurs with no lexical and semantic overlap between prime and target stimuli. Bock and Loebell (1990) showed, for example, that passive *by*-phrases and locational *by*-phrases lead to an equal amount of syntactic priming effect, e.g., *The construction worker was hit by the bulldozer* and *The construction worker was digging by the bulldozer* (p. 18), and argued that sentence frames are identified independent of lexical and conceptual information. Their results suggest that the syntactic representation that is primed and reused for targets in Bock and Loebell's study is conceived of as a highly abstract syntactic representation, such as [NP V NP NP] from *Max gave Ann a present*, *The rumor cost Max his job* and *I consider him a good friend*. However, a good number of syntactic priming studies that used argument alternations as experimental stimuli (e.g., the contrast between *Max gave Ann a present* and *Max gave a present to Ann*) leave open the possibility that syntactic priming occurs at the level of role-specified syntactic representations such as [NP_{agt} V NP_{rec} NP_{thm}] because it is inherently difficult to separate event-semantic information from those syntactic structures as they tend to co-vary (see Chapter 1). Chang et al. (2003) demonstrated explicitly that the order of semantic roles also influences syntactic priming. In a nutshell, the majority of syntactic priming studies support that what underlies syntactic priming is at least a lexically independent level of syntactic representations, not affected by particular verb meanings, as opposed to my Verb Anchor hypothesis I introduced in Chapter 1.

There are also studies in the literature that demonstrate lexical and semantic effects on syntactic priming, though. Most relevant to my hypothesis is Cleland and Pickering's (2003) demonstration that semantic relatedness of head nouns enhances syntactic priming between two noun phrases. In English, there are two ways of modifying a noun, either pre-nominally by an adjective (*the red goat*) or post-nominally by a relative clause (*the goat that's red*). Cleland and Pickering found speakers are more likely to reuse the same type of noun modification when the head nouns in prime and target NPs belong to the same conceptual category (*goat* and *sheep*) than when they belong to different categories (*door* and *sheep*). Their results seem to provide at least partial support for my hypothesis. However, we need to exert caution when generalizing from the behavior of NPs over to VPs due to some of their qualitative differences. In general, nouns do not inherently select or require modifiers while verbs do select co-occurring arguments. For example, the noun *goat* does not require any modifier like *red* but the verb *give* semantically requires a giver, a recipient and a gift, all or part of which are pre-determined to occur as the verb's syntactic dependents in a sentence. Therefore it gets unclear whether semantic similarity between head verbs influences the syntactic priming of VP structures in the same way conceptual similarity between head nouns affects the syntactic priming of NP structures.

Griffin and Weinstein-Tull (2003) provide some evidence for the effect of verbs on syntactic priming. They tested two groups of verbs, known as raising and control verbs. Object raising and object control verbs differ, whether the object NP in the infinitival complement is assigned an event role. For example, the direct object of an object raising verb, e.g., *Mary* in *John believed Mary to be nice*, is not assigned any event role, whereas

the direct object of an object control verb, e.g., *Mary* in *John persuaded Mary to be nice*, is assigned an event role. Sentences with object raising verbs are paraphrasable using either an infinitival or a sentential complement. Then the the direct object in the infinitival complement is marked as a subject in the sentential complement, e.g., *John believed that Mary was nice*. In constructing the stimuli, they took advantage of the alternative complementation types, either infinitival complements or sentential complements (e.g., the contrast between *John believed Mary to be nice* and *John believed that Mary was nice*). Griffin and Weinstein-Tull found that speakers are more likely to reuse the same type of complementation when prime and target verbs belong to the same conceptual group than when they are from different groups. Although the differences between these two verb groups are concerned with (some aspect of) their semantic and conceptual properties, verbs' semantic similarity was not directly manipulated. For example, object control verbs include a wide range of verb meanings such as *persuade*, *force*, *convince*, *order*, *ask*, *tell*, *allow*, *encourage*, *beg*, and so on; object raising verbs include *wish*, *confirm*, *assume*, *acknowledge*, *hear*, *think*, *judge*, *predict*, and so on.

More recently, Goldwater et al. (2011) demonstrated the contribution of sentential meanings to syntactic priming in young children. They proposed an analogy-based account of syntactic priming, involving *structure-mapping* (Gentner, 1983). Namely, speakers draw parallels between prime and target sentences and make inferences based on those parallels. Due to the nature of analogical reasoning, the degree of similarity between prime and target sentences matters. They argued semantic similarity can further facilitate structural mappings, on top of structural similarity most previous studies focused on. Their proposal is to some degree related to my hypothesis as they

are concerned also with the cognitive mechanisms underlying syntactic priming. However, what they intend as semantic similarity refers to a much broader notion of similarity than I focus on here, including similarities of thematic relations as well as of scenes that utterances describe, i.e., similarities beyond the similarity of verb meanings.

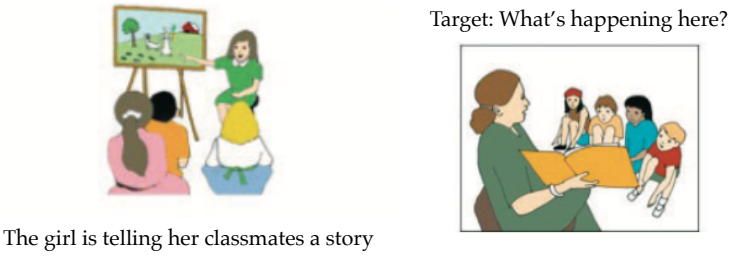


Figure 2.2 An example of scene similarity in Goldwater et al. (2011)

In their experiments for example, as illustrated in Figure 2.2, young children were given a prime sentence such as *The girl is telling her classmates a story* or *The man is teaching the students the alphabets* and then asked to verbally describe a picture. Here, the prime and the target are conceptually highly similar to each other no matter what verb is used to describe them. Therefore, it is difficult to figure out what linguistic or non-linguistic concepts are tapped in these syntactic priming effects. Their stimuli seem to be concerned with a less abstract or more concrete level of semantic and syntactic representation than the ones I test in this thesis where only a verb and a frame is associated, because scene similarity involve similarities of semantic arguments between prime and target verbs as well as many other potential similarities. Moreover, when formulating a target sentence, the 4- to 5-year-old participants in Goldwater et al.' study may use the same verb they have experienced in the prime sentence due to the relatively

small size of their vocabulary. In such cases, the effects can be attributed more to what is known as the *lexical boost* effect, namely the fact that the likelihood of syntactic repetition significantly increases if prime and target share the same verb, rather than to syntactic priming. Several studies have shown that there are qualitative differences between syntactic priming and lexical boost. For example, syntactic priming may last for an extended period of time while lexical boost disappears very quickly (Hartsuiker et al., 2008). Therefore, in order to test my Verb Anchor hypothesis, it is important to remove or control for factors that modulate prime and target similarity other than verb similarity in constructing experimental stimuli.

Lastly, note that the mechanisms of syntactic priming are still under debate. Bock (1986) originally proposed syntactic priming occurs because of the transient activation of a syntactic structure. Chang et al. (2006) on the other hand suggested that syntactic priming results from implicit learning as it lasts for a relatively long time, rather than being transient. Reitter et al. (2011) suggested that these two mechanisms may not be mutually exclusive but can occur concurrently or sequentially. The overall mechanisms underlying syntactic priming are beyond the scope of this chapter and will be discussed more in detail in Chapter 4 where I evaluate current sentence production models in the context of the results of this thesis (see Branigan et al., 1995; Ferreira & Bock, 2006; Pickering & Branigan, 1999; Pickering & Ferreira, 2008; Tooley & Traxler, 2010, for further review of the literature on syntactic priming).

In the next section I introduce two kinds of experimental methods most commonly used in syntactic priming research, i.e., picture descriptions and sentence recalls. The strengths and weaknesses of each method will be discussed as a justification

for why the sentence-recall method was used for the experiments presented in the present thesis.

2.2.2 Experimental methods used for syntactic priming

Two types of experimental methods have been widely used in syntactic priming experiments. In experiments using the *reading-and-picture-description* methods (Bock, 1986), primes are sentential stimuli while targets are pictorial stimuli, as illustrated in Figure 2.3.

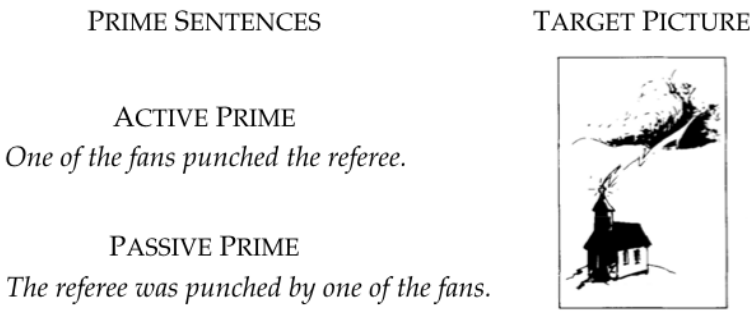


Figure 2.3 Example stimuli from Bock's (1986) syntactic priming experiment

Prime sentences are presented to participants in either of two possibly alternating syntactic frames, for example, in the passive or in the active frame. Participants are directed to read a prime sentence out loud as exactly as it is presented. Experimenters intend the reading phase to activate or "prime" the syntactic frame used in this sentence. Participants are then given a picture and asked to verbally describe it. After reading an active or passive prime, they are presented with a target picture that

describes an event that involves two entities. Participants are expected to describe the picture either using an active frame (e.g., *Lightening is striking the church*) or a passive frame (e.g., *The church is being struck by lightening*). It is taken as evidence of syntactic priming that participants tend to describe a target picture using a passive sentence more often after they have read a passive prime.

Note that in this experimental setting it is also possible that participants happen to describe the target picture in the prime's frame even without syntactic priming, e.g., by chance. The likelihood of a target picture involving two entities being described in the active or in the passive form may also vary item by item due to idiosyncratic properties of the pictures. Thus, it is important to provide a baseline relative to which the observed putative priming effect can be compared. The baseline here is the percentage of each target picture being described using a particular syntactic frame, say, active or passive, when no active or passive prime sentence is present. It is often measured by presenting syntactically irrelevant prime sentences before the target pictures. For example, an intransitive prime sentence may be paired with a target picture that contains two entities. The magnitude of syntactic priming is then measured by subtracting the baseline percentage of using the frame without priming from the percentage of using the frame after seeing the relevant prime.

In experiments using the *reading-and-recall* method, both primes and targets are sentence stimuli. Participants are presented with sentences to read and are then asked to verbally recall them. Each trial consists of two sentences. The sentence they are asked to recall first serves as prime and the sentence they recall later is the target. Importantly, the syntactic frames of the prime and target sentences differ, but the target sentence has to

be paraphrasable using the syntactic frame of the prime sentence. Syntactic priming is measured by the likelihood of recalling the target sentence using the syntactic structure of the prime sentence they have recalled just before.

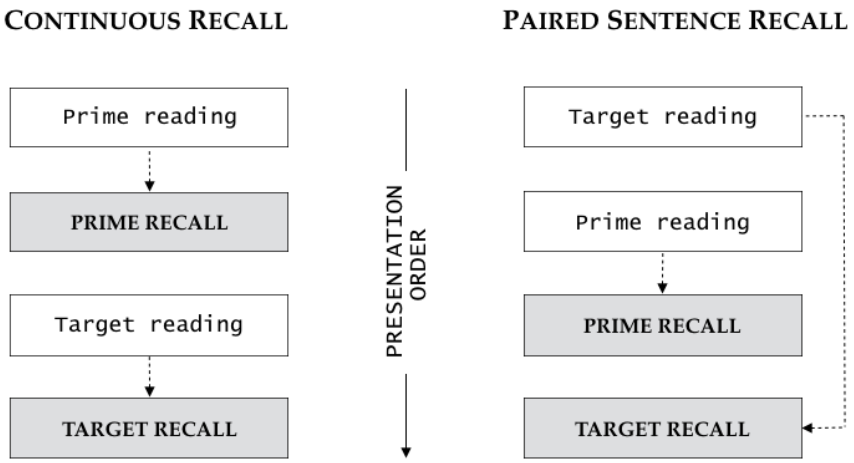


Figure 2.4 Two types of presentation order in the sentence recall design

Experimenters use either of the two different orders in presenting sentence stimuli and prompts for recall or recall cues, as illustrated in Figure 2.4. In continuous recalls, participants read and recall each and every sentence continuously (Chang et al., 2003; Konopka & Bock, 2009). Each trial consists of three phases, namely reading a sentence, solving a number comparison task, and recalling the sentence they have just read before. The extralinguistic task (e.g., given a fleeting array of numbers, 4 3 1 6 5, then asked if "three" was one of them) intervenes between the reading and recalling of a sentence stimulus and thereby helps prevent participants from rehearsing the sentence to recall by rote.

In paired sentence recalls, participants read two sentences one after the other in the reading phase and are then presented with cues to recall the prime and target sentences one after the other (Griffin & Weinstein-Tull, 2003). The target sentence precedes the prime sentence during the reading phase, but the prime sentence precedes the target sentence in the recall phase. Thus the recalling of the prime immediately follows the reading of the prime sentence. The fact that the reading and recalling of the prime is back-to-back is expected to facilitate the accurate recalling of primes. Successful recall of a prime is a prerequisite for a successful trial. In addition, here, as reading and recalling the target sentence is separated by the reading and recall of the prime sentence, no extralinguistic task is required to prevent rote recalls of the target.

The advantages of the continuous recall design are, first, it prevents participants from noticing prime-target pairs and, second, the task is easier as every sentence is recalled immediately after being read. However, this design involves some complications. A prime sentence in a particular syntactic frame is read and recalled (e.g., *One of the fans punched the referee*) and then is immediately followed by reading of a target sentence (which instantiates an alternative syntactic frame, e.g., *The church is being struck by lightening*). Reading of the target sentence may cancel the priming effect of the prime sentence and the target's syntactic frame might partly prime the recall of the target sentence, assuming comprehension of a sentence also initiates syntactic priming (Arai et al., 2007; Bock et al., 2007). Thus, the two different syntactic frames may be competing for priming when participants are to recall the target sentence, one from reading and recalling the prime and the other from reading the target. The paired recall design avoids these disadvantages of the continuous recall design. The downside of paired

recalls is, though, that it may be difficult for participants to keep the content of the target sentence in memory from its reading all the way to its recall as reading and recalling of the target are separated by the reading and recalling of a prime sentence. This paired sentence recall design thus possibly requires a larger number of participants and items to get reliable results than continuous recall experiments due to many failed trials. As will be shown in the following sections, the four syntactic priming experiments I report in this chapter used the paired sentence recall procedure and follow closely the design used in Griffin and Weinstein-Tull (2003).

The motivation behind the reading-and-recall design in syntactic priming experiments is largely based on the research in sentence memory. Studies of immediate recall found that speakers tend to remember the gist of a sentence and unpack it using their own language when they are to recall it, rather than remember and recall the sentence verbatim (Lombardi & Potter, 1992; Potter & Lombardi, 1990). Taking advantage of this fact, experimenters of syntactic priming test how participants recall the gist of the target sentence under the influence of the prime structure. Roughly speaking, participants are expected to retain the core message from reading a target sentence, for example, in the active form like *The lightening hit the church*, e.g., a message consisting of 'church,' 'lightening,' and 'hit,' with little verbatim syntactic memory. When reformulating the target sentence in recall after producing a passive prime, for example, *The referee was punched by one of the fans*, they are expected to produce the target sentence in the passive form as well, *The church was hit by the lightening*, rather than in the active form in which the sentence was originally presented for reading. Thus in this context, the priming effect manifests itself in misrecalls of the target sentences or syntactic shifts

from the structure the target was originally read in to the prime structure produced just before.

One empirical advantage of the recall design over the picture description design is that experimenters can have more control over target sentences. Not only syntactic frames but also words, phrasal types and length of phrases of target stimuli can be carefully controlled for while preparing the stimuli. It is particularly useful when these factors have been previously acknowledged to affect the phenomena as well. Also, it is easier in the recall design to use as experimental stimuli a wide range of meanings including abstract concepts which are often difficult to depict. The downside of this method is that it can possibly reflect factors not involved in free sentence production as recalling is less natural than verbalizing the description of a picture.

2.3 Argument alternations as experimental materials

In the syntactic priming experiments reported below, I used two kinds of argument alternations known as the dative and locative alternations. (Chapter 3 investigates verbs that participate in these alternations as well.) These alternations involve a contrast between two alternate syntactic frames which convey more or less the same meaning. Namely, one variant can serve as a rough paraphrase of the other variant. In the following two sections, I provide definitions of the dative and locative alternations and introduce some of their semantic and syntactic properties relevant to the present investigation.

2.3.1 The dative alternation

The dative alternation refers to the contrast between the Ditransitive or Double Object frame (e.g., *John gave his son a toy*) and the Prepositional Dative or Prepositional Object frame (e.g., *John gave a toy to his son*), illustrated in (2.1).

(2.1) The Dative Alternation

a. [V NP_{rec} NP_{thm}] Double Object (DO) frame

b. [V NP_{thm} to-$PP_{rec/goal}$] Prepositional Object (PO) frame

Both frames involve three semantic arguments, an *agent* who acts, a *recipient* who receives, and a *theme* which is transferred to the recipient. In the Double Object or DO

frame, the recipient argument is realized as an NP, which precedes the gift argument realized as another NP. In the Prepositional Object or PO frame, the same or similar set of three semantic arguments are syntacticized in a different way. Namely, a recipient argument is realized as a (*to*-headed) PP that follows a theme argument realized as an NP.

The dative alternation has provided both linguists and psycholinguists with ample opportunity to empirically investigate the factors that modulate speakers' syntactic frame selection. Speakers are basically given two alternative syntactic options to choose from. Thus, we can investigate under what conditions speakers prefer to choose, for example, the DO rather than the PO frame to realize three semantic arguments in a single sentence, e.g., *John*, *a toy*, and *his son*. Previous research has documented some crucial determinants of the choice between the two alternating frames (e.g., phonological length, pronominality, and givenness of the recipient and theme arguments; See Chapter 3 in this thesis; Bresnan et al., 2007, for more details). Experiments 1 and 3, reported below, used the dative alternation to test the role of verb similarity on speakers' choice of syntactic frame in online sentence production.

In most cases, the DO and PO frames can be interchangeably used while causing no dramatic difference in meaning. However, it can also be the case that either frame does not sound as good as the other or is even grammatically ill-formed, as illustrated in (2.2). The contrast in (2.2a) shows that in the DO frame the recipient argument should be a potential recipient, or 'a possessor or an intended or projected possessor' (Green, 1974; Oehrle, 1976), but in the PO frame it can be a spatial goal or location as well. The DO

frame may sound better if the location argument can be understood as a metonym of a recipient such as 'someone at the border.'

(2.2) a. *John sent the border a package. (Bresnan, 1978)
John sent a package to the border.

b. Mary's behavior gave John an idea. (Green, 1974, p. 82)
*Mary's behavior gave an idea to John.

The contrast in (2.2b) also demonstrates that the DO and PO frames are associated with slightly different semantic constraints. The PO frame is compatible with the notion of physical or metaphorical 'transfer' from one place to another (e.g., from the agent to the recipient), at least more so than the DO frame. That is why the NP argument in the *to*-PP phrase is often understood as a *goal* argument rather than a recipient. In contrast, the DO frame may not require 'transfer' as long as the notion of 'caused-possession' is satisfied. Given these semantic constraints, many theories of argument alternation propose that the DO frame is associated only with a caused possession event, while the PO frame is associated either with a caused possession or with a caused motion event. When using the dative alternation as experimental stimuli of syntactic priming as I do in this thesis, it is therefore necessary to verify that each stimulus that uses one syntactic variant is paraphrasable into the other variant (e.g., from DO to PO or from PO to DO) while causing no significant change in meaning or in grammaticality.

Although the two syntactic variants of the dative alternation are interchangeable in many cases, they are in fact not equally frequent in natural language use. Based on my

study in the British National Corpus, most of the verbs that participate in the dative alternation occur far more frequently in the PO frame than in the DO frame in naturally occurring language. Only a few verbs such as *give* and *tell* occur more frequently in the DO frame than in the PO frame. (See Chapter 3 for more details on my corpus studies.) More generally, verbs differ as to which frame they prefer to occur in. In the context of syntactic priming experiments, it means participants may prefer to use the frequent syntactic frame (i.e., PO in general) in the absence of a priming manipulation when asked to produce target sentences with alternating verbs (i.e., verbs that can occur in both frames). Moreover, if the reading-and-recall method is used as an experimental paradigm (see Section 2.2.2 for details), priming is measured by participants' syntactic shifts from the frame in which a target sentence is presented for reading to the frame in which its prime sentence has just been produced. For example, a target sentence presented in the DO frame will be followed by a prime in the PO frame, and after producing the PO prime, participants may recall the target in the DO frame as was read or in the PO frame by shifting the syntactic frame they read to the prime's frame. Therefore, depending on which variant is set as the prime structure in the experiment, priming is measured either by shifts in targets towards the preferred frame or by shifts towards the dispreferred frame. It is apparent the former is easier than the latter and it is possible that participants show different behavior in these two cases. In Experiment 1 of this chapter, priming is measured by syntactic shifts towards the less preferred frame (i.e., the DO frame); in Experiment 3, priming is measured by shifts towards the preferred frame (i.e., the PO frame). More details will be presented in Sections 2.4.1 and 2.5.1, respectively.

2.3.2 The locative alternation

The locative alternation refers to the contrast between the Ground Object (GO) frame (*John loaded the truck with boxes*) and the Figure Object (FO) frame (*John loaded boxes onto the truck*), illustrated in (2.3). Both variants are used with verbs whose meanings include three semantic arguments, one who does the action, another that refers to a kind of location and the other that ends up being placed or created in that location. As with the dative alternation, the three arguments can be syntactically configured in two distinct ways. This alternation is also referred to as the *spray/load* alternation because the verbs *spray* and *load* are representative of the two alternating frames.

(2.3) The Locative Alternation

a.	[V NP_{loc} with-PP_{thm}]	Ground Object (GO) frame
b.	[V NP_{thm} (in/on)to-PP_{loc}]	Figure Object (FO) frame

In both variants, the VP consists of a verb and two postverbal arguments, an NP and a PP. In the Ground Object or GO frame in (2.3a), the NP denotes the ground or location argument and the PP denotes the figure or theme argument. In the Figure Object or FO frame illustrated in (2.3b), the mappings between semantic arguments and syntactic positions are reversed, such that the figure argument occurs as an object NP and the ground argument occurs as a PP. Note that in the GO frame, the preposition that heads the PP is almost invariably the preposition *with*. However, in the FO frame, several different prepositions can head the PP that denotes the ground argument. Common examples include *in(to)*, *on(to)*, *to*, and *around*. As is in the dative alternation,

these two alternating frames lead to sentences that are rough paraphrases of each other. This alternation has also been used in experimental stimuli in previous syntactic priming experiments (Chang et al., 2003).

Although the GO and FO frames are used to encode more or less the same meaning, it is acknowledged by many that each frame is associated with a slightly different meaning, illustrated in (2.4). Namely, the meaning of the GO frame focuses on the resultant state by adding the figure object to the ground, while the meaning of the FO frame focuses on the movement of the figure object in a particular manner to the ground (Pinker, 1989, p. 80).

(2.4) Rappaport and Levin (1988) (x: agent, y: figure, z: ground)

a. The GO frame: [[x cause [z to come to be in STATE]]
BY MEANS OF [x cause [y to come to be at z]]

b. The FO frame: [x cause [y to come to be at z]]

The alternating frames are also semantically differentiated by what is known as the *holism* effect. Semanticists have noted that the GO frame in (2.3a) and (2.4a), but not the FO frame in (2.3b) and (2.4b), is associated with a holistic interpretation. For example, the sentence in the GO frame *John loaded the truck with boxes* often leads to a holistic reading that the truck is full of boxes, but the FO frame *John loaded boxes onto the truck* does not necessarily lead to such an interpretation. These semantic differences suggest the alternate frames of the locative alternation can be roughly truth-

conditionally equivalent but at a finer-grained level of semantic analysis they are associated with slightly different meanings.

The range of verbs that participate in the locative alternation seem semantically more diverse, compared to verbs that participate in the dative alternation. *Spray-* and *load*-like verb meanings are at the center of the locative alternation. But, verbs of inscribing, verbs of presenting and verbs of forceful contact participate in the same type of alternation (Levin, 1993, pp. 65-67), as illustrated in (2.5).

(2.5) Image impression verbs: *engrave the date on the ring* / *the ring with the date*
Fulfilling verbs: *present a prize to the winner* / *the winner with a prize*
With/against alternation verbs: *hit the stick against the wall* / *the wall with the stick*

The image impression verbs in particular are often subsumed under the *spray/load* alternation due to their conceptual similarity to *spray/load* verbs. Image impression verbs do not denote a moving event, but they involve some motion that makes a figure (image) appear in a ground (location). In this thesis, I call the locative alternation the sum of *spray-*, *load-*, and *engrave*-type verbs. Therefore, the sentence stimuli used in the present experiments (and also the verbs investigated in Chapter 3) involve one of the three basic events such as *moving, applying some material in a particular manner*, or *creating something*.[2]

[2] There are other types of verbs in the literature that are also assumed to participate in the locative alternation, illustrated in (i)-(iii) below. The location arguments refer to a source location (*of/from* ~) in (i)-(ii) and a midway location rather than a final location (*through* ~) in (iii).

(i) *Clear* verbs: *clear dishes from the table* / *the table of dishes*
(ii) Material-product alternation verbs: *carve a toy out of a wood stick* / *a wood stick in a toy*
(iii) *Through-with* alternation verbs: *pierce a needle through the cloth* / *the cloth with a needle*

As with the alternating frames of the dative alternation, the GO and FO frames also show frequency biases in naturally occurring language use. Based on my study of the locative alternation in the British National Corpus, the FO frame is in general more frequently used than the GO frame. However, the frequency bias towards the preferred FO frame is not as strong as the bias towards the preferred PO frame in the dative alternation. Verbs that participate in the locative alternation, though, vary in their frequency biases much more than verbs of the dative alternation (see Chapter 3 for more details). In the experiments where I used the sentence-recall method, priming is measured by target shifts towards the dispreferred frame in Experiment 2 where the prime structure is the GO frame, as is in Experiment 1 (i.e., target shifts towards the GO frame) and by target shifts towards the preferred frame in Experiment 4 where the priming structure is the FO frame, as is in Experiment 3 (i.e., target shifts towards the FO frame).

To summarize, the locative as well as the dative alternation involve a pair of alternating syntactic frames, DO and PO frames and GO and FO frames, respectively. Each frame is associated with a syntactic and semantic representation, illustrated in Table 2.1. In natural language use, PO and FO frames are more frequently used than the alternate DO and GO frames, respectively.

Table 2.1 Comparisons and contrasts between the dative and locative alternations

	DATIVE ALTERNATION		LOCATIVE ALTERNATION	
ALTERNATING FRAMES	DO	PO*	GO	FO*
Syn-Sem representations	V NP_{rec} NP_{thm}	V NP_{thm} $PP_{rec/goal}$	V NP_{loc} PP_{thm}	V NP_{thm} PP_{loc}
Phrase structures	V NP NP	V NP PP	V NP PP	

Note: Asterisks (*) indicate the more frequent one of the two alternating frames.

As a last note, it is often unclear in many of previous syntactic priming studies which level of syntactic abstraction they attribute priming effects to, i.e., what is being primed. This is mainly because the majority of them use the dative alternation as experimental stimuli. As shown in Table 2.1, the alternating frames of the dative alternation, DO and PO, differ not only in their syntactic and semantic representations but also in the phrase structures irrespective of meaning. The order of semantic roles and phrasal types are correlated between the two frames. Using the locative alternation thus can help tease apart the role of phrase structure and meaning in interpreting syntactic priming.

2.4 Experiments 1 & 2: *Dispreferred* Syntactic Frames as Primes

This section reports on two syntactic priming experiments that investigated the effect of recent experience with a verb in a sentence on upcoming sentence production. In order to test whether semantic similarity between priming and target verbs modulates syntactic priming, the experiments have three prime types per target. Apart from control primes (baseline), the other two prime types are manipulated so that verbs in the two prime sentences differ in their semantic similarity to the verb in the target. The verb in *high-similarity* primes is semantically highly similar to the target verb and the verb in *low-similarity* primes is much less similar or dissimilar to the same target verb. If my Verb Anchor hypothesis is correct (see Section 1.2 for more details of my hypothesis), I predict that low- and high-similarity primes will lead to different amounts of syntactic priming, namely more priming by the high-similarity primes than by the low-similarity primes.

The two experiments reported in this section deal with different sets of alternating frames. Experiment 1 in Section 2.4.1 uses the dative alternation, i.e., the choice between the Double Object and Prepositional Object frames. Experiment 2 in Section 2.4.2 uses the locative alternation, i.e., the choice between the Ground Object and Figure Object frames. As introduced in the previous section, although either of the alternating frames can be used for more or less the same meaning with minimal changes except syntactic forms, one of them was found to be much less frequently (or more frequently) used than the other in natural language use. In the dative alternation, the Double Object frame is less frequent than the Prepositional Object frame; in the locative

alternation, the Ground Object frame is less frequent than the Figure Object frame. Since the present experiments use a sentence recall task, the syntactic priming effect is measured by the number of targets that are misrecalled or accurately recalled in the structure of the prime sentence (i.e., syntactic shift, see Section 2.2.2 for more details of this methodology). Depending on which frame is set as the priming frame, priming effects may involve a shift towards a more frequent or preferred frame or a shift towards a less frequent or dispreferred frame in target recalls. In the two experiments in this section, the priming structure is the dispreferred construction, namely the Double Object frame in Experiment 1 and the Ground Object frame in Experiment 2. Consequently, priming effects or target shifts should be more difficult for participants, as the shift is towards a less preferred frame, and there is pressure to produce or recall the more frequent frame.

The present experimental setting, using dispreferred syntactic frames in the primes, is particularly useful for teasing apart well-attested syntactic priming effects (which are argued to be irrespective of semantic overlap between prime and target) from the priming effects investigated through the present experimental manipulation, i.e., semantically (dis)similar verbs between prime and target sentences. A robust finding in the literature on sentence production is that syntactic priming can occur with no lexical and semantic overlap between prime and target stimuli (see Section 2.2.1 for more details). Thus it is possible that syntactic priming reaches a ceiling if shifts are supposed to be towards a preferred frame, leaving no room to test the additional contribution of verbs' semantic similarity in meaning. By using dispreferred frames as primes, we expect to observe the usual no-semantics-involved syntactic priming in the *low-similarity*

condition, conforming with the results of previous research. But my hypothesis predicts an increase in the size of the priming effect in the *high-similarity* condition, compared to the low-similarity condition. Such a result would show that verbs' semantic similarity plays a unique role in syntactic priming above and beyond the syntactic priming effects observed when there is no semantic overlap between prime and target. It would also suggest that speakers tend to choose the frame recently experienced in a sentence more when a verb is semantically similar to the verb in that sentence.

2.4.1 Experiment 1: the Double Object frame as prime

2.4.1.1 Methods

Participants

Ninety native English-speaking undergraduate students from the University at Buffalo participated in this experiment and received partial course credit for their participation.

Materials

Fifteen sentence triplets were constructed as prime sentences. Each triplet was paired with one single target sentence. Target sentences always exemplified the Prepositional Object or PO frame. One of the three prime sentences was an intransitive sentence whose meaning and structure were unrelated to target sentences. The two other prime sentences exemplified the Double Object or DO frame. The DO primes were

intended to induce priming effects in the target; the intransitive prime was intended to provide a baseline measure of how likely the target sentence was to be produced in the DO frame when DO primes are not present (i.e., to be misrecalled syntactically).

Target and DO prime sentences contained verbs that participate in the dative alternation, namely verbs that can occur in either the DO or PO frame. As discussed in Section 2.3.1, most of these verbs occur more frequently in the PO frame than in the DO frame. A few verbs that prefer to occur in the DO frame in natural language use, e.g., *give* and *tell*, were excluded. As a result, all verbs in this experiment occur more frequently in the PO frame than in the DO frame. In other words, verbs in this experiment disprefer the DO frame.

Semantic similarity between the verbs in the two DO primes and the verb in the PO target is this experiment's key manipulation. More specifically, verbs in the two DO primes differ in their degree of semantic similarity to the verb in the target. One of the DO primes contains a verb that is semantically highly similar to the target verb (a *high-similarity* prime) while the other contains a verb semantically much less similar to the target verb (a *low-similarity* prime). For example, when the verb *promise* occurs in the target sentence, the semantically similar verb *guarantee* occurs in its high-similarity DO prime and the less similar *bounce* occurs in its low-similarity DO prime. The full list of stimuli is appended at the end of this thesis (see Appendix A.1).

Verb similarity between prime and target sentences was assessed first using Latent Semantic Analysis (Landauer & Dumais, 1997) and was additionally normed through a human judgment experiment. As both high- and low-similarity verbs are needed for a single target verb, two pairs of verbs were prepared out of each triplet of

verbs, one for the target and two for the primes (e.g., *promise* to *guarantee* and *promise* to *bounce*). Thirty pairs of verbs were constructed from fifteen verb triplets. Semantic similarities in the high- and low-similarity verb pairs were first tested using Latent Semantic Analysis (LSA), which is a computational technique that estimates semantic similarity between words or a set of words on the basis of natural language corpora. I used LSA's pairwise comparison available online (http://lsa.colorado.edu) to estimate semantic similarity in each pair of verbs. The mean LSA cosine was 0.36 (SD = 0.21) in the high-similarity verb pairs, and 0.07 (SD = 0.06) in the low-similarity verb pairs.

These high- and low-similarity verb pairs were presented to participants in a pseudo random order with thirty distracting verb pairs. Degrees of semantic similarity were counterbalanced across two lists in a Latin square. Thus, each participant saw only one pair of verbs for a particular target verb, either a high- or low-similarity pair. Forty native English-speaking undergraduate students from the University at Buffalo participated in this norming study for partial course credit. Participants were asked to rate semantic similarity for each pair of verbs on a likert scale from 1 (completely different) through 7 (almost synonymous). Paired t-tests confirmed that verbs in the high-similarity condition and verbs in the low-similarity condition differed significantly in their semantic similarity to their matched target verbs. Mean similarities between prime and target verbs were 5.33 (SD = 0.94) and 1.82 (SD = 0.53) in the high- and low-similarity conditions, respectively. The mean ratings for individual high-similarity verb pairs ranged from 3.80 (*slide - roll*) to 6.55 (*push - shove*); the mean ratings for low-similarity verb pairs ranged from 1.20 (*bounce - promise*) to 3.15 (*forward - repay*).

Although verb semantic similarity was manipulated between the semantic similarity conditions, the set of verbs chosen for our experiment, namely dative verbs, by their very nature, share some degree of semantic similarity due to the semantic constraints imposed by the dative frames themselves. All dative verbs involve the same set of semantic arguments, *agent*, *recipient/goal* and *theme*. Moreover, the recipient argument tends to be animate or a human to whom the theme argument can eventually belong (see Section 2.3.1 for more discussion). In order to minimize any similarity effects derived from factors other than verb similarity, other possible semantic factors were carefully controlled for, e.g., scene similarity and noun similarity between prime and target sentences.[3] Prime and target sentences always describe different kinds of scenes, for example, an office scene vs. a sports scene vs. a movie-making scene. In addition, conceptually different nouns were used for the same argument positions across all prime and target sentences. For example, the recipients could be company employees vs. a sports player vs. an actress in the two DO primes and the target sentence, respectively. Agent and theme arguments were similarly controlled for. A set of example stimuli is provided in Table 2.2.

[3] Noun (or NP) similarity between prime and target has been shown to modulate syntactic priming (Cleland & Pickering, 2003). Scene similarity between prime and target sentences has also been shown to boost syntactic priming (Goldwater et al., 2011, see Section 2.2.1 for more details).

Table 2.2 A set of example stimuli for Experiment 1

TARGET	(read in PO)	The director *promised* a large part to the actress.
PRIMES (3 types)	Intransitive Control	Organic foods are increasing in popularity recently.
	High-similarity DO	The CEO *guaranteed* all employees a Christmas bonus.
	Low-similarity DO	The ball boy *bounced* the player a new ball.

Twenty-four sentence pairs and twelve pictures were prepared as distractors. These sentences were related neither to the caused-possession meaning semantically nor to the DO and the PO syntactically. However, the sentences within each sentence distractor pair were intended to be related in some respect either in verb meanings, event types, and/or syntactic forms. As the experiment uses a paired sentence recall procedure where participants first read two sentences and then recall them one after another, participants may notice some relationships between the two sentences and develop a strategy. By relating the two sentences in distractor pairs as well, any similarity between prime and target sentences in experimental pairs may stand out less, blurring the distinction between experimental and distractor trials. Picture distractors consisted of a picture and a sentence fragment. Pictures were simple line drawings that described a scene where one person did something or something happened to somebody and never involved more than two agentive entities. Sentence fragments consisted of the beginning of a sentence that can be used to verbally describe the scene in a picture.

Experimental trials and distractor trials were presented in a pseudo-random order such that at least two or three distractors intervened between any two experimental trials. Prime types were counterbalanced across three lists in a Latin square design. All participants were presented with the same set of target sentences but with only one of the three types of prime for each target. Each participant experienced the same set of fifteen target sentences paired with three different prime types, five items per prime condition, namely control, low-similarity and high-similarity primes. Each prime and target pair was seen by thirty participants. Thus, ninety participants in total saw fifteen target verbs with one of the three prime sentences.

Procedure and design

Participants were tested individually in a quiet room equipped with a computer monitor and a keyboard. The experiment was disguised as a memory test for sentential and pictorial stimuli. In sentence trials, participants were presented with two sentences in a row on the screen they first read and were then asked to recall them in reverse order out loud upon presentation of cues (Griffin & Weinstein-Tull, 2003). In picture trials, participants were presented with a simple picture that disappeared quickly and were asked to describe it by continuing a sentence fragment they were provided with. Picture trials were interspersed with sentence trials.

At the beginning of each experimental session, participants were informed that they would be asked to orally recall sentences or pictures that they had briefly seen on the computer screen while their oral responses were recorded. Sentence trials began with 'Ready?' appearing on the middle of the screen. When participants pressed a key, the

reading phase began. As illustrated in Figure 2.5, two sentences were presented back-to-back and word by word on the middle of the screen at the rate of 200 milliseconds per word (Rapid Serial Visual Presentation or RSVP). The word-by-word RSVP presentation is often used in recall-based syntactic priming experiments in order to minimize chances that participants memorize the sentence structure more than the gist of the sentence. Each sentence pair began with a mask consisting of ten asterisks, followed by the target sentence and then by the prime sentence. The last word of each sentence was followed by a mask consisting of seven pound signs marking sentence boundaries. Masks were presented at the same rate of 200 milliseconds.

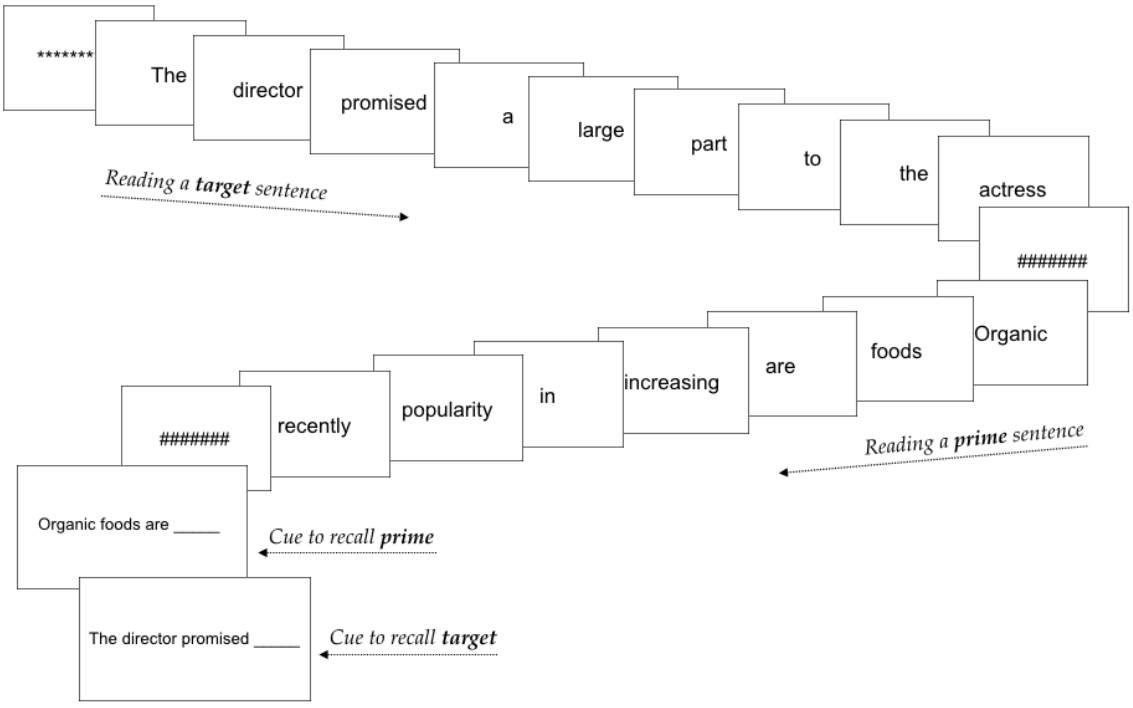


Figure 2.5 An example trial presented in RSVP

The recall phase began immediately after the reading phase. A cue to recall the prime sentence, namely the beginning of the prime sentence up to its verb, appeared and stayed on the screen (e.g., *Organic foods are* _____). Upon this cue, participants orally recalled the prime sentence. When they pressed the spacebar after finishing the first recall, a cue to now recall the target sentence appeared on the screen (e.g., *The director promised* _____). Participants then recalled the target sentence using this cue and pressed the spacebar. Then they were presented again either with 'Ready?' for sentence trials or with 'Picture, ready?' for picture trials. Pressing the spacebar started the next trial. Participants were informed beforehand that they could take time between trials by delaying pressing the key if they felt tired or needed time.

Importantly, in the paired sentence recall procedure, the recall order is the mirror image of the reading order (see Section 2.2.2 for more details). This reverse order between the reading and recall phases (i.e., $_{READ}$[Target → Prime] → $_{RECALL}$[Prime → Target]) was expected to make it easier for participants to recall the prime sentence more or less exactly as it was presented because it was the more recently-read sentence when the recall phase started. In contrast, they had read and recalled the prime sentence by the time participants were about to recall the target sentence that was read at the very beginning of each trial. Due to the temporal distance between the reading and recalling of the target sentence and the possible interference of the prime sentence, participants are expected not to remember as much of the target sentence except for its gist. This was meant to increase the possibility that they recalled the target sentence using a syntactic frame of their own choice rather than repeat it verbatim as long as they remembered the gist of the sentence. We are therefore more likely to be able to determine whether the

verb and the syntactic frame experienced in the recall of the prime sentence modulates speakers' choice of syntactic frame in the target recall.

Picture trials began with 'Picture, ready?' and when participants pressed the spacebar, a picture appeared and stayed on the screen for 200 milliseconds and was immediately replaced by a sentence fragment that could be continued to form a description of the picture they had just seen. As with sentence trials, participants orally completed the sentence and pressed the spacebar to move to the next trial. Picture trials are relatively easy for participants to complete as they require less cognitive load (e.g., no sentence memory is required). Thus, they serve not only as distractors but they are also meant to help the experiment become less intensive overall.

Data coding and analysis

Each and every sentence recalled was individually coded as a successful or unsuccessful recall. Recalls of prime sentences, both intransitive and DO primes, counted as successful recalls if the sentences were produced in the same syntactic frame they were presented in, i.e., in the intransitive and the DO frame, respectively. Recalls of target sentences counted as successful recalls if the sentence was produced either in the DO or in the PO frame. Otherwise, the sentences were coded as failed recalls. The percentages of successful recalls were 67.4% and 62.4% for prime and target sentences, respectively. As a trial is made up of a pair of prime and target sentences, a trial counts as successful only if the prime and target sentences are both successful recalls. The percentage of successful trials was 44.9% of all experimental trials. The coding scheme for successful trials is summarized in Table 2.3.

Table 2.3 Coding criteria for Experiment 1

RECALLED	PRIME CONDITION (*High- & Low-Similarity*)		CONTROL CONDITION	
PRIME SENTENCE	DO	DO	Intrans	Intrans
TARGET SENTENCE	PO	DO	PO	DO
Target shift	0	1	0	1
shift (=1) no shift (=0)		*(priming effect)*		(*baseline shift*)

Given that prime sentences were always successfully recalled as intended in the data used for analysis, each trial was evaluated by the syntactic frames used in the target sentence recalls. If the target was incorrectly recalled in the DO frame rather than in the PO frame it was read in, the trial was coded as 1. If the target was correctly recalled in the PO frame, the trial was coded as 0. Syntactic shifts or no-shifts after control primes served to estimate the base likelihood of a given target sentence being shifted in recall when no syntactic prime is present. Increase in target shifts after DO primes can be interpreted as evidence of syntactic priming. No shifts would mean the absence of syntactic priming effects.

I used mixed-effects logistic regression to analyze the data (Jaeger, 2008). The dependent variable was binary, target shift (=1) vs. no shift (=0). The independent variable used in my analysis was prime condition (control prime vs. high-similarity DO prime vs. low-similarity DO prime) with participants and items as random factors. High- and low-similarity conditions were compared to the control condition. Post-hoc

analysis of the contrast between high- and low-similarity conditions was also performed.

2.4.1.2 Results

The results showed that the percentages of target sentences being misrecalled in the DO frame (i.e., shifts in target recalls) varied by condition, namely 7.9% after intransitive controls, 11.0% after low-similarity DO primes, and 14.8% after high-similarity DO primes. When analyzed using a mixed-effects logistic regression, the model revealed that high-similarity primes induced a statistically significant increase in target shifts to the DO frame, compared to control primes. Low-similarity primes also led to an increase in target shifts but the effect did not reach statistical significance (i.e., $p < .05$). These results are summarized in Table 2.4. No statistical difference was found between high-similarity and low-similarity primes ($b = 0.117$, $p = .78$). In other words, statistically meaningful syntactic priming effects were found *only* when the verbs in prime and target sentences were highly semantically similar.

Table 2.4 Summary of the fixed effects in the mixed logit model in Experiment 1

Effect	Estimate (b)	*SE*	z value	p	
Intercept	-3.58	0.48	-7.45	.000	***
Control vs. Low-similarity	0.679	0.43	1.58	.115	
Control vs. High-similarity	0.796	0.37	2.13	.033	*

Formula: Target shift ~ Condition + (1 | Subject) + (1 | Item), '.' $p < .1$, '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

The results suggest that the semantic similarity of verbs in neighboring sentences impacts the choice of syntactic structure in sentence production as predicted. However, the results do not exactly conform to the patterns I expected. I expected a significant amount of syntactic priming in the low-similarity condition as the priming effect reported in previous studies did not require semantic similarity between verbs in the prime and target sentences. I also expected a significant increase in the priming effect when the prime was highly semantically similar to the target as compared to when it was not. The results of Experiment 1 only indirectly confirm the role of verb similarity in syntactic frame selection in that semantic similarity between prime and target verbs significantly boosted target shifts (e.g., $p < .05$). But low similarity between prime and target verbs still led to a numerical increase in target shifts, compared to baseline.

I tested the same hypothesis using the same procedure but with the locative alternation in Experiment 2. If the results of Experiment 1 are replicated, it will suggest that the results of Experiment 1 are unlikely to be due to the specific verbs or syntactic frames I used in Experiment 1.

2.4.2 Experiment 2: the Ground Object frame as prime

2.4.2.1 Methods

Participants

Ninety native English-speaking undergraduate students from the University at Buffalo participated in this experiment and received partial course credit for their participation. None of them had participated in Experiment 1.

Materials

Semantic similarity between prime and target verbs was assessed, as before, first using Latent Semantic Analysis and then normed through a study where participants rated semantic similarity among verb pairs. In the norming study, a high-similarity (e.g., *spread* to *smear*) and a low-similarity verb pair (e.g., *load* to *smear*) were prepared for each of fifteen target verbs. I used the same experimental methods as I did for the norming study of dative verbs (see Section 2.4.1.1 for more details). Thirty-two University at Buffalo undergraduate students participated in this norming study for partial course credit. Participants were asked to rate semantic similarity in each pair of verbs on a likert scale from 1 (completely different) through 7 (almost synonymous). Paired *t*-tests revealed that high- and low-similarity verbs differed significantly in their semantic similarity to their matched target verbs, for twelve out of fifteen sets of two verb pairs tested in this study. Three high- and low-similarity pairs that did not show significant difference in similarity were excluded in constructing the sentence priming materials. The average LSA cosine of the twelve high-similarity verb pairs was 0.28 (SD = 0.12) and

that of twelve low-similarity verb pairs was 0.09 (SD = 0.07). The means of human judgments were 5.38 (SD = 1.38) and 1.87 (SD = 1.10) for the high- and low-similarity pairs, respectively. The mean ratings for individual high-similarity verb pairs ranged from 4.06 (*brush - rub*) to 6.25 (*smear - spread* & *cram - stuff*); the mean ratings for low-similarity verb pairs ranged from 1.31 (*smear - load*) to 2.50 (*jam - splatter* & *mark - stock*).

Twelve target sentences were constructed in the Figure Object frame. Each target was paired with two Ground Object prime sentences and one intransitive prime sentence. One of the GO primes included a verb that is highly similar in meaning (*spread* in the *high-similarity* prime condition) to the target verb (*smear*) and the other included a much less semantically similar verb (*load* in the *low-similarity* prime condition) to the same target verb (*smear*). Control primes were intransitive sentences as they were in Experiment 1. However, I took extra care to avoid using prepositions such as *with*, *on*, and *to* after the verbs in the control prime sentences because the occurrence of the same prepositions in a control prime and a target may lead to unwanted priming effects. A set of example stimuli is provided in Table 2.5.

Table 2.5 A set of example stimuli for Experiment 2

TARGET	(read in FO)	The kid *smeared* mom's lipstick on her face.
PRIMES (3 types)	Intransitive Control	The congressman decided to run for the next election.
	High-similarity GO	The New Yorker *spread* a toasted bagel with cream cheese.
	Low-similarity GO	The freight driver *loaded* the huge truck with lots of boxes.

The locative verbs in the GO or FO frames have the same or a similar set of semantic arguments, an *agent*, a *ground* (*location*) and a *figure* (*theme*). Not only may verb similarity be confounded with argument similarity if similar themes or locations are chosen for prime and target sentences, it may also be confounded with conceptual similarity if location and theme pairs have similar conceptual relationships in prime and target sentences. In order to mitigate such confounding factors, I chose post-verbal arguments that belonged to different conceptual categories and evoked different scenarios as much as possible for prime and target sentence (e.g., *face* vs. *bagel*, *lipstick* vs. *cheese*). In other words, high- and low-similarity primes were intended to differ from their respective targets in all semantic aspects other than verb similarity.

Twenty additional sentence pairs and ten picture-and-sentence-fragment pairs served as distractors. As before, experimental trials were at least two or three distractor trials apart. Prime and target sentences in distractor pairs were also similar to each other in some respects in order to blur the distinction between experimental and distracting trials. Prime types were counterbalanced across three lists in a Latin square design. All participants were presented with the same set of twelve target sentences but with only one of the three prime types for each target. Thus, they experienced all target verbs only once through an experimental session and four items for each prime type.

Procedure and design

The procedure and design used in this experiment was the same as in Experiment 1.

Data coding and analysis

Recalls of prime sentences counted as successful recalls if they were produced in the syntactic frame they were presented in, i.e., control primes in the intransitive frame and GO primes in the GO frame, respectively. Recalls of target sentences counted as successful recalls if they were produced in either the GO or the FO frame. The percentages of successful recalls of prime and target sentences were 79.9% and 71.8%, respectively.

As before, successful recalls of both prime and target sentences make up a successful trial. The percentage of successful trials was 48% of all trials. Failed trials were excluded from analysis. Among successful trials, targets shifted towards the prime GO frame were coded as 1 and those recalled as they were read were coded as 0. The coding scheme for successful trials is summarized in Table 2.6.

Table 2.6 Coding criteria for Experiment 2

RECALLED	**PRIME CONDITION** (***High- & Low-Similarity***)		**CONTROL CONDITION**	
PRIME SENTENCE	GO	GO	Intrans	Intrans
TARGET SENTENCE	FO	GO	FO	GO
Target shift	0	1	0	1
shift (=1) no shift (=0)		*(priming effect)*		(*baseline shift*)

The data were analyzed using mixed-effects logistic regression just as in Experiment 1. The dependent variable was the target shifts, shifts (= 1) vs. no-shifts (= 0).

The independent variable was the prime condition which had three levels, i.e., control, high-similarity GO, and low-similarity GO primes. The control condition was initially set as the base level to which other levels were compared. The contrast between the high- and low-similarity GO prime condition was also tested post hoc.

2.4.2.2 Results

The results showed that the percentages of target sentences being misrecalled in the GO frame (i.e., shifts in target recalls) varied by condition, namely 9.4% after intransitive controls, 14.1% after low-similarity GO primes, and 18.4% after high-similarity GO primes. There was a stepwise numerical increase in the percentages of target shifts from the control to the *low*-similarity condition and from the *low*-similarity condition to the *high*-similarity condition, as was the case in Experiment 1. When analyzing the data using a mixed-effects logistic regression, however, the results of Experiment 1 were not replicated in Experiment 2. A significant syntactic priming effect was obtained not only when prime and target sentences contained verbs that are semantically very similar to each other but also when prime and target verbs were semantically much less similar to each other. The effects of both similarity conditions reached statistical significance (i.e., $p < .05$). In Experiment 1, only high-similarity primes led to statistically significant syntactic priming. These results are summarized in Table 2.7.

Table 2.7 Summary of the fixed effects in the mixed logit model in Experiment 2

Effect	Estimate	*SE*	*z* value	*p*	
Intercept	-4.013	0.73	-5.52***	.000	***
Control vs. Low-similarity	0.943	0.38	2.48*	.013	*
Control vs. High-similarity	1.167	0.38	3.08**	.002	**

Formula: Target shift ~ Condition + (1 | Subject) + (1 | Item), '.' $p < .1$, '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

Note that the coefficient estimates (b) and the levels of statistical significance differed between the two similarity conditions, as in Experiment 1. The coefficient estimate (b) is larger and the p value is smaller in the high-similarity condition than in the low-similarity condition, when both are compared to the control condition. It suggests that high-similarity primes led to a relatively larger amount of syntactic priming and did so more reliably ($b = 1.167$, $p = .002$) than low-similarity primes ($b = 0.943$, $p = .013$). However, the difference in the size of syntactic priming between high-similarity and low-similarity conditions did not reach statistical significance ($b = 0.223$, $p = .560$).

The results of the logistic regression models in Experiments 1 and 2 differ in terms of inferential statistics, although the descriptive statistics (e.g., the percentages of target shifts) and the changes in the size of coefficients and p values look much alike across the two experiments. In the next section, I explore possible reasons behind these discrepancies and conduct further statistical analyses on the data from Experiments 1 and 2, in an attempt to get a better picture of the effect of verb semantic similarity in priming.

2.4.3 Summary and post hoc analyses

Experiments 1 and 2 tested my Verb Anchor hypothesis in online sentence production. Using a syntactic priming paradigm, I investigated whether recent experience with a verb in a particular syntactic frame affects syntactic frame selection in subsequent sentence production. My hypothesis was that speakers would tend to choose the same syntactic frame for neighboring sentences when those sentences were constructed with semantically similar verbs.

Experiments 1 and 2 were syntactic priming experiments with three prime conditions (*control*, *high-similarity* and *low-similarity)* using the dative and locative alternations. The dative and locative alternations are known to exhibit frequency biases between alternate frames in natural use. Namely, the DO and GO frames are less frequently used than their alternate PO and FO frames, respectively. In this context, Experiments 1 and 2 tested my hypothesis by examining whether a prime can lead speakers to select the less preferred frame rather than the more preferred frame, i.e., priming effects required speakers to "go against the grain," so to speak.

The data were analyzed using a mixed-effects logistic regression and the results were not identical across experiments. In the high-similarity condition where verbs in prime and target sentences were highly semantically similar, I found statistically meaningful syntactic priming in both Experiments 1 and 2 (i.e., $p < .05$); in the low-similarity condition where prime and target verbs are semantically much less similar, I observed statistically meaningful syntactic priming only in Experiment 2 with locative sentence stimuli. The difference between the *low*- and *high*-similarity conditions did not reach significance. In sum, only the results of Experiment 1 provide statistical support to

my hypothesis that high semantic similarity between prime and target verbs plays a crucial role in syntactic priming.

The descriptive statistics, however, suggest that we should not too easily conclude that semantic similarity has no effects in syntactic priming. As illustrated in Figure 2.6, a stepwise increase in syntactic repetition between prime and target sentences or target shifts was observed when comparing the control to the low-similarity condition as well as when comparing the low-similarity condition to the high-similarity condition.

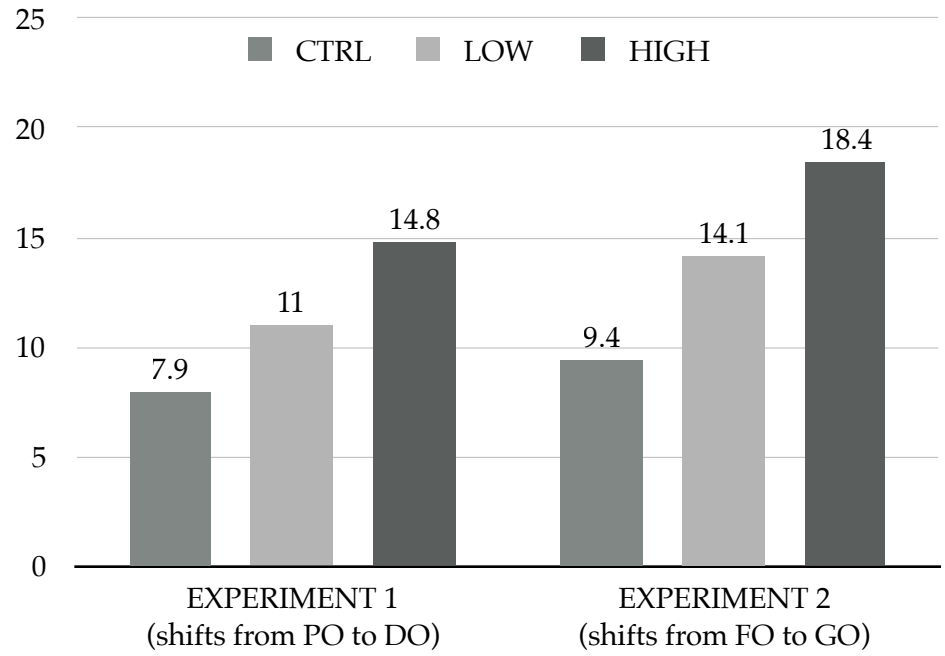


Figure 2.6 Percentages of target shifts by condition in Experiments 1 and 2

In addition, a qualitative evaluation of the results of the mixed-effects regression analyses shows that higher semantic similarity also led to larger coefficient estimates and smaller *p* values, suggesting statistically more reliable and possibly larger priming obtains when similarity between primes and targets increases. To clarify the effects of

verb semantic similarity in syntactic priming, I report below two further sets of post hoc analyses on the data from Experiments 1 and 2.

First, I found that when participants recalled the prime sentences, they sometimes shifted the structure of the primes to its alternate frame, although primes were intended to be recalled as they were read. Interestingly, in the majority of such cases, they recalled the targets in the same frame as the prime's. In other words, prime and target sentences were then syntactically aligned through *prime* shifts, as opposed to target shifts. For example, the intended order of reading and recalls in the high- and low-similarity conditions in Experiment 1 was $_{read}[PO_T - DO_P] - _{recall}[DO_P - DO_T]$ to count as evidence of syntactic priming, but what occurred in these cases was $_{read}[PO_T - DO_P] - _{recall}[PO_P - PO_T]$ instead. In Experiment 2, the order $_{read}[FO_T - GO_P] - _{recall}[GO_P - GO_T]$' was intended but $_{read}[FO_T - GO_P] - _{recall}[FO_P - FO_T]$ also occurred. The percentages of the intended prime recalls and prime shifts were 56.4% and 12.7% in Experiment 1 and 70.3% and 16.4% in Experiment 2, respectively. As is characteristic of the recall paradigm, participants read both alternate frames before recalling prime sentences. It is possible that when they were to recall primes, the syntactic frame primed the most was the first frame the target sentences were read in rather than the frame the primes were read in. It seems to be related to the previous finding that simply comprehending a sentence may lead to syntactic priming (Arai et al., 2007; Bock et al., 2007; see Section 2.2.2 for discussion). However it is also possible that participants simply recalled the sentences, either prime or target, in the preferred syntactic frame.

Interestingly, it seems semantic verb similarity also affects this type of syntactic alignment or repetition between prime and target sentences. In Experiment 1, the recall

of both prime and target sentences in the PO frame amounted to 4.9% and 10.7% of all trials in the low- and high-similarity conditions, respectively. In Experiment 2, the recall of both prime and target sentences in the FO frame amounted to 9.8% and 13.3% in the low- and high-similarity conditions, respectively. When combining the two types of syntactic alignment, considering both types of shifts as syntactic priming (i.e., combining DO-DO and PO-PO recalls in Experiment 1 and combining GO-GO and FO-FO recalls in Experiment 2), there was significant contrast between low- and high-similarity conditions, using mixed-effects logistic regression analyses again, as shown in Table 2.8.

Table 2.8 Post hoc analysis of the contrast between low- and high-similarity conditions in a broader range of syntactic alignment

Experiment	Effect	Estimate	*SE*	*z* value	*p*	
Experiment 1 (dative)	Intercept	-1.357	0.24	-5.56	.000	***
	Low- vs. high-similarity	0.539	0.25	2.16	.031	*
Experiment 2 (locative)	Intercept	-1.110	0.25	-4.38	.000	***
	Low- vs. High-similarity	0.464	0.20	2.34	.019	*

Formula: Syntactic alignment ~ Condition + (1 | Subject) + (1 | Item), '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

High-semantic similarity between prime and target verbs leads to a significant increase in syntactic alignment compared to low-similarity between prime and target verbs. Note that, in this analysis, only high- vs. low-similarity conditions can be compared to each other, to the exclusion of the control condition. Control trials were included to provide a baseline estimate of the shifts towards the prime's frame in target

recalls (i.e., DO in Experiment 1 and GO in Experiment 2) when no priming is at play. Thus, they cannot serve as a baseline when target recalls in either frame (i.e., DO/PO in Experiment 1, GO/FO in Experiment 2) are considered together for syntactic priming.

Second, I conducted an additional mixed-effects logistic regression, treating verb semantic similarity between prime and target as a continuous predictor, rather than treating similarity as a binary predictor (low vs. high). The results of my similarity norming studies for Experiments 1 and 2 show, indeed, that mean similarity ratings form a continuum, although the middle part of the scale is less populated, as shown in Figure 2.7.

Given that semantic similarity is gradient, the results reported in the previous sections might partially be due to the artifact of binning, i.e., due to the loss of variance in degrees of semantic similarity. Thus, in the new model below, I used the rated semantic similarity of each verb pair as predictor variable instead of the high and low binary predictor. Note that sentence pairs in the control condition are excluded from analysis as before (but for a different reason). As those pairs consist of an intransitive sentence and a dative or locative sentence, comparison of semantic similarity between pairs consisting of an intransitive verb and a dative or locative verb can be meaningless (e.g., *is* - *promise*) or in part irrelevant for present purposes (e.g., *die* - *award*). The results of two models for Experiments 1 and 2, respectively, are summarized in Table 2.9. I found, in both experiments, verb meaning similarity was a significant predictor of syntactic priming, which confirms my hypothesis.

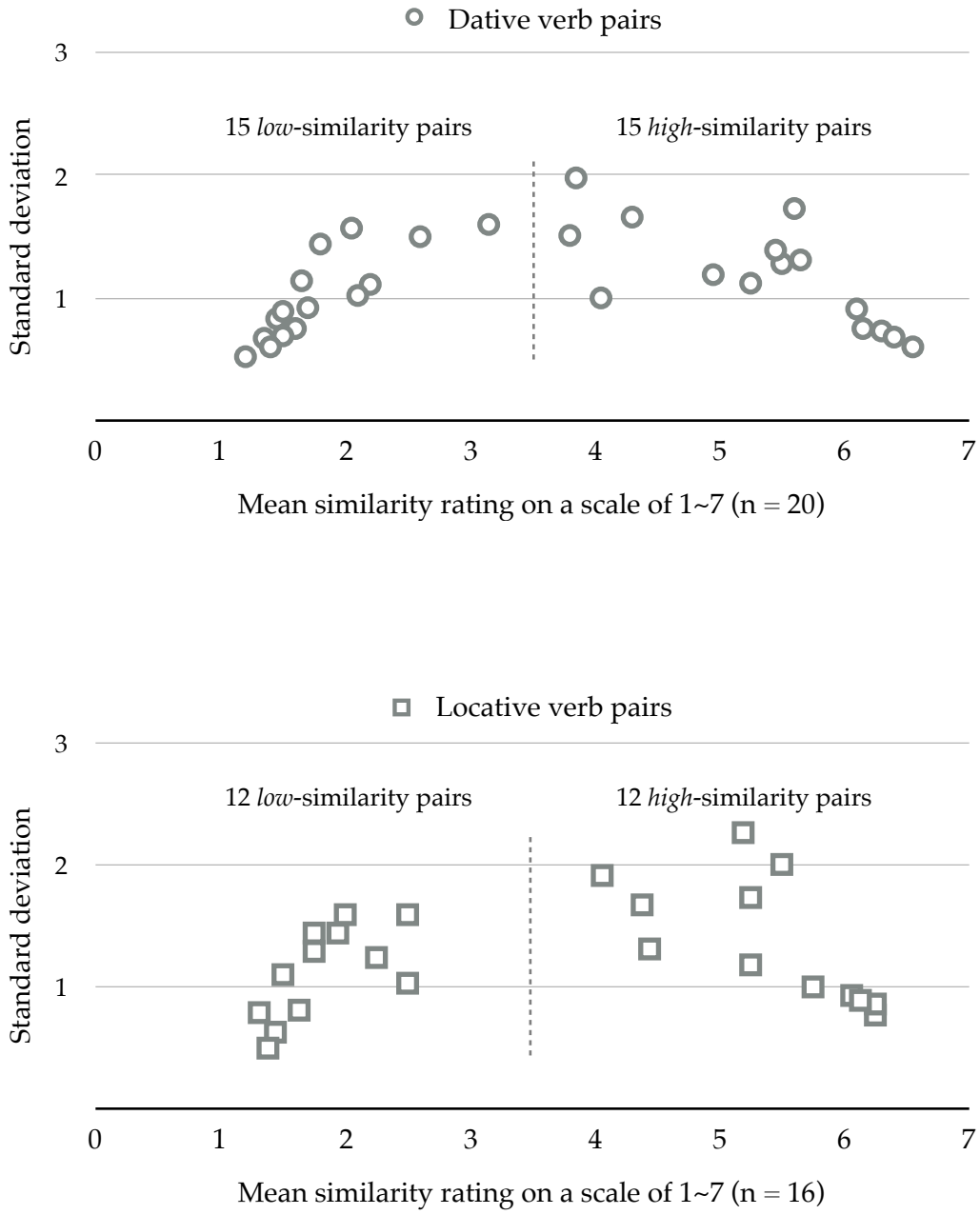


Figure 2.7 Similarity ratings of verb pairs from human subjects

Table 2.9. Summary of the fixed effects in the mixed logit models using verb meaning similarity as continuous independent variable in Experiments 1 and 2

Experiment	Effect	Estimate	*SE*	*z* value	*p*	
Experiment 1 (dative)	Intercept	-3.413	0.45	-7.62	.000	***
	Verb meaning similarity	0.132	0.06	2.06	.039	*
Experiment 2 (locative)	Intercept	-3.733	0.71	-5.27	.000	***
	Verb meaning similarity	0.178	0.07	2.55	.010	*

Formula: Shift ~ Verb meaning similarity + (1 | Subject) + (1 | Item), '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

Although the post hoc analyses I reported in this section strongly suggest that verb meaning similarity plays an important role in syntactic priming as I predicted, the results of Experiments 1 and 2 reported in the previous sections still leave us with a question, namely why I did not consistently replicate the *usual* syntactic priming effects when there was no or at least weak semantic overlap between prime and target verbs. Two possible explanations come to mind. One is that the results are due to the present manipulation, which was intended to make the target shifts highly difficult by choosing the dispreferred frame as the prime structure. I also tried not to use, as target, verbs that rarely disprefer the prime structures (e.g., *give*). It may be the case that target shifts were more difficult in the present experiments than typical priming experiments, so that significant priming reliably occurred when semantic similarity between prime and target verbs provided an additional boost. The other possibility is that the results are due to the experimental procedure I used, namely the use of a two-sentence recall procedure, or both. To my knowledge, no previous syntactic priming studies have tested the dative

and locative alternations using this procedure (cf. Griffin & Weinstein-Tull, 2003). In order to decide between these two possibilities, another pair of syntactic priming experiments were conducted where the prime sentences used the other frame of each alternation. In these experiments, the prime structures were the preferred frames. Thus target shifts were expected to occur more easily than in Experiments 1 and 2.

2.5 Experiments 3 & 4: *Preferred* Syntactic Frames as Primes

Experiments 1 and 2 investigated, using a recall-based syntactic priming paradigm, whether a verb recently experienced in a particular syntactic frame influences syntactic frame selection in subsequent sentence production. Based on my Verb Anchor hypothesis, I predicted larger syntactic priming when verbs in neighboring sentences are semantically similar than when they are not. The results showed that high semantic similarity of a target verb to the verb in the prime sentence (previous sentence experience) facilitates the repeated use of the same syntactic frame in the target (subsequent sentence production). Although Experiments 1 and 2 partially demonstrated the importance of verb similarity in speakers' selection of syntactic frames, the fact that, in contrast to previous studies, no syntactic priming effect was consistently observed when there was little semantic aid remains unexplained.

One possibility I considered initially was that the null results in the low-similarity condition in Experiment 1 might be due to the fact that target shifts were harder in that experiment because shifts were towards the dispreferred frame. This possibility turned out to be unlikely as the low-similarity condition in Experiment 2 successfully led to significant syntactic priming. Since the results of Experiment 1 that used the dative alternation and of Experiment 2 that used the locative alternation are not identical, it is important to verify that differences in results are due to differences in verbs and syntactic frames used in the two experiments.

In order to examine this possibility, two other syntactic priming experiments were conducted where the syntactic frames used in the prime and target sentences were

simply reversed from what it was in Experiments 1 and 2 while all other experimental settings were kept constant, i.e., the same set of verbs and frames. The prime and target sentences in Experiments 3 and 4 make target shifts, as a measure of syntactic priming, relatively easy because the shifts are towards the preferred frame, in contrast to Experiments 1 and 2. If the same patterns of syntactic priming effects are observed in Experiments 3 and 4, we may conclude that semantic similarity in prime and target verbs significantly modulates the priming of the dative frames, DO and PO, but not the priming of the locative frames, GO and FO. Of interest will also be possible differences in syntactic priming between the low- and high-similarity conditions, given the differences in coefficients and p values between these two conditions in Experiments 1 and 2 as well as given the post hoc analyses I reported in the previous section.

2.5.1 Experiment 3: the Prepositional Object frame as prime

In this experiment, the prime structure is the Prepositional object (PO) frame and the target structure is the Double Object (DO) frame. Other than changes in the syntactic frames of primes and targets, Experiment 3 is identical to Experiment 1. Syntactic priming was measured by the number of syntactic shifts towards the prime PO frame when recalling targets originally read in the DO frame. As pointed out earlier, shifts from the DO to the PO frame in targets are predicted to be easier, compared to shifts from the PO to the DO frame since the PO frame is the more frequent alternative for the verbs I used in these two experiments. Therefore, significant priming may occur even when verbs in prime and target sentences are not semantically similar to each other, in

contrast to what occurred in Experiment 1. However, if the dative alternation is substantially affected by verb semantic similarity between prime and target, as shown in Experiment 1, significant syntactic priming may be observed only in the high-similarity condition as before.

2.5.1.1 Methods

Participants

Sixty native English-speaking undergraduate students from the University at Buffalo participated in this experiment and received partial course credit for their participation. None of them had participated in Experiments 1 and 2.

Materials

Sentence stimuli from Experiment 1 were used for this experiment. The content of the dative sentences were kept the same but were syntactically reformulated. The high- and low-similarity DO primes from Experiment 1 were rephrased in the PO frame. The targets previously presented in the PO frame in Experiment 1 were rephrased in the DO frame in the reading phase. A set of example stimuli is provided in Table 2.10. Intransitive control primes were kept the same as in Experiment 1. Sentence and picture distractors and the order of stimulus presentation also stayed the same. In sum, all settings were kept constant in Experiment 3 except prime and target frames.

Table 2.10 A set of example stimuli for Experiment 3

TARGET	(read in DO)	The director *promised* the actress a large part.
PRIMES (3 types)	Control in intransitive	Organic foods are increasing in popularity recently.
	High-similarity in PO	The CEO *guaranteed* a Christmas bonus to all employees.
	Low-similarity in PO	The ball boy *bounced* a new ball to the player.

Procedure and design

The procedure and design used in this experiment was the same as in Experiments 1 and 2.

Data coding and analysis

Each sentence recall was assessed using the same criteria as in Experiment 1 to be coded as successful and failed recalls. The percentages of successful recalls of prime and target sentences were 90.4% and 55.8%, respectively. A successful trial consisted of a successful recall of a prime in the PO frame and a target recall in either the DO or the PO frame. Failed trials were excluded from analysis. The percentage of successful trials was 51.7%. Among successful trials, target recalls in the PO frame were coded as 1 (shifts towards the prime structure) or as 0 (no-shifts or recalled as read), as summarized in Table 2.11.

Table 2.11 Coding criteria in Experiment 3

RECALLED	PRIME CONDITION (*High- & Low-Similarity*)		CONTROL CONDITION	
PRIME SENTENCE	PO	PO	Intrans	Intrans
TARGET SENTENCE	PO	DO	PO	DO
Target shift	1	0	1	0
shift (=1) no shift (=0)	*(priming effect)*		(*baseline shift*)	

As before, the data was analyzed using mixed-effects logistic regression. The dependent variable was the syntactic frame of target recalls, shifts (=1) vs. no-shifts (=0). The independent variable was the prime condition with three levels, namely, control, high-similarity PO and low-similarity PO condition, with participants and items as random factors. The high- and low-similarity conditions were first compared to the control condition to verify syntactic priming above a baseline and the high- and low-similarity PO prime condition were also compared.

2.5.1.2 Results

Significant syntactic priming was observed in both high- and low-similarity conditions, compared to the control condition, as summarized in Table 2.12. Prime verbs with high semantic similarity to target verbs led to syntactic priming, as was the case in Experiment 1, but in contrast to Experiment 1, so did prime verbs with minimal semantic similarity to target verbs. The p values of the coefficients in both low- and high-similarity conditions were much smaller in this experiment than those in Experiment 1.

No statistical difference was found in the size of the priming effect between high- and low-similarity conditions. The percentages of target shifts were 42.3% after intransitive controls, 62.8% after low-similarity PO primes, and 62.5% after high-similarity PO primes.

Table 2.12 Summary of the fixed effects in the mixed logit model in Experiment 3

Effect	Estimate	*SE*	*z* value	*p*	
Intercept	-0.404	0.47	-0.85	.394	
Control vs. Low-similarity	1.196	0.30	4.05	.000	***
Control vs. High-similarity	1.403	0.30	4.72	.000	***

Formula: Shift ~ Condition + (1 | Subject) + (1 | Item), '.' $p < .1$, '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

The results showed that low semantic similarity between prime and target verbs can lead to a significant amount of syntactic priming as predicted and in conformity with the results of previous research on syntactic priming. But the result in the low similarity condition of Experiment 1 was not replicated. This suggests that the results of Experiment 1 was not due to the particular experimental materials I used, i.e., dative verbs, but more likely to the relative difficulties of syntactic shifts to the dispreferred frame. In Experiment 3, however, my prediction was not borne out. When the prime structure is a highly preferred frame, the degree to which prime and target verbs are semantically similar to each other seems to make little difference in the size of syntactic priming. Semantic similarity between verbs was not required when speakers use the preferred frame of the alternation.

The results suggest, more generally, that semantic similarity may play a crucial role in increasing speakers' tendency to repeat the same frame when they are to produce a dispreferred frame. However, when they are to produce a preferred frame, the degree of semantic similarity between verbs does not modulate syntactic frame selection. Even a minimal degree of verb similarity between prime and target sentences can lead to as much syntactic priming as a high degree of semantic similarity.

Note, however, that the results of Experiment 3 showed an increasing trend in the coefficient estimates between low- and high-similarity conditions, as was the case for Experiments 1 and 2. The effect of verb semantic similarity will be further examined as before by treating semantic similarity as a continuous variable.

2.5.2 Experiment 4: the Figure Object frame as prime

In Experiment 4, the materials from Experiment 2 were used, but the prime and target frames were reversed. The syntactic structure of prime sentences is the Figure Object (FO) frame and the structure of target sentences is the Ground Object (GO) frame. Syntactic priming was measured by target shifts from the GO frame to the FO frame. As noted earlier this type of shifts are predicted to be easier as they go from the dispreferred to the preferred frame. Other than the changes in syntactic frames, Experiment 4 is identical to Experiment 2.

There are two possible results for this experiment. We may replicate the results of Experiment 2. Low verb similarity between prime and target led to syntactic priming but no difference was found between low and high degrees of verb similarity, suggesting

high semantic similarity between prime and target verbs exerts no statistically meaningful influence on syntactic priming, although there is some numerical boost beyond the effect of low-similarity primes. The other possibility is what I originally predicted as to the effect of semantic similarity between prime and target verbs in syntactic priming. That is, low semantic similarity leads to syntactic priming and high semantic similarity results in a significant increase in the priming effect.

2.5.2.1 Methods

Participants

Ninety native English-speaking undergraduate students from the University at Buffalo participated in this experiment and received partial course credit for their participation. None of them had participated in Experiments 1, 2, and 3.

Materials

The locative sentence stimuli of Experiment 2 were rephrased in the alternate frames while the content of the locative sentences were kept the same. High- and low-similarity primes were reformulated in the FO frame and targets were in the GO frame. A set of example stimuli is provided in Table 2.13.

Table 2.13 A set of example stimuli for Experiment 4

TARGET	(read in GO)	The kid *smeared* her face with mom's lipstick.
PRIMES (3 types)	Intransitive Control	The congressman decided to run for the next election.
	High-similarity FO	The New Yorker *spread* cream cheese on a toasted bagel.
	Low-similarity FO	The freight driver *loaded* lots of boxes on the huge truck.

No other modifications to Experiment 2 were made in the stimuli. Intransitive control primes were kept the same as in Experiment 2. Sentence and picture distractors and the order of stimulus presentation also stayed the same. In sum, all settings were kept constant in Experiment 4 except prime and target frames, when compared to Experiment 2.

Procedure and design

The procedure and design used in this experiment was the same as in Experiments 1, 2 and 3.

Data coding and analysis

Recalls of prime sentences counted as successful recalls if they were produced in the syntactic frame they were presented in, i.e., control primes in the intransitive frame and FO primes in the FO frame, respectively. As in Experiment 2, recalls of target sentences counted as successful recalls if they were produced in either the GO or the FO

frame. The percentages of successful recalls of prime and target sentences were 89.6% and 68.3%, respectively.

As opposed to Experiment 2, a successful recall of a control prime or a locative prime recalled in the FO frame makes a successful trial with a target recalled either in the GO or in the FO frame. The percentage of successful trials was 51.9%. Failed trials were excluded from analysis. Successful trials with targets being recalled in the FO frame were coded as 1, meaning the frame of the target sentence was shifted towards that of the prime sentence. If targets were recalled in the GO frame in which they were originally read, the trials were coded as 0, meaning no shifts occurred. The coding criteria are summarized in Table 2.14.

Table 2.14 Coding criteria for Experiment 4

RECALLED	**PRIME CONDITION** (***High- & Low-Similarity***)		**CONTROL CONDITION**	
PRIME SENTENCE	FO	FO	Intrans	Intrans
TARGET SENTENCE	FO	GO	FO	GO
Target shift	1	0	1	0
shift (=1) no shift (=0)	*(priming effect)*		(*baseline shift*)	

2.5.2.2 Results

The percentages of target shifts were 54.3% after intransitive controls, 63.2% after low-similarity FO primes, and 71.3% after high-similarity FO primes. A stepwise

increase in the percentages of target shifts from control to low- to high-similarity conditions was observed as in Experiments 1 and 2.

In the mixed-effects logistic regression analysis, significant syntactic priming was observed both when verbs in prime and target were highly similar in meaning to each other and when they were not very similar in meaning, which is the same pattern reported for Experiment 2. Note, however, that in contrast to Experiment 2, a significant difference was found between the high and the low semantic similarity conditions. A statistically significant increase in syntactic priming was found both when comparing the baseline condition to the low-similarity condition and when comparing the low-similarity condition to the high-similarity condition. The results are summarized in Table 2.15.

Table 2.15 Summary of the fixed effects in the mixed logit model in Experiment 4

Effect	Estimate	*SE*	*z* value	*p*	
Intercept	0.268	0.47	-0.85	.605	
Control vs. Low-similarity	0.629	0.25	2.57	.010	*
Control vs. High-similarity	1.191	0.25	4.78	.000	***

Formula: Shift ~ Condition + (1 | Subject) + (1 | Item), '.' $p < .1$, '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

In order to better convey this stepwise increase in priming between the three kinds of primes, I provide another result table, Table 2.16, where the low-similarity condition (not the control condition) was set as the reference level to which the other two levels were compared. The negative coefficient of the baseline in comparison to the low-

similarity condition refers to a decrease in target shifts towards the FO frame in the control condition, compared to the shifts in the low-similarity condition. In other words, it indicates an increase in shifts in the low-similarity condition, compared to the control condition (cf. Table 2.15). The difference in the effect of syntactic priming between low- and high-similarity conditions was statistically significant in this experiment, while in the previous experiment, high verb similarity boosted syntactic priming numerically but that numerical increase did not reach statistical significance.

Table 2.16 Fixed effects in Experiment 4 with *low*-similarity as reference level

Effect	Estimate	*SE*	*z* value	*p*	
Intercept	0.898	0.53	1.70	.089	
Low-similarity vs. Control	-0.629	0.25	-2.57	.010	*
Low-similarity vs. High-similarity	0.561	0.27	2.12	.034	*

Formula: Shift ~ Condition + (1 | Subject) + (1 | Item), '.' $p < .1$, '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

The results suggest that even a minimum amount of verb similarity successfully induces syntactic priming when the prime structure is the preferred frame of an alternation, confirming the results of Experiment 3. The results also suggest that even when the prime structure is the preferred frame of an alternation for the target verbs, the degree of semantic similarity between prime and target verbs can make a difference in syntactic priming, as in Experiment 1. In Section 2.5.3 below, I will discuss some probable causes behind the different results between Experiments 3 and 4 and report a post hoc analysis where verb semantic similarity was treated as continuous variable.

2.5.3 Summary and post hoc analyses

Experiments 3 and 4 investigated the same hypothesis, whether recent experience with a verb in a particular syntactic frame affects syntactic frame selection in subsequent sentence production, as in Experiments 1 and 2. But syntactic priming was measured in Experiments 3 and 4 by target shifts towards the preferred frame of an alternation, which is expected to be easier to occur, i.e., to PO in Experiment 3 and to FO in Experiment 4.

In both Experiments 3 and 4, as predicted, significant syntactic priming was observed when there was little semantic similarity between verbs in prime and target sentences, in conformity with the results of previous research. Experiment 3 did not replicate the results of Experiment 1 where high-similarity primes, but not low-similarity primes, led to significant syntactic priming, although both experiments used the same set of verbs and the same syntactic alternation. This difference refutes the possibility I raised that the non-significant effect in the low-similarity condition of Experiment 1 might be due to some unknown property of the dative alternation.

Experiments 3 and 4 differed, however, when verbs in prime and target sentences were highly semantically similar. A significant increase in priming was observed in Experiment 4 but not in Experiment 3. In other words, not only did Experiment 4 replicate the findings from previous syntactic priming research, where there is typically no need of semantic aid for syntactic priming to occur, it also confirmed my prediction that high semantic similarity between prime and target verbs facilitates the repetition of the same syntactic frame. But in Experiment 3, my prediction was not borne out.

In order to explore probable causes behind the discrepancy between Experiments 3 and 4, I further examined the results from all four experiments and compared them by condition. Table 2.17 summarizes the percentages of target shifts found in Experiments 1-4.

Table 2.17 Percentages of target shifts by prime types in Experiments 1-4

EXP 1 *Shifts to* DO	**EXP 2** *Shifts to* GO	**PRIME TYPE**	**EXP 3** *Shifts to* PO	**EXP 4** *Shifts to* FO
7.9%	9.4%	Control	42.3%	56.7%
11.0% (3.1%)	14.1% (4.7%)	Low-similarity	62.8% (20.5%)	63.3% (6.6%)
14.8% (6.9%)	18.4% (9.0%)	High-similarity	62.5% (20.2%)	71.6% (14.9%)

Note: Percentages in parentheses indicate increases in the percentages of shifts from the control condition.

The results of Experiment 3 seem peculiar in at least two respects. Firstly, the baseline shifts are much lower than expected. Comparing Experiments 1 and 2 where target shifts were towards the dispreferred frame, baseline shifts were similar but target shifts after prime conditions occurred more in Experiment 2 than in Experiment 1. It may mean that generally shifts from PO to DO are difficult relative to shifts from FO to GO, which conforms to the frequency biases of the two alternate frames in these alternations. The dative verbs used in Experiments 1 and 3 are biased towards the PO frame much more than the locative verbs used in Experiments 2 and 4 are biased towards the FO frame. If so, one might predict that shifts in the other direction from DO

to PO are easy relative to shifts from GO to FO. Comparing Experiments 3 and 4, however, target shifts in the control condition occurred more in Experiment 4 than in Experiment 3, contrary to what is predicted from frequency biases. It indicates target shifts are still more difficult in the dative alternation than in the locative alternation. Note that even after control primes, participants made target shifts more towards the FO frame than towards the PO frame, i.e., the baseline shift was lower in Experiment 3.

Secondly, target shifts in prime conditions are much higher than expected. PO primes increased target shifts by about 20%, which is a much larger increase than those by any other primes in the present experiments. It should be noted that even low-similarity PO primes led to 20% increase, which is an unusually large increase in comparison to the increase by low-similarity FO primes (i.e., 6.6%). The result suggests that shifts from the DO to the PO frame are more susceptible to syntactic priming than any other shift discussed here and also that it cannot be accounted for simply by frequency biases or degrees of preference.

In what follows, I speculate about probable reasons for those peculiarities observed in Experiment 3. The fact that more syntactic shifts occurred in one alternation than in another means that participants chose alternate frames to recall target sentences more often in one frame than in another. Given that participants were asked to recall the target sentences as correctly as possible (i.e., in the disguise of a memory test), they must have tried not to make any semantic difference in target recalls. In other words, they would tend not to shift to the other syntactic frame in target recalls if it causes a semantic difference. Thus, more shifts may indicate that the alternate frames of the alternation are semantically more interchangeable or less distinctive from each other. If

so, the results indicate the DO and PO frames are semantically less interchangeable than the GO and FO frames. How much or little semantic difference resides in two alternate frames of each alternation may play an important role in shifting or not shifting to another frame in target recalls. Syntactic shifts are expected to be easy when shifts incur no or little incongruence in meaning between sentences they read before and sentences they produced in recall. As discussed in Section 2.3, alternate frames of each alternation are in a "near-paraphrase relation" (Rappaport & Levin, 1988), but finer-grained semantic analyses has suggested alternate frames differ in their semantic properties to different degrees. In the dative alternation, the most characterizing semantic difference between the DO and PO frames is that they may have different semantic entailments (see Section 2.3.1 for more details). The DO frame invariably entails caused possession while the PO frame entails either caused possession or caused motion. In other words, caused-possession entailment can possibly be eliminated when a DO sentence is rephrased in the PO frame. This difference is non-trivial as it may cause a truth-conditional difference as well. The GO and FO frames of the locative alternation also differ in semantics, but the difference is trickier to define (see Section 2.3.2 for more details). While no entailment difference is involved, the GO frame focuses on the (resultant) state of an action (e.g., the change of state of the object's referent is emphasized, *loading the truck with boxes*) and the FO frame focuses on the action (e.g., the change of location of the object's referent is emphasized, *loading boxes into the truck*). This difference seems analogous to the difference between accomplishment and activity, thus being a matter of aktionsart or degree of completion. In short, alternate syntactic frames

may possibly lead to bigger semantic changes, which may lead to less shifts, in the dative alternation than in the locative alternation.

Another possibility is that less baseline target shifts in the dative alternation might be influenced by a quantitative distinction, or more specifically speakers' cognitive responses to the quantitative difference. The natural tendency of using a particular frame is often estimated by the frequency with which a frame occurs in natural use. However, some studies have shown that the degree of certain effects are not always positively proportionate to frequency of occurrences in experience. For example, the *inverse base-rate effect* shows that people use base-rate (i.e., frequency) information from experience in an inverse manner. They choose a relatively rare rather than common category given a stimulus (Medin & Edelson, 1988). Research in sentence processing has also shown that less frequent syntactic structures tend to lead to a bigger priming effect (Hartsuiker & Kolk, 1998; Jaeger & Snider, 2013). Thus it might be that in the dative alternation baseline shifts occur less because the target structure is highly dispreferred (thus, participants stick with it), but shifts occur more in the low-similarity condition also because the target structure is dispreferred (thus, priming of the alternate frame is more effective).

Next, I suspect the unusually large priming effect in Experiment 3 is related to the syntactic structure of postverbal arguments in the experimental stimuli (i.e., two full NPs after verbs). Previous studies in the dative alternation have shown that the choice between the alternate DO and PO frames is significantly modulated by the properties of NPs (Collins, 1995; Thompson, 1990; Wasow, 2002; Bresnan et al., 2007). For example, if a sentence occurs with a recipient argument in a short and structurally simple NP (e.g.,

pronouns), it tends to occur in the DO frame (*John sent him the present*). Conversely, if a sentence occurs with a theme argument in a short and simple NP, then it tends to occur in the PO frame (*John sent it to the man*). The length difference between a recipient NP and a theme NP was shown to be a significant predictor of the dative alternation (Bresnan et al., 2007). This tendency is consistent with the so-called principle of end-weight in English (Wasow, 2002): A longer, grammatically more complex or "heavier" phrase tends to occur later in a sentence. It is also referred to as the short-before-long tendency or heavy NP shifts in the literature. However, little is known about the effect of NP weights on the locative alternation.

I examined syntactic patterns of postverbal NPs in the four syntactic frames of the dative and locative alternations in the British National Corpus. I categorized the NP patterns into four types, illustrated in (2.6).

(2.6)	a.	Jen gave her assistant a signed letter.	Full NP + Full NP
		Sam loaded the car with the boxes.	
	b.	Jen gave her a signed letter.	Pronoun + Full NP
		Sam loaded it with the boxes.	
	c.	Jen gave her assistant it.	Full NP + Pronoun
		Sam loaded the car with them.	
	d.	Jen gave her it.	Pronoun + Pronoun
		Sam loaded *it* with them.	

A survey in the British National Corpus showed the DO and PO frames differ substantially in the frequency distributions of the four patterns of postverbal NPs. As illustrated in Figure 2.8, the combination of two full NPs in (6a) accounts for only 27% of all DO uses, but accounts for 69% of all PO uses in this corpus. Conversely, the combination of a pronoun and a full NP in (6b) explains 70% of the DO uses and 24% of the PO uses. These frequency differences suggest that the DO frame is particularly susceptible to the principle of end weight. The combination of two full NPs, which the DO sentence stimuli in the present experiments exemplify, is in fact quite a rare case.

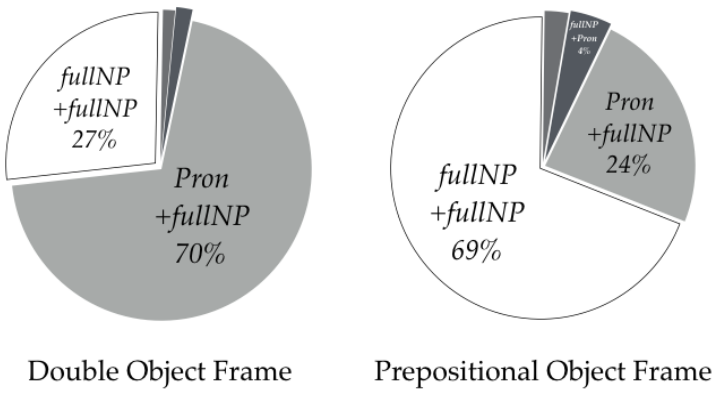


Figure 2.8 Percentages of postverbal phrasal types in the dative alternation

My corpus study, however, found little difference in the NP patterns between the GO and FO frames of the locative alternation, as illustrated in Figure 2.9. In both frames, the combination of two full NPs is the most common type of syntactic patterns (72% and 77%). The combination of a pronoun and a full NP is the second most frequent but much less frequent than two full NPs in both frames (28% and 15%). Note that these patterns in the GO and FO frames are similar to those in the PO frame uses.

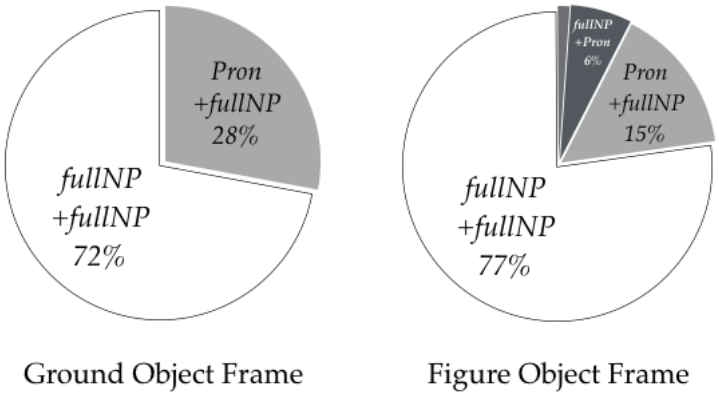


Figure 2.9 Percentages of postverbal phrasal types in the locative alternation

The results of this corpus study suggest that the presence of two postverbal NPs may affect the choice between between the DO and PO frames while they have no or little influence on the choice between the GO and FO frames. I suspect the exceptionally large number of shifts after PO primes in Experiment 3 are due to the effects of syntactic priming plus a boost due to the good fit between the occurrence of two full NPs in the sentence stimuli and the PO frame, or at least a better fit than between two full NPs and the DO frame. In other words, when the PO prime is also a more natural structure (i.e., when there are two postverbal NPs), the priming effect is significantly boosted.

If the large priming effect after low-similarity primes in Experiment 3 is not just the result of typical syntactic priming but also includes a boost from poor fit of the syntactic frame of target sentences to the encoding of the two full NP arguments, then it may be the maximum amount of syntactic priming one can expect (i.e., priming has reached its ceiling), leaving no room for an extra boost from semantic similarity between prime and target verbs.

Lastly, as I have done for Experiments 1 and 2 (see Section 2.4.3 for details), I conducted an additional mixed-effects logistic regression, treating similarity ratings from human participants as a continuous predictor of target shifts. As before, I excluded the control condition from analysis.

Table 2.18 Summary of the fixed effects in the mixed logit models using verb meaning similarity as continuous independent variable in Experiments 3 and 4

Experiment	Effect	Estimate	*SE*	*z* value	*p*	
Experiment 3 (dative)	Intercept	-0.086	0.46	-0.189	.851	
	Verb meaning similarity	0.215	0.05	4.01	.000	***
Experiment 4 (locative)	Intercept	-0.374	0.50	0.74	.460	
	Verb meaning similarity	0.206	0.05	4.48	.000	***

Formula: Shift ~ Verb meaning similarity + (1 | Subject) + (1 | Item), '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

As in Experiments 1 and 2, I found in both Experiments 3 and 4 that semantic similarity between prime and target verbs, when treated as continuous variable, was a significant predictor of syntactic priming, confirming my hypothesis.

2.6 Meta-analyses of all experiments

In this section, I report two mixed-effects logistic regression analyses on the combined data from all four experiments, which tested multiple predictors including verb semantic similarity, (dis-)preference of syntactic frames and type of argument alternation. I added as predictor syntactic frame preference for prime structures, i.e., preferred frame (Experiments 3 and 4) vs. dispreferred frame (Experiments 1 and 2). I also added argument alternation to the list of predictors to determine whether there is a systematic difference in syntactic priming between the dative alternation (Experiments 1 and 3) and the locative alternation (Experiments 2 and 4). I first included all interaction terms in a full mixed-effects model. Since none of the interaction terms were significant, I removed them from analysis. I report in Table 2.19 the results of a simpler model that includes only three factors (semantic similarity, frame preference, and alternation). Note that the low-similarity condition was set as the reference condition. As a result, comparisons between control and low similarity conditions and between low similarity conditions and high similarity conditions are shown in the table.

Table 2.19 Results of meta-analysis of Experiments 1-4 (binned similarity)

Effect	Estimate	*SE*	*z* value	*p*	
Intercept	-1.888	0.18	-10.17	.000	***
Low-similarity vs. Control	-0.521	0.13	-4.08	.000	***
Low-similarity vs. High-similarity	0.291	0.13	2.21	.026	*
Preferred frame (or dispreferred)	2.613	0.13	19.84	.000	***
Dative (or locative)	-0.318	0.21	-1.54	.124	

Formula: Shift ~ Condition + Preferred + Dative + (1 | Subject) + (1 | Item)
Significance levels: '.' < .1, '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

A significant increase in syntactic priming was found both between the control and low-similarity condition and between the low- and high-similarity conditions. (The negative coefficient of low- vs. control means less target shifts after control primes than after low-similarity primes, or, conversely, more shifts after low-similarity primes than after control primes.) This result confirms what is predicted by the Recent Verb Anchor hypothesis and also conforms to what has been shown in previous syntactic priming studies. Whether prime structures were the preferred or dispreferred frames also had a significant effect on the amount of priming: Preferred prime structures lead to more target shifts than dispreferred prime structures. But alternation (dative vs. locative) was not a significant predictor of target shifts.

In the next model, I used the same logic as in the above but used the continuous verb similarity ratings as independent variable instead of using blocks of verb similarity. The results are summarized in Table 2.20. All interaction terms were not significant in a

full model and removed from analysis. Note, as before, that the control prime and target pairs (for which verb similarity ratings were not performed) were also excluded from analysis.

Table 2.20 Results of meta-analysis of Experiments 1-4 (continuous similarity)

Effect	Estimate	*SE*	*z* value	*p*	
Intercept	-1.986	0.23	-8.69	.000	***
Verb meaning similarity	0.059	0.04	1.68	.092	.
Preferred frame (or dispreferred)	2.604	0.15	16.86	.000	***
Dative (or locative)	-0.260	0.23	-1.16	.248	

Formula: Shift ~ Verb meaning similarity + Preferred + Dative + (1 | Subject) + (1 | Item)
Significance levels: '.' < .1, '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

In these results, the preferred vs. dispreferred prime structure, but not the dative vs. locative distinction, was a significant predictor of target shifts, confirming the results above. There was a trend ($p = .092$) that verb meaning similarity tends to increase the target shifts. Overall the results of the two analyses reported in this section confirm that semantic similarity in prime and target verbs contributes to increase syntactic priming effects.

2.7 Summary and General Discussion

The Verb Anchor hypothesis, outlined in Chapter 1, proposes that a verb recently experienced in a particular syntactic frame serves as an anchor of the syntactic frame and a verb's semantic similarity to this anchor verb influences the likelihood of the same syntactic frame being chosen for the verb. It predicts, in other words, that the more semantically similar a verb is to the anchor, the more likely it is to occur in the same syntactic frame. In this chapter, I investigated the consequences of this hypothesis when recent sentence experience is what matters. What I dubbed the Recent Verb Anchor hypothesis is that recent experience of a sentence leads to an association between a verb and the syntactic frame it occurred in and that semantic similarity to that verb modulates the likelihood of the subsequent production of other verbs in the same frame.

I investigated the hypothesis employing two well-known argument alternations, namely the dative and locative alternations. Using the recall-based syntactic priming paradigm, I manipulated semantic similarity between verbs in each prime and target pair. In one condition, verbs in prime and target sentences were highly semantically similar to each other (high-similarity condition, e.g., *promise* - *guarantee*). In the other condition, verbs in prime and target sentences were much less similar to each other (low-similarity condition, e.g., *promise* - *bounce*). The Recent Verb Anchor hypothesis predicts that the effect of syntactic priming is greater when verbs in prime and target sentences are highly semantically similar than when they are semantically dissimilar.

In Section 2.4, I reported two experiments, one using the dative alternation (Experiment 1) and the other using the locative alternation (Experiment 2), where

speakers were primed to choose the less preferred syntactic frame out of the two alternate frames in each alternation when producing target sentences. The results of Experiments 1 and 2 showed an increasing trend in syntactic priming from low- to high-similarity conditions, but differed in that only high semantic similarity of the verbs in neighboring sentences significantly increased the use of the same syntactic frame as the prime sentence in Experiment 1 but both high and low similarity primes led to statistically significant syntactic priming (e.g., $p < .05$). The results of these two experiments provided partial support for my hypothesis that semantic similarity between prime and target verbs matters in choosing syntactic frames for target sentences. However, the results also raised the issue of why in Experiment 1 no statistically significant priming effects were observed when prime and target verbs were only minimally similar in meaning, since previous studies on syntactic priming have reported significant syntactic priming with little semantic overlap between prime and target. I suspected this difference might have been due to my choice of verbs that were highly biased against the syntactic frame of the primes. This may have made the production of targets in the prime structure overly difficult without a semantic similarity boost. Post hoc analyses also suggested that the smaller increases in syntactic priming than normally expected may be partly due to the two-sentence recall method I used in these experiments. Additional analyses of a broader notion of syntactic priming in a broader range (i.e., syntactic alignment between prime and target sentences in either frame) showed there was a significant difference between high- and low-similarity conditions.

In Section 2.5, I reported other two experiments where speakers were primed to use the preferred syntactic frame in producing target sentences in the dative alternation (Experiment 3) and in the locative alternation (Experiment 4). In these experiments, the prime structures were the preferred frame of each alternation while everything else was kept constant. Thus the prime and target structures in Experiments 3 and 4 were a mirror-image of those tested in Experiments 1 and 2. The results of Experiments 3 and 4 showed that, as predicted, when target structures were the preferred ones, low semantic similarity between prime and target verbs can lead to significant syntactic priming. But, in the dative alternation in Experiment 3, high semantic similarity between prime and target verbs did not lead to a statistically meaningful amount of increase in syntactic priming, compared to the low semantic similarity condition while it did so in the locative alternation in Experiment 4. The results of Experiment 4 corroborated all my predictions in that low semantic similarity between prime and target verbs led to significant syntactic priming shown by previous syntactic priming research and at the same time high semantic similarity led to a significant boost as my hypothesis predicted. Post hoc analyses on the inconsistent results of Experiment 3 suggested that the results might have been affected by other syntactic properties of the dative alternation than syntactic priming manipulations. For example, the prime structure seems even more preferred for the present experimental sentences due to the so-called end-weight constraint in English. Thus, priming effects might have already reached the ceiling in the low similarity condition.

Additionally, the results of an analysis in which the data of all four experiments were included and verb similarity ratings were used as a continuous independent

predictor of target shifts confirmed that semantic similarity of prime and target verbs matters in syntactic priming. The percentages of target shifts in all four experiments are provided in Figure 2.10 and the results of mixed-effects logistic regression models are summarized in a simplified manner in Table 2.21.

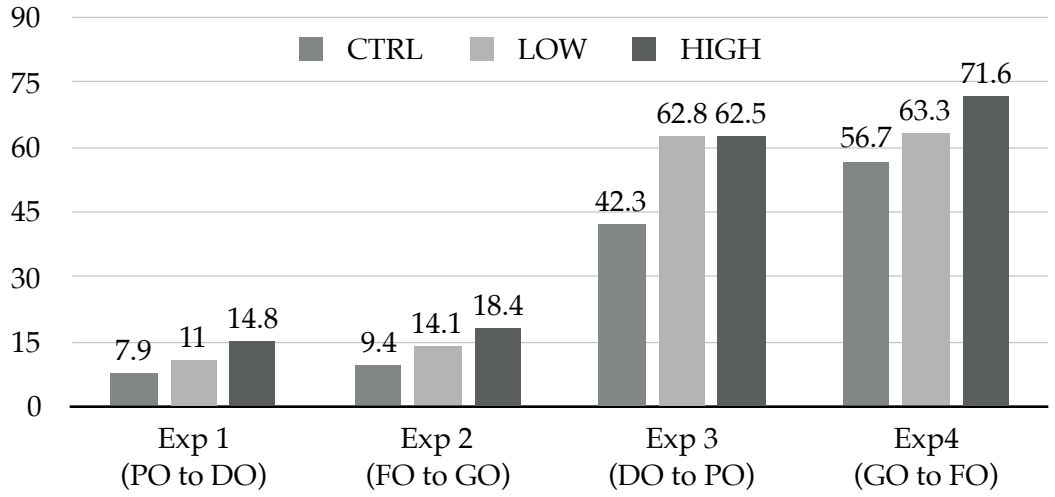


Figure 2.10 Summary of the percentages of target shifts in Experiments 1-4

Table 2.21 Summary of the fixed effects in all models in Experiments 1-4

Predictor (Binned vs. Scalar)		Exp1	Exp 2	Exp 3	Exp 4
Tabulated similarity conditions	Ctrl vs. Low	0.679 (.115)	0.943 (.013)	1.196 (.000)	0.629 (.010)
	Ctrl vs. High	0.796 (.033)	1.167 (.002)	1.403 (.000)	1.191 (.000)
	Low vs. High	0.117 (.783)	0.223 (.560)	0.206 (.502)	.561 (.034)
Similarity as continuous vb	Similarity rating (on a scale of 1~7)	0.132 (.039)	0.178 (.010)	0.215 (.000)	0.206 (.000)

Overall the present set of studies provides support for the Recent Verb Anchor hypothesis as, taken together, the four experiments I reported demonstrated the facilitatory effects of prime and target verbs' semantic similarity in reusing the same syntactic frame when producing sentences one after the other. More specifically, Experiments 1 showed high semantic similarity between prime and target verbs is necessary to demonstrate statistically significant syntactic priming. Experiment 4 also showed high similarity between prime and target verbs adds a significant boost in the repeated use of the same frame. There was some indication, descriptively, in the results of all experiments that syntactic priming increases between the low- and high-similarity conditions in all experiments (i.e., higher coefficients and lower p values). In addition, post hoc analyses treating verb similarity as a continuous variable confirmed the significant effect of verb similarity on syntactic priming in all four experiments. Taken together, the results of these four experiments suggest that what matters in syntactic priming is not just the syntactic frame recently recently experienced in a sentence but also the meaning of the verb in that recently experienced sentence. The verb associated with a recently experienced syntactic frame, the recent anchor of the frame, has a stronger influence on speakers' use of the same syntactic frame for verbs that are semantically similar to the verb in the recently experienced sentence, confirming my hypothesis.

CHAPTER 3 The Effect of Frequency-Driven Verb Typicality on Syntactic Frame Selection

3.1 The Typical Verb Anchor Hypothesis

I proposed in Chapter 1 that experience with a verb occurring in a syntactic frame results in the emergence of a cognitive association between the verb and the syntactic frame. I claimed that that verb becomes an anchor of the syntactic frame via the sentence experience and plays a crucial role in the choice of syntactic frame for other verbs that may (or may not) occur with the frame as well. I hypothesized that being an anchor means that the verb meaning is firmly connected with the syntactic frame at least temporarily and thus semantic similarity to the anchor modulates the likelihood of other verbs occurring in the same frame. I dubbed the hypothesis the Verb Anchor hypothesis.

High semantic similarity to the anchor is predicted to increase the likelihood of verbs occurring in the same frame, i.e., similar verb meanings tend to be realized in the same syntactic frame. One way of testing this hypothesis is to examine the role of recently experienced verbs, as previous research showed recent sentence experience may have an immediate impact on subsequent sentence processing (Bock, 1986). In Chapter 2, I investigated the effect of recent anchors in sentence production using the syntactic priming paradigm. The results of four syntactic priming experiments demonstrated that high semantic similarity between a recent anchor verb of a syntactic frame and a subsequent verb (i.e., prime and target verbs) leads to an increased use of the same syntactic frame, confirming the Recent Verb Anchor hypothesis.

Another way of testing the Verb Anchor hypothesis, which I use in this chapter, is to take advantage of the effect of frequency on behavior. Not only are speakers affected by recent and one-time sentence experience, but speakers are also known to be influenced by frequent and repeated experience with a particular linguistic pattern (Diessel, 2007, for a review). The most notable frequency pattern relevant to present purposes is that there tends to be a strong bias in the occurrences of verbs that instantiate a particular syntactic frame. Researchers have observed that only a small number of verbs (or even a single verb) tend to account for the majority of occurrences of a particular syntactic frame (Gropen et al., 1989; Goldberg et al., 2004). In terms of the Verb Anchor hypothesis, it means that language users experience a number of sentences that instantiate an association between a particular verb and a particular frame, which is expected to increase the strength of such an association and make the the frequent verb cognitively prominent with respect to that syntactic frame. Building on an analogy of the

relationship between a category and a typical category exemplar, I hypothesize that if a syntactic frame is instantiated by a particular verb highly frequently, such an anchor verb can become representative of and also typical of the syntactic frame. If so, then we can also expect that high semantic similarity to this typical anchor would increase the likelihood of other verbs occurring in the same frame. I dubbed this mechanism the Typical Verb Anchor hypothesis in Chapter 1.

The Typical Verb Anchor hypothesis is much inspired by research in categorization. Theories of categorization have demonstrated that increased frequency of a stimulus tends to make the stimulus more typical of a category (Nosofsky, 1988). In other words, frequently occurring exemplars of a category are likely to become more typical category exemplars compared to infrequent ones. Being typical, here, means that the relevant exemplars are considered the best-fitting or the most characteristic members of the category. In the context of the present study, a verb that typically occurs in a particular syntactic frame is supposed to have a meaning that best fits in that syntactic frame. The typicality effect is known to manifest itself in a variety of cognitive tasks. Typical exemplars lead to faster recognition and more accurate categorization of new stimuli. Moreover, when a list of category members are asked for, typical exemplars are more likely to come up first or earlier. It suggests that although not necessarily recent, repeated experience with a category exemplar makes it a psychologically prominent member of the category. Typicality is related to the skewed distribution of occurrences of exemplars in natural categories. Within the bird category, for example, robins are more frequently observed than penguins and this is why robins are considered a more typical bird than penguins.

Skewed frequencies are pervasive in language as well. Previous research has shown that frequency of occurrence exerts a profound influence on many facets of natural language (see Chapter 1 for more discussion). As alluded to above, it has also been suggested that there is much resemblance between the distribution of syntactic frames and verbs and the distribution of categories and their exemplars. An example of typicality effects with respect to syntactic frames is that, when a verb-less frame is presented for completion, e.g., *"I _____ him something"* and *"He _____ me that,"* the blanks are most likely to be filled with verbs like *give* and *tell*, the most frequent verbs to occur in the Double Object frame.

Given the similarities between natural categories and syntactic categories (or frames), I test the Typical Verb Anchor hypothesis by investigating whether a typical anchor verb plays a role in the choice of syntactic frame for other verbs in the same way a typical category exemplar influences other exemplars to be assigned onto the same category. My hypothesis will be confirmed if high semantic similarity to a typical anchor verb of a syntactic frame increases the tendency for other verbs to occur in the same frame.

The mechanism is illustrated in Figure 3.1 below. If a syntactic frame (e.g., V NP_{rec} NP_{thm}) occurs with a particular verb predominantly frequently (e.g., *give*), it will give rise to a strong association between them, which is illustrated by the connecting line in the figure. This is assumed to be a learned association, so that it is expected to affect other verbs in a constant manner, as opposed to the effect of recent verb anchors (cf. Figure 2.1 in Chapter 2). Therefore we can expect the role of a typical anchor to be in effect as long as the frequency-driven strong association stays in place, e.g., no changes

in its frequency. Given the typical anchor that is strongly associated with a particular frame, verbs semantically connected with the anchor are affected to the degree to which they are semantically similar to the anchor in the same way recent anchors have influence on other verbs in their syntactic realizations. Namely, I predict the more semantically similar a verb is to the typical anchor, the more likely it is occur in the same syntactic frame.

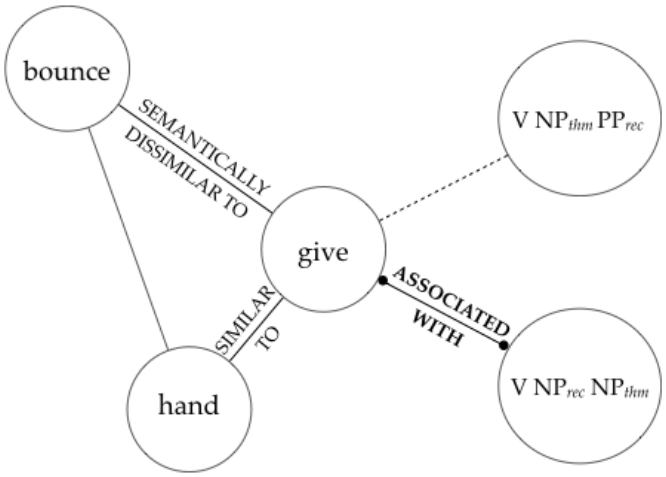


Figure 3.1 Association between a typical verb anchor and a syntactic frame

An empirical study on the effects of typical verb anchors calls for other techniques than online experiments, because speakers acquire the frequency information through their own experience with language over time and also because the frequency information, once acquired, is expected to affect their language use not only immediately, but for a long time, as opposed to the recency effect which is by definition temporally constrained. One of the best ways to estimate frequencies of any linguistic units is to study corpora. A (good) corpus, or a collection of naturally occurring

language, is often assumed to reflect speakers' experience with language. By looking into a corpus, we can simulate the actual language use and also investigate its influence back on one's language use in certain contexts. For my purposes, I will study the British National Corpus to get information on the frequencies of verbs and syntactic frames and decide which verb is typical of a chosen syntactic frame. On this basis, I will then test whether semantic similarity to the typical verb has a significant impact on syntactic realizations of other verbs. As in Chapter 2, the Typical Verb Anchor hypothesis will be tested on the dative alternation (Section 3.2) and on the locative alternation (Section 3.3).

3.2 Study I: Verbs that participate in the Dative Alternation

In this section, I report on an extensive corpus study of the dative alternation in the British National Corpus and the procedure and results of statistical modeling on the data by which I test the effect of the putative typical anchor of the Double Object frame (i.e., *give*). In Section 3.2.1, I examine the frequency distribution of verbs occurring in the two alternate frames of the dative alternation and explore whether there exists a verb that instantiates either frame particularly frequently (i.e., a candidate for typical anchor status). I also propose a way of estimating verb typicality based on their frequency of occurrences in the corpus. In Section 3.2.2, I report the results of statistical modeling that tests whether semantic similarity to *give*, the typical anchor of the Double Object frame, can modulate other verbs' occurrences in the two alternate frames, more specifically, whether semantic similarity to this anchor predicts the likelihood of occurrence in the two syntactic frames of other verbs that participate in the dative alternation (e.g., the more similar to *give*, the more likely a verb will occur in the Double Object frame). In Section 3.2.3, I report on further tests of the validity of the effect of this typical anchor in the context of previously known predictors of the dative alternation (e.g., Bresnan et al., 2007). Lastly in Section 3.2.4, I investigate whether the Typical Verb Anchor hypothesis is also valid in a much narrower range of verb meanings, using Pinker's (1989) notion of narrow verb classes. Section 3.2.5 summarizes the results.

3.2.1 A corpus study in the dative alternation

3.2.1.1 Data collection

In this corpus study, sentences containing verbs known to participate in the dative alternation were collected from the British National Corpus (BNC). The dative alternation involves two roughly meaning-preserving syntactic frames, the Double Object (DO) and the Prepositional Object (PO) frame, illustrated in (3.1a) and (3.1b), respectively. See Section 2.3.1 above for a more detailed introduction to the dative alternation.

(3.1) a. John gave his son a toy. [$_{VP}$ *V* [$_{NP}$ RECIPIENT] [$_{NP}$ THEME]]

b. John gave a toy to his son. [$_{VP}$ *V* [$_{NP}$ THEME] [*to*-$_{PP}$ RECIPIENT]]

In order to collect sentences occurring in the two types of syntactic frames, I used a version of the British National Corpus syntactically annotated via the Charniak parser (Charniak, 1997).[4] I first retrieved verb phrases that instantiate the DO and PO frames, namely those parsed as [V NP NP] and [V NP PP] respectively. I then discarded sentences whose main verbs do not belong to the group of 122 verbs that Levin (1993) listed as participating in the dative alternation. This was because, for my purposes, the sentences I used in the following analyses should be able to be rephrased in the alternate frame. If a verb can occur only in one of the two frames, I will not be able to test whether

[4] According to Roland et al. (2007), the correct parsing rate in the BNC was estimated to be 71%. The *precision*, *recall*, and the *F measure* are 82%, 92%, and 87%, respectively, for the PO frame and 81%, 85%, and 83%, respectively, for the DO frame.

my predictor has a significant influence on the *choice* of syntactic frame in the first place. Another reason to limit the range of verbs to Levin's list is that it is almost impossible to make an exhaustive list of alternating verbs, partly because the frames can possibly occur with "new" verbs whether improvised or coerced and partly because how acceptable a verb is in either frame may differ to a great extent by individuals and by dialects as well.

Levin (1993) originally listed 127 verbs as occurring in both constructions. The number of unique verbs I started with, however, was 122 because five verbs are listed twice but in two different senses (i.e., *kick*, *shove*, *wire*, *pass*, and *relay*) and the use of the parsed BNC cannot discriminate between verb senses. Thirteen verbs from Levin's list were lost because they never occurred in this corpus in either frame (i.e., *schlep*, *tote*, *bus*, *truck*, *modem*, *netmail*, *satellite*, *semaphore*, *telecast*, *telex*, *wireless*, *bunt*, and *punt*). Four verbs were manually excluded (i.e., *render*, *vote*, *pass*, and *relay*). The actual tokens of *render* and *vote* in this corpus did not instantiate the meaning of caused possession, which is expected for the dative frames DO and PO. The verbs *pass* and *relay* were excluded as they cannot serve the purpose of testing the entailment of caused possession. In many of the following analyses, whether a verb entails caused possession or not was tested as a predictor of the dative alternation. However, these two verbs cannot be specified for this distinction because they may or may not entail caused possession depending on which sense is intended in a sentence (Rappaport & Levin, 2008). The finalized dataset consisted of 63,403 sentences in either the DO or PO frame. The sentences instantiated 105 distinct verbs. An overview of the frequency distributions by verbs and by frames is provided in the next section.

3.2.1.2 *The frequency distribution of verbs in the dative alternation*

Many researchers have suggested that the frequency distribution of verbs in the DO and PO frames is highly skewed (Gropen et al., 1989; Goldberg et al., 2004). My corpus study corroborates previous research with the larger-scale natural usage data I extracted from the British National Corpus (BNC). More specifically, my corpus search confirms the previous observation that the verb *give* accounts for the lion's share of the use of the DO frame, as illustrated in Table 3.1.

Table 3.1 Overview of the frequency distribution of 'give' and other verbs in the the dative alternation in the British National Corpus

Verb	Tokens					Proportions
	DO		PO		DO + PO	DO:PO
give	15,311	59%	8,402	22%	23,713	65:35
other 104 verbs	10,762	41%	28,928	78%	39,690	27:73
Total	26,073	100%	37,330	100%	63,403	41:59

Although the mean proportions of the DO and PO frames for all the 105 verbs I considered in this study exhibit no striking biases (i.e., DO:PO = 41:59), there is a split between *give* and the other 104 verbs. The verb *give* shows some unique characteristics: First, *give* is overwhelmingly more frequent in the DO frame than any other verb in this dataset. It accounts for 59% of all 26,073 DO sentences in our data. In other words, if one encounters ten DO sentences, about six of them will have *give* as their main verb. The

second most frequent verb in the DO is the verb *tell*, which accounts for 10% of the tokens of the DO frame. 41% of all DO sentences occurred with verbs other than *give*. In fact they are only 57 other verbs that occurred in the DO frame, since the remaining 47 verbs never occurred in the DO frame but only in the PO frame in my data.

Second, *give* occurs more frequently in the DO frame than in the PO frame (i.e., DO:PO = 65:35) whereas the vast majority of other verbs occur more frequently in the PO frame than in the DO frame (i.e., DO:PO = 27:73, the mean distribution for the other verbs). Thus, *give*'s strong preference for the DO frame also stands out when most alternating verbs have a preference for the PO frame. There are only six verbs that are biased towards the DO frame in the BNC (i.e., *give*, *tell*, *ask*, *teach*, *loan*, and *email*).

These two distributional facts (absolute and relative high frequency of *give* in the DO frame) seem to suggest there may exist a strong cognitive association between the verb *give* and the DO frame, leading to the high typicality of *give* as an exemplar of the DO frame. In the next section, I introduce a method of measuring verb typicality based on frequency of occurrences, which will be used throughout this chapter as an estimate of the strength of association between a particular verb and a syntactic frame.

3.2.1.3 My measure of verb typicality

There may be various ways to quantitatively estimate the typicality of a verb for a particular syntactic frame. One way is to let people decide how typical a verb is as an instantiation of a syntactic frame, e.g., using typicality ratings. There are also many ways

to assess typicality based on frequency of occurrences.[5] For my purposes, it suffices to measure the difference between how many times a verb occurs in one construction and how many times it occurs in its meaning-preserving alternate frame. The logic behind this idea can be found in the assumptions widely shared across associative learning theories. I assume that experience with a sentence leads to speakers' learning of the association between a verb and the syntactic frame the sentence exemplifies. The co-occurrence between a verb and the syntactic frame it occurs in is analogous to, for example, the "firing together" of the two in a Hebbian model (Hebb, 1949), one of the well-known models of associative learning. The joint activation of the verb and the frame is assumed to lead to a change in the weight of the connection between them, which is illustrated by the equation in (3.2).

(3.2) $\Delta w = \eta a_v a_F$

The terms a_v and a_F refer to the activation of the verb v and the activation of the frame F, respectively, and η refers to a learning rate constant. In the context of the present study, each and every occurrence of a verb in a particular frame is assumed to result in the change in the weight of the connection between them, i.e., Δw. The cumulative weight of the connection is assumed to serve as a proxy for the degree of the verb's typicality for the frame. Throughout this chapter, the weights will be computed

[5] See Schmid and Kücenhoff (2013) for a review of other measures. The crucial differences in the assumptions between the present measure and others (odds-ratio; ΔP, Ellis & Ferreira-Junior, 2009; distinctiveness of collexeme, Gries & Stefanowitsch, 2004) are (i) first, the association strength of a particular verb with a syntactic frame is computed independently from that of other verbs and (ii) second, raw counts of occurrence in each frame matter more than ratios of occurrence in the two frames.

based on the following logic: As the two alternate frames of an alternation are competing in the sense that a verb cannot simultaneously occur in two frames for a single token sentence, the possible activation for a token of a frame is either *1* or *-1*. That is, if one frame is active when an alternating verb is chosen, the other frame is not just inactive, it is inhibited. In contrast, when a verb v is active, its activation value is 1 and the values of all other alternating verbs is 0. This is because what matters is the bias of *a given verb* towards one of the alternate frames while other verbs are simply irrelevant to the estimation of this bias. In other words, they are inactive rather than inhibited. Under these assumptions, the weight of the connection between a verb v and a syntactic frame F after encountering t tokens of the verb is that in (3.3), where F and $-F$ are encountered t_1 times and t_2 times, respectively ($t = t_1 + t_2$).

(3.3) $w_{vF}(t) = \eta(t_1(v, F) - t_2(v, -F))$

The formula in (3.3) is to be read as follows: When a verb v occurs in one frame F, the weight is increased by η since both the verb and the frame have *1* as their activation values. When a verb occurs in the alternate frame, the weight is decreased by η since the verb node has value *1* and the alternate frame has value *-1*. When the chosen verb is not v, the strength of association between v and F does not change since the activation of v is 0. That is, the association strength between a verb and a syntactic frame is not affected by tokens of other verbs in either frame. We can then compute the association strength between a verb v and a frame F by subtracting the number of times v occurs in its alternative construction $-F$ from the number of times v occurs in the construction F.

Note that although the learning rate η is unknown, it is constant across all verbs. What matters most for my purpose is not the absolute values of w_{vF} but is the relative sizes of w_{vF} among verbs. As illustrated in (3.4), I thus rank-ordered verbs with respect to their association strengths and selected the verb with the highest association strength as the most typical verb that exemplifies a frame *F*.

(3.4) $\textit{Typical-Verb}(F) = \max_v(w_{v1F}, w_{v2F}, w_{v3F, \ldots})$

Using (3.3), I computed the association strengths between each alternating verb and each frame. The list of verbs and their association strengths is attached in Appendix B. The results showed that the verb *give* is, as expected, most strongly associated with the DO frame (i.e., $w_{give\text{DO}} = 6909$).[6] The verb *tell* is the second most strongly associated verb ($w_{tell\text{DO}} = 2363$). The third is *ask* ($w_{ask\text{DO}} = 494$), the fourth is *teach* ($w_{teach\text{DO}} = 72$) and then *loan* ($w_{loan\text{DO}} = 1$) and *email* ($w_{email\text{DO}} = 1$) follow. These six verbs are all positively associated with the DO frame. The verb *promise* has zero weight, or is unbiased with respect to frame, as it occurred in my corpus the same number of times in the DO and in the PO frame. Except for these verbs, all the other verbs had negative values of association strength with the DO frame, which means that, in the context of the dative alternation, they are associated more strongly with the PO frame than with the DO frame.

Based on the results of my typicality estimation, I selected the verb *give* as the most typical verb for the DO frame. In the next section, I test whether semantic

[6] The unknown η term, a constant for the learning rate in (3.2), is omitted for expository purposes.

similarity to this typical verb modulates the choice of syntactic frame for verbs that allow the same syntactic possibilities. My hypothesis will be confirmed if I find that verbs that are more semantically similar to *give* are more likely to occur in the DO frame than verbs that are not as semantically similar to *give*.

Lastly, two things should be noted regarding the results of my typicality measure. Firstly, the present measure puts more importance on the raw frequency of each alternate frame than on the ratio between the occurrences of two alternate frames (i.e., proportions). For example, one may wonder whether *email* and *tell*, for example, can be more typical verbs of the DO frame than *give* as they have even higher proportions of occurrence in the DO frame than *give* (i.e., *email*, 100% (DO:PO = 1:0) and *tell*, 89% (DO:PO = 2702:339). Neither of them, according to the present measure of typicality, though, constitutes a more typical verb for the DO frame than *give*. As argued before, what makes an association stronger between a verb and a frame is not only the preference the verb exhibits for that frame (relative frequency; *give* occurs more frequently in the DO than in the PO), but also how frequently it occurs in that frame (absolute frequency; *give* occurs very frequently in the DO). Such is the case for the verb *give* and the DO frame. Verbs like *email* or *tell* may activate the DO frame more relative to the PO frame, but *give* activates the DO frame more strongly than *email* or *tell* do (i.e., $w_{email\text{DO}} = 1$ and $w_{tell\text{DO}} = 2363$). According to my estimation, a verb becomes more typical of a syntactic frame than any other verb (i) when it occurs most frequently and far more frequently than any other verb in that construction and (ii) it prefers that frame over its alternative. Given these assumptions, my corpus study reveals that the verb *give* is the most typical anchor of the DO frame. Secondly, one may interpret positive and negative

association strength scores symmetrically. For example, one might say that a positive high score means a strong association with the DO frame; a negative low score means a strong association with the PO frame. *Bring*, *take*, and *send* for example are the lowest scoring three verbs (i.e., $w_{bring\text{DO}}$ = -4347, $w_{take\text{DO}}$ = -3576, and $w_{send\text{DO}}$ = -2476) and may be thought to be strongly associated with the PO frame. For now, I interpret these negative values simply as not being associated with the DO frame and do not assume that *bring* is the verb that is most strongly associated with the PO frame (i.e., $w_{bring\text{PO}}$ = 4347). Because I only consider alternating verbs in my analysis, it may not be the case that *bring* is the most typical of the PO frame *in general*. As introduced in Chapter 2 (Section 2.3.1), the PO frame is associated with a wider range of meanings than the DO frame (e.g., caused possession and caused motion) and, as a result, the PO frame can occur with many more verbs than the DO frame. Verbs that occur in the DO frame are very likely to also occur in the PO frame; only a limited range of verbs that occur in the PO frame can also occur in the DO frame. Moreover, as noted above, many of the verbs Levin (1993) listed as alternating never occurred in the DO frame in my corpus of natural use. The verb *give* occurs the most frequently in the DO frame among all the verbs that occur in the DO frame, including non-alternating DO verbs. The verb *bring* is not the most frequent verb in the PO frame among all possible PO verbs. We may conclude that *bring* is more strongly associated with the PO frame than *take* or *send*, but may not conclude that *bring* is the most strongly associated with or most typical of the PO frame. For my purposes, it will suffice to show the role of *give* as a typical verb for the DO frame. Finding a verb

most typical of the PO frame requires further research and goes beyond the scope of the present analysis.[7]

3.2.2 Modeling the effect of verb semantic similarity to 'give'

3.2.2.1 Predictor variable: verbs' semantic similarity to 'give'

Researchers have proposed various methods to estimate semantic similarity between two words. In general, three different types of approaches have been used. One of them is the use of rating experiments, in which participants are presented with two words and asked to decide on their similarity on a scale. Another group of approaches attempts to compute similarity based on the definitions of word meanings (glosses) and their hierarchical classifications (taxonomy). Some WordNet-based similarities are a well-known measure of this kind. These kinds of measures depend mainly on speakers' intuitions, judgments, definitions, and classifications. The third group of approaches that diverge from the other two both philosophically and technically are computational, e.g., Latent Semantic Analysis, where word or text similarity is computed via an analysis of word co-occurrences. As opposed to the first two types of approach, mathematical/ computational approaches depend on the *uses* of words rather than on human judgment about word meanings and taxonomies.

The different types of measures of word similarity have been compared in previous literature. The performance of word similarity measures was mostly assessed

[7] The verb *leave* which has a negative association strength with the DO frame is discussed in the context of narrow-range verb classes in Section 3.2.4.

on noun-noun similarities such as *bird* and *feather*, though. The performance of verb similarity measures have much rarely been assessed. Verb similarity is typically considered more difficult to measure, partly because because verb meanings are relational. Different similarity measures seem to model different aspects of verbs' semantic representations and different usages (Resnik & Diab, 2000). Even human ratings of similarity tap into different aspects of verb meaning. When comparing two verbs, humans may depend on a particular feature or set of features the two verbs share or do not share (Tversky, 1977). They can also put an emphasis on particular aspects of similarities in argument structures, taxonomic classifications, or properties of semantic arguments. In addition, the strategies they adopt may vary depending on the particular semantic properties of verb pairs. Thus the criteria on which similarities are determined can vary person by person as well as item by item. To conclude, no single method seems to model verb semantic similarity entirely accurately. Thus, it is important to choose a measure that can capture aspects of verb similarity most relevant to one's research questions. For my purpose, it is best to capture verb similarity based on natural language use, not based on human strategic judgments or linguists' definitions, because this thesis is concerned with the effect of semantic similarity that average speakers acquire through their language use has on the selection of syntactic frame in sentence production. This is why I chose a computational measure of verb semantic similarities in the present studies.

Another benefit of using a computational measure was that it is, for my purpose, technically more straightforward to use than other measures. First of all, a drawback I found in using WordNet similarity is that I would have to manually choose a particular

sense of a verb in each of the dictionary-type verb entries. Note that, the *give* entry, as a verb, contains 44 different senses. Three of those entries are concerned with the most common semantic definitions associated with the dative frames; other senses can occur but do not necessarily occur in the dative alternation (e.g., transitive). It can be arbitrary to some degree to judge which sense(s) to include or to exclude. Even when senses are chosen, the measure produces different similarity values for each pair of senses. For example, when measuring the semantic similarity between *give* and *grant* as verbs of the dative alternation, there are at least three senses of *give* and seven senses of *grant*, so this measure ends up with 21 pairwise comparisons (e.g., *give*#1 vs. *grant*#1, *give*#2 vs. *grant*#3, *give*#3 vs. *grant*#7 and so on). The WordNet vector similarities of these pairs range from .087 (*give*#1-*grant*#7) to .810 (*give*#1- *grant*#2). There can be many ways of putting together these measures of sense similarities into a single-numbered verb similarity. Previous studies often solve this problem by averaging them out or using the median or the maximum number. However, choosing any of the solutions may also be arbitrary.

Using human similarity ratings on verb pairs (e.g., to *give* : to *leave*) seems to face similar problems. Researchers cannot guarantee participants rate semantic similarities between two verbs based on the verbs' dative meanings, for example. When no particular frame is present (i.e., without a full sentence for non-linguist participants), they may decide on the verbs' semantic similarity thinking of their non-dative uses, for example, the departing sense of *leave*. If a full sentence is given, it is difficult to tease apart verb similarity from overall sentence similarity to which not only the verbs' meanings but also the meanings of other words in the sentence contribute. Using a

computational measure, although not perfect, seems to be least affected by researchers' arbitrary decisions or manipulations. Below, I provide a brief introduction to the computational similarity measure I chose, Latent Semantic Analysis (LSA), and also detail how I matched up verbs to measure their semantic similarities using LSA.

Latent Semantic Analysis (LSA, hereafter; Landauer et al., 1998) is a computational technique widely used in natural language processing research to analyze the semantic relationship between words or sets of words. LSA computationally and statistically simulates the contextual usage of words and computes their similarities using natural language corpora that are meant to reflect our experience with language. Crucially, LSA does not take into account semantic definitions, taxonomies or the syntactic behavior of words and phrases in computing semantic similarity. The intuition behind LSA is that the similarity in meaning of two words can be estimated by the similarity of the contexts in which they occur: Do they occur in the same documents? Do they co-occur with the same words in those documents? When applied to two expressions or sets of expressions, LSA produces cosines ranging from 0 to 1 as a measure of similarity (see Landauer et al., 2007, for more technical details).[8] In the present study, verb similarity was measured by a matrix that computes LSA cosines based on the British National Corpus.[9]

The verb semantic similarity I need to measure here is the similarity between a verb typical of a syntactic frame and other verbs that can occur in the same frame and in

[8] LSA cosines can be slightly negative. This is known to be an artifact of the calculation process.

[9] LSA cosines can be obtained in the official website at http://lsa.colorado.edu. The BNC-based LSA cosines were chosen in the present study, first because it is based on a larger dataset or semantic space than the one used in the online version and also because it can help make our analyses more consistent in that the sentences tested in regressions are also collected from the BNC.

the other frame of an alternation, namely semantic similarity between *give*, typical of the DO frame, and other alternating verbs. To prepare for the predictor or independent variable, I identified the main verb in every sentence from my corpus dataset, consisting of DO and PO sentences with alternating verbs. Then, I measured the semantic similarity between *give* and the verb of every sentence using LSA and I then coded each sentence with the LSA cosines (i.e., semantic similarity between its main verb and *give*).

Technically, LSA computes cosines based on word forms, not on lemmas. In other words, *give*, *gives*, *gave* and *given* are treated independently in this measure. I used the past tense forms to measure verb similarities. I found that using *gave* alone vs. using multiple forms *give*, *gives*, *gave* together result in slightly different cosines, although there was a very strong correlation between the two measures (Pearson's $r = .946$, $p < .001$). A close review of individual verbs' cosines revealed that the cosines tend to be slightly boosted for verbs whose present tense forms can also be used as a noun, e.g., *kick* and *offer*. In order to minimize inconsistencies across verbs (as not all verbs have present forms that can equally by used as nouns), I chose to use the past tense forms alone for all verbs. The LSA cosines for all 104 pairwise comparisons ranged from .047 to .946.

Unfortunately, I found LSA semantic similarity is partly confounded with word frequency: LSA cosines seem to be higher for high frequency words relative to low frequency words. A correlation analysis showed that verb frequency significantly correlated with LSA cosines (Pearson's $r = .443$, $p < .001$), using the number of occurrences of a verb in the present dataset (i.e., totaling DO and PO sentences) as an estimate of the frequency of the verb. To improve the accuracy of the semantic similarity measure, I residualized LSA cosines over verb frequency. Conceptually this means that I

removed the portion of LSA cosines contributed by the effects of verb frequency. Using residualized LSA cosines, we can see the effect of semantic similarity on syntactic frame selection when the effect of verb frequency is controlled for. A high correlation between original LSA cosines and residualized ones (Pearson's $r = .896$, $p < .001$) shows the residualization made no dramatic change in the relative sizes of LSA cosines across verbs. However, residualization tended to lower the LSA cosines of high-frequency verbs. For example, *hand* and *bring* have similar raw LSA cosines to *give* (.53 and .56) but when the cosines are residualized over, or corrected by, their frequencies (567 and 5507, totaling both frames), the relative sizes of cosines greatly differ between *hand* and *bring* (. 247 and .098).[10]

3.2.2.2 Outcome variable: alternate frames (DO or PO)

The outcome or dependent variable is binary, whether a sentence occurs in the DO frame or in the PO frame. Individual sentences in the corpus data were coded with 1 if they occurred in the DO frame or with 0 if they occurred in the PO frame, illustrated in the sentences from the BNC in (3.5) (*italics* added).[11]

---

[10] Our post hoc analysis showed the technical corrections I made to get as much unbiased a measure of LSA cosines as possible (e.g., using past tense forms and residualization) do not modulate the main effect of semantic similarity to *give*, we report in this section, in predicting the dative alternation. Similar patterns were replicated using LSA cosines from the online matrix with multiple verb forms and also by unresidualized LSA cosines from the BNC-based matrix with a past tense form.

[11] This is the default coding scheme in the present studies. However, when using Bresnan et al.'s data in Section 3.2.3.3 below, the coding was reversed to match their coding scheme for ease of comparison, namely DO and PO were coded as 0 and 1, respectively.

(3.5) I *gave him a jam sandwich* just before you arrived. DO (= 1)

Margaret *gave all the credit to her Mr. MacQueen*. PO (= 0)

When the outcome variable is binary, we can use logistic regression to analyze the data. The next section details a logistic regression model which the present data is fitted to and reports the results, i.e., whether semantic similarity between *give* and the main verbs in each dative sentence is a significant predictor of the dative alternation.

3.2.2.3 Logistic regression and results

As introduced at the outset of this chapter, this study aims to test the effects that verb semantic similarity to *give* (the typical verb of the DO frame) have on speakers' syntactic choices. I hypothesized that verbs that are semantically similar to a verb highly typical of a particular syntactic frame are more likely to occur in that same frame than less similar verbs. Given that the verb *give* is chosen as the most typical verb of the DO frame, I predict the more semantically similar a verb is to *give*, the more likely it is to occur in the DO frame.

In the following logistic regression model, I entered residualized LSA cosines as predictor variable and syntactic frames as the outcome variable. The results will show whether LSA cosines, a proxy for the verbs' semantic similarity to *give*, make a significant contribution to predicting the syntactic frame, either DO or PO, each sentence in the dataset instantiates. Note that the sentences whose main verb is *give* are excluded from this regression analysis. Including those sentences would artificially boost the effect

as those sentences have the highest value in the predictor variable (i.e., semantic similarity between *give* and *give*) and instantiate the DO frame predominantly and most frequently. In other words, they may make a regression model "look better" in predicting the outcome. In all the models reported in this chapter, I excluded those sentences that occurred with the verb(s) chosen as the typical verb of a syntactic frame for the same reason.

The results showed that, as predicted, verb semantic similarity to *give* is a significant predictor of the syntactic frame ($b = 3.77$, $z = 35.41$, $p < .001$) and as indicated by the positive value of the coefficient (b), higher semantic similarity means higher likelihood of occurring in the DO frame. The results confirmed my hypothesis. The frequency-driven strong association between the verb *give* and the DO frame suggests that the verb *give* plays a significant role as the most typical verb of the DO frame in speakers' choice between the DO and PO frames.

Previous research found several other factors may also affect speakers' choice between the DO and PO frames. Rappaport and Levin (2008), for example, suggested syntactic choices depend to a great extent on the inherent semantic properties of the main verb. Bresnan et al. (2007) showed the importance of many other factors. Not only do the results of the present study confirm my hypothesis regarding the effect of the most frequent verb on frame selection in the dative alternation, but these results also add a new factor to the body of previous research on the determinants of the dative alternation. Section 3.2.3 investigates whether the role of *give* as the most typical DO verb demonstrated by the simple logistic regression model reported in this section

remain as a significant predictor of the dative alternation when other known factors are also taken into account.

3.2.3 Considering other known predictors of the dative alternation

As alluded to above, many factors are known to modulate syntactic frame selection when formulating a sentence, in particular when choosing one of the two alternate frames of the dative alternation. I just examined the effect of *give* as the typical DO anchor as a predictor of the choice between the DO and PO frames. I will now examine whether similarity to *give* makes a unique contribution to predicting the choice of syntactic frame, above and beyond other known factors, using multiple logistic regression analyses. The following three subsections will present the results of models that test the effect of semantic similarity to *give* in the context of other known factors and will show that the effect of a verb's semantic similarity to *give* is in fact not reducible to the effects of those other factors.

As a preliminary, I provide a brief and informal introduction to the multiple logistic regression analyses used to analyze the data. In the following multiple logistic regression models, the dependent (outcome) variable or what is observed is whether a verb occurs in one frame or in the alternate frame as before; however, multiple independent variables (predictors) are considered simultaneously, as opposed to the analysis I conducted previously. Previous research has shown the choice of syntactic frame is affected by many different factors. In order to tease apart the effect of my predictor, *semantic similarity of a verb to the typical anchor of a frame*, those other factors

need to be included in the model. Otherwise, I cannot determine whether my predictor plays a significant role above and beyond other known predictors. When conducting psycholinguistic experiments, we can to a large extent control for the other factors by carefully constructing experimental materials. For example, the type and length of post-verbal NP arguments (two of the known predictors of the dative alternation) were kept constant across different priming conditions in Experiments 1-4 in Chapter 2. Thus, semantic similarity to the verb recently experienced in a sentence could be tested as a single independent variable in the experiments. All other predictors were *experimentally* controlled for. When working with natural language data, though, we have no control over these other factors. It is therefore necessary that all the known factors be *statistically* controlled for in order to test a new potential predictor. When several factors are expected to predict an outcome, we can use *multiple regression* to analyze the data. The basic equation for multiple regression is given in (3.6).

(3.6) a. $\text{outcome}_i = (\text{model}) + \text{error}_i$

b. $Y_i = (b_0 + b_1X_{1i} + b_2X_{2i} + \ldots + b_nX_{ni}) + \varepsilon_i$

When the outcome is predicted by a combination of multiple predictors (X_1, X_2, … X_n), the model consists of the sum of the values of all the predictors multiplied by their respective coefficients (b) and an error term (ε), as illustrated in (3.6b). Coefficients ($b_1, b_2 \ldots b_n$) represent the change in the logit of the outcome (Y) induced by one unit change in a predictor X_n.[12] If a predictor does not change in the outcome or does not

[12] The *logit* of the outcome refers to the natural logarithm of the odds of Y occurring (Field et al., 2012, p.332).

contribute to predicting the outcome, it should have a zero coefficient. A significant predictor should have a coefficient significantly different from zero (statistical significance is here tested by the *z*-statistic). In a nutshell, each predictor has its own coefficient whose statistical significance *p* is tested individually. We can assess the effect of individual predictors by looking at the coefficients and the significance of their respective *z* scores ($p < .05$), which I will report for all the following multiple logistic regression models.

Another part of the results I will report is R_L^2 or pseudo-R^2 (the subscript *L* stands for *logistic*). As logistic regressions do not come with an equivalent statistic to R^2 for ordinary linear regressions, several pseudo-R^2 have been proposed to evaluate the goodness-of-fit of logistic models (e.g., Hosmer and Lemeshow, Cox and Snell, Nagelkerke, etc.; Nagelkerke's R_L^2 will be reported in the following models). Pseudo-R^2 should not be interpreted in the same way as ordinary R^2, which represents how much of the variance in the outcome is explained in a linear regression model. The value of a single pseudo-R^2 has little meaning independently but is useful only when compared to a pseudo-R^2 of another model that predicts the *same* outcome on the *same* dataset. Namely, what matters is the relative size of these values across models (i.e., the higher pseudo-R^2 is an indication of a better fit). Their values range from 0 (indicating the predictors fail to predict the outcome) to 1 (indicating the model predicts the outcome perfectly).[13] When comparing models, for example when comparing a model with *n* number of predictors with a model with *n+1* number of predictors, we can see if there is a significant increase in the amount of variance in the outcome explained by the second

[13] See Field et al. (2012, pp. 316- 318) for more details on these three pseudo-R^2 measures.

model. Namely the change in R_L^2 from the first to the second model indicates whether the new predictor (X_{n+1}) contributes to the improvement of the overall model performance. The significance of the change is measured by subtracting the log-likelihood of the second model from that of the first model, called the *model chi-square* statistic. Thus, when discussing the fit of a model, R_L^2, the *model chi-square*, and its significance level will all be reported.

3.2.3.1 Verbs' semantic entailment of caused possession

I have assumed so far that both the DO and PO frames convey more or less the same meaning. However, several researchers have argued that the two frames are associated with different conceptual or semantic structures (Pinker, 1989, among others). The DO frame is argued to entail the meaning of *caused possession*, namely 'the recipient ends up possessing the gift', while the PO frame does not necessarily do so. Rappaport and Levin (2008) have further argued that the meaning difference between the two syntactic frames depends on the meaning of the main verb. For some verbs, both frames necessarily entail caused possession; for others, only the DO frame always entails caused possession. The contrast between the two classes of verbs is illustrated in (3.7) (Koenig & Davis, 2001).

(3.7) a. A man *gave*/*threw* his friend a ball. (DO)

b. A man *gave*/*threw* a ball to his friend. (PO)

The verb *give* equally leads to the entailment of caused possession in the DO and PO frames (see (3.7a) and (3.7b)). However, the verb *throw* necessarily evokes caused possession only when it occurs in the DO frame as in (3.7a). The verb *throw* in the PO frame in (3.7b) can be uttered for an event of transferring a ball to a friend so that he or she possesses it at the end of the event, but also for an event where a man throws a ball at a woman to hit her, not necessarily to cause her to possess the ball. In other words, the PO frame is a meaning-preserving alternative to the DO frame only for *give*-like verbs. *Throw*-like verbs conventionally convey caused possession information only in the DO frame.

This contrast in the caused-possession entailment suggests that the verbs considered in the regression analysis in Section 3.2.2 actually consist of two semantically distinct subgroups of verbs. It is likely that these differences in semantic entailment are reflected in the measure of semantic similarity. Intuitively, verbs that carry the same entailments in both frames are expected to be semantically more similar to each other than verbs that carry different entailments in the two frames: As our typical DO anchor *give* is argued to entail caused possession irrespective of the syntactic frame it occurs in, *give*-like verbs are expected to be more similar to *give* than *throw*-like verbs. That is, the cause-possession entailment may be responsible in part for a verb's semantic similarity to *give*. I therefore need to make sure that the semantic similarity to the typical DO anchor *give* plays a role in syntactic frame selection above and beyond the effect of the caused-possession entailment.

To this end, the binary caused-possession entailment predictor was added in a multiple logistic regression model. Verbs that always entail caused possession were

coded as 1, whereas verbs that do not always entail caused possession were coded as 0. The goal of this model was to determine whether both semantic similarity to *give* and the caused-possession entailment make an independent contribution to predicting the dative alternation or one is reducible to the other. Except for the addition of the new binary entailment variable, all other settings were kept the same as in the previous model.

The results show that the present model is better at predicting which frame, either DO or PO, is selected than the previous model (Nagelkerke's $R_L^2 = .18$, Model $\chi^2(1) = 3686.93$, $p < .001$), and that both the binary entailment and the continuous semantic predictor contribute independently to predicting the choice of syntactic frame (always entailing caused possession, $b = 1.47$, $z = 58.25$, $p < .001$ and similarity to *give*, $b = 4.81$, $z = 47.37$, $p < .001$). Model performance indicates that there is some portion of variance in the outcome variable where the effects of the two predictors do not overlap, i.e., the caused-possession entailment predictor can explain a certain portion of variance but the semantic similarity predictor cannot and vice versa. Coefficients also show that *give*-like verbs tend to occur more in the DO frame than *throw*-like verbs and most importantly that semantic similarity to *give* plays a significant role in explaining speakers' choice in the dative alternation independently of the caused-possession entailment, as my hypothesis predicted.

3.2.3.2 Pronominality of postverbal arguments

The previous two regression models investigated the role of the semantic properties of verbs in predicting the dative alternation. They contrast with most previous studies of the dative alternation in that previously 'verb-external' factors were considered as crucial determinants of syntactic choices, namely syntactic and semantic properties of postverbal arguments. For example, a recipient argument that is shorter in length, pronominal, definite, and given information tends to result in the DO frame. Bresnan et al. (2007) conducted a comprehensive analysis on a dataset of dative sentences collected from natural language corpora and showed these factors do predict the dative alternation either together or individually. In the context of the present study, it is important to know whether my predictor, namely, a verb's semantic similarity to the verb *give*, plays a role independently of these verb-external factors, in choosing between the two dative frames.

Two other logistic regressions analyses were conducted to further address this question. In one model I report in this section, the same dataset was used as in the previous models. But three verb-external factors, namely whether recipient and theme arguments are pronominal or nonpronominal and the length difference between the expressions that realize the recipient and theme arguments, were added to the list of predictors of the prior model. Thus, this model tests five predictors, (1) a verb's semantic similarity to *give*, (2) a verb's caused-possession entailment, (3) pronominality of the recipient, (4) pronominality of the theme variables, and (5) the length difference between two postverbal complements in predicting the outcome, i.e., either DO or PO. In the other model I will report in Section 3.2.3.3, I use the collection of dative sentences

Bresnan et al. (2007) used in their analyses. Their corpus collection is much smaller in size, but is annotated by hand with nearly the full set of known verb-external predictors. I will add to their predictors list my predictor of verbs' semantic similarity to *give*.

I can conveniently compare the first model with the previous models as all are consistently based on the same dataset from the British National Corpus (BNC). A shortcoming of using this BNC-based dataset is that it was difficult, due to its large size, to manually annotate it with all previously known properties of semantic arguments. The second model that used Bresnan et al.' corpus, however, will test almost all known verb-external predictors but makes use of only a small number of observations from the Switchboard and the Wall Street Journal corpus (i.e., three million words, as opposed to the 100-million-word BNC). The present model considers fewer predictors than Bresnan et al.'s but benefits from the increase in statistical reliability afforded by the large size of the corpus. Despite the small size of the corpus, the second model can consider all predictors.

For the BNC-based model, each sentence in the dataset was further annotated with the pronominality of the recipient and theme arguments and with the length difference between the expressions realizing the recipient and theme arguments, respectively. As the Charniak parser tags NPs with syntactic types, the uses of pronouns were automatically identified and annotated accordingly. I used the number of letters in theme and recipient NPs as a proxy for the lengths of the expressions realizing the recipient and theme arguments. Length difference was thus estimated by subtracting the length of the recipient NP from the length of the theme NP (i.e., positive values indicate the theme is longer than the recipient argument). Although this model does not include

the entire set of Bresnan et al.'s factors, it includes the three verb-external factors that have been considered crucial in predicting the dative alternation. Furthermore, pronominality is widely agreed to correlate with other factors such as definiteness and givenness of information. In sum, this first model includes four predictors, the two semantic predictors already present in the model discussed in the previous section and two verb-external predictors from Bresnan et al.'s list, i.e., pronominality of the recipient argument and pronominality of the theme argument. The outcome variable is as before the syntactic frame each sentence instantiates, i.e., either DO or PO.

The results of this model are as follows: (i) When the two factors of argument pronominality are added to the model, a significant improvement is found in the model fit (Nagelkerke's $R_L^2 = .61$, Model $\chi^2(3) = 16279.74$, $p < .001$), indicating that those verb-external factors make an independent contribution above and beyond that of the verb-internal factors; (ii) All five predictors are independently significant predictors of syntactic frames of the sentences, i.e., verb similarity to *give*, $b = 3.88$, $z = 27.79$, $p < .001$, entailing caused possession, $b = 0.86$, $z = 24.89$, $p < .001$, pronominal recipient, $b = 3.11$, $z = 78.07$, $p < .001$, and pronominal theme, $b = -2.55$, $z = -42.03$, $p < .001$. The results suggest that the likelihood of a sentence occurring in the DO frame increases (and the likelihood of a sentence occurring in the PO frame decreases) when the verb in the sentence is semantically similar to *give*, always entails caused possession, as well as when the recipient argument is expressed as a pronoun, while it decreases when the theme argument is expressed as a pronoun. This model shows that semantic similarity to the verb *give* as typical anchor of the DO frame survives, when verb-internal and external

factors are added, as an independent contributor to predicting the choice of frame for the dative alternation, confirming the predictions of my hypothesis.

3.2.3.3 Bresnan et al.'s (2007) predictors

I now report an analysis based on the corpus dataset that Bresnan et al. (2007) used in their analyses and is publicly available online.[14] It is manually annotated mostly with properties of postverbal arguments and with a minimum amount of information on verbs such as verb senses. This dataset is relatively noise-free, but its size is small. It consists of only 3,265 sentences or observations drawn from the Switchboard and Wall Street Journal corpora. Those sentences occur with 75 different verbs. My BNC-based dataset contains sentences that occur with the verbs Levin (1993) listed as alternating between the DO and PO frames. Bresnan et al.'s data contains 34 verbs that are in fact not on Levin's list. However, these verbs account for only about 10% of the total tokens (329 sentences), and only three out of them (*cost*, *charge*, and *do*) make up three quarters of those tokens (242 DO sentences and two PO sentences). I excluded those sentences from the present analysis so that I can more easily compare the results with that of the other models reported in this chapter. As with all other models reported in this chapter, sentences that contained the typical anchor verb (i.e., *give*) were excluded in this model as well (see Section 3.2.2.3 for discussion). Table 3.2 presents an overview of the verb distribution in Bresnan et al.'s corpus.

---

[14] The data is available at the website of the publisher of *Quantitative methods in linguistics* by Keith Johnson (2008), Blackwell. Four criteria in the annotation are omitted in this online version, i.e., *person, number, structural parallelism* and *concreteness of theme*. All available variables were used in the present analysis.

Table 3.2 'Give' and other verbs in the Bresnan et al.'s (2007) dataset

Verb	Tokens					Proportions
	DO		PO		DO + PO	DO:PO
give	1,411	63%	256	31%	1,667	85:15
other 40 verbs	704	33%	565	69%	1,269	55:45
Total	2,115	100%	821	100%	2,936	72:28

As in the BNC, the verb *give* is by far the most frequent verb among the sentences occurring in the DO frame in this dataset (cf. Table 3.1). It accounts for 63% of all DO tokens, an even higher proportion than 59% in the entire BNC. Also, its relative bias towards the DO frame is stronger in Bresnan et al.'s corpus than in mine (DO:PO = 85:15, cf. DO:PO = 65:35 in Table 3.1). In contrast to the results from the BNC, verbs other than *give* show a slight bias towards the DO construction (DO:PO = 55:45, cf. DO:PO=27:73 in Table 3.1). Those differences are most probably due to the larger proportion of spoken language data in Bresnan et al.'s corpus.

All settings were kept the same as in Bresnan et al.'s study, except that I added an additional predictor, a verb's semantic similarity to *give*. To assess the contribution of a verb's semantic similarity to *give* more precisely, I first replicated Bresnan et al.'s model with their own predictors. This model serves as a base model to which the new model that includes semantic similarity to *give* as additional predictor is compared. The coefficients and the significance levels of each predictor are summarized in Table 3.3. Note that Bresnan et al. coded the DO frame as 0 and the PO as 1, which is the opposite

of my coding in previous BNC-based models. Thus, negative coefficients indicate an increase in the use of the DO frame.

Table 3.3 A comparison of the relative magnitude of predictors (coefficients (*b*))

Predictors	Model *with* similarity to *give*	Model *without* similarity to *give* (Replication of Bresnan et al.'s)
verb similarity to *give* (LSA cosines)	-2.00 **	-
inanimate recipient	3.45 ***	3.59 ***
inanimate theme	-1.38 *	-1.20 *
nonpronominal recipient	1.08 ***	1.21 ***
nonpronominal theme	-0.72 *	-0.70 *
nongiven recipient	1.37 ***	1.38 ***
nongiven theme	-1.21 *	-1.14 ***
indefinite recipient	0.60 *	0.56 *
indefinite theme	-1.22 ***	-1.25 ***
transfer semantic class	-0.08 ns	0.05 ns
communication semantic class	-2.46 ***	-2.62 ***
future having semantic class	-1.49 **	-1.36 **
length difference (log scale)	-0.90 ***	-0.91 ***

DO = 0, PO = 1, Significance: 'ns' $p > .05$, '*' $p < .05$, '**' $p < .01$, '***' $p < .001$

The results of this model show that verb similarity to *give* (b = -2.00, $p < .01$, see the top row in Table 3.3) is a significant predictor of speakers' choice of syntactic frame even when most of Bresnan et al.'s predictors are considered. A higher degree of similarity to *give* predicts less occurrence in the PO frame and more occurrence in the DO frame, which is consistent with the results of all my previous models. Also, when this model is compared to the base model without semantic similarity to *give*, verb similarity to *give* significantly improves model fit (Model $\chi^2(1) = 9.79$, $p < .01$). These results

suggest similarity-to-*give* makes an independent contribution above and beyond known verb-external predictors. In addition, the fact that all the coefficients and significances of verb-external predictors remain essentially the same whether or not similarity to *give* is included suggests that semantic similarity to *give* is orthogonal to verb-external factors.

Note that I did not replicate two of Bresnan et al.'s results. First, the effect of the *transfer semantic class* turned out not to be significant. This difference seems to be due to the fact that the present model excludes sentences with the verb *give* as main verb. Post hoc analyses revealed that *transfer class* is a significant predictor for sentences with *give* ($b = 1.48$, $z = 5.02$, $p < .001$) while it is not for other verbs. Second, the *future having class* has a negative coefficient, as opposed to Bresnan et al.'s original model, indicating an increase in the likelihood of choosing the DO frame. This result is in fact counter to what I observed in the BNC. The future having class will be discussed in detail in the next section.

3.2.4 Testing the hypothesis within narrower-range semantic classes

So far we have tested the role of the verb *give* as typical DO anchor on the entire set of verbs listed in Levin (1993) as alternating between the DO and PO frames. In other words, *give* was treated as the most typical verb among verbs that loosely share the semantic notion of 'transfer' when used in the DO and PO frames. However, previous research suggests that when trying to predict which verb can or cannot alternate between two frames, the "right" level of semantic abstraction is smaller and thus semantically more coherent than the entire class of alternating verbs. Pinker (1989), in

particular, argued that the possibility for a verb to participate in the dative alternation is conditioned by whether the meaning of that verb instantiates a meaning common to a narrow-range class of verbs or *narrow class* in short. Pinker argued that it is within the narrow classes that the dative alternation can be productively used and it is the nature of the narrow classes that children must acquire to properly use the dative alternation. Similarly, Goldberg (1995) argued that the DO frame can be associated with slightly different meanings depending on verbs the frame occurs with. Pinker's and Goldberg's proposals suggest that narrower and more semantically coherent subclasses of verbs are involved in the representation of the dative alternation.

If Pinker and Goldberg are correct, the verb *give* may not be the sole typical anchor of the DO frame to which all the verbs in the broad class should be compared. Rather, it may be that there are typical anchors within each narrow class and each typical anchor within a narrow class exerts an effect similar to the the effect of *give* for the entire broad class of verbs. More specifically, verbs within each narrow class share more specific semantic properties than a rather loose or broad notion of 'transfer'. For example, verbs such as *tell*, *teach*, *write*, and other verbs in the *message transfer* class all describe a type of event in which an abstract message is metaphorically transferred. Verbs such as *offer*, *promise*, *bequeath*, and other verbs in the *future having* class share the semantic property that the transfer is expected to occur in the future. Just as *give* plays the role of typical DO anchor for the entire broad class of alternating verbs, there may be a highly frequent verb within each narrow class that is strongly associated with the DO frame. This possibility is particularly likely if the DO frame is associated with a slightly different meaning across narrow classes, as Goldberg argues. To draw an analogy from

natural categories, there can be one typical exemplar of the 'bird' category and another for the subordinate 'eagle' category. In this context, I hypothesize that, as was the case for *give* and the entire class of alternating verbs, the degree of semantic similarity to the typical anchor within a narrow class affects which frame the other narrow class members tend to occur in. The goal of this section is to examine whether the Typical Verb Anchor hypothesis holds for narrow classes as it does for the entire class of alternating verbs. Three of the narrow classes that participate in the dative alternation, the *give* class, the *message transfer* class, and the *future having* class, were analyzed as test cases.

The first step is to study the frequency distribution of verbs within each narrow class and see whether there exists any highly frequent anchor verb that exhibits characteristics similar to those of the verb *give*. The frequency distributions of verbs within each narrow class are illustrated in Figure 3.2.

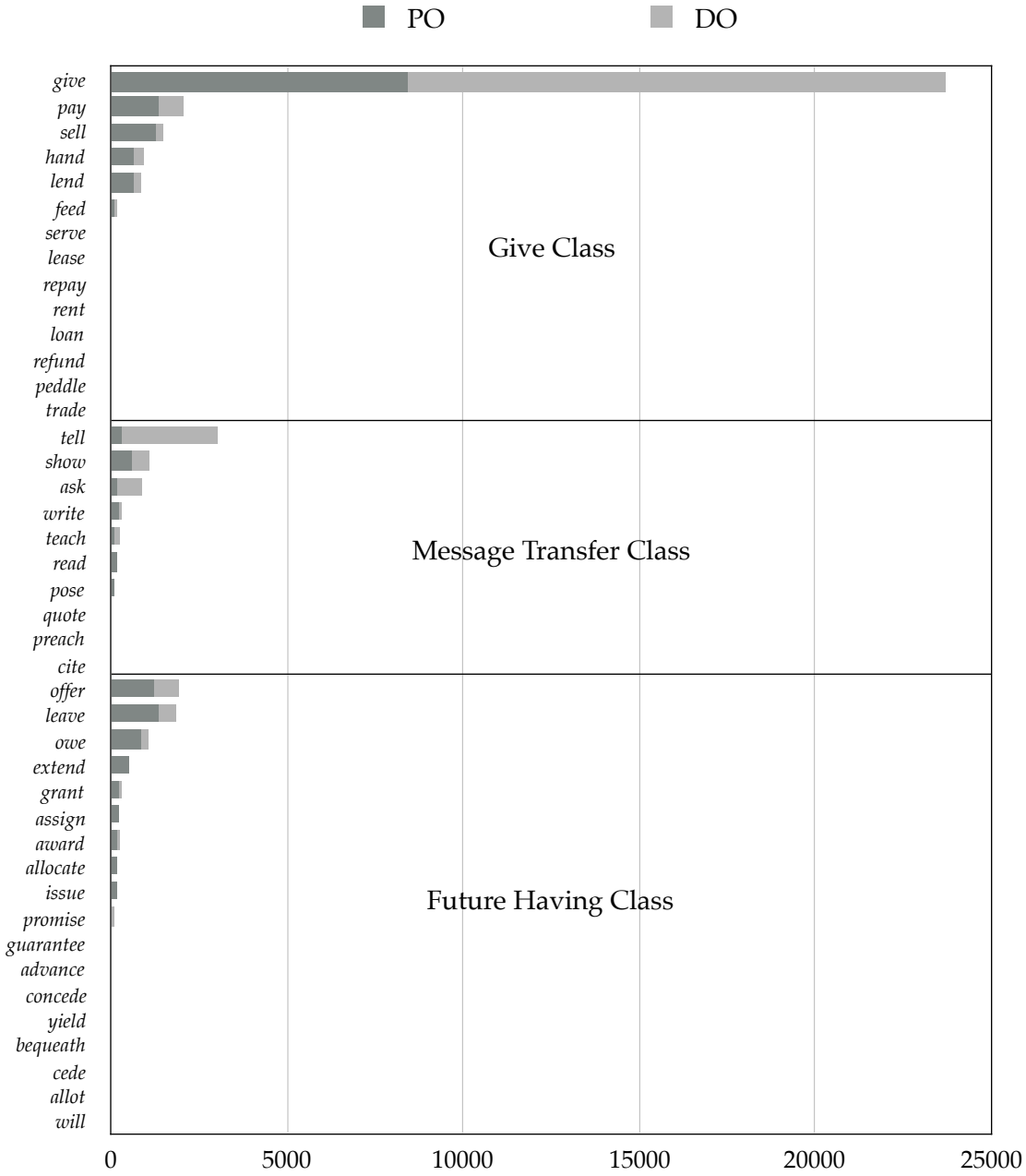


Figure 3.2 Verb frequencies in three narrow verb classes[15]

Within the *give* class, as one can expect, *give* has by far the highest strength of association with the DO frame. For this narrow class, we can test whether semantic

[15] All the verbs listed on the Y-axis have occurred in either the DO or PO frame in my corpus (i.e., frequency > 0). The bars of infrequent verbs do not appear in the graph due to the scale of the X-axis (i.e., for *give*).

similarity to *give* predicts the dative alternation only for a smaller range of verbs than in the previous regression models. In the *message transfer* class, the verb *tell* occurs far more frequently with the DO frame than any other verb and is also strongly biased towards the DO frame as well. *Tell* exhibits frequency patterns that are very similar to those that *give* exhibits. No verb in the *future having* class seems particularly strongly associated with the DO or PO frame. All verbs in this class actually favors the PO frame. Relatively frequent verbs such as *leave* and *offer* in particular occur more frequently in the PO frame than in the DO frame. Based on the typicality equation introduced in Section 3.2.1.3, the verb *leave* was tentatively chosen as a typical anchor for the PO frame for verbs within this narrow class (see Appendix B1 for the full list of typicality estimates). It means that the more similar a verb is to *leave*, the more likely it is to occur in the PO frame, opposite to the effects of other DO anchors.[16]

Note that the frequency patterns of the future having class in the BNC are inconsistent with what Bresnan et al. (2007) observed in the Switchboard and the Wall Street Journal corpus. As noted in Section 3.2.3, the predictor *future having semantic class* in Bresnan et al.'s model was shown to increase the DO uses. In their dataset, the sentence tokens of this class (annotated with '*f*') consist of 47 DO sentences and 12 PO sentences, i.e., 80% and 20%, respectively. However, sentences whose main verbs are future having verbs in my dataset consist of 1,717 DO sentences and 5,317 PO sentences, i.e., 24% and 76%, respectively. I suspect the difference is related to the syntactic forms of

[16] Apart from the main research question of this section, it is interesting to speculate on why verbs in the future having class favor the PO frame. These verbs have been argued to entail caused possession in both DO and PO frames just like verbs of giving as well as verbs of transfer of a message (Rappaport & Levin, 2008). One tentative answer is that the 'goal' meaning associated with the preposition *to* may better match the future component in the meaning of these verbs, namely the fact that the transfer is temporally remote.

the postverbal semantic arguments. The dative alternation is known to be modulated by pronominality of recipient and theme arguments as well as length difference between them (see Section 2.5.3 in Chapter 2 for discussion). For example, pronominal and/or shorter forms of a recipient tend to give rise to the choice of the DO frame. I found in post hoc analyses of both datasets that 64% of the future having sentences in Bresnan et al.'s occurred with a pronominal recipient, 82% of which occurred in the DO frame; however, only 22% of the future having tokens in my data occurred with a pronominal recipient, 69% of which occurred in the DO frame. This difference in recipient argument properties seems to be due to different properties of the corpora. I found most of the future having sentences in Bresnan et al.'s data came from the spoken Switchboard corpus (i.e., 47 sentences, about 80%), as opposed to sentences from the BNC which is known to consist of about 90% written and 10% spoken data. Generally, speakers use pronouns highly frequently in spoken language. In the following analyses based on the BNC, pronominality of recipient and theme arguments are consistently included as predictors to control for any difference due to these properties and not my main predictor, i.e., semantic similarity to narrow-class typical anchors.

Having selected narrow-range typical anchor verbs, I conducted on each narrow class the same kind of logistic regression analyses as before. Sentences whose verbs belonged to each of the three narrow classes were sorted out and put in three different datasets. I then ran a regression analysis on each narrow dataset. Semantic similarity between narrow class members and their respective within-class typical anchor verbs was measured using Latent Semantic Analysis as before, i.e., *give* vs. give verbs, *tell* vs. message transfer verbs, and *leave* vs. future having verbs. This measure of semantic

similarity was added as predictor to the formerly existing predictors list such as semantic similarity to the broad anchor *give* and pronominality of recipient and theme arguments. However, the entailment of caused possession was not included as predictor since all verbs in these narrow classes entail caused possession in both frames (Rappaport & Levin, 2008).

Given that we know that semantic similarity to *give*, pronominality of recipient and theme, and length difference between the expressions realizing recipient and theme NPs help predict the choice of syntactic frame for verbs I consider here, what matters most is whether semantic similarity to the narrow-class typical anchors contributes to predicting the dative alternation independently of the contribution of those other predictors. Except for the *give* class where *give* is tested also as the within-class typical anchor, I ran two logistic regression analyses, one with the four predictor variables tested in prior models and the other with the additional predictor of semantic similarity to the narrow-class typical anchor. Comparing these pairs of models is supposed to reveal whether semantic similarity to the narrow-class typical anchors improves the explanatory power of the model on top of the effects of semantic similarity to *give*.

3.2.4.1 Verbs of giving

The data for verbs of giving consists of 5,731 sentences with 13 distinct verbs, *pay*, *sell*, *hand*, *lend*, *feed*, *serve*, *lease*, *repay*, *loan*, *rent*, *refund*, *peddle*, and *trade*. As before, sentences with the typical DO anchor *give* were excluded from the analysis. For this class, I can simply test whether previous findings can be replicated within this smaller

set of verbs as the narrow-range anchor is the same as that of the entire set of alternating verbs, i.e., *give*. In this model, all four predictors make independent contributions to predicting the choice of syntactic frames, verb similarity to *give* (b = 1.53, z = 4.67, p < .001), pronominal recipient (b = 2.58, z = 27.02, p < .001), pronominal theme (b = -2.53, z = -16.39, p < .001), and length difference (b = 0.02, z = 13.81, p < .001).[17] The results of the previous analyses based on the entire class was replicated in this narrow-range class, suggesting that *give* serves as the typical anchor for verbs of giving.

3.2.4.2 Verbs of transferring a message

The data for verbs of transfer of a message includes 2,960 sentences with 9 non-*tell* verbs, *show*, *ask*, *write*, *teach*, *read*, *pose*, *quote*, *preach*, and *cite*. Two models were run on this class, one with and the other without semantic similarity between *tell* and other class members as predictor variable. When both similarity to *give* and similarity to *tell* were entered in the analysis, the similarity to *tell* turns out not to be a significant predictor (b = 1.33, z = 1.35, p = .18) while similarity to *give* stays significant (b = 6.51, z = 4.70, p < .001). Moreover, adding the predictor of similarity to *tell* to the model does not improve model performance compared to the model without this predictor (Nagelkerke's R_L^2 = .72, Model $\chi^2(1)$ = 1.82, p = .18). This suggests that what we defined as the narrow-range typical anchor for message transfer verbs, namely *tell*, does not make a unique contribution to predicting the choice of syntactic frame for message transfer verbs.

[17] The structural predictors, *pronominality of recipient* and *pronominality of theme*, are included in all regression models in this section, and they always turned out to be significant predictors. The numbers for these predictors will not be reported in the following models as they are not crucial for current purposes.

To further investigate the reasons for this outcome, I ran another model that included similarity to *tell* rather than similarity to *give* as the sole semantic similarity predictor. In this case, similarity to *tell* was a significant predictor of choice of syntactic frame ($b = 5.64$, $z = 14.39$, $p < .001$). The divergence of the results between this model and the model that includes both semantic similarity to *give* and semantic similarity to *tell* seems to be due to the fact that there is a very strong correlation between the two similarity predictors (Pearson's $r = .97$, $p < .001$). In other words, the more similar a message transfer verb is to *give*, the more similar it is to *tell*. Furthermore, *give* and *tell* share a lot in common in their frequency profiles. Both occur far more frequently than other class members and both are highly associated with the DO frame. In a nutshell, semantic similarity to *give* and *tell* plays a similar predictive role, but semantic similarity to *give* is a better predictor when both similarities compete, as shown by the relative magnitude of the coefficients for *give* ($b = 8.23$, $z = 14.78$, $p < .001$) and *tell* ($b = 5.64$, $z = 14.39$, $p < .001$) in the models where they are considered as sole semantic similarity predictor.

Lastly, I examined whether there was an interaction between the effects of the semantic similarity to *tell* and the semantic similarity to *give* by including the interaction term between the two similarities in the model. Results revealed that the interaction between similarity to *give* and similarity to *tell* is a significant predictor of frame

selection ($b = 17.95$, $z = 5.87$, $p < .001$) while the main effect of similarity to *give* remains a significant predictor ($b = 9.14$, $z = 6.01$, $p < .001$).[18]

In conclusion, my hypothesis of the narrow-class typical anchor was partially borne out. In this narrow class, it is inherently difficult to tease apart the role of the narrow-range typical anchor from that of the broad one due to the extremely high correlation between them. The verb *tell* exerts the same role for message transfer verbs as the verb *give*. But the present results do not exclude the possibility that *tell* may serve as the typical anchor of the DO frame for verbs in this narrow class, at least if we allow narrow-class typical anchors to affect syntactic frame selection jointly with the frame's broad-class anchor.

3.2.4.3 Verbs of future having

Lastly, the data for verbs of future having consists of 5,149 sentences with 17 different verbs, excluding sentences with the verb *leave*, i.e., *offer*, *owe*, *extend*, *grant*, *assign*, *award*, *allocate*, *issue*, *promise*, *guarantee*, *advance*, *concede*, *yield*, *bequeath*, *cede*, *allot*, and *will*. I tested both similarity to *give* and similarity to *leave* as predictor variables. Note that the verb *leave* was hypothesized to be a typical anchor of the PO frame within this narrow semantic class, as opposed to *give*. The model showed that both variables are significant predictors of the dative alternation, but they exert their effects in opposite

[18] Due to the high correlation between the two similarity predictors, multicollinearity can be a concern in this model. A high VIF (variance inflation factor) makes determining the importance of a given predictor difficult. The rule of thumb is that any *VIF > 10* is problematic. For similarity to *tell* VIF was 22.99. The VIFs of similarity to *give* and the interaction term between the two similarity predictors were 9.19 and 9.85, respectively, values close enough to 10 to have concerns about the reliability of the effects of these two predictors as well.

directions, as predicted. The positive coefficient of semantic similarity to *give* (b = 4.83, z = 11.21, $p < .001$) indicates that a higher degree of semantic similarity to *give* increases the likelihood of a verb occurring in the DO frame while the negative coefficient of semantic similarity to *leave* (b = -3.99, z = -7.38, $p < .001$) indicates that a higher degree of semantic similarity to *leave* increases the likelihood of a verb occurring in the PO frame. The results are consistent with my predictions as the verb *leave* is associated more strongly with the PO frame than with the DO frame unlike other typical anchors discussed so far. The addition of similarity to *leave* to similarity to *give* as predictor improves the model's performance (Nagelkerke's R_L^2 = .67, Model $\chi^2(1) = 56.89$, $p < .001$). That is, this model explains more of the variance in the outcome variable than the simpler model. Lastly, I tested whether there was an interaction between similarity to *give* and similarity to *leave*. In addition to the usual three structural predictors, all three similarity terms were significant predictors of syntactic frame selection, similarity to *give* (b = 5.49, z = 10.82, $p < .001$), similarity to *leave* (b = -5.22, z = -7.13, $p < .001$), and the interaction between similarity to *give* and similarity to *leave* (b = 8.61, z = 2.55, $p < .05$).[19] The results support my hypothesis on the effect of similarity to narrow-range typical anchors on syntactic frame selection and confirm the role of frequent verbs as typical anchors of a syntactic frame.

[19] In this model, multicollinearity was not a concern (i.e., similarity to *give*, VIF = 1.49, similarity to *leave*, VIF = 1.88, and the interaction of the two, VIF = 2.08). Although these two similarities were correlated quite a bit (Pearson's r = .70, $p < .01$) , they were much less so than similarity to *give* and similarity to *tell* (cf. Pearson's r = .97, $p < .001$).

3.2.5 Summary of the results

In Section 3.2, I have investigated the role of a frequent verb as typical anchor of a syntactic frame by conducting statistical analyses on a collection of naturally occurring dative sentences. I hypothesized in the beginning of this chapter that any verb that occurs highly frequently in a particular syntactic frame is strongly associated with the frame and plays a role as typical anchor when speakers construct a sentence with a verb whose meaning is similar to the typical anchor, i.e., the Typical Verb Anchor hypothesis. This section tested the role of the predominantly frequent verb *give* as a typical anchor of the DO frame. Section 3.2.1 reported an extensive study of the dative alternation in the British National Corpus, which conforms to the previous observation that *give* accounts for the 'lion's share' of the DO occurrences in natural language use. Section 3.2.2 showed that high degrees of semantic similarity to the verb *give* tend to increase the likelihood of other alternating verbs occurring in the DO frame. In addition, Section 3.2.3 showed the effect of the typical anchor verb cannot be reduced to the effects of other factors known to affect the choice of syntactic frame in the dative alternation, but makes a unique contribution to predicting the choice of syntactic frame. Finally, Section 3.2.4 investigated whether the same hypothesis can be borne out within a much narrower domain of verb classes than in the previous models, i.e., whether a typical anchor verb within each narrow-range semantic class has the same effect on verbs of the same narrow class as that of *give* on the entire class of alternating verbs. The results were mixed. *Give* in the *give* class and *leave* in the future having class both behaved as typical anchor verbs. But it was only partially replicated in the message transfer class as the highly frequent verb *tell* played a significant role, but it did not play a role beyond the

role of *give*. Overall, the results in this section support the role of the highly frequent verb *give* as typical anchor of the DO frame and confirms my hypothesis.

3.3 Study II: Verbs that participate in the Locative Alternation

In this section, I present a corpus study of the locative alternation in the British National Corpus and report a series of logistic regression models that investigate the Typical Verb Anchor hypothesis. In Section 3.3.1, I study the frequency distribution of verbs occurring in the alternate frames of the locative alternation and examine whether there are any verbs that instantiate either frame particularly frequently (i.e., candidates for a typical anchor of either frame). In Section 3.3.2, I report the results of statistical modeling that tests whether verbs' occurrences in alternate frames are modulated by semantic similarity to *rub* or to *stick* as typical anchor of the Figure Object frame, or by semantic similarity to *shower* as typical anchor of the Ground Object frame, more specifically whether semantic similarity to these putative anchors predicts the syntactic frames of other verbs that participate in the locative alternation (e.g., the more semantically similar to *rub* or to *stick* an alternating verb is, the more likely it is to occur in the Figure Object frame). In Section 3.3.3, I further test the effect of these anchors including as additional predictors semantic properties of the locative alternation, i.e., the contrast between container- and content-oriented verbs and pronominality of figure and ground objects. Section 3.3.4 summarizes the results.

3.3.1 A corpus study in the locative alternation

3.3.1.1 Data collection

As introduced in Section 2.3.2, the term 'locative alternation' refers to the possibility that more or less the same message can be formulated using either frame illustrated in (3.8). These frames involve two postverbal semantic arguments but in an alternate order as was the case in the dative alternation. At a highly abstract level, the syntactic categories of the postverbal arguments do not vary across the two frames, i.e., V NP PP. However, the semantic roles of the PP argument phrases in each frame are distinct and reflected in the choice of prepositions. In one syntactic variant named as the Ground Object (GO) frame in (3.8a), the postverbal PP is invariably headed by the preposition *with*. In the other variant, the Figure Object (FO) frame, the PP can be headed by a variety of prepositions as long as they can designate a location or locational configuration. *In(to)* and *on(to)* are among the most common prepositions in this position.

(3.8) a. John loaded the truck with hay. [VP V [NP GROUND] [*with*-PP FIGURE]]

b. John loaded hay onto the truck. [VP V [NP FIGURE] [*(in/on)to*-PP GROUND]]

I collected sentences from the British National Corpus that occurred with verbs that participate in the locative alternation. As opposed to the dative alternation, the locative frames cannot be defined purely by the phrasal categories involved or by particular prepositions. A slightly different approach was taken, from that taken in the

previous study of the dative frames. First, I selected verbs from Levin's (1993, p. 50) and Pinker's (1989, pp. 126-127) list of verbs participating in the locative alternation. My selection of verbs was not exhaustive but contained 45 verbs that were reported to occur relatively frequently and sound natural in both alternate frames in an informal survey with native speakers of English.[20] Most of these locative verbs were also used in the sentence stimuli in Experiments 2 and 4 in Chapter 2.

This study also used a version of the British National Corpus annotated via the Charniak parser. Using Tgrep2, I retrieved VPs with the [V NP PP] structure with the 45 verbs chosen for present analyses. The search result included all kinds of PPs, many of which are irrelevant to the locative alternation, as I did not specify in the query particular prepositions. Then I manually searched through the data and discarded sentences that instantiated syntactic frames other than the locative frames. The initial data consisted of about six thousand sentences, but only about 20% of the original data remained after screening. I then annotated the sentences with the types of frames, either the GO or FO frame.

3.3.1.2 An overview of frequency distributions

Overall the FO frame occurs more frequently than the GO frame with the verbs chosen for analysis. In other words, those verbs tend to be biased towards the FO frame. Although the syntactic bias is similar to what was found in the dative alternation, the

[20] This survey was conducted in-person with graduate students in the Department of Linguistics and with undergraduate research assistants in the Psycholinguistics Laboratory in the Department of Psychology at the University at Buffalo. All interviewees were native speakers of English.

frequency distribution by verb and by frame exhibits quite a different pattern than that of the dative alternation. The results are provided in Table 3.4.

Table 3.4 Overview of the frequency distribution of verbs in the locative alternation in the British National Corpus

Verb	Tokens				Proportions	$w_{verb\text{GO}}$
	GO		FO		GO:FO	GO-FO
rub	92	19%	231	17%	28:72	-139
shower	34	7%	12	1%	74:26	22
other 43 verbs	367	74%	1,138	82%	24:76	–
Total	493	100%	1,381	100%	26:74	–

In the locative alternation, none of the verbs seems to occur predominantly frequently in either frame. The verb *rub* was found to be the most frequently occurring verb in the sample and highly biased towards the FO frame, which is, as mentioned before, the favored frame for most of the other verbs as well. Despite the bias, *rub* accounts for similar portions of the total occurrences in each frame (i.e., 19% of GO vs. 17% of FO).

Rub contrasts with *give* in the dative alternation in many respects (cf. Section 3.2.1.2). *Give* was overall noticeably more frequent than other dative verbs as it accounts for more than one third of the DO plus PO sentences total (37%). *Give* was, in particular a highly prominent DO verb as it accounts for more than a half of all DO tokens in my

data (59%). *Give* shows a strong bias towards one of the frames, the DO frame that most of other dative verbs disfavor. Therefore, even without the help from mathematical estimation of typicality ($w_{give\text{DO}}$ = 6,909, see Section 3.2.1.3 for details), one can intuitively capture the fact that *give* represents the DO frame to the greatest extent.

Rub is hardly such a typical verb in the locative alternation. Based on my measure of typicality estimation, *rub* in fact seems to be a more typical verb of the preferred FO frame rather than of the dispreferred GO construction ($w_{rub\text{GO}}$ = -139).[21] It is questionable, however, whether *rub* serves as the most typical FO anchor among the locative verbs considered here. Its strength of association with the FO frame is not particularly high compared to other verbs. For example, the verb *stick* ($w_{stick\text{GO}}$ = -153) shows an even higher degree of association with the FO frame than *rub*.[22] Another verb *spread* ($w_{spread\text{GO}}$ = -119) is also quite close to *rub*. In other words, verbs differ in the degrees of association strength with the FO frame in a very gradient manner and it is thus relatively difficult to conclude that any one of them is a cognitively prominent anchor. The full list of typicality estimates for locative verbs are appended in Appendix B.2.

It is also necessary to consider verbs with the opposite biases. As shown above, the GO frame is on average less preferred than the FO frame in the locative alternation. And much fewer verbs show relatively stronger association with the GO frame than

---

[21] In the present study, typicality estimates of the locative verbs are computed by subtracting the number of occurrences in the FO frame from that of the GO frame (see Section 3.2.1.3 for details). Thus, a positive value of $w_{verb\text{GO}}$ indicates that a verb is relatively more associated with the GO than with the FO frame and a negative value means the opposite.

[22] None of the GO sentences in our corpus occurred with the verb *stick*. An informal survey showed native speakers could accept this verb only in carefully formulated GO sentences. In most cases, this verb does not easily alternate between the GO and FO frames.

with the FO frame. In the present locative dataset, the verb with the highest typicality estimate in favor of the GO frame was *shower* ($w_{shower\text{GO}} = 22$). Although its association strength is relatively weak, far less strong than that of *give*, it is worth testing whether it can lead to similar effects as *give* as a typical anchor of a frame.

In the following section, multiple candidates of typical anchors will be tested for the GO and FO frames in the same way as was done for the dative alternation in Section 3.2. I may replicate the patterns shown by *give* in the dative alternation or fail to do so due to the relatively low strength of association as well as competition among verbs that show similar frequency and syntactic biases. The former case would further support my hypothesis on the role of frequent verbs in syntactic frame selection; the latter case would suggest such an effect may not be universal across syntactic frames.

3.3.2 Modeling the effect of verb semantic similarity to GO and FO anchors

3.3.2.1 'Rub' and 'stick' as candidates for typical FO anchor status

As discussed in the previous section, *rub* is the most frequently occurring verb among the locative verbs considered in the present study and is biased towards the FO frame. The verb *stick*, the third most frequent verb, however, shows a slightly stronger bias towards the FO frame than *rub* (i.e., $w_{rub\text{GO}} = -139$ vs. $w_{stick\text{GO}} = -153$). In this section, both verbs are tested separately as typical FO anchor candidate.

For the model where *rub* was chosen as the typical anchor, I measured semantic similarity between *rub* and each of the other 44 verbs and coded each sentence token with the LSA scores as well as its frame, it.e., GO as 1 and FO as 0. As before, sentences

that occurred with the verb *rub* itself were excluded from analysis (see Section 3.2.2.3 for discussion). The dataset included 1,554 sentences in total, i.e., 402 tokens in the GO and 1,152 in the FO frame. A logistic regression model was fitted to the data. The dependent variable was the frames used in a sentence token; the independent variable was semantic similarity between the main verb of each sentence token and the verb *rub* approximated by LSA cosines. The independent variable was not a statistically significant predictor of the outcome ($b = 0.32$, $z = 1.02$, $p = .31$). So my hypothesis that the verb *rub* may constitute a typical anchor of the FO frame was not borne out.

In another model, the verb *stick* was tested as typical anchor of the FO frame in the same way. The independent variable, namely semantic similarity between *stick* and verbs used in each sentence token, was measured by LSA. The dependent variable was the frames used in each token as before. Excluding sentence tokens that have *stick* as main verb, the final dataset included 1,722 sentence observations, i.e., 494 in the GO and 1,228 in the FO frame. Semantic similarity to *stick* was again not a statistically significant predictor of the frames ($b = 0.48$, $z = 1.35$, $p = .18$).

Both models revealed that the verbs *rub* and *stick*, when chosen as typical anchors of the FO frame, turn out not to have the same effect as *give* on the choice of syntactic frame in the dative alternation. The results are consistent with the fact that the frequency biases are not very strong, far less so than the putative typical anchor verb for dative verbs. Small frequency gaps between verbs may not be enough to lead to typicality effects.

3.3.2.2 *'Shower' as a candidate typical GO anchor*

In this section, I test whether the verb *shower* is a typical anchor candidate for the GO frame. As pointed out in Section 3.3.1.2, while most locative verbs are biased towards the FO frame to different degrees, *shower* shows a frequency bias towards the GO frame. Given what we know of the verb *give* as the typical DO anchor in the dative alternation, it may be that a verb that represents the less preferred frame relatively more strongly than others can function as a typical exemplar of the frame. It is obvious however that due to its low absolute frequency, *shower* cannot represent the GO construction as much as *give* represents the DO construction.

The dataset included 1,830 sentence tokens, i.e., 460 GO tokens and 1,830 FO tokens, excluding the sentences that occurred with the verb *shower* as main verb. The verbs' semantic similarity to *shower* was set as the independent variable and the frames, either GO or FO, was the dependent variable in the same way as in the previous models. Similarity to *shower* was not a significant predictor of the choice of syntactic frame (b = -0.18, z = -0.45, p = .65). The results suggest that we may not expect the role of a frequent verb as typical anchor when there is a medium-to-low degree of skewedness in the frequency distribution.

3.3.3 Considering other semantic and syntactic factors

Although Section 3.3.2 showed the Typical Verb Anchor hypothesis was not borne out for the locative alternation, other semantic and structural factors may also influence the choice of syntactic frame in the locative alternation as the caused-

possession entailment and pronominality of postverbal arguments did in predicting the choice of syntactic frame in the dative alternation. The following two subsections deal with semantic features of locative verbs, in particular, the contrast between content- and container-oriented verbs and pronominality of the theme and goal arguments, respectively.

3.3.3.1 Content- vs. container-oriented verbs

It seems more difficult to circumscribe the semantic space of verbs that participate in the locative alternation than that of verbs that participate in the dative alternation. Verbs that participate in the dative alternation can be characterized by a single semantic feature such as 'transfer of possession.' Verbs of the locative alternation cannot be so clearly defined. But, as is the case for dative verbs, locative verbs can also be divided into narrow-range semantic classes depending on how force is imposed on the figure, how it moves, in what shape it appears in the ground in the end, and so on (Pinker, 1989). The criteria are for the most part highly detailed descriptions of the event types the verbs denote.

One of the semantic and syntactic properties that divides locative verbs into two subclasses is the distinction between content- and container-oriented verbs. Locative verbs require two semantic arguments in addition to an agent, namely one that denotes an object or substance and the other that denotes a container or surface. The former is often referred to as theme, content, or locatum and the latter is as goal, container, or location. Pinker suggested that some locative verbs, i.e., content-oriented verbs, put

more emphasis on the figure object than on the ground object and thus the theme is syntactically obligatory, while others, i.e., container-oriented verbs, take the location object as syntactic dependent obligatorily (Pinker, 1989, pp. 124-129). This contrast is illustrated by (3.9) and (3.10). Content-oriented verbs include, for example, *smear*, *brush*, *dab*, *plaster*, *rub*, *slather*, *smudge*, *spread*, *pile*, *stack*, *splash*, *sprinkle*, *spray*, *sow*, and *drizzle*; container-oriented verbs include *pack*, *cram*, *jam*, *stuff*, *load*, *pack*, and *stock*.

(3.9) a. He piled the books. (Content-oriented)

b. *He piled the shelf.

(3.10) a. *He stuffed the breadcrumbs. (Container-oriented)

b. He stuffed the turkey.

Based on this distinction, Pinker proposed that the base form of content-oriented verbs are the FO frame or the *into*/*onto* variant in his terms while that of container-oriented verbs are the GO frame or the *with* variant. If so, we can infer that the meaning of content-oriented and container-oriented verbs fits better with the FO frame and with the GO frame, respectively. In this context, I expect that content-oriented verbs prefer to occur in the FO frame, whereas container-oriented verbs prefer to occur in the GO frame. In other words, the differences in verbs' semantic orientation may predict their preferences for either frame in the locative alternation.

To prepare for a logistic regression analysis, sentence tokens were coded with this binary semantic distinction. In Pinker's work, 22 verbs are categorized as content-oriented verb and 7 verbs as container-oriented verb. Sentences occurring with the verbs

that are not explicitly categorized as to this distinction were excluded for present analysis. If the main verb of a sentence was a content-oriented verb, the sentence token was tagged with 0. If it was a container-oriented verb, it was tagged with 1. This distinction served as the independent or predictor variable and the syntactic frame used in each token was as before the dependent or outcome variable. I found this semantic distinction among verbs was a significant predictor of the choice of syntactic frame (b = 0.41, $z = 3.19$, $p < .01$), confirming our prediction. It suggests that the choice of syntactic frame can be modulated by verbs' semantic properties in the locative alternation, as was the case for the dative alternation. It also suggest that, despite the failure to replicate the effect of typical verb anchors in the locative alternation, the choice of syntactic frame is to some degree also affected by verb meanings in the locative alternation as well.

3.3.3.2 Pronominality of postverbal semantic arguments

As introduced above in Section 3.2.3.2, previous research has shown that whether a postverbal argument is pronominal or not modulates the choice of syntactic frame in the dative alternation. More specifically, pronominal recipient arguments favor the choice of the DO frame while pronominal theme arguments favor the choice of the PO frame. This tendency was also confirmed by the regression analyses on the BNC data (see also Section 2.5.3 for discussion).

Note that this relationship is in line with the tendency for a pronominal argument to occur earlier as well as with the tendency for a definite argument and given information to appear earlier. Furthermore, it coincides with the observation that shorter

elements tend to occur earlier in English, as pronouns are usually shorter in length than full noun phrases.[23] Importantly, these factors are at play not just in the dative alternation but across many other syntactic structures in English (Wasow, 2002). Thus we may expect a similar effect of pronominality in the locative alternation which involves two postverbal arguments as in the dative alternation. If that is the case, we would find that a pronominal ground or location argument facilitates the GO frame while a pronominal figure or theme argument facilitates the FO frame. To my knowledge there is no study that has addressed this question using natural language data in the literature. This section tests this prediction.

The syntactic category of postverbal arguments was labeled as either *pronoun* or *full-NP*. Pronouns included standard pronouns and reflexive pronouns. Two variables, whether the location object was pronominal and whether the theme object was pronominal, were tested jointly as predictors in a single model. Results revealed that the location object as a pronoun is a significant predictor of syntactic frame (b = 1.54, z = 10.34, $p < .001$), but the theme object expressed as a pronoun is not (b = -17.66, z = -0.04, p = .97). As the positive coefficient indicates, a pronominal location object facilitates the choice of the GO frame, confirming my prediction.[24]

[23] This phenomenon is often referred to as the *short-before-long* tendency or as the *principle of end weight* in the sense that "phrases are presented in order of increasing weight" (Wasow, 2002, p. 3). This phenomenon contrasts with the observation made for other languages such as Korean and Japanese where longer or heavier phrases tend to occur earlier, namely the *long-before-short* tendency. Researchers have speculated that this difference is related to the word order difference between languages, e.g., SVO vs. SOV.

[24] One concern is that the null effect of the pronominal themes may be due to modeling errors. Unreasonably boosted coefficients can be a sign of such an error. If that is the case, we need to conclude that the effect of pronominal themes is untestable for now.

Table 3.5 Frequencies of locative verbs with pronominal vs. non-pronominal ground and figure objects

Ground (Location)	**Figure (Theme)**	**GO**	**FO**	**Total**
pronominal	pronominal	0	17	17
	nonpronominal	138	88	226
nonpronominal	pronominal	0	211	211
	nonpronominal	356	1066	1,422

Table 3.5 summarizes the number of tokens in either syntactic frame in the two postverbal argument positions. Overall nonpronominal arguments and the FO frame are far more common than pronominal ones and the GO frame, respectively. However, when the ground object is a pronoun, the GO construction is more frequent than the FO frame. Note that none of the GO tokens occurred with a pronominal theme, meaning pronominal themes occurred only with the FO frame. However, it does not seem that pronominal themes make the FO frame more likely, given the high frequency of the FO frame when the theme is not a pronoun.

The following model tests whether both the semantic and structural factors work together to increase model fit, namely the predictability of the model, or instead one effect predominates over the other. Thus, in this model the independent variables were the semantic class of the verbs, either content-oriented (=1) or container-oriented (=0), and the pronominality of the ground object, either pronominal (=1) or nonpronominal (=0). As before, verbs that were not categorized as content- or container-oriented were excluded from analysis. All other settings were kept constant. Results showed that when

both factors are considered simultaneously, the pronominality of the location objects turns out to be a significant predictor of the locative alternation ($b = 1.56$, $z = 9.82$, $p < .001$) while the semantic distinction does not make a statistically significant contribution ($b = 0.19$, $z = 0.14$, $p = .16$).

Table 3.6 Mean frequencies of locative verbs by pronominality x verb type x frame

Ground (Location)	**Verb type**	**GO**	**FO**	**Total**
pronominal	content-oriented	2.5	2.7	5.1
	container-oriented	8.6	4.3	12.9
non-pronominal	content-oriented	10.2	39.4	49.6
	container-oriented	9.3	35.3	44.6

Note: The raw frequency of sentences was divided by the number of verbs (i.e., by 22 for content-oriented and by 7 for container-oriented).

Post-hoc review of the frequency distributions is presented in Table 3.6. Each cell shows the average number of occurrences for a single verb. In other words, I divided the raw number of occurrences in each cell by the number of verbs to eliminate the effect of the bias in the number of verbs between content- and container-oriented verbs, i.e., 22 content-oriented verbs and 7 container-oriented verbs. Table 3.6 reveals that when the ground object is *not* a pronoun, the content-/container-oriented distinction makes almost no difference as to the frequency patterns of the GO and FO frames. However, when the ground object is a pronoun, it is clear that the container-oriented verbs occur frequently relative to content-oriented verbs and also that the use of the GO frame is boosted more than the FO frame. A follow-up regression model confirmed the

interaction between the semantic distinction and the pronominal ground object as a significant predictor of the locative frames ($b = 0.76$, $z = 2.30$, $p < .05$). This suggests the semantic distinction may play a role to some degree when "structural" effects are controlled for.

3.3.4 Summary of the results

Section 3.4 tested on the locative alternation the Typical Verb Anchor hypothesis that a highly frequent verb can serve as a typical anchor of a syntactic frame and that as a result, how semantically similar a verb is to the typical anchor can modulate the choice of syntactic frame. Present analyses were based on the same assumptions and methodologies as those I used in Section 3.2. Sentence tokens of the locative alternation were collected from the British National Corpus. The frequency distribution of verbs and frames was examined. It was obvious that no verb is predominantly frequent in this alternation, contrary to what is the case in the dative alternation. None seems to be the equivalent of the verb *give* in the dative alternation. However, based on my formula for estimating typicality, three candidates for typical anchors were chosen and tested for any effects of semantic similarity. Results showed that none were a statistically significant predictor of the locative alternation. Lastly, I verified whether the choice of syntactic frame in the locative alternation is modulated by semantic constraints or other known structural factors in a similar way as the choice of syntactic frame in the dative alternation. Results suggested that verb types, i.e., the distinction between content- and container-oriented verbs and the pronominality of ground objects influence the choice of

syntactic frame in the locative alternation. In conclusion, no typical anchors were found to play a role in the choice of syntactic frame in the locative alternation while other effects, such as semantic properties of verbs or pronominality of arguments were shown to influence the locative alternation.

3.4 Summary and General Discussion

In this chapter, I investigated the effect of a frequent verb on the choice of syntactic frame. The dative and locative alternations served as test cases. In order to test the Typical Verb Anchor hypothesis, I first assumed that frequent use of a verb in a particular syntactic frame increases the association of the verb with the syntactic frame. Drawing on the analogy of category exemplars, the frequent verb was predicted to play the role of a typical anchor for the frame, facilitating other verbs with similar meaning to occur in the same frame.

A study of the British National Corpus for the dative alternation revealed that there is a highly skewed distribution in verb frequencies in the actual uses of the DO and PO frames. As noted in previous studies, the verb *give* occurs predominantly frequently in the DO frame. Both its relative frequency (vs. its frequency in the PO frame) and absolute frequency (vs. other verbs in the DO frame) make *give* stand out as a highly representative verb of the DO frame. A series of logistic regression models showed a verb's semantic similarity to *give* is a significant predictor of the choice of syntactic frame in the dative alternation, as predicted. More specifically, the results showed verbs semantically similar to *give* tend to become likely to occur in the DO frame. The role of *give* as a typical DO anchor was tested in isolation as well as in the context of other known predictors such as the caused-possession entailment and pronominality of postverbal arguments. The hypothesis was additionally tested within narrower-range semantic classes of dative verbs. Overall the results of these analyses confirmed my hypothesis.

In Section 3.3, I investigated the locative alternation in order to test whether the results from the dative alternation can be replicated with other syntactic frames. A corpus study of the locative alternation showed it is similar to the dative alternation in that the frequency of occurrences was biased towards one of the alternate frames, namely towards the FO frame. As opposed to the dative alternation, however, there was no verb that accounted for the 'lion's share' of either frame in the locative alternation. Some verbs occur more frequently and exhibit a stronger bias towards one of the two frames than other verbs. However, no verb in the locative alternation was found to be equivalent to *give* in the dative alternation. Three verbs, *rub*, *stick* and *shower*, were tested as typical anchors as they exhibited a minimum amount of what is hypothesized to be necessary properties for being a typical anchor of a frame. Regression models revealed that semantic similarity to none of the three verbs is a significant predictor of the choice of syntactic frame in the locative alternation. Lastly, the distinction between content- and container-oriented locative verbs and whether the object was expressed as a pronoun or not were shown to influence syntactic frame selection. These results suggest that the locative alternation shares some qualitative similarities with the dative alternation although no verb behaved as a typical anchor of either frame.

The corpus-based studies, presented in this chapter, provide some empirical support for the Typical Verb Anchor hypothesis that posits that if any verb occurs in a particular syntactic frame frequently enough to represent that frame, it can serve as typical anchor of the frame similar to category exemplars. On the other hand, the study of the locative alternation casts doubt on the generalizability of the phenomenon. Given the disparity in the results between the dative and the locative alternation, we may not

expect the effect of typical anchors in every construction. It may be that the effects of typical anchors found in the dative alternation are exceptional or that syntactic frames that have a highly frequent and representative verb are rare. Based on the two alternations investigated here, I can only conclude that not all syntactic frames feature a predominantly frequent verb but, if a frame does, the verb typicality effect I found in the dative alternation is expected.

In the present studies, the rationale behind the selection criterion for typical anchor of a frame was that frequency determines typicality. I have assumed that frequency of occurrence is the sole determinant or the most critical determinant of verb typicality. Consequently, I attributed the null results in the locative alternation to the fact that those locative verbs are not frequent enough to represent either of the frames in the locative alternation. However, there may be various other factors that increase or decrease the typicality of a verb with respect to a particular syntactic frame.

Verb typicality may be modulated by the size of the semantic space denoted by a syntactic frame. For example, the PO frame is associated with a relatively broad-range of meanings. A sentence like *John threw the ball to Kim* may entail either caused possession or caused motion. A sentence like *John drove Kim to the church* is also an instantiation of the PO frame but only entails caused motion and a sentence like *John handed a ball to Kim* only entails caused possession. There are also metaphorical extensions of the caused-motion meaning in PO uses, e.g., *The news brought Kim to tears*. Given the range of meanings associated with the PO frame, it may be difficult for any single frequent verb to "stand" for the meanings associated with the syntactic frame.

In contrast, the DO frame is associated with relatively restricted semantic space, as it invariably entails caused possession, and can be represented by a single most frequent verb relatively conveniently, i.e., *give*. In fact, previous research has noted that the semantics of *give* overlaps to a great extent with the semantics of the DO frames.[25]

The GO and FO frames of the locative alternation seem to span a relatively wide semantic space just like the PO frame. Locative frames involve a caused motion event with a kind of location argument. However, shared semantic properties for the postverbal arguments are quite difficult to pin down, as a comparison between *load*-type verbs and *spray*-type verbs, for example, suggests. *Load*-type verbs (e.g., *load*, *stuff*, *cram*, *stock*) denote an event where one moves a theme that ends up in a certain location. This type of event is similar to the event of *putting* in that theme arguments are not supposed to undergo any physical change and location arguments are similar to containers construed as spatial goals. But, *spray*-type verbs (e.g., *brush*, *smudge*, *rub*, *splash)* denote an event where one applies some material to an object, usually the surface of it, in a particular manner and the object's physical condition is supposed to be affected to a relatively large extent. In this case, the object is not just a location, but it fits the criteria for an affected *patient* argument. In the end state, the theme and the location tend to be closely related with each other. They can even be construed as inalienably attached (e.g., *Kim sprayed the artwork with fixative*). These properties suggest that *spray*-type events are qualitatively different from events of *putting*. It may thus be difficult for any single locative verb to represent either the GO or FO frame. Even verbs like *spray* and *load*

[25] For example, Pinker (1989, p. 212) stated that *give* is a verb whose representations are "virtually identical to the double-object thematic core." Goldberg (1997, p. 386) noted that *give* codes an "elaboration of the meaning of the construction." Rappaport and Levin (2008, p. 135) also stated that *give*'s root "does not contribute anything beyond what is already encoded in the caused possession event schema."

usually considered to be most representative of the meaning of the locative frames are unable to serve as semantically typical verb of the frames. In my corpus data, *spray* and *load* are also infrequent, accounting for 2% and 1% of all GO and FO occurrences, respectively.

To summarize, the DO frame has one overwhelmingly representative verb *give* with respect to both frequency and meaning (but neither the FO and GO frames). It may be that *give* occurs in the DO frame most frequently because it is semantically most representative of the frame, or vice versa. But no verb has the same properties or play the role of *give* in the locative alternation.

CHAPTER 4 Implications of This Thesis Results for Sentence Production Models

4.1 Introduction

In this thesis I explored the cognitive underpinnings of the correspondence between verb meanings and syntactic frames, i.e., the tendency for verbs that have similar meanings to occur in similar syntactic contexts. Assuming that the correspondence is not accidental but is a consequence of general properties of human cognition, I hypothesized that a cognitive association between a particular verb meaning and a particular syntactic frame (e.g., formed via sentence experience) plays an important role in speakers' choice of syntactic frame in sentence production. I dubbed this hypothesis the Verb Anchor hypothesis. More specifically, I hypothesized that

semantic similarity to the verb (anchor) associated with the frame modulates the likelihood of other verbs occurring in the same frame. In Chapters 2 and 3, I reported a series of empirical studies that investigated that hypothesis. Chapter 2 investigated the effect of a recently experienced anchor of a frame and Chapter 3 studied the effect of a repeatedly experienced typical verb anchor of a frame. Both chapters studied speakers' syntactic frame selection in sentence production. In this chapter, I discuss implications of the present results in the context of previously proposed models of sentence production.

Modeling sentence production involves many subdisciplines of language science. Sentence formulation is usually construed as a three-step procedure, message generation, lexical access, and syntacticization. In other words, people think of a message first in a non-linguistic stage, then select words necessary or appropriate to convey the intended message, and finally put the words together in an order licensed by the grammar of a given language. In the following discussion, I focus on the final stage of this process, particularly the choice of syntactic frames once lexical items, particularly verbs, have been selected.

In Section 4.2 below, I provide an introduction to some of the proposed models of sentence production which can vary immensely in both theoretical assumptions and technical implementations. This introduction is intended to be brief and only convey the central ideas of each model. Then, in Section 4.3, I discuss whether these models can accommodate the results of Chapters 2 and 3. The discussion is based on conceptual rather than mathematical or computational evaluations of the models. The primary goal of this chapter is not to select a superior model that best explains the present results but

to provide an opportunity of reviewing strengths and weaknesses of each model in the context of this thesis and explore ways to enhance models to account for my results.

4.2 An Overview of Proposed Sentence Production Models

4.2.1 Spreading activation model (Pickering & Branigan, 1998)

Pickering and Branigan (1998) propose a model of the relationship between syntactic information and verb lemmas where individual verbs are directly associated with combinatorial information or the syntactic frames they can occur in, extending Roelofs' spreading-activation model (1992, 1993). This model is based on the view that the lexicon consists of concepts, lemmas, and word forms which constitute individual nodes and are connected by labeled links in a network. This type of model generally assumes that lemma retrieval is led by enhanced activation of a selected node and also that activation automatically spreads to other nodes linked to it. Pickering and Branigan's proposal is sketched in Figure 4.1 below.

Pickering and Branigan assume that experience with a sentence where a verb occurs in a particular syntactic frame activates both the verb lemma node and the relevant combinatorial node. For example, processing a sentence like *Sam gave them a letter* activates the lemma '*give*' node as well as the combinatorial 'NP_NP' node. They also assume the use of particular forms of a verb activates the relevant featural nodes. The use of *gave* activates the 'Past' node, for example. They show, through a series of syntactic priming experiments, that combinatorial information is linked with verb lemma nodes rather than with individual word forms fully specified with featural information such as tense, aspect, and number. In other words, no matter in what forms a verb occurs in a sentence (e.g., *give*, *gives*, *gave* or *has given*), the verb lemma ('*give*') and its associated syntactic information get activated.

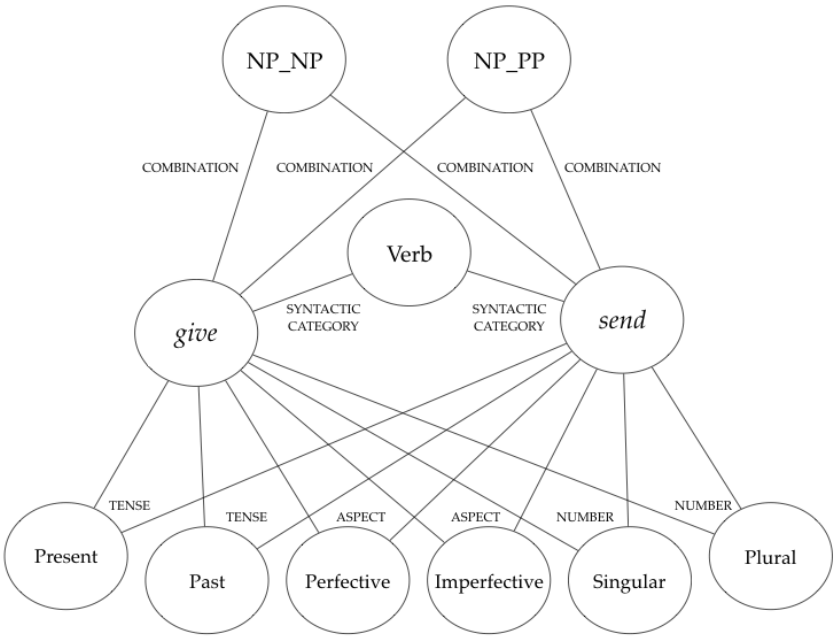


Figure 4.1 A partial model of the syntactic representation associated with verbs (from Pickering & Branigan, 1998, p. 635)

In this architecture, the effects of syntactic priming (i.e., a tendency to reuse the syntactic frame previously experienced) is explained by the residual activation of the combinatorial node. For example, the use of a sentence *Sam gave them the letter* leads to the activation of the 'NP_NP' node, an activation that lasts for some time until it completely decays. During that time interval, the activation level of the 'NP_NP' node is higher than that of the 'NP_PP' node. Therefore, if speakers are to produce a verb that fits both DO and PO frames, they are more likely to choose the DO frame due to the residual but transient activation of the 'NP_NP' node. This model successfully explains the so-called lexical boost effects, i.e., the fact that syntactic priming or syntactic frame repetition enhances significantly when the verb lemma is repeated across sentences. In

this model, this phenomenon can be attributed to the residual activation of the verb node, the combinatorial node and the link between them.

Despite its elegance, Pickering and Branigan's model was challenged by further findings in syntactic priming. Most importantly, researchers found that the syntactic priming effect lasts relatively longer than predicted by their model (Bock & Griffin, 2000). Under a residual activation view, activations of nodes are expected to be short-lived. Due to its longer temporal duration, syntactic priming is now widely considered as a form of implicit learning. The model I discuss in the next section (Chang et al., 2006) is known to successfully deal with this aspect of syntactic priming. Despite its limitations, Pickering and Branigan's proposal is still worth considering as it offers a plausible conceptual architecture that explicitly incorporates the relationships between lexical (verb) and combinatorial (syntax) information. Their leading idea can evolve into a more advanced model that has wider coverage such as the hybrid model that includes transient activation and implicit learning components proposed by Reitter et al. (2013) (see Section 4.2.4 for details).

4.2.2 Error-based learning model (Chang et al., 2006)

Chang, Dell and Bock (2006) proposed a connectionist model of sentence production that explains syntactic priming as a form of implicit learning. Chang et al.'s model was tested through simulations and the model was shown to be quite successful in replicating the results from behavioral studies of sentence production. In this brief

review, I focus on the main assumptions and the general architecture of this model that clearly differentiate it from other models.

Chang et al.'s model is characterized by its use of connectionist networks and error-based learning algorithms and by its dual-path architecture. First, in a connectionist framework, words, features, semantics and syntax are all represented as patterns of activation over units in a network. The units are connected to each other, which is conceptually similar to the network introduced in the previous section, but the representations correspond to packets of nodes rather than localized in a single node and the nodes are connected by weighted links. This network can improve its success in performing tasks by adjusting the weights over a training period.

Second, an error-based learning model is a system that makes corrections on the weights based on the difference between what is predicted and what actually occurs. When encountering an erroneous prediction, it 'back-propagates' the error through the network and penalizes any node or link that led to the faulty prediction. This procedure cyclically enhances the accuracy of the model predictions.

Third, Chang et al.'s model consists of two separate pathways connected to each other restrictively, as schematized in Figure 4.2. The *meaning* system deals with lexical semantic information of words ('the *what* system'), role assignment on nouns or arguments ('the *where* system') and event-semantic information representing relationships among arguments. The *sequencing* system learns the way words are sequenced, so it has limited contact with the units in the meaning system. When a sentence is fed into this model as an input sequence, each word ('*c*word' or comprehended word), one after another, goes through the cycle described in Figure 4.2.

At the end of every cycle the model predicts the next word and compares its prediction with the actual word that follows. If the prediction is wrong, the model recognizes the error and makes adjustments accordingly, namely performs 'learning.'

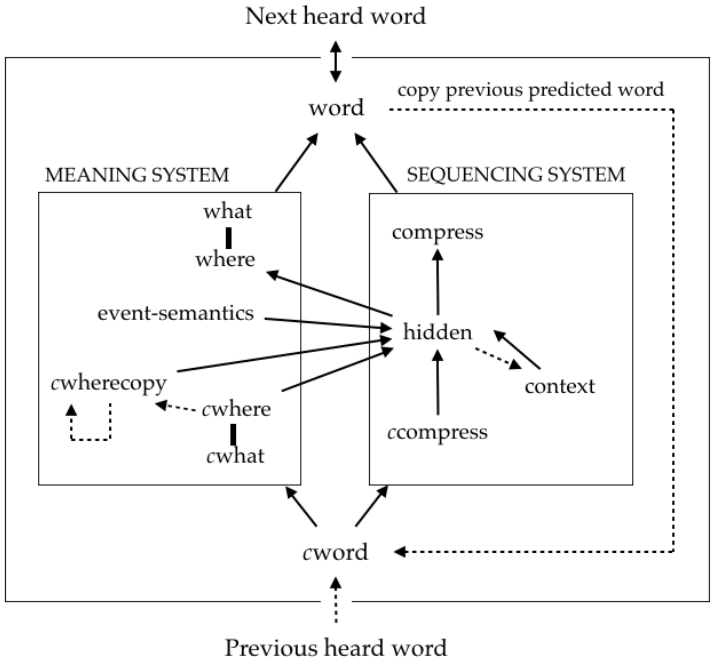


Figure 4.2 Error-based learning model (from Chang et al., 2006, p. 239)

Chang et al.'s simulations show that this model can account for most of the syntactic priming phenomena and strongly supports the idea that speakers choose to reuse the same syntactic structure because they have implicitly learned the relevant mapping between a message type and a sequence from prior sentence experience, not just because the mental representation of the syntactic frame stays activated and temporarily available for reuse. However, they report that this model fails to account for the lexical boost effect, i.e., syntactic repetition boosted by the repetition of lexical items.

They suspect that the lexical boost effect may occur due to the explicit memory of a lexical item that their model (as a model of implicit learning) is not intended to deal with. It may be a reasonable explanation as research has shown that syntactic priming and lexical boost effects have different time courses, i.e., long-lasting syntactic priming vs. temporally short-lived lexical boost (Hartsuiker et al., 2008), suggesting they involve distinct mechanisms. In this respect, Chang et al.'s model seems to be in a complementary relationship with Pickering and Branigan's model discussed in the previous section in that Chang et al.' model explains the long-lasting effect of syntactic priming but not the lexical boost effect and conversely Pickering and Branigan's model explains the short-lived lexical boost effects but not the enduring effect of syntactic priming.[26]

4.2.3 Exemplar-based probabilistic model (Bod, 1992, 2006)

This section presents a brief and informal sketch of Bod's (1992) formal probability model of natural language. His model, called *Data Oriented Parsing (DOP)*, is based on Scha's (1990) idea that statistical properties of language use are necessary for properly modeling natural language processes, given the problems that competence-oriented models have encountered.[27]

---

[26] More recently, Malhotra (2009) also proposed a connectionist model that is based on a 'dynamic systems' approach rather than on error-based learning. This model was shown to have a wider coverage than Chang et al.'s model.

[27] Scha, R. (1990). Taaltheorie en taaltechnologie; competence en performance. [written in Dutch] In de Kort and Leerdam (Eds.), *Computertoepassingen in de Neerlandistiek*.

The architecture of Bod's model is as follows. Natural language corpora are treated as input and are syntactically analyzed, or *parsed* into subtrees, which are analogous to constructions of different sizes, in the sense of Fillmore (1988) and Goldberg (1995). For example, if a sentence such as *John likes Mary* is entered into the model, the model performs so-called decomposition operations on this corpus sentence and generates a bag of subtrees, as illustrated in Figure 4.3. Importantly, these subtrees are, whether small or large, conceived of as "representations of concrete language tokens rather than as bunches of rules" (Bod, 2006, p. 298). In other words, they are fragments of language *exemplars*.

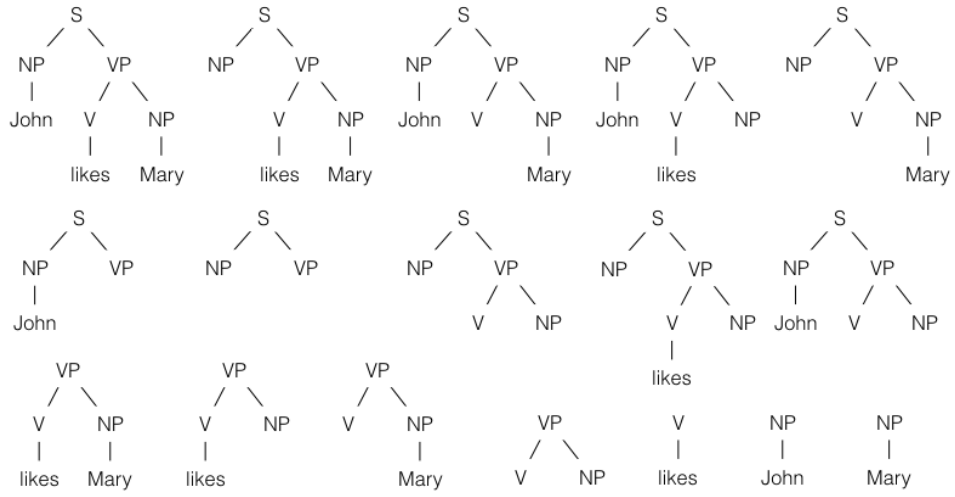


Figure 4.3 A bag of subtrees for *John likes Mary* (from Bod, 2006, pp. 301-302)

Once the model has parsed a large corpus of input sentences, it includes a huge collection of these subtrees many of which are redundantly stored. The model can also combine some subtrees into new trees by so-called composition operations. Importantly, through a stochastic process, the model takes frequency distributions of the subtrees into

account and the probability of every subtree and every utterance or sentence is generated. As Bod (2006, p. 307) notes, there are many possible ways to compute the probabilities and even to select the best parse tree in this type of models. In a nutshell, the collection of subtrees, each appended with probabilistic information, serves as "a store of representations of all previous language experiences" (p. 293). In this sense, Bod's model is an exemplar-based model.

Bod's model outlined here is one of the earliest DOP models that uses syntactic trees as representations. There are many other variants in the literature that vary in their syntactic representations. Basically, the idea of DOP does not depend on any particular syntactic theory, e.g., LFG-DOP makes use of Lexical Functional Grammar-style representation. DOP requires a minimal amount of rules that decompose exemplars into fragments (or recompose fragments into exemplars) and a systematic tool to represent the fragments. No other theoretical syntactic operations are involved in this model, such as syntactic derivations from one structure to another.[28]

A DOP model may seem similar to Chang et al.'s (2006) model as they both take natural language data as input to the models. Other than that, however, they differ immensely in their architectural design. Chang et al.'s model learns to simulate natural language use by repeatedly correcting its own errors, where usage information is like a teacher in a supervised learning environment, while Bod's model computes from usage

[28] Exemplar-based models are not necessarily DOP models. There are various forms of exemplar theories of language processing, e.g., Walsh et al. (2010). In the current linguistics literature, the term 'exemplar-based' tends to be loosely defined. It seems any model can be called 'exemplar-based' as long as natural language use is the primary source of the data in model construction and frequency distributions are taken into account.

the probabilities of each linguistic unit and then select the most probable combination of units via unsupervised induction.

Studies have shown that DOP models can explain various linguistic problems. In particular, Snider (2008) showed that one DOP-based model can explain syntactic priming effects (e.g., DOP-LAST, which stands for Local Activation Spread Theory; Kapatsinski, 2006). In particular, he showed that the model successfully simulates the inverse frequency effect on syntactic priming (i.e., a less frequent structure primes more than a more frequent one) and also similarity effects (i.e., semantically similar exemplars prime more).[29]

4.2.4 Computational cognitive model (Reitter et al., 2011)

Reitter, Keller and Moore's (2011) model of syntactic priming contrasts with the models discussed above in its theoretical foundation. While previous models are designed to mainly deal with linguistic problems, Reitter et al.'s model is based on an architecture aimed at simulating human cognition in general. Reitter et al. used the principles and mechanisms of the ACT-R cognitive architecture to implement their sentence production model (i.e., 'adaptive control of thought - rational'; Anderson et al., 2004) and used Combinatorial Categorial Grammar (CCG) as its syntactic basis (Steedman, 1999). Figure 4.4 illustrates the portion of the ACT-R architecture most relevant to their sentence production model.

[29] Semantic similarity between exemplars in Snider (2008) seems better to be conceived of as message similarity computed from the whole sentence rather than verb similarity, as he used k-Nearest Neighbor models as similarity measure.

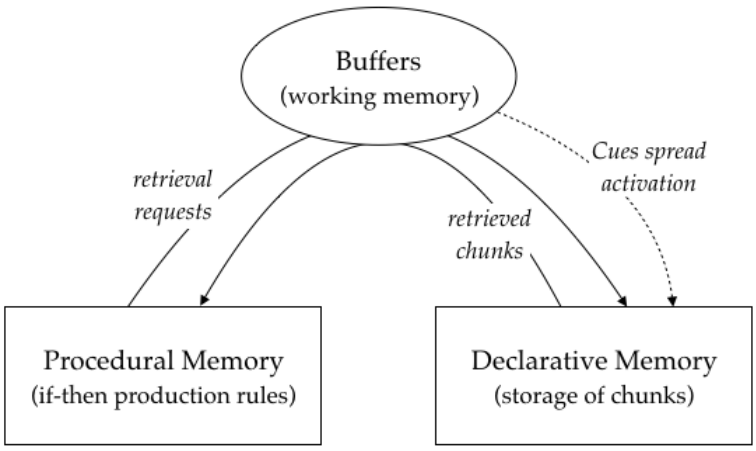


Figure 4.4 A schematic description of the ACT-R architecture in Reitter et al.'s model (simplified from Reitter et al., 2011, p. 598)

There are three modules in this model. *Procedural memory* generates requests for memory retrieval. *Buffers* hold temporary information about the goals or state of the system. *Declarative memory* stores *chunks* or bundled information (e.g., attribute-value pairs), which is considered most essential in this model as lexical and syntactic decision-making is supposed to take place there. Activation of stored chunks and also their competition for activation are crucial for modeling sentence production phenomena. A chunk's overall activation amounts to the sum of two components, namely activation transmitted from a cue (or cues) and activation learned over retrieval cycles. The former is a form of *spreading activation*, by which a chunk in a buffer serves as a cue to stored chunks in declarative memory and activates some of these chunks, provided they are associated with the cue. It is meant to explain facilitatory effects in retrieving related linguistic units. The latter is a form of *base-level activation*, which tends to increase as

more and more retrievals occur. It is meant to explain preferred or easier access to stored chunks that have been frequently retrieved before.

Reitter et al.'s model takes advantage of the presence of two activation mechanisms, spreading activation and base-level activation, in simulating behavioral patterns in sentence production. More specifically, Reitter et al. argued that the duality of syntactic priming can be explained by the presence of two kinds of activation. On the one hand, *short-term priming* is concerned with cue-based activation which decays rapidly. Reitter et al. suggest it results from the spreading-activation mechanism in the model. *Long-term priming* is, on the other hand, a type of implicit learning that can be explained via base-level activation. To summarize, in their ACT-R model, Reitter et al. implement two kinds of mechanisms that may be behind syntactic priming, namely *priming as spreading activation* and *priming as learning*, and show this model successfully simulates both kinds of syntactic phenomena discussed in the previous literature. In addition, they simulate other aspects of syntactic priming such as lexical boosts, cumulative priming (Jaeger & Snider, 2007) and inverse-frequency effects. In this respect, this model overcomes the limited coverage of both Pickering and Branigan's (1998) and Chang et al.'s (2006) models.

Reitter et al. also argue that it is a strength of their model that it can represent hierarchical syntactic structures (i.e., the CCG-based representations). In this respect, Reitter et al.'s shares some similarity with Bod's (1992) DOP model which is also based on syntactic representations, although Reitter et al. criticize DOP models' inability to explain the temporal properties of syntactic priming and the heavy memory load which may be caused by excessive storage of exemplars.

The use of CCG lets this model accord well with lexical and constructional approaches to syntax (Fillmore, 1988; Pollard & Sag, 1994; Goldberg, 1995, among others). Lexical items and syntactic frames are CCG categories or chunks represented by attribute-value matrices which contain semantic and syntactic information as well. And sentence production is modeled as "the retrieval of a pair of lexical and syntactic chunks from declarative memory" (Reitter et al., 2011, p. 605). Stored chunks are linked, if they are qualitatively compatible with each other, namely if they can co-occur. Thus, words that can occur in more than one syntactic frame are linked with multiple chunks of syntactic categories, as illustrated in Figure 4.5.

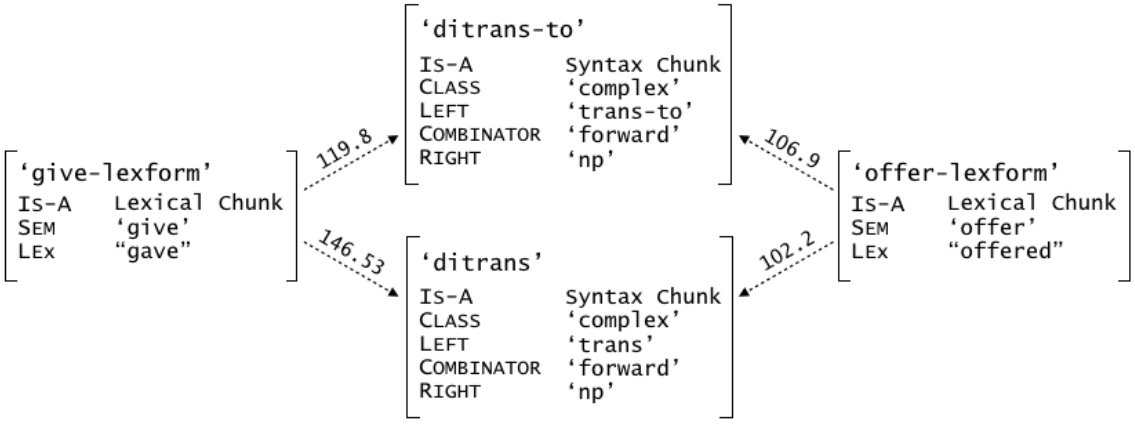


Figure 4.5 Representations of lexical forms, syntactic categories and the link strengths (from Reitter et al., 2011, p. 605)

The strength of links between lexical and syntactic forms, designated by arrows and numbers in the figure, is determined through associative learning (Anderson, 1993). For example, the association between *gave* and the Double Object frame is learned every

time the retrieval of the chunk 'ditrans' is requested while another chunk *gave* is in the buffer. The strength of a link is thus a learned association that stems from mutual retrievals. Due to the use of lexicalized syntactic representations, it is easier to capture the relationships between lexical items and syntactic representations in Reitter et al.'s model than in other learning-based models such as Chang et al.'s (2006).

4.3 Discussion: How the Models Accommodate my Thesis Results

For the purpose of investigating the cognitive mechanisms behind the relationship between verbs and syntactic frames, I supposed that similarity, recency and frequency, three of the key factors acknowledged to influence general cognitive processes, each played a role: More similar, more recent, and more frequent units, whether linguistic or nonlinguistic, tend to be processed more easily and faster.

More specifically, in Chapter 2, a series of online syntactic priming experiments showed that semantic similarity between verbs in adjacent prime and target sentences influenced speakers' syntactic frame selection in target production. The results of those studies suggest that recent experience with a verb associated with a syntactic frame facilitates the choice of the same syntactic frame for semantically similar verbs. In Chapter 3, statistical modeling of a large corpus of natural language use showed that high frequency of joint occurrence of a particular verb with a particular syntactic frame affects speakers' syntactic frame selection in general and that speakers tend to choose the same syntactic frame for verbs semantically similar to the verb occurring most frequently with that syntactic frame. The results of this study suggest that experience with frequent verb-syntax combinations facilitates the use of the same syntactic frame for other semantically similar verbs, in a way analogous to typicality effects of frequent stimuli on categorizing new stimuli. Assuming that the way speakers use language has a profound influence on linguistic structures, the results suggest that the correspondence between verbs and syntactic frames may not be a coincidence but is closely related to, or even caused by, the way language input is processed.

A model's ability to explain or predict the effects of both recency and frequency is of the utmost importance to accommodate the results of this thesis. It appears that Reitter et al.'s (2011) model best captures the two phenomena I described in this thesis. It should be noted, however, that other models may be modified to account for all the phenomena reported in this thesis. For example, although Chang et al.'s (2006) model was unable to explain the recency effect, Malhotra (2009) showed that connectionist learning models can explain the recency effect if properly modified. For my purposes, it seems more relevant or useful to see how verbs and syntactic frames are represented (or how the representations are extracted from usage experience) and how verbs and frames interact in each model.

Pickering and Branigan's (1998) model is, *a priori*, easier to evaluate than the other three models as their representational scheme is quite straightforward. Namely, each verb lemma and each syntactic frame is independently represented in separate strata and they are connected by direct links through which activation spreads. Links between verbs and syntactic frames seem to be easily represented. However, Pickering and Branigan's proposal is, as yet, missing direct links between verbs (e.g., no direct link between *give* and *send* in Figure 4.1). Verbs are only indirectly linked through their respective connection to the lexical category *verb*. A large body of semantic priming studies suggests that activation of a word spreads to other words, thereby suggesting that words are connected with each other. Moreover, using the analogy of distance, semantically similar words are represented relatively more closely to each other in the mental lexicon than semantically dissimilar verbs. And thus, the activation of a word spreads to similar words faster and more than to dissimilar words. Because of the lack of

direct links in Pickering and Branigan's model, it is difficult to expect activation to spread between verbs.

If lexical priming is integrated into Pickering and Branigan's model, hearing or producing a sentence should activate its verb and it syntactic frame, but the activation of the verb will also simultaneously spread to another verb to the degree to which they are semantically similar to each other. Consequently, similar verbs will be more activated than less similar or dissimilar verbs. Semantically similar verbs will also receive more of activation from the already-activated syntactic frame than dissimilar verbs as similar verbs are, so to speak, closer to the verb associated with the frame than dissimilar verbs (Roelofs, 1992). For example, a sentence like *John sent him the letter* would activate the *send* lemma node as well as Double Object (DO) node and activation of *send* spreads more to *mail* than to *promise* due to the higher semantic similarity of *send* to *mail* than to *promise*. As a consequence, *mail* is more likely to occur in the DO frame than *promise* is, assuming the next message involves either concept. This modification of Pickering and Branigan's model suffices to explain at least the similarity-based recency effect discussed in Chapter 2.

In order to accommodate the frequency effect discussed in Chapter 3, Pickering and Branigan's model needs to be further augmented by a mechanism that deals with varying strengths of association between verbs and syntactic frames. In other words, the model should be able to accommodate the fact that frequently experienced nodes have higher degrees of base-level activation than infrequent ones. It is often assumed that links between nodes are weak or strong depending on how often the nodes are co-activated. For example, the *give* node has a higher base-level activation than the *promise*

node as *give* occurs more frequently than *promise* in natural use. Also, the link between the *give* node and the DO node is stronger than the link between the *promise* node and the DO nodes as *give* occurs in the DO frame more frequently than *promise* does.

Chang et al.'s (2006) model discussed in Section 4.2 is difficult to evaluate in the context of this thesis's results as their model does not make use of explicit syntactic representations. Each utterance by which the model is trained is conceived of as a sequence of words rather than as a syntactically structured unit. However, I do not necessarily believe this model makes no use of syntactic representations at all, as Reitter et al. (2011) has argued. The meaning system of the dual pathways contains the event-semantic units and also assigns semantic roles to nominal input, whose information is passed onto the sequencing system, as illustrated in Figure 4.2. Event-semantic information is concerned with what semantic roles are necessary for a verb and in what order they occur together with it. Namely, it is a part of the information associated with a verb that is highly relevant to its syntactic realization. Thus their sequencing system is not simply based on the probability of a prior word or of a string of prior words. It does take syntactically relevant semantic information into account. The model learns the syntactic realization of a verb from an input utterance, for example, either in the DO or in the PO frame, although the model has no explicit and independent node or storage system for abstract syntactic representations such as trees (Bod, 1992) or CCG types (Reitter et al., 2011).

Given my results, what seems most unclear in Chang et al.'s model is the status of verb semantics other than event-theoretic information. Chang et al. noted that only a limited portion of the meaning system can be in contact with the sequencing system,

e.g., event-semantics units and the role-assignments units. What is crucial for explaining my results, however, is a mechanism to perform more detailed comparisons between verb meanings, above and beyond the similarity of roles and event semantics. For example, *give*, *send*, and *promise* can be syntactically realized with the same set of event roles and in the same order but the meaning of each verb obviously differs and semantic similarity between them differs. It seems difficult within Chang et al.'s architecture to see how two verbs in two separate utterances can be semantically compared at the lexical level.[30] I speculate this is related to a previously known problem, namely that this model is unable to simulate the lexical boost effect. Given that the model analyzes role information for NPs by *what* and *where* units, though, it should be possible to add units dedicated to the meaning of verbs.

Bod's (1992) model discussed in Section 4.3 has an advantage over other models in that it can easily represent the association between a verb and a syntactic frame that derives from experiencing a particular sentence token. As illustrated in Figure 4.3, there is no theoretical divide between abstract syntactic representations and terminal words. Each subtree which consists of syntactic parses and specific lexical items serves as an exemplar or token of stored linguistic experience. For example, experiencing a DO sentence whose main verb is *give*, the model generates a subtree where the syntactic parse of the DO frame is linked with a lexical form of the lemma *give* under the verb node. If one often experiences this subtree pattern, this subtree will be redundantly stored in the model, which will lead to verbs' frequency or typicality effects. However, a Bod-style model seems to require an additional assumption to accommodate the recency

[30] Chang et al.'s model seems to assess semantic similarity at the message level.

effect. More specifically, it needs a mechanism to adjust the probability upwards for patterns experienced recently and penalize those experienced long before (Bod, 2006). Putting aside implementation issues, such a modification of the model is plausible as it is reasonable to assume that stored experience that is old is likely to be gradually forgotten.

Finally, the principles and architectures of Reitter et al.'s (2011) model accommodate the present study relatively well. First of all, the model is designed to accommodate both recency and frequency effects in sentence production as it includes both a spreading-activation mechanism and a learning mechanism, i.e., adjusting base-level activation on the basis of learned weights on links between representations or chunks. Also, the model shares with the present study similar theoretical assumptions about lexical and syntactic representations in its use of Combinatorial Categorial Grammar as its syntactic bases. For example, lexical items are directly connected with syntactic CCG types, as illustrated in Figure 4.5, which is similar to Pickering and Branigan's (1998) approach. Within this model, the strength of a link between the chunks that represent, for example, *give* and the DO frame strengthens over the growing number of retrievals of these chunks. An individual retrieval constitutes recent experience with a syntactic structure while the sum of individual retrievals amounts to repeated and frequent experience with the same syntactic structure.

The implementation of the model also takes into account the notion of syntactic *heads*, e.g., verbs as the syntactic heads of sentences. The model determines the order of arguments when a lexical head (verb, here) and a syntactic frame are both retrieved. Its ability to recognize verbs explicitly would be a plus if it is expanded to accommodate

verb similarity effects. What is as yet left undefined in this architecture is the connection weights among lexical items or verbs themselves, just as was the case for Pickering and Branigan's model. Given the fact that spreading activation is one of the two key mechanisms this model makes use of, it is necessary for the model to integrate a component that enables the activation of a verb to spread to other verbs to the degree they are semantically similar to each other. The model would then be able to take into account lexical semantic relationships in the retrieval of a syntactic frame.

The discussion of each model I provided in this chapter are somewhat speculative. My aim was to explore possible ways to accommodate my results. I pointed out for each model which mechanisms are missing or necessary to make the model account for the results of the present thesis. To sum up, it seems that none of the models I discussed can fully account for my results given their current architectures. They each need modifications. Pickering and Branigan's and Reitter et al.'s models need an additional component that takes care of relationships among verbs. Chang et al.'s model needs a mechanism to account for the recency effect, as was already pointed out in previous literature. Bod's model needs a component that enables 'forgetting' of stored exemplars. Chang et al.'s and Bod's models both need a mechanism that can recognize and compare verbs in input sentences.

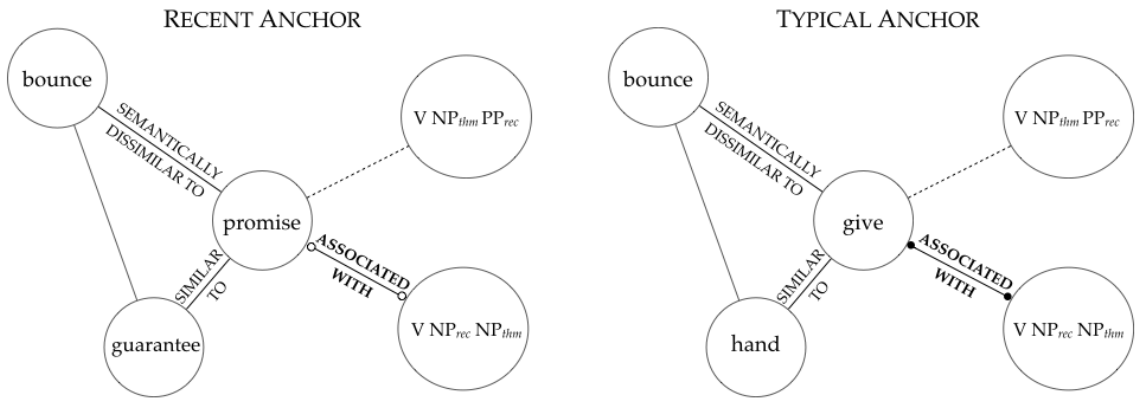
CHAPTER 5 Summary and Conclusion

In this thesis, I investigated the cognitive underpinnings of the *correspondence between verb meaning and syntax* widely observed in language. Linguists have noted that similar verb meanings tend to be realized in similar syntactic contexts and that semantic properties of verbs are, to a great extent, a determinant of the syntactic frames they may occur in. This thesis started out with an assumption that such correlational patterns between verb meanings and syntactic forms are not coincidental but have much to do with the way speakers actually process sentence input and produce sentence output. In line with the findings of linguistic investigations, I assumed that when formulating a sentence, speakers make use of verb meanings in the syntactic frame selection stage. In the following sections, I provide a summary of my hypotheses and findings from a series of experimental and corpus-based studies, discuss implications as well as remaining issues, and conclude this thesis.

5.1 Summary: Hypotheses and Findings

The Verb Anchor hypothesis I proposed is that experience (either via comprehension or production) with a sentence gives rise to a cognitive association between the verb of the sentence and the syntactic frame the sentence exemplifies and the verb serves as anchor verb of the frame. I predicted that high semantic similarity between verbs leads to an increase in the likelihood of speakers' choosing the same syntactic frame across sentences. Namely, the more semantically similar a verb is to the anchor, the more likely it is to occur in the same frame.

I investigated this hypothesis in two separate contexts. First, I tested the hypothesis that *recent* sentence experience leads to an association between a verb and a syntactic frame and the verb becomes at least temporarily an anchor for the syntactic frame. Second, I assumed that highly *frequent* experience with an association pattern between a particular verb and a particular syntactic frame makes the verb typical of that syntactic frame. Thus, the verb becomes a typical anchor of the frame that has a constant effect. I dubbed the first the Recent Verb Anchor hypothesis and the second the Typical Verb Anchor hypothesis. In both, I hypothesized that semantic similarity of other verbs to the anchor of a frame modulates the likelihood of those verbs occurring in that same frame. Illustrations of these two subhypotheses are repeated below (i.e., Figures 1.4, 2.1, and 3.1).



If a speaker just experienced a sentence like *They promised him a present*, it activates both the *promise* node and the [V NP NP] node and the association link between them beomes highly activated (indicated by a solid line with circled ends). This activation and association pattern affects other verbs to the degree to which these other verbs are semantically similar (close) or dissimilar (remote) to the verb *promise* (indicated by varying distances between verbs), the recent anchor of the [V NP NP] frame. Semantically similar verbs to the recent anchor (e.g., *guarantee*) are more likely to be associated with the same [V NP NP] frame than semantically dissimilar verbs (e.g., *bounce*).

If one experiences a particular association pattern over and over again, for example, *He gave me the book*, *Jen gave the man a pen*, *She always gives me love, The teacher has given her A's*, and so on, highly frequent experience strengthens the association between the verb *give* and the frame [V NP NP] and makes *give* typical of the frame, analogous with typical category exemplars, i.e., frequently experienced exemplars of a category become typical or prototypical of the category. Without recent activation, the base activation of the [V NP NP] frame is higher than other frames for the verb *give*. As

with the recent anchor verb, this frequency-driven strong connection between the typical anchor and the frame affects other verbs to the degree to which they are semantically similar to the typical anchor. Higher semantic similarity of a verb to the anchor leads to an increase in the choice of the same frame.

Four syntactic priming studies (Experiments 1-4) tested the Recent Verb Anchor hypothesis. The syntactic priming paradigm allows us to investigate the influence of a recently experienced sentence (prime) on the production of a subsequent sentence (target). Given previous findings that speakers tend to reuse the syntactic frame experienced in the prime sentence when producing a target sentence, I manipulated semantic similarity between the verbs between prime and target sentences and examined whether verb semantic similarity modulates syntactic priming. In the high-similarity condition, verbs in prime and target sentences are highly semantically similar to each other (e.g., *promise* and *guarantee*); in the low-similarity condition, verbs in prime and target sentences are much less semantically similar to each other than the high-similarity pairs (e.g., *promise* and *bounce*). The Recent Verb Anchor hypothesis predicts that high semantic similarity between prime and target verbs leads to an increase in the tendency to reuse the prime structure in target sentence production, over and above the usual syntactic priming effect in which there is no or little aid of lexical similarity between prime and target. The dative alternation (Experiments 1 & 3) and the locative alternation (Experiments 2 & 4) were used as experimental stimuli as they provide speakers with two alternate frames to use to convey the message for target sentences (e.g., the contrast between *The director promised the actress a large part* and *The director promised a large part to the actress* or between *I sprayed the dough with some oil* and *I sprayed*

some oil on the dough). The experiments demonstrated that high semantic similarity of prime and target verbs is necessary for a statistically significant syntactic priming effect (Experiments 1) or can lead to a significant increase in syntactic frame repetitions above and beyond the usual syntactic priming effect expected when there is little semantic overlap between prime and target sentences (Experiment 4) and when treating verb similarity as a continuous variable, semantic similarity between prime and target was shown to increase syntactic priming effects in all four experiments. Overall, the results confirmed my Recent Verb Anchor hypothesis.

Two extensive corpus studies and statistical modeling were, then, conducted to investigate the Typical Verb Anchor hypothesis. My corpus study of the dative alternation in the British National Corpus confirmed previous observations that the Double Object frame (e.g., *The director promised the actress a large part*) occurs most frequently with the verb *give* and conversely the verb *give* occurs with the Double Object frame more frequently than the alternate Prepositional Object frame (e.g., *The director promised a large part to the actress*). Given the high frequency of *give* in the Double Object frame, the verb *give* was hypothesized to be a typical anchor of the Double Object frame. Sentence tokens that exemplify either the Double Object or the Prepositional Object frame were collected from the British National Corpus. Each sentence token was coded with semantic similarity between its main verb and the typical Double Object anchor *give*. This dataset was fitted to a logistic regression model where the predictor variable is the main verbs' semantic similarity to *give* and the outcome variable is syntactic frames (either Double Object or Prepositional Object) sentence tokens actually occurred in. Results showed that verbs' semantic similarity to *give* is a significant predictor of the

choice of syntactic frame, confirming the Typical Verb Anchor hypothesis. This verb similarity predictor was also tested in the context of other known predictors of the dative alternation and survived as a significant predictor. However, the corpus study of the locative alternation in the British National Corpus revealed no such highly frequent verb as *give* that exemplifies either of the alternate frames of the locative alternation. Three verbs *rub*, *stick* and *shower*, though, were chosen as typical anchor candidates as they have the highest numbers from my formula for typicality estimation. Results of another logistic regression analysis revealed that semantic similarity to these verbs do not play the role in the choice of syntactic frame. To summarize, the Typical Verb Anchor hypothesis was confirmed in the dative alternation but not in the locative alternation. Note however that the anchor candidates of the locative frames I chose exhibited quite different frequency patterns from those of *give*. Thus it seems reasonable to conclude that the Typical Anchor hypothesis was confirmed when there exists a true typical anchor of a syntactic frame, e.g., *give*, but typical anchors may not be expected for all syntactic frames.

Overall, these empirical investigations have demonstrated that the mechanism proposed by the Verb Anchor hypothesis does affect speakers' syntactic frame selection processes. In other words, speakers are sensitive to or make use of verb meaning in syntactic frame selection and as a result, languages exhibit a close relationship between verbs meanings and syntactic frames.

Lastly, in order to contextualize my thesis results, I discussed four sentence production models, Pickering and Branigan (1996), Chang et al. (2006), Bod (1992, 2006) and Reitter et al. (2011), and explored ways to accommodate the present findings in each

model. I found all models need modifications to fully accommodate the present results. For example, Pickering and Branigan's and Reitter et al.'s models need a mechanism that deals with the effect of verb semantic similarity. Chang et al.'s model needs a mechanism to account for the effect of recent verb anchors. Bod's model needs a component that takes care of decay of activations. To sum up, although none of the models discussed here can fully simulate this thesis' results given their current architectures, there seem to be ways to make them do so.

5.2 Remaining Issues and Future Research

Although the data I have presented in this thesis support my claims, there remain some technical as well as theoretical issues that call for further research. One has to do with how frequently a verb must occur in a particular frame for it to become typical of that syntactic frame. In the current analyses, I chose as typical anchor candidates the verbs that have the highest typicality estimates. No criteria were set to distinguish between small and wide gaps between the most typical and the second most typical verb, for example and no threshold for typicality was set. I observed the expected results when the most typical verb is far more so than the second most typical one (i.e., *give* in Section 3.2), and not when it was not the case (i.e., *shower*, *rub*, and *stick* in Section 3.3). This contrast suggests that the verbs tested for the locative alternation frames are less frequent in the GO or FO frames than required to exhibit the typicality effect. Thus, refinements in the choice of a typical anchor are necessary in future work, e.g., finding a threshold level in frequency of co-occurrence with a syntactic frame for a verb to be a typical anchor of that syntactic frame.

Another issue has to do with how much the verb typicality effect I demonstrated with *give* and the Double Object frame can be generalized over to other syntactic frames. As noted above, the effect was not borne out for the frames of the locative alternation. Thus, in future work, it is necessary to study many other syntactic frames and see whether they tend to show results like the former or results like the latter. We may expect (at least) three kinds of outcome. It may be that many frames show a highly-biased verb distribution and confirms the verb typicality effect. It may be that many

frames show a highly-biased verb distribution but do not exhibit the verb typicality effect. Lastly it may be that many frames show only a medium-sized bias in verb distribution and show no typicality effect, suggesting the results from *give* are rare.

Finally, the last but probably the most important issue in this kind of research has to do with whether (and how) speakers' tendency that I demonstrated in thesis, i.e., the tendency to use similar syntactic frames for similar verb meanings, ultimately affects syntactic realization of new verb meanings. Assuming that cognitive mechanisms may cause grammars to be the way they are, it is important to show that syntactic frame selection for new verbs are governed by the same mechanism that I have shown to affect the choice of syntactic frame for verbs for which speakers already "know" the possible frames they can choose from. Due to the nature of linguistic research, it is technically difficult to test new verbs and new syntactic frames. Researchers may use artificial languages or create nonce words, but it is not entirely clear whether participants use the same (automatic) mechanisms in processing artificial languages that they normally use to process natural language. There may also be other ways of exploring this issue, for example by investigating the syntactic behavior of recently-introduced verbs such as *fax* and *email* or conducting experiments with nouns that may possibly occur as denominal verbs.

5.3 Conclusion

In conclusion, this thesis has provided evidence for some possible cognitive underpinnings of the linguistic correspondence between verb meanings and syntactic frames. I have shown that speakers tend to select the same syntactic frame for semantically similar verbs and also shown that such a tendency is modulated by both recent and highly frequent verb experienced in a particular syntactic frame. The results provide an (at least partial) answer to the question *why* verbs with similar meanings tend to occur in similar syntactic contexts, supporting my claim that the linguistic correspondence between verb meaning and syntax is not coincidental but is related to or may even be caused by the *priming* effects I discussed. This thesis thus contributes to one of the ultimate questions linguists must address, namely why grammars are the way they are.

APPENDICES

APPENDIX A Experimental Stimuli

A.1 Experiments 1 & 3 (Dative)

The fifteen sets of experimental sentences used in Experiment 1 are presented below. The prime (P1, high-similarity & P2, low-similarity) and target (T) structures in Experiment 1 are reversed in Experiment 3. In both experiments, control primes (P3) were kept constant. One trial set of sentences used in Experiment 3 are presented below (1), as an example.

(1) (Experiment 1)

T The soldier wrote a long letter to his fiancee.

P1 The intern texted her boss an apology.

P2 The rescuer flung the swimmer a life preserver.

P3 It is great that the weather is getting better.

(Experiment 3)

T The soldier wrote his fiancee a long letter.

P1 The intern texted an apology to her boss.

P2 The rescuer flung a life preserver to the swimmer.

P3 It is great that the weather is getting better.

(2)	T	The Department of Education awarded a large contract to UB.
	P1	The manager granted his secretary a maternity leave.
	P2	The judge read the jury supplementary instructions.
	P3	The patient died after years of suffering.
(3)	T	The rookie pitched a fastball to the heavy hitter.
	P1	The kid threw his friend a Frisbee.
	P2	The publisher advanced the author a large amount.
	P3	This question is too difficult to answer immediately.
(4)	T	The kindergartner rolled a crayon to his friend.
	P1	The bartender slid the customer a beer.
	P2	The governor assigned the committee an urgent task.
	P3	Iced tea is especially refreshing in the summer.
(5)	T	The producer promised a large part to the actress.
	P1	The CEO guaranteed all employees a Christmas bonus.
	P2	The ball boy bounced the player a new ball.
	P3	Organic food is increasing in popularity recently.
(6)	T	The zookeeper fed some meat to the lion.
	P1	The host served his guests vodka martinis.
	P2	The trainer taught the secretaries the new database.
	P3	The baby has been crying all day long.
(7)	T	The robber kicked a gun to his partner.
	P1	The teenager punted his friend a football.

	P2	The millionaire left his widow his entire estate.
	P3	Fresh basil is more aromatic than dried one.
(8)	T	The lovesick teenager recited a poem to his girlfriend.
	P1	The babysitter sang the baby a lullaby.
	P2	The waiter carried the diners the entrées.
	P3	The chairman who was late yesterday apologized.
(9)	T	The dealership loaned a BMW to the director.
	P1	The student lent his classmate a pen.
	P2	The politician told the columnist a dirty joke.
	P3	Success often relies on hard work and perseverance.
(10)	T	The dealer pushed a stack of chips to the gambler.
	P1	The rude driver shoved the policeman his papers.
	P2	The school official issued lecturers parking permits.
	P3	Technique is always an issue for good dancers.
(11)	T	The homeowner rented his carriage house to the newlyweds.
	P1	The realtor leased the city two office suites.
	P2	The online bookstore shipped customers a catalog.
	P3	The sports car is not fit to drive in country roads.
(12)	T	The businessman repaid the money to his bank.
	P1	The landlord refunded her former tenants the deposit.
	P2	The marketing director forwarded the CEO the press release.
	P3	The director hopes his film will be successful.
(13)	T	The screenwriter emailed a new script to his agent.

P1 The accountant faxed the IRS the tax return.

P2 The lady tipped the waiter an extra 20%.

P3 Jen and Ted always cook together after work.

(14) T A Yankees fan passed his binoculars to his buddy.

P1 The show host tossed the singer a microphone.

P2 The businessman owed the investors a million dollars.

P3 Joe's weird housemate moved out last night.

(15) T The school mailed the tuition bills to the students.

P1 The mother sent her daughter a care package.

P2 The pub owner drew the customer a pint of beer.

P3 The athlete believed in himself and his team.

A.2 Experiments 2 & 4 (Locative)

The twelve sets of experimental sentences used in Experiment 2 are presented below. The prime (P1, high-similarity & P2, low-similarity) and target (T) structures in Experiment 2 are reversed in Experiment 4. In both experiments, control primes (P3) were kept constant. One trial set of sentences used in Experiment 4 are presented in (1), as an example.

(1) (Experiment 2)

T The kid smeared mom's lipstick on her face.

P1 The New Yorker spread a toasted bagel with cream cheese.

P2 The freight driver loaded the huge truck with lots of boxes.

P3 The congressman decided to run for the next election.

(Experiment 4)

T The kid smeared her face with mom's lipstick.

P1 The New Yorker spread cream cheese on a toasted bagel.

P2 The freight driver loaded lots of boxes on the huge truck.

P3 The congressman decided to run for the next election.

(2) T The abstract artist spattered acrylic paint on the black wall.

P1 The reckless driver splashed the pedestrians with dirty water.

P2 The muscle man tattooed his upper arm with his girlfriend's birthdate.

P3 The students were looking forward to a summer break.

(3) T The baker sprinkled powdered sugar on the fruitcake.

P1 The art restorer sprayed the oil painting with preservative solution.

P2 The head nurse draped the patient's stomach with a sterile sheet.

P3 The girl acted very weird as if she came from Mars.

(4) T The waitress piled empty plates on the kitchen counter.

P1 The bookworm stacked the mantelpiece with new books.

P2 The sonographer squirted the woman's belly with lubricating gel.

P3 The mega store will open before the Christmas season.

(5) T The waitress piled empty plates on the kitchen counter.

P1 The bookworm stacked the mantelpiece with new books.

P2 The sonographer squirted the woman's belly with lubricating gel.

P3 The mega store will open before the Christmas season.

(6)	T	The adventurer crammed camping gear into his old SVU.
	P1	The housewife stuffed the large turkey with chopped meat.
	P2	The farmer seeded the entire field with winter crops.
	P3	The firefighters worked on extinguishing the fire after the plane crashed.
(7)	T	The adventurer crammed camping gear into his old SVU.
	P1	The housewife stuffed the large turkey with chopped meat.
	P2	The farmer seeded the entire field with winter crops.
	P3	The firefighters worked on extinguishing the fire after the plane crashed.
(8)	T	The careful boy marked his last name on all his belongings.
	P1	The rancher branded the baby cows with the ranch's symbol.
	P2	The carpenter stocked his old shelves with brand new chisels.
	P3	The collector auctioned off his entire collection last Sunday.
(9)	T	The careful boy marked his last name on all his belongings.
	P1	The rancher branded the baby cows with the ranch's symbol.
	P2	The carpenter stocked his old shelves with brand new chisels.
	P3	The collector auctioned off his entire collection last Sunday.
(10)	T	The chef brushed soy sauce onto the fish fillets.
	P1	The skin therapist rubbed the dry area with soothing oil.
	P2	The killer injected the victim with a Russian poison.
	P3	The city is known as one of the most bike-friendly cities.
(11)	T	The wedding guests showered the confetti on the bride.
	P1	The cook drizzled the grill pan with some olive oil.
	P2	The child tracked the carpet with dirty snow.

	P3	The film was written and directed by Steven Spielberg.
(12)	T	The home owner sowed grass mixtures on bare spots.
	P1	The millionaire planted all roadsides with exotic trees.
	P2	The teenager smudged her eyelids with charcoal shadow.
	P3	The church was rebuilt in the current form in 1920.

APPENDIX B Verbs, Frequency, and Measures of Typicality & Similarity

B.1 Dative verbs

The following tables include 109 verbs that Levin (1993) listed as alternating between the Double Object and the Prepositional Object frame, i.e., the dative alternation. Thirteen verbs from Levin's original list (*schlep*, *tote*, *bus*, *truck*, *modem*, *netmail*, *satellite*, *semaphore*, *telecast*, *telex*, *wireless*, *bunt*, and *punt*) were dropped as they never occurred in either frame in my corpus collected from the British National Corpus. The tables also include Levin's verb class information, number of occurrences in either frame (DO and PO), values of verb typicality estimated by subtracting POs from DOs (w_{DO}, see Section 3.2.1.3 for details) and finally semantic similarity to the verb *give* estimated by Latent Semantic Analysis (LSA-*give*, based on the BNC, raw numbers (not residualized over frequency), see Section 3.2.2.1 for details). Verb classes are based on Levin (1993): B&T, Carry, Drive, FutHav, Give, Instrmt, Send, TrsMsg, and Throw stand for, respectively, *Bring&Take* class, *Carry* class, *Drive* class, *Future having class*, *Give* class, *Instrument of message* class, *Send* class, *Transfer of a message* class, and *Throw* class.

No	Verb	Verb class	DO	PO	w_{DO}	LSA-*give*
1	*GIVE*	Give	15311	8402	6909	1.0
2	*TAKE*	B&T	2044	5620	-3576	0.946
3	*BRING*	B&T	580	4927	-4347	0.891
4	*SEND*	Send	658	3134	-2476	0.765
5	*TELL*	TrsMsg	2702	339	2363	0.859
6	*PAY*	Give	712	1363	-651	0.555

No	Verb	Verb class	DO	PO	w_{DO}	LSA-*give*
7	*OFFER*	FutHav	752	1203	-451	0.681
8	*LEAVE*	FutHav	468	1390	-922	0.857
9	*SELL*	Give	190	1288	-1098	0.405
10	*OWE*	FutHav	227	856	-629	0.462
11	*SHOW*	TrsMsg	502	571	-69	0.697
12	*HAND*	Give	308	659	-351	0.759
13	*ASK*	TrsMsg	688	194	494	0.857
14	*LEND*	Give	177	677	-500	0.493
15	*PASS*	Give/Throw	32	619	-587	0.794
16	*CARRY*	Carry	0	615	-615	0.662
17	*EXTEND*	FutHav	2	541	-539	0.5
18	*DRIVE*	Drive	4	530	-526	0.686
19	*WRITE*	TrsMsg	96	257	-161	0.619
20	*PUSH*	Carry	0	344	-344	0.755
21	*GRANT*	FutHav	72	265	-193	0.448
22	*TEACH*	TrsMsg	172	100	72	0.464
23	*THROW*	Throw	25	222	-197	0.757
24	*ASSIGN*	FutHav	10	228	-218	0.294
25	*PULL*	Carry	0	231	-231	0.742
26	*AWARD*	FutHav	70	151	-81	0.269
27	*READ*	TrsMsg	24	157	-133	0.58
28	*ALLOCATE*	FutHav	6	172	-166	0.243
29	*ISSUE*	FutHav	4	171	-167	0.321
30	*DRAG*	Carry	0	158	-158	0.669
31	*FEED*	Give	52	96	-44	0.561
32	*FLY*	Drive	0	143	-143	0.512

No	Verb	Verb class	DO	PO	w_{DO}	LSA-*give*
33	*POSE*	TrsMsg	3	134	-131	0.454
34	*PROMISE*	FutHav	43	43	0	0.767
35	*SLIP*	Send	7	67	-60	0.695
36	*HAUL*	Carry	0	73	-73	0.445
37	*GUARANTEE*	FutHav	33	39	-6	0.385
38	*SHIP*	Send	0	69	-69	0.266
39	*TOSS*	Throw	6	63	-57	0.607
40	*SERVE*	Give	12	52	-40	0.553
41	*POST*	Send	1	55	-54	0.428
42	*RENDER*	Give	12	43	-31	0.42
43	*SLIDE*	Send	4	50	-46	0.597
44	*ADVANCE*	FutHav	5	48	-43	0.398
45	*CONCEDE*	FutHav	1	52	-51	0.548
46	*SIGN*	Instrmt	1	50	-49	0.388
47	*YIELD*	FutHav	2	47	-45	0.358
48	*LEASE*	Give	0	49	-49	0.162
49	*RELAY*	TrsMsg/Instr	0	49	-49	0.395
50	*FERRY*	Drive	0	48	-48	0.248
51	*FLING*	Throw	7	38	-31	0.635
52	*ROLL*	Send	0	43	-43	0.661
53	*SHOOT*	Throw	13	27	-14	0.537
54	*QUOTE*	TrsMsg	2	37	-35	0.391
55	*HIT*	Throw	2	36	-34	0.603
56	*BEQUEATH*	FutHav	2	34	-32	0.278
57	*FORWARD*	Send	1	34	-33	0.216
58	*CEDE*	FutHav	0	33	-33	0.198

No	Verb	Verb class	DO	PO	w_{DO}	LSA-*give*
59	*TIP*	Throw	1	30	-29	0.615
60	*KICK*	Carry/Throw	1	27	-26	0.591
61	*ALLOT*	FutHav	4	24	-20	0.331
62	*VOTE*	FutHav	15	12	3	0.271
63	*REPAY*	Give	4	21	-17	0.233
64	*FLICK*	Throw	8	17	-9	0.57
65	*RENT*	Give	2	21	-19	0.33
66	*LOAN*	Give	12	11	1	0.19
67	*HOIST*	Carry	0	22	-22	0.508
68	*HEAVE*	Carry	0	18	-18	0.517
69	*SHOVE*	Carry/Throw	0	15	-15	0.491
70	*HURL*	Throw	0	14	-14	0.448
71	*MAIL*	Send	3	10	-7	0.162
72	*FLIP*	Throw	0	12	-12	0.414
73	*PREACH*	TrsMsg	1	11	-10	0.284
74	*TUG*	Carry	0	11	-11	0.516
75	*REFUND*	Give	0	11	-11	0.071
76	*SIGNAL*	Instrmt	0	11	-11	0.09
77	*CITE*	TrsMsg	0	11	-11	0.278
78	*PEDDLE*	Give	0	10	-10	0.235
79	*FAX*	Instrmt	2	8	-6	0.271
80	*PITCH*	Throw	0	10	-10	0.437
81	*WILL*	FutHav	1	8	-7	0.501
82	*TELEPHONE*	Instrmt	0	9	-9	0.507
83	*WHEEL*	Drive	0	8	-8	0.495
84	*CART*	Drive	0	8	-8	0.197

No	Verb	Verb class	DO	PO	w_{DO}	LSA-*give*
85	*SMUGGLE*	Send	0	8	-8	0.367
86	*FLOAT*	Send	0	8	-8	0.607
87	*CATAPULT*	Throw	0	8	-8	0.288
88	*TOW*	Carry	0	6	-6	0.231
89	*WIRE*	Drive/Instrmt	0	6	-6	0.238
90	*SLAM*	Throw	0	6	-6	0.552
91	*ROW*	Drive	0	5	-5	0.322
92	*PHONE*	Instrmt	0	5	-5	0.455
93	*LOB*	Throw	1	4	-3	0.212
94	*LUG*	Carry	0	4	-4	0.375
95	*TRADE*	Give	0	4	-4	0.141
96	*BOUNCE*	Send	0	4	-4	0.542
97	*CHUCK*	Throw	1	3	-2	0.315
98	*TELEGRAPH*	Instrmt	0	3	-3	0.279
99	*SHUTTLE*	Drive	0	2	-2	0.243
100	*RADIO*	Instrmt	0	2	-2	0.22
101	*SLING*	Throw	0	2	-2	0.503
102	*HEFT*	Carry	0	1	-1	0.099
103	*BARGE*	Drive	0	1	-1	0.431
104	*CABLE*	Instrmt	0	1	-1	0.249
105	*E-MAIL*	Instrmt	1	0	1	0.325
106	*SNEAK*	Send	0	1	-1	0.514
107	*BASH*	Throw	0	1	-1	0.348
108	*SLAP*	Throw	0	1	-1	0.581
109	*BAT*	Throw	0	1	-1	0.127

B.2 Locative verbs

The following tables list 45 verbs known to alternate between the Ground Object and the Figure Object frames and studied in Chapter 3. The tables also show the verbs' number of occurrences in either frame (GO and FO), values of verb typicality estimated by subtracting FOs from GOs (w_{GO}, see (3.2) and (3.3) in Section 3.2.1.3 for discussion) and finally three values of semantic similarity used in Section 3.3.2, i.e., similarity to the verb *rub*, to the verb *stick*, and to the verb *shower* estimated by Latent Semantic Analysis (based on the BNC, raw numbers (not residualized over frequency), measured using past forms, see Section 3.2.2.1 for discussion).

No	Verb	GO	FO	w_{GO}	LSA-*rub*	LSA-*stick*	LSA-*shower*
1	*RUB*	92	231	-139	1	0.548	0.422
2	*WRAP*	67	98	-31	0.727	0.66	0.55
3	*STICK*	0	154	-154	0.548	1	0.442
4	*SPREAD*	8	127	-119	0.435	0.451	0.393
5	*INJECT*	27	83	-56	0.13	0.158	0.084
6	*STUFF*	19	79	-60	0.575	0.686	0.477
7	*BRUSH*	31	63	-32	0.711	0.49	0.644
8	*PLANT*	1	78	-77	0.185	0.228	0.213
9	*MARK*	39	39	0	0.233	0.308	0.231
10	*SPRAY*	43	27	16	0.371	0.398	0.265
11	*PACK*	14	46	-32	0.45	0.653	0.485
12	*SPRINKLE*	13	45	-32	0.48	0.33	0.286
13	*SCATTER*	2	46	-44	0.426	0.391	0.377
14	*SPLASH*	14	33	-19	0.711	0.531	0.503

No	Verb	GO	FO	w_{GO}	LSA-*rub*	LSA-*stick*	LSA-*shower*
15	*SHOWER*	34	12	22	0.422	0.442	1
16	*LOAD*	16	21	-5	0.311	0.447	0.288
17	*DAB*	16	15	1	0.597	0.43	0.421
18	*SMEAR*	12	16	-4	0.588	0.447	0.309
19	*DRAPE*	3	24	-21	0.556	0.461	0.513
20	*SQUIRT*	2	25	-23	0.361	0.309	0.236
21	*CRAM*	1	24	-23	0.499	0.549	0.409
22	*PILE*	3	14	-11	0.623	0.586	0.521
23	*SOW*	0	14	-14	0.121	0.182	0.244
24	*PLASTER*	9	5	4	0.39	0.435	0.388
25	*STREW*	1	12	-11	0.536	0.466	0.499
26	*JAM*	1	9	-8	0.486	0.578	0.467
27	*STACK*	0	9	-9	0.507	0.557	0.399
28	*DUST*	3	5	-2	0.247	0.266	0.221
29	*STOCK*	7	0	7	0.19	0.273	0.183
30	*ETCH*	0	7	-7	0.344	0.233	0.26
31	*STRING*	0	6	-6	0.364	0.425	0.362
32	*SPATTER*	3	2	1	0.586	0.455	0.37
33	*STREAK*	3	2	1	0.511	0.365	0.45
34	*SWAB*	3	1	2	0.352	0.23	0.158
35	*SPLATTER*	2	2	0	0.451	0.497	0.355
36	*ENGRAVE*	0	3	-3	0.209	0.173	0.2
37	*SEED*	2	1	1	0.069	0.081	0.064
38	*DRIZZLE*	0	2	-2	0.017	-0.001	0.004
39	*TATTOO*	1	1	0	0.287	0.242	0.183
40	*SMUDGE*	0	1	-1	0.453	0.377	0.359

No	Verb	GO	FO	w_{GO}	LSA-*rub*	LSA-*stick*	LSA-*shower*
41	*BRAND*	1	0	1	0.179	0.189	0.173
42	*POWDER*	1	0	1	0.361	0.296	0.22
43	*SLATHER*	0	0	0	0.336	0.256	0.279
44	*TRACK*	0	0	0	0.358	0.394	0.431
45	*VACCINATE*	0	0	0	0.051	0.035	0.05

REFERENCES

Anderson, J. R. (1993). Problem solving and learning. *American Psychologist*, *48*, 35-44

Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S., Lebiere, C., & Qin, Y. (2004). An integrated theory of the mind. *Psychological Review*, *111*, 1036-1060.

Arai, M., van Gompel, R. P. G., & Scheepers, C. (2007). Priming ditransitive structures in comprehension. *Cognitive Psychology*, *54*, 218-250.

Bock, J. K. (1986). Syntactic persistence in language production. *Cognitive Psychology, 18*, 355–387.

Bock, J. K., & Griffin, Z. M. (2000). The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology: General*, *129*, 177-192.

Bock, J. K., Dell, G. S., Chang, F., & Onishi, K. H. (2007). Persistent structural priming from language comprehension to language production. *Cognition, 104*, 437-458.

Bock, J. K., & Loebell, H. (1990). Framing sentences. *Cognition*, *35*, 1-39.

Bod, R. (1992). A computational model of language performance: Data Oriented Parsing. In C. Boitet (Ed.), *Proceedings of the 14th International Conference on Computational Linguistics (COLING-92), Volumn 3* (pp. 855-859). Association for Computational Linguistics

Bod, R. (2006). Exemplar-based syntax: how to get productivity from examples. *The Linguistic Review*, *23*, 291-320.

Branigan, H. P., Pickering, M. J., Liversedge, S. P., Stewart, A. J., & Urbach, S. P. (1995). Syntactic priming: investigating the mental representation of language. *Journal of Psycholinguistic Research*, *24,* 489-506.

Bresnan, J. (1978). A realistic transformational grammar. In M. Halle, J. Bresnan & G. A. Miller (Eds.), *Linguistic Theory and Psychological Reality* (pp. 1–59). MIT Press.

Bresnan, J., Cueni, A., Nikitina, T. & Baayen, R. H. (2007). Predicting the dative alternation. In G. Boume, I. Kraemer & J. Zwarts (Eds.), *Cognitive foundations of interpretation* (pp. 69-94). Royal Netherlands Academy of Science.

Bybee, J. (2006). From usage to grammar: the mind's response to repetition. *Language, 82*, 711-733.

Bybee, J. (2013). Usage-based theory and exemplar representations of constructions. In T. Hoffmann & G. Trousdale (Eds.), *The Oxford handbook of Construction Grammar* (pp. 49-69). Oxford University Press.

Bybee, J. (2007). Diachronic linguistics. In D. Geeraerts & H. Cuyckens (Eds.), *The Oxford handbook of Cognitive Linguistics* (pp. 945-987). Oxford University Press.

Chang, F., Bock, K., & Goldberg, A. E. (2003). Can thematic roles leave traces of their places? *Cognition, 90*, 29-49.

Chang, F., Dell, G. S., & Bock, K. (2006). Becoming syntactic. *Psychological Review, 113*, 234-272.

Charniak, E. (1997). Statistical Parsing with a Context-Free Grammar and Word Statistics. In K. Ford (Ed.), *Proceedings of the Fourteenth National Conference on Artificial Intelligence and Ninth Annual Conference on Innovative Applications of Artificial Intelligence* (*AAAI-97)* (pp. 598-603). American Association for Artificial Intelligence.

Chomsky, N. (1965). *Aspects of the theory of syntax*. MIT Press.

Cleland, A. A., & Pickering, M. J. (2003). The use of lexical and syntactic information in language production: Evidence from the priming of noun-phrase structure. *Journal of Memory and Language*, *49*, 214-230.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, *82*, 407-428.

Collins, P. (1995). The indirect object construction in English: an informational approach. *Linguistics*, *33*, 35-49.

Diessel, H. (2007). Frequency effects in language acquisition, language use, and diachronic change. *New Ideas in Psychology, 25*, 108-127.

Ellis, N. C., & Ferreira-Junior, F. (2009). Constructions and their acquisition: Islands and he distinctiveness of their occupancy. *Annual Review of Cognitive Linguistics*, *7*, 187-220.

Ferreira, V. S., & Bock, K. (2006). The functions of structural priming. *Language and Cognitive Processes*, *21*, 1011-1029.

Field, A., Miles, J., & Field, Z. (2012). *Discovering statistics using R*. SAGE Publications.

Fillmore, C. J. (1968). The case for case. In E. Bach & R. T. Harms (Eds.), *Universals in linguistic theory* (pp. 1-90). Holt, Rinehart & Winston.

Fillmore, C. J. (1988). The mechanisms of Construction Grammar. In A. Axmaker, A. Jaisser & H. Singmaster (Eds.), *Proceedings of the Fourteenth Annual Meeting of the Berkeley Linguistics Society (BLS14)* (pp. 35-55). Berkeley Linguistics Society.

Gentner, D. (1983). Structure-mapping: a theoretical framework for analogy. *Cognitive Science*, *7*, 155-170.

Goldberg, A. E. (1995). *Constructions: A construction grammar approach to argument structure*. Chicago: The University of Chicago Press

Goldberg, A. E. (1997). The relationships between verbs and constructions. In M. H. Verspoor, K. D. Lee & E. Sweetser (Eds.), *Lexical and syntactic constructions and the construction of meaning: Proceedings of the bi-annual ICLA meeting in Albuquerque, July 1995* (pp. 383-398). John Benjamins Publishing Company.

Goldberg, A. E., Casenhiser D. M., & Sethuraman, N. (2004). Learning argument structure generalizations. *Cognitive Linguistics, 15*, 289-316.

Goldberg, A. E. (2006). *Constructions at work: The nature of generalization in language*. Oxford University Press.

Goldberg, A. E., Casenhiser, D., & White, T. R. (2007). Constructions as categories of language. *New Ideas in Psychology*, *25*, 70-86.

Goldwater, M. B., Tomlinson, M. T., Echols, C. H., & Love, B. C. (2011). Structural priming as structure-mapping: children use analogies from previous utterances to guide sentence production. *Cognitive Science*, *35*, 156-170.

Green, G. (1974). *Semantics and syntactic regularity*. Bloomington: Indiana University Press.

Gries, S. Th. & Stefanowitsch, A. (2004). Extending collostructional analysis: A corpus-based perspective on 'alternations.' *International Journal of Corpus Linguistics*, *9*, 97-129.

Griffin, Z., M., & Weinstein-Tull, J. (2003). Conceptual structure modulates structural priming in the production of complex sentences. *Journal of Memory and Language*, *49*, 537-555.

Grimshaw, J. (1990). *Argument structure*. MIT Press.

Gropen, J., Pinker S., Hollander, M., Goldberg, R., & Wilson, R. (1989). The learnability and acquisition of the dative alternation in English. *Language, 65*, 203-257.

Gruber, G. (1965). *Studies in Lexical Relations.* Doctoral dissertation. MIT.

Hartsuiker, R. J., & Kolk, H. H. J. (1998). Syntactic persistence in Dutch. *Language and Speech*, *41*, 143-184.

Hartsuiker, R. J., Bernolet, S., Schoonbaert, S., Speybroeck, S., & Vanderelst, D. (2008). Syntactic priming persists while the lexical boost decays: Evidence from written and spoken dialogue. *Journal of Memory and Language*, *58*, 214-238.

Hawkins, J. A. (2011). Processing efficiency and complexity in typological patterns. In J. J. Song (Ed.), *The Oxford handbook of language typology* (pp. 206-226). Oxford University Press.

Hawkins, J. A. (1994). *A performance theory of order and constituency*. Cambridge University Press.

Hebb, D. O. (1949). *The organization of behavior*. Wiley & Sons.

Hintzman, D. L. (1986). "Schema abstraction" in a multiple-trace memory model. *Psychological Review, 93*, 411-428.

Jaeger, T. F. (2008). Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language*, *59*, 434-446.

Jaeger, T. F., & Snider, N. (2007). Implicit learning and syntactic persistence: Surprisal and cumulativity. In D. S. McNamara & J. G. Trafton (Eds.), *Proceedings of the 29th annual Cognitive Science Society Conference* (pp. 1061-1066). Cognitive Science Society.

Jaeger, T. F., & Snider, N. (2013). Alignment as a consequence of expectation adaptation: Syntactic priming is affected by the prime's prediction error given both prior and recent experience. *Cognition*, *127*, 57-83.

Katz, J. J., & Fodor, J. A. (1963). The structure of a semantic theory. *Language*, *39*, 170-210.

Kemmer, S., & Barlow, M. (2000). Introduction: A usage-based conception of language. In M. Barlow & S. Kemmer (Eds.), *Usage-based models of language* (pp. vii-xxii). CSLI Publications.

Kiparsky, P. (1968). Linguistic Universals and Linguistic Change. In E. Bach & R. Harms (Eds.), *Universals in Linguistic Theory* (pp. 170-202). Holt, Rinehart & Winston.

Koenig, J.-P., & Davis, A. R. (2001). Sublexical modality and the structure of lexical semantic representations. *Linguistics and Philosophy*, *24*, 71-124.

Koenig, J.-P., & Davis, A. R. (2006). The KEY to lexical semantic representations. *Journal of Linguistics*, *42*, 71-108.

Komatsu, L. K. (1992). Recent views of conceptual structure. *Psychological Bulletin*, *112*, 500-526.

Konopka, A. E., & Bock, K. (2009). Lexical or syntactic control of sentence formulation? Structural generalizations from idiom production. *Cognitive Psychology*, *58*, 68-101.

Krug, M. G. (2000). *Emerging English modals: A corpus-based study of grammaticalization*. Mouton de Gruyter.

Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The Latent Semantic Analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review*, *104*, 211-240.

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). An introduction to Latent Semantic Analysis. *Discourse Processes, 25*, 259-284.

Landauer, T. K., McNamara, D. S., Dennis, S., & Kintsch, W. (2007). *Handbook of Latent Semantic Analysis*. Lawrence Erlbaum Associates, Inc.

Langacker, R. (1987). *Foundations of Cognitive Grammar: Theoretical prerequisites*. Stanford University Press.

Lakoff, G. (1965). *On the nature of syntactic irregularity*. Doctoral dissertation. Indiana University.

Lakoff, R. (1968). *Abstract syntax and Latin complementation*. MIT press.

Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. MIT Press.

Levin, B. (1993). *English verb classes and alternations: A preliminary investigation*. Chicago: University of Chicago Press.

Lombardi, L., & Potter, M. C. (1992). The regeneration of syntax in short term memory. *Journal of Memory and Language*, *31*, 713-733.

Malhotra, G. (2009). *Dynamics of structural priming*. Doctoral dissertation. University of Edinburgh.

McCawley, J. D. (1968). The role of semantics in a grammar. In E. Bach & R. Harms (Eds.), *Universals in linguistic theory* (pp. 124-169). Holt, Rinehart & Winston.

McRae, K. & Boisvert, S. (1998). Automatic semantic similarity priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*, 558-572.

Medin, D. L. (1989). Concepts and conceptual structure. *American Psychologist, 44*, 1469-1481.

Medin, D. L., & Schaffer, M. M. (1978). Context theory of classification learning. *Psychological Review, 85*, 207-238.

Medin, D. L., & Edelson, S. M. (1988). Problem structure and the use of base-rate information from experience. *Journal of Experimental Psychology: General, 117*, 68-85.

Melinger, A., & Dobel, C. (2005). Lexically-driven syntactic priming. *Cognition*, *98*, B11-B20.

Nosofsky, R. M. (1988). Similarity, frequency, and category representations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 54-65.

Oehrle, R. T. (1976). *The grammatical status of the English dative alternation*. Doctoral dissertation. MIT.

Pickering, M. J., & Branigan, H. P. (1998). The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and Language*, *39*, 633-651.

Pickering, M. J., & Branigan, H. P. (1999). Syntactic priming in language production. *Trends in Cognitive Sciences*, *3*, 136-141.

Pickering, M. J., & Ferreira, V. S. (2008). Structural priming: a critical review. *Psychological Bulletin*, *134*, 427-459.

Pinker, S. (1989). *Learnability and cognition: The acquisition of argument structure*. MIT Press.

Pollard, C., & Sag, I. A. (1994). *Head-drive Phrase Structure Grammar*. The University of Chicago Press.

Potter, M. C., & Lombardi, L. (1990). Regeneration in the short-term recall of sentences. *Journal of Memory and Language*, *29*, 633-654.

Potter, M., & Lombardi, L. (1998). Syntactic priming in immediate recall of sentences. *Journal of Memory and Language*, *38*, 265–282.

Ramchand, G. C. (2008). *Verb meaning and the lexicon*. Cambridge University Press.

Rappaport Hovav, M., & Levin, B. (1988). What to do with theta-roles? *Syntax and Semantics*, *21*, 7-36.

Rappaport Hovav, M., & Levin, B. (2008). The English dative alternation: The case for verb sensitivity. *Journal of Linguistics*, *44*, 129-167.

Reitter, D., Keller, F., & Moore, J. D. (2011). A computational cognitive model of syntactic priming. *Cognitive Science*, *35*, 587-637.

Resnik, P. S. (1993). *Selection and information: A class-based approach to lexical relationships*. Doctoral dissertation. University of Pennsylvania.

Resnik, P., & Diab, M. (2000). Measuring verb similarity. In L. R. Gleitman & A. K. Joshi (Eds.), *Proceedings of the 22nd Annual Conference of the Cognitive Science Society* (pp. 399-404). Cognitive Science Society.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition*, *42*, 107-142.

Roelofs, A. (1993). Testing a non-decompositional theory of lemma retrieval in speaking: Retrieval of verbs. *Cognition*, *47*, 59-87.

Rosch, E. (1978). Principles of categorization. In E. Roach, & B. B. Lloyd (Eds.), *Cognition and categorization* (pp. 27-48). Lawrence Erlbaum Associates.

Roland, D., Dick, F., & Elman, J. L. (2007). Frequency of basic English grammatical structure: A corpus analysis. *Journal of Memory and Language, 57*, 348-379.

Schmid, H.-J.,& Küchenhoff, H. (2013). Collostructional analysis and other ways of measuring lexicogrammatical attraction: Theoretical premises, practical problems and cognitive underpinnings. *Cognitive Linguistics*, *24*, 531-577.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, *96*, 523-568.

Snider, N. (2008). *An exemplar model of syntactic priming*. Doctoral dissertation. Stanford University.

Steedman, M. (1999). Connectionist sentence processing in perspective. *Cognitive Science*, *23*, 615–634.

Tomasello, M. (1992). *First verbs: A case study of early grammatical development*. Cambridge University Press.

Tomasello, M. (2003). *Constructing a language: A usage-based theory of language acquisition.* Harvard University Press.

Thompson, S. A. (1990). Information flow and dative shift in English discourse. In J. A. Edmondson, C. Feagin & P. Mühlhäusler (Eds.), *Development and diversity: Language variation across time and space: a festschrift for Charles-James N. Bailey* (pp. 239–253). Summer Institute of Linguistics.

Tooley, K. M., & Traxler, M. J. (2010). Syntactic priming effects in comprehension: A critical review. *Language and Linguistics Compass*, *4*, 925-937.

Trueswell, J. C. (1996). The role of lexical frequency in syntactic ambiguity resolution. *Journal of Memory and Language, 35*, 566-585.

Trueswell, J. C., & Kim, A. E. (1998). How to prune a garden path by nipping it in the bud: fast priming of verb argument structure. *Journal of Memory and Language*, *39*, 102-123.

Tversky, A. (1977). Features of similarity. *Psychological Review*, *84*, 327-352.

Walsh, M., Möbius, B., Wade, T., & Schütze, H. (2010). Multilevel Exemplar Theory. *Cognitive Science*, *34*, 537-582.

Wasow, T. (2002). *Postverbal behavior*. CSLI Publications.

Yi, E., & Koenig, J.-P. (to appear). Why verb meaning matters to syntax. In J. Fleischhauer, A. Latrouite & R. Osswald (Eds.), *Exploring the Syntax-Semantics-Pragmatics Interface*. Düsseldorf University Press.