Transfer Verbs vs. Transfer Constructions: How Verb-Construction Interactions Modulate Motor Simulation Effects in English[1]

Prior studies suggest that language users perform motoric simulations when construing action sentences, and that verbs and constructions each contribute to simulation-based representation (Glenberg & Kaschak 2002, Richardson et al. 2003, Bergen et al. 2007, Bergen & Wheeler 2010). These findings raise the possibility that motorically grounded verb and construction meanings can interact during sentence understanding. In this experiment, we use the action-sentence compatibility effect methodology to investigate how a verb's lexical-class membership, constructional context and constructional bias modulate motor simulation effects. Stimuli represent two classes of transfer verbs and two constructions that encode transfer events, Ditransitive and Oblique Goal (Goldberg 1995). Findings reveal two kinds of verb-construction interactions. First, verbs in their preferred construction generate stronger simulation effects overall than those in their dispreferred construction. Second, verbs that entail change of possession generate strong motor-simulation effects irrespective of constructional context, while those entailing causation of motion exert such effects only when enriched up to change-of-possession verbs in the semantically mismatched Ditransitive context. We conclude that simulation effects are not isolable to either verbs or constructions but instead arise from the interplay of verb meaning and construction meaning.

Keywords: simulation semantics; action-sentence compatibility effect; lexical class; construction grammar; verb frequency; English dative alternation

1. Introduction

What do we, as language users, know about verbs? An emerging consensus is that verbs have rich, variegated representations: we know something about a verb's usage history, we know something about a verb's semantic neighbors and the idealized scene that it encapsulates (Fillmore et al. 2004), and we know something about a verb's combinatoric potential—the syntactic patterns with which it combines (Gahl & Garnsey 2006, Goldberg 2006). Usage frequency, syntactic behavior, and lexical class are cornerstones of lexical description efforts (Bybee 2001, Bybee 2010, Goldberg 1995, Goldberg 2006, Levin 1993), but they have typically been overlooked in psycholinguistic experimentation, particularly within simulation semantics (see, e.g., Barsalou 1999; Glenberg & Kaschak 2002; Richardson et al. 2003). In simulation semantics experiments, stimuli are typically generated from a norming study in which a group of participants makes semantic judgments about a series of words or phrases, e.g., ***Does this verb convey manual motion toward the body, away from the body, or neither?*** (Bergen & Wheeler 2010). Semantic analysis is by consensus: those words or phrases that are most widely viewed as having a specific target meaning are then used in the larger study. This practice creates ***ad hoc*** verb classes that may or may not align with lexical classes used in linguistic

[1] We gratefully acknowledge the insights and advice we received from Bhuvana Narasimhan, Rebecca Scarborough and Adele Goldberg. None of these scholars should be held responsible for mistakes herein.

descriptions. It also isolates each verb from its usage history, its contexts of occurrence and its semantic neighbors.

In this experiment, we demonstrate that semantic representations extrinsic to individual lexemes significantly modulate motor simulation results. First, we show that two previously identified motion-verb classes interact with the two constructions participating in the English dative opposition (the Ditransitive construction and the Oblique Goal construction), with the result that in some situations, simulation effects are driven by lexical class semantics (irrespective of the construction being presented to participants), while in other situations, constructional semantics (and not lexical class semantics) appear to be driving the simulation effects observed. The lexical classes in question, originally identified by Rappaport Hovav & Levin 2008, are composed of verbs having distinct entailments despite their apparently identical syntactic properties. Second, we demonstrate that the constructional biases of those verbs that participate in the dative opposition significantly predict the strength of simulation effects observed: verbs appearing in a preferred construction generate stronger motor facilitation and interference effects than verbs appearing in a dispreferred construction.

From these findings we draw several conclusions. Chief among them is that lexical simulation effects are modulated by lexical-class membership and usage frequency. We also conclude that lexical and constructional meanings have distinct but interacting effects on simulation. In addition, we validate Barsalou's (1999) claim that "connections [that are] processed repeatedly become stronger" (p. 591): we find that more entrenched predication patterns (instances in which a verb appears in its 'preferred' construction) generate stronger simulation effects than less entrenched predication patterns. Finally, we apply these findings to what Zwaan (2014) calls the 'secondary scaling problem' of simulation-based theories of representation: such theories cannot account for abstract (non-grounded) representations. We demonstrate that abstract forms of semantic representation (in particular, lexical-class affiliation and construction meaning) can be linked to differences in measured motor simulation effects as members of higher-order (two-way and three-way) statistical interactions.

Ultimately, we suggest that two different kinds of concord (or 'match') conditions matter when we attempt to determine whether meaning construction will involve mental simulation. First, we recognize a gradient notion of concord, ***frequency-based concord***: a verb appearing in the syntactic frame in which it most typically appears. A simple example is a highly transitive verb like ***kick*** appearing in an active voice sentence as opposed to a passive one (Gahl et al. 2003). Second, we recognize a categorical notion of concord, ***lexical-semantic concord***: a match between the semantic roles assigned by the verb and those assigned by the construction. For example, the three-argument verb ***put*** matches the argument structure of the Caused Motion construction in sentences like ***She put the glass on the counter*** but the two-argument directed-motion verb ***swim*** does not, and must be augmented up to a trivalent verb of caused motion in order to serve in this frame, as in, e.g., ***The kids swam the logs upstream*** (Goldberg 1995, Rappaport Hovav & Levin 1998).[2] Augmentation in this instance involves the addition of a theme argument, supplied by the Caused Motion construction's semantics. Particularly

[2] Our notion of semantic-role mismatch involves the ***type*** of roles assigned, respectively, by verb and construction rather than the ***number*** of roles (valence). As noted, a semantic-role mismatch can but need not involve a valence mismatch.

relevant for our purposes are verb-construction interactions involving the two trivalent constructions targeted by this study: the 'double object' construction, as in ***She gave me a compass***, and the '***to***-dative' construction, as in ***She gave gifts to her friends***. The verb ***give*** matches both of these syntactic contexts: it has three semantic roles (agent, theme and recipient), each of which instantiates a role of the construction. To illustrate, let us focus on the recipient role of the verb, which can be encoded in two different ways: as direct object (in the 'double object' construction) and as preposition phrase (in the '***to***-dative' construction). The recipient argument of the verb ***give*** is identical to the recipient argument of the 'double object' construction, while it is a subtype of the '***to***-dative' construction's role ***goal*** (we view a recipient as a goal that happens to be a volitional human). Let us contrast this situation with that of the trivalent verb ***kick***, as in ***She kicked the ball to the step***. The verb ***kick*** matches only the '***to***-dative': its three semantic roles (agent, theme, goal) map to the respective roles of the '***to***-dative' construction. When it combines with the 'double object' construction, however, the verb ***kick*** must adapt to the context: its goal argument must be construed as a recipient. Note that the sentence ??***She kicked the step the ball*** is acceptable only inasmuch as the step is interpreted as a potential possessor of the ball. In such cases we say that that the verb ***kick*** has been reinterpreted as a 'change of ownership' verb. We will suggest that such 'constructional override' effects can strengthen the simulation effects that the verb would trigger outside of the relevant context.

In Section 2, we discuss the theoretical and methodological foundations of this study. In Section 3, we enumerate the major predictions of this study, after which we describe the methods used in this study (Section 4). In Section 5, we report the results of the study, followed by an extended discussion (Section 6). Lastly, we offer concluding remarks in Section 7.

2. Theoretical and Methodological Background

In this section, we discuss both our approach to verb-construction interaction and the method used to examine effects of constructional context. In the first subsection (2.1), we describe the constructional opposition that we will investigate here (the English dative opposition), verbal constructional bias, and Rappaport Hovav and Levin's (2008) lexical classes. In the following subsection (2.2), we discuss the motor simulation methodology to be used in this experiment, and how this particular instantiation of the paradigm relates to prior art.

2.1 The Dative Opposition, Verb Classes, and Syntactic Preference

A dative 'alternation' is posited for English based on the observation that speakers can use either of two distinct syntactic patterns to express the semantic roles assigned by verbs of transfer like ***give***, ***send***, and ***mail***. There are three such roles: agent, theme, and recipient. We will refer to the two options for syntactic encoding as the ***ditransitive construction*** (DC) and the ***oblique goal construction*** (OGC). In the active voice, the DC links agent to subject, recipient to object and theme to a 'secondary' object (referred to by Fillmore and Kay (1995) as a ***nominal oblique*** argument). The following sentence exemplifies this pattern:

(1) Lisa gave Pongo the treat.

In the active-voice version of the OGC, agent again appears as subject, but the theme argument appears as object and the recipient as an oblique (prepositionally marked) argument:

(2) Lisa gave the treat to Pongo.

The DC and OGC are often described as participating in the English dative 'alternation' (see, e.g., Pinker 1989). A typical implementation of this idea views the DC as the output of either a lexical rule or syntactic transformation whose input is the OGC pattern. For example, Gropen et al. (1989) propose a semantically based lexical rule whereby the componential semantic representation of an input transfer verb is converted from 'x cause y to go to z' to 'x cause z to have y', ensuring, via general linking principles, that in the former case the theme argument is linked to the grammatical function direct object (thus yielding oblique-goal syntax), and in the latter case that the recipient is linked to direct object (thus yielding ditransitive syntax). Goldberg (1995) suggests that this view is untenable, in part because the necessary input forms are lacking in some cases. She observes:

> [A]pproaches that rely on transformations … posit an often unwarranted asymmetry between two constructions that are thought to be related. In the case of the ditransitive, ***He gave the book to her*** is usually supposed to be more basic than ***He gave her the book*** … A typical reason given is that the verbs which allow ditransitives are a proper subset of those that allow prepositional paraphrases. However, this is not actually so: ***refuse*** and ***deny*** do not have paraphrases with ***to*** or ***for***, and neither do many metaphorical expressions. (Goldberg 1995: 106)

Thus, we see the following grammaticality contrasts, in which the ditransitive pattern is acceptable while putative 'input,' the oblique-goal pattern, is not:

(3) The manager denied the employee a raise.
(4) ??The manager denied a raise to the employee.

(5) The noise gave my mother a headache.
(6) *The noise gave a headache to my mother.

In an alternative implementation of the lexical rule idea, neither pattern is derived from the other; rather, we assume that verbs within a given lexical class (say, transfer verbs) are underspecified with regard to the syntactic expression of their semantic roles (Bresnan 1994) and thus subject to competing linking principles (among them, the default principle that requires a theme argument to link to direct object). Both the transformational model and the underspecification models share an assumption that Michaelis and Ruppenhofer (2001) refer to as ***conservation of thematic structure***. According to this assumption, linking rules change the syntactic expression of the verb's argument roles, but do not add or subtract semantic participant roles from those assigned by the verb. The conservation assumption cannot be maintained in the case of the dative alternation, as shown by ditransitive examples like (7-8):

(7) Aunt Ruby knitted her a pillow.
(8) Fred tossed me the ball.

Neither the creation verb ***knit*** nor the ballistic-motion verb ***toss*** can be said to select for a recipient role on the basis of their lexical meanings, and yet each appears with a recipient argument in (7-8). Where does this recipient argument come from if not from verb meaning? Goldberg (1995) argues that it comes from the DC, which she considers to be a conventionalized pairing of form (the skeletal pattern V-NP-NP) with a coarse-grained event structure, 'X causes Y to have Z'.[3] Such constructions, which Goldberg refers to as ***argument-structure constructions***, have their own semantic-role sets, which can differ from the role sets assigned by verbs. In such cases, as in (7-8), the construction 'overwrites' the verb's array of semantics roles so that it matches that of the construction. In sum, syntactic patterns like the DC do not merely regulate the syntactic expression of arguments; they are meaningful patterns that can make semantic contributions to the clause that is not traceable to its main verb. Thus, when we consider the dative alternation, it should be borne in mind that we are discussing a choice between nearly synonymous constructions, rather than, say, a transformational relationship or lexical rule.

What factors drive the language user to select one construction or the other to convey a particular message about a transfer event? This question has been widely debated. On one side of this debate, many scholars posit that the choice is driven by discourse-pragmatic factors, in particular the relative discourse statuses of recipient and theme arguments (see, e.g., Erteschik-Shir 1979, Givón 1984, Thompson 1995, Wasow 2002, Ruppenhofer 2004). On the other side of this debate are scholars who propose that lexical-semantic entailments, often represented via decomposed semantic structure, condition the use of one form over the other (see, e.g., Mazurkewich and White 1980, Pinker 1989, Jackendoff 1990, Groefsema 2001, Levin 2008, Rappaport Hovav & Levin 2008). It would appear that neither side has entertained a sufficiently complex array of predictive factors. Probabilistic models of the type described by Bresnan et al. 2007 suggest that the choice of dative construction is influenced by a complex array of factors—lexical-semantic, referential, prosodic and discourse-pragmatic. We adopt this assumption. Crucially, we also assume that the relevant constructions do not merely encode thematic structure but also on occasion contribute thematic structure: as presumed by Goldberg (1995), constructional meaning serves to enrich (or alter) the

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[3] The semantic analysis of the DC offered here does not follow Goldberg (1995) in all details. Goldberg treats the DC as a polysemous construction, based on the fact that certain senses of the construction (e.g., the 'future giving' sense illustrated by ***She promised him a car***) lack the entailment of successful transfer (a person who promises to provide a car may later fail to do so). The semantic representation that we offer here is that associated with the 'core' sense of the DC. We assume here that a prototype-based analysis is not in fact necessary: it is feasible to assume a monosemic analysis of the DC, in which verb meaning determines whether successful transfer is entailed by any given sentence that instantiates the DC. On this monosemic analysis, sentences like ***I made/promised/bequeathed her a painting***, etc. entail only ***intent*** to transfer (rather than actual transfer) because their verbs do not denote acts of transfer.

frame-semantic representations of verbs, e.g., by augmenting the verb's array of participant roles.

For our purposes here, a crucial fact about the English dative alternation is that the various verbs that participate in it almost always 'prefer' one alternant over the other. For example, in a 2005 corpus study, Mukherjee found that the ratio of DC instantiations to OGC instantiations for the verb ***show*** was 3.58, whereas for ***send***, this same ratio was 0.97 (see Ruppenhofer (2004) for similar quantitative measures). In this study, this same ratio was calculated via corpus study for a range of verbs using the British National Corpus (a 100-million-word corpus of spoken and written British English distributed by Oxford University Computing Services on behalf of the BNC Consortium); these ratios will be provided below. More detailed counts for each verb are provided in Appendix C.

As noted above, verbal constructional preference is viewed in this experiment as a form of frequency, and expressing this preference as a ratio (rather than as a combination of raw scores) taps into a different form of frequency from that which raw scores would represent. For example, a verb with a ratio of 2:1 may be found in the corpus in a DC context a total number of 2 times or 200,000 times; indeed, the combined total of DC and OGC appearances in the BNC for the verbs used in this study ranges from less than 10 (***flip***, ***lob***) to over 40,000, for ***give***.[4] What concerns us here, however, is not how often a verb is used but, rather, ***where*** a verb is used—what construction speakers are more likely to pick in order to describe a transfer event using that verb. Thus, a transfer verb that has a ratio of 2:1 is encountered in the DC twice as often as in the OGC, while a different verb with a ratio of 1:2 is used twice as often in the OGC as in the DC.

Previous research in linguistic cognition has demonstrated that verbal constructional bias is a cue that speakers use to organize linguistic experience. Verbal syntactic preference is, for example, a cornerstone of interactive models of sentence comprehension and production. Garnsey et al. (1997) show that a verb's syntactic preference (in particular, where it is more apt to take a direct object or a clausal complement) influences the resolution of syntactic ambiguity in temporarily ambiguous structures in which clausal and nominal completions are equally sensible (e.g., ***The senator acknowledged the reporter…***). Similarly, using a plausibility judgment task, Gahl et al. (2003) show that lexical bias affects the comprehension difficulties experienced by aphasic subjects presented with undergoer-subject sentences. They find that sentences whose structure matches the lexical bias of the main verb are significantly easier to comprehend than sentences in which structure and lexical bias do not match. Additionally, Gahl and Garnsey (2004) find that verbal syntactic bias affects the syntactic structures that speakers anticipate hearing, thereby affecting certain aspects of pronunciation. Verbal syntactic bias also underpins functionally oriented models of language acquisition. For example, Goldberg (2006) reports prior research in which certain verbs were found to be highly predictive of certain syntactic environments in child-directed speech:

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[4] A post-hoc analysis without the two least frequent verbs (***flip*** (***n***=10) and ***lob*** (***n***=7) was conducted in order to verify that the low ***n***s used to calculate these ratios were not somehow skewing the data. Apart from the loss in statistical power resultant from removing one seventh of participant responses, removing these two items from the analysis did not appear to have a major effect. See Appendix C for more detail.

> [W]e found a strong tendency for there to be one verb occurring with very high frequency in comparison to other verbs used in each of the constructions analyzed. That is, the use of a particular construction is typically dominated by the use of that construction with one particular verb. For example, ***go*** accounts for a full 39 per cent of the uses of the intransitive motion construction in the speech of mothers addressing twenty-eight-month-olds in the Bates et al. (1988) corpus. (Goldberg 2006: 75)

Goldberg concludes that the predictive power of verb bias is the mechanism by which constructional meaning is extrapolated. For example, if in acquiring the DC, a child is predominantly exposed to instances of this construction wherein ***give*** is its main verb, then he or she will build an association between that particular syntactic configuration and the type of transfer entailed by the verb ***give***. After the child learns to generalize beyond that most prototypical verb-construction pairing, the residual meaning of that verb remains, with the result that even if a verb like ***head*** is used in the DC (as in ***I headed him the soccer ball***), a change of possession frame will still be invoked.

We postulate that verbal constructional bias should significantly predict simulation effects. Specifically, we posit that verbs of transfer appearing in their preferred construction will generate stronger motor simulation effects. Why should there be such an effect? We assume here that frequency-based concord has the effect it does because the representations associated with high-frequency linguistic collocations are more entrenched, and thus have stronger motor representations. According to this assumption, the verb ***show***, since it tends strongly to occur in the DC, will generate stronger motor simulation effects in the DC: ***show*** is a more predictable part of a DC predication than an OGC predication. A low predictability verb simply adds noise to a signal that might otherwise have been interpreted as a pattern of motor-simulation-based activation. Put differently, the less interpretive effort must be directed toward combining verb meaning and construction meaning, the more interpretive resources are available for simulation. This prediction builds upon recent research that has found that verbs and constructions can interact to produce significantly different processing patterns. Van Dam and Desai (2016) find that two different verb types (action verbs and abstract verbs) interact with two different constructional environments (intransitive and OGC) to significantly predict different patterns of neurological activation. Similarly, we believe that a verb's construction bias (its tendency to favor one particular construction type over another) and the construction in which it appears will interact to significantly predict different patterns of simulation-based neurological activation.

It is important to recognize that verb biases (like the complementation biases reported by Garnsey et al. 1997) may have many sources—including historical accident—although they are often ascribable to semantic factors like lexical-semantic concord. Thus, because the verb ***give*** entails change of possession, we might predict it to favor the DC, and because the verb ***send*** denotes caused motion (but doesn't entail successful transfer), we might predict it to favor the OGC. These predictions are borne out by the corpus analysis: ***give*** has a DC:OGC ratio of 2.98/1 and ***send*** has a DC:OGC ratio of 0.47/1. At the same time, however, the effect of bias must be distinguished from that of semantic concord. Of the verbs used in this study, there are several in the CP class that heavily favor the OGC (***pass***, ***hand***, and ***lend***), and in the CM class, there are verbs that only slightly prefer the OGC to the DC (***slide*** and ***throw***).

In other words, while there may be some degree of overlap between lexical-semantic concord and frequency-based concord (i.e. constructional bias), the data suggest that they are distinct.

Further, a verb's combinatoric potential—in the present case, the verb's ability to combine with both the DC or OCG—underdetermines its semantic analysis. As Rappaport Hovav and Levin (2008) observe, there are verbs that denote acts of successful transfer irrespective of syntactic context. They postulate a major division within the class of motion verbs that participate in the English dative alternation: (1) Caused Possession (CP) verbs, like ***give*** and ***sell***, and (2) Caused Motion (CM) verbs like ***kick*** and ***throw***.[5] When CP verbs are used in the DC or OGC, they entail causation of possession. This class comprises verbs expressing physical change of possession like ***give*** and ***hand***, verbs of future having like ***bequeath*** and ***promise*** and verbs of communication like ***tell*** and ***ask***. By contrast, the CP class (which includes, e.g., verbs of sending, verbs of instantaneous causation of ballistic motion, verbs of instrument of communication, etc.), expresses change of possession in the DC, but expresses causation of motion in the OGC. Thus, we see a semantic asymmetry between the two classes of verbs. This asymmetry is illustrated by the following contrast pairs:

(9) #Anna gave Debbie the present, but she never received it.
(10) #Anna gave the present to Debbie, but she never received it.

(11) #Anna sent Debbie the present, but it never got there.
(12) Anna sent the present to Debbie, but it never got there.

Rappaport Hovav and Levin explain the pattern in (9-12) in the following way. If change of possession is entailed either by a predication's construction or by its main verb (or by both), then it is incoherent to deny that change of possession occurred. Thus, both (9) and (10) are internally contradictory, either because both construction and the verb entail change of possession (9) or because the verb alone entails it (10) or because the construction alone entails it (11). Conversely, if change of possession is ***not*** entailed by either a predication's construction or its main verb, then stating that a change of possession did not occur is perfectly felicitous, as in (12).

Given all of the above, we expect that CP verbs should produce identical simulation effects in both DC and OGC, as their change-of-possession entailment is constant across both types. By contrast, CM verbs are presumed to entail a change of possession only in a DC predication, merely entailing a change of location in the OGC. Therefore, we expect to see simulation-based differences between the two constructions when the predication contains a CM verb.

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[5] It should be noted that Rappaport Hovav and Levin refer to the above classes of verbs as "dative verbs having only a caused possession meaning" and "dative verbs having both caused motion and possession meanings," as the latter class is observed to have a caused motion meaning when appearing in the OGC and a caused possession reading when appearing in the DC. These labels are here replaced with the labels 'caused possession verbs' (CP verbs) and 'caused motion verbs' (CM verbs) not only for the sake of brevity but also because we believe it is misleading to imply that verbs in the CM class have both a caused-motion and a caused-possession entailment. Verbs like ***throw***, which do not inherently select for a recipient argument, gain a caused-possession entailment only by virtue of combining with the DC construction; thus, the caused-possession entailment is contributed by the construction and not by the verb.

Why would a predication denoting an event of change of possession generate different motor simulation effects from one denoting an event of change of location? We expect to observe simulation-based differences between scenes of caused motion and scenes of caused possession because only the latter type of scene involves human interaction, and in particular an animate recipient (see, e.g., Goldberg 1995, Goldberg 2006, Rappaport Hovav & Levin 2008). In depicting a scene of caused motion, one could speak of ***kicking a football to the fifty-yard line***, but in this case ***the fifty-yard line*** is a goal rather than a recipient: it does not come to possess the football as a result of the kick. While both transfer of possession and causation of motion scenes could in principle evoke mental simulation, we presume that the former are more likely to be mentally reenacted, because an act of transferring possession requires a specific coordinated action. A causation-of-motion event involves a relatively uncontrolled trajectory (e.g., we cannot predict with certainty where a ball once kicked will come to rest). A transfer-of-possession event, by contrast, is controlled by humans at either end of the theme's path: the donor releases the possession as the recipient accepts it. The special significance that language users accord to such transfer events is reflected in the fact that the DC is acquired earlier by children than the OCG, probably as a result of the DC's prevalence in the adult input (Campbell & Tomasello 2001).

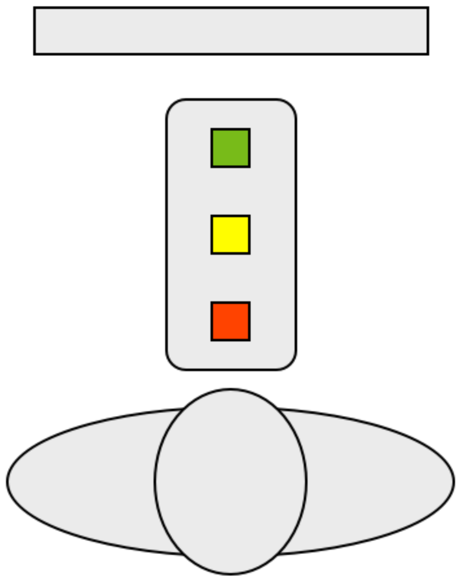
2.2 Motor Simulation Effects and Methodologies

The methodology used in this study (henceforth referred to as the motor facilitation and interference paradigm) was initially utilized in a landmark study by Glenberg & Kaschak (2002). Numerous subsequent studies have used this methodology (or variations thereof) and achieved significant but varying results (for a general review, see, e.g., Fischer & Zwaan 2008, Anderson & Spivey 2009). As in other simulation semantics experimental methodologies, at the core of the paradigm lies the idea that representation utilizes some of the same resources as action execution and/or perception (Barsalou 1999), and, therefore, that activating certain linguistic representations should, in some form, affect motor execution. This notion finds support in various neuroimaging studies (see, e.g., Pulvermüller 1999, Pulvermüller 2001 and Hauk et al. 2004), which have demonstrated that the act of reading words that denote motor actions activates the motor cortex, and that the act of reading words denoting visual scenes similarly activates the visual cortex. Hauk and colleagues (2004) showed that verbs denoting physical actions involving various body parts (hand, leg, face) activated the specific sub-regions of the motor cortex responsible for controlling those body parts.

Like the neuroimaging methodologies used in the aforementioned studies, the motor facilitation and interference paradigm detects language-induced motor-cortical activation. The extent of this activation is gauged via arm movement time in a button-press task (to be discussed in greater detail below).

In the motor facilitation and interference paradigm, participants are presented with some form of linguistic stimulus (either written or auditory) and then given a binary response choice, one of which is physically congruent in some way with the linguistic stimulus, and the other which is physically incongruent with the linguistic stimulus. In the majority of motor facilitation/interference studies, this is done through a rig consisting of three buttons (often a keyboard rotated ninety degrees from its typical orientation on the transverse (horizontal) plane). This is illustrated in Figure 1.

Fig. 1: A bird's-eye view diagram of the motor facilitation/interference setup used in the study.



In the three-button rig shown in Figure 1, we see a central yellow button that is used to display stimulus sentences on the computer monitor. Stimulus sentences are displayed only as long as the yellow button is held down, and upon its release, these sentences disappear. After reading a stimulus sentence, participants may then choose either the green or red button. Crucially, these buttons are oriented such that pressing one button requires arm movement away from the body while pressing the other button requires arm movement toward the body. Thus, under the right experimental conditions, investigators may gather both motion-congruent and motion-incongruent responses by providing stimulus sentences that are compatible or incompatible with the location of the green button. For instance, the sentence ***You are throwing the ball*** is congruent with an away button press but incongruent with a toward button press. Conversely, the sentence ***You are touching your nose*** is congruent with a toward button press but incongruent with an away press.

If, upon reading and understanding a stimulus sentence, a participant has recruited parts of the motor cortex for mental simulation, this may either facilitate or interfere with arm movement in sentence-to-button-press congruent and incongruent trials. Which of the two effects is observed is dependent on timing (see Borreggine and Kaschak, 2006 for discussion). In the present experiment, we expect to observe a facilitation effect (a quickening of user response times) when button press direction and stimulus sentence are congruent, and, conversely, we expect to observe an interference effect (a slowing down of user response times) when button press direction and stimulus sentence are incongruent.

The motor simulation methodology used in this experiment differs slightly from previous approaches (see, e.g., Glenberg & Kaschak 2002, Bergen & Wheeler 2010) in that all of its critical trials involve a single direction of motion; previous studies have implemented both ***toward*** and ***away*** variants. Because this study is concerned solely with verb and construction classes that convey removal from a person (the subject argument), only predications with main verbs that denote acts of transfer ***away from the body*** (with verbs like ***throw***, ***send*** and ***hand***) were implemented; all such predications featured second-person subjects. More information on this design is provided in Section 4, below.

3. Predictions

We offer two major predictions regarding the effects of both frequency-based and lexical-semantic concord in this experiment:

> **Prediction One (effects of frequency-based concord)**: Each verb's constructional bias will interact with the construction in which it appears and the semantic congruity condition in which it appears with the result that, for example, a verb that 'prefers' to appear in one construction (e.g., the OGC) will generate stronger facilitation or interference effects in that construction than in its dispreferred counterpart (e.g., the DC). We expect this bias effect because, as discussed above, representations that are more heavily entrenched should yield strengthened simulation effects.
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> **Prediction Two (effects of lexical-semantic concord)**: There will be no difference in motor simulation effects between CP verbs appearing in the DC and CP verbs appearing in the OGC. As CP verbs (e.g., ***give, lend***) entail successful receipt in either syntactic environment, it is expected that predications containing CP verbs will yield nearly identical simulation effects in the two constructional conditions. By contrast, for predications containing CM verbs like ***toss*** and ***send***, we expect to observe motor simulation differences between the DC and the OGC contexts: CM verbs do not assign a recipient role unless the DC imposes this construal on the verb's goal argument; it is only when the goal argument is interpreted as a recipient that a sentence depicts a change of ownership.[6]

These predictions and other findings will be revisited and discussed below.

4. Methods

In the following subsections, we describe the study's participants (4.1), materials (4.2), and design and procedure (4.3).

4.1 Participants

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[6] As discussed earlier, we presume that caused-possession predications—whether these feature a CP verb or Ditransitive form or both—have more readily simulated content, because they depict coordinated acts of transfer. The caused-motion scenario does not intrinsically involve human interaction; therefore, the motor-simulation effects evoked by CM verbs in the OCG context are expected to be weaker than those evoked by CP verbs in either constructional context.

After receiving approval of the protocol from the University of Colorado Boulder IRB, the authors recruited forty native English-speaking subjects over the age of eighteen years. Subjects participated in the experiment for either course credit or monetary compensation. Those who participated for course credit were undergraduate students enrolled in Linguistics courses at the University of Colorado Boulder. Those who participated for monetary compensation were members of the larger Boulder community who were recruited via flyer. All forty participants successfully completed the experiment. These participants ranged in age from 18 to 50 years of age (average = 23.32, SD = 7.25). Thirty-six participants described themselves as right-handed, two participants described themselves as left-handed, and two participants described themselves as ambidextrous. All participants had normal or corrected vision.

Participants were also asked about their linguistic backgrounds; forty participants described themselves as native English speakers. Thirty-seven of these participants described themselves as native monolinguals, while the remaining three participants were native bilingual. Of the bilingual speakers, two spoke Spanish and English, and one spoke Korean and English. This factor was included in the analyses performed, and did not significantly predict response time (the dependent variable in this study).

4.2 Materials

In this study, 56 critical stimuli were grouped with 64 non-critical stimuli to yield a total of 120 stimulus sentences (see Appendices A and B). These stimulus sentences were broken up into two blocks of 60 trials each. Critical stimuli were tagged for several different variables: Dative alternation variant used (DC or OGC), verb constructional 'preference' (expressed as the ratio of instances where the verb appears in the DC to instances where the verb appears in the OGC), verb class according to the taxonomy provided by Rappaport Hovav & Levin (2008) (CP or CM), sentence-to-button-press congruity (congruent or incongruent), and number of mentions of the stimulus's main verb in the experiment (1-4). Fourteen different verb lexemes were used in the study. These verbs were selected based on a combination of factors. First, each verb was one classified by Rappaport Hovav & Levin (2008) as either CM or CP. Second, each verb was construable as depicting manual transfer; this criterion ruled out verbs which, like ***kick***, do not denote acts of manual manipulation. Third, each verb appeared in the BNC at least once in both the DC and OGC patterns.

Each verb appeared four times (twice in the DC and twice in the OGC). Seven of these fourteen verbs were members of the CM class, while the other seven were members of CP class. These class memberships (along with each verb's constructional ratio) are provided in Table 1 below:

Table 1: Verb classes and constructional 'preference' ratios (DC to OGC)

Verb	**Class**	**Ratio**
Fling	Caused Motion	0.813
Flip	Caused Motion	0.667
Lob	Caused Motion	0.4
Send	Caused Motion	0.472
Slide	Caused Motion	0.852

Throw	Caused Motion	0.981
Toss	Caused Motion	0.545
Give	Caused Possession	2.98
Hand	Caused Possession	0.616
Lend	Caused Possession	0.498
Loan	Caused Possession	1.353
Offer	Caused Possession	1.649
Pass	Caused Possession	0.494
Show	Caused Possession	4.135

It should be briefly noted that all of the critical trials featured in this study denoted some form of manual motion ***away*** from the body, while none could be readily construed as denoting some form of manual motion ***toward*** the body. This interpretation was ensured by placing a second-person subject in each sentence along with a transfer verb and a third-person recipient, as in the following:

(15) ***You are flinging Freddie the Frisbee.***
(16) ***You are giving the package to Marla.***

Stimulus sentences were designed with additional specifications in mind so as to maximize consistency across trials and minimize the extent to which other linguistic factors could be affecting participant responses. As stated above, every stimulus sentence presented to participants began with the second person singular pronoun ***you***.[7] Verbs were also presented every time in the present progressive. Each stimulus sentence's recipient argument was also presented as a disyllabic proper name (e.g., ***Ernie***, ***Sally***, ***Lisa***), and each stimulus sentence's theme argument was presented as a definite noun phrase. Thus, all stimulus sentences occurred in one of two general forms: (1) ***You are <verb>ing <name> the <noun>*** or (2), ***You are <verb>ing the <noun> to <name>***.

Critical trials were generated by inserting any of the verbs featured in Table 1, above, into one of the above two constructions. Each verb was paired with two different theme objects such that each verb-object pairing was seen by participants in both the ditransitive and oblique goal constructions. These verb-theme pairings were determined by selecting themes that would pair naturally with their partner verbs. Thus, ***fling*** was paired with ***frisbee*** but not ***basket***, while ***offer*** was paired with ***basket*** but not ***frisbee***, and so forth.

Finally, filler trials were created by simply taking verbs whose argument structure configurations were incompatible with both the ditransitive and oblique goal constructions, and plugging them into the two constructional templates mentioned above. This yielded sentences like ***You are snoring Christian the whistle*** and ***You are existing the child to Harold***. As the task required participants to make grammaticality judgments about the sentences they saw, these stimuli served as ungrammatical counterparts to the grammatical critical trials.

[7] Use of second-person subjects in stimulus sentences has been shown to generate motor simulation effects in previous studies, and was implemented most notably in a subset of the stimulus sentences used in Glenberg and Kaschak (2002).

4.3 Design and Procedure

Participants were tested in one session that lasted roughly fifteen minutes from start to finish. Participants were seated at a desk with a laptop computer and response collection apparatus and asked to fill out a brief survey detailing their linguistic and cognitive background information. Following this, the main task was commenced. Instructions asked participants to decide whether or not the sentences they saw were grammatical. Following a brief block of practice trials (***n*** = 5), any questions on the part of the participant about the experiment procedure were answered, and then participants were free to complete the experiment in self-paced fashion. Halfway through the experiment, an optional break was provided to participants.

Each individual trial of the experiment began with a blank screen. The act of holding down the central yellow button on the response collection apparatus would cause a stimulus sentence to appear onscreen. As soon as the participant released the yellow button, the onscreen sentence would disappear (pressing the yellow button down again would not cause it to reappear), and participants would then press either the green button or the red button to record a judgment, where a green button press signified perceived grammaticality, and a red button press signified perceived ungrammaticality. After one of these response buttons had been pressed, the screen would briefly flash to let the participants know that the response had been received and that the participant had progressed to the next trial in the experiment.

This study employed a mixed design which had both within-subjects and between-subjects dependent variables. Specifically, of the variables mentioned above, all were within-subjects except for sentence-to-button press congruity. In the case of this variable, one half of the experiment participants (n = 20) completed the task with the target button in the sentence-congruent location (farthest from the body), while the other half (n = 20) completed the task with the button in the sentence-incongruent location (closest to the body).

The main dependent variable of this study was response time—specifically, the time between participants' releasing of the yellow button (the button used to display sentences) and the pressing of the green response button. As with other simulation-based studies in the motor facilitation and interference paradigm, variations in these response times are presumed to signal simulation-based motor interference or facilitation effects.

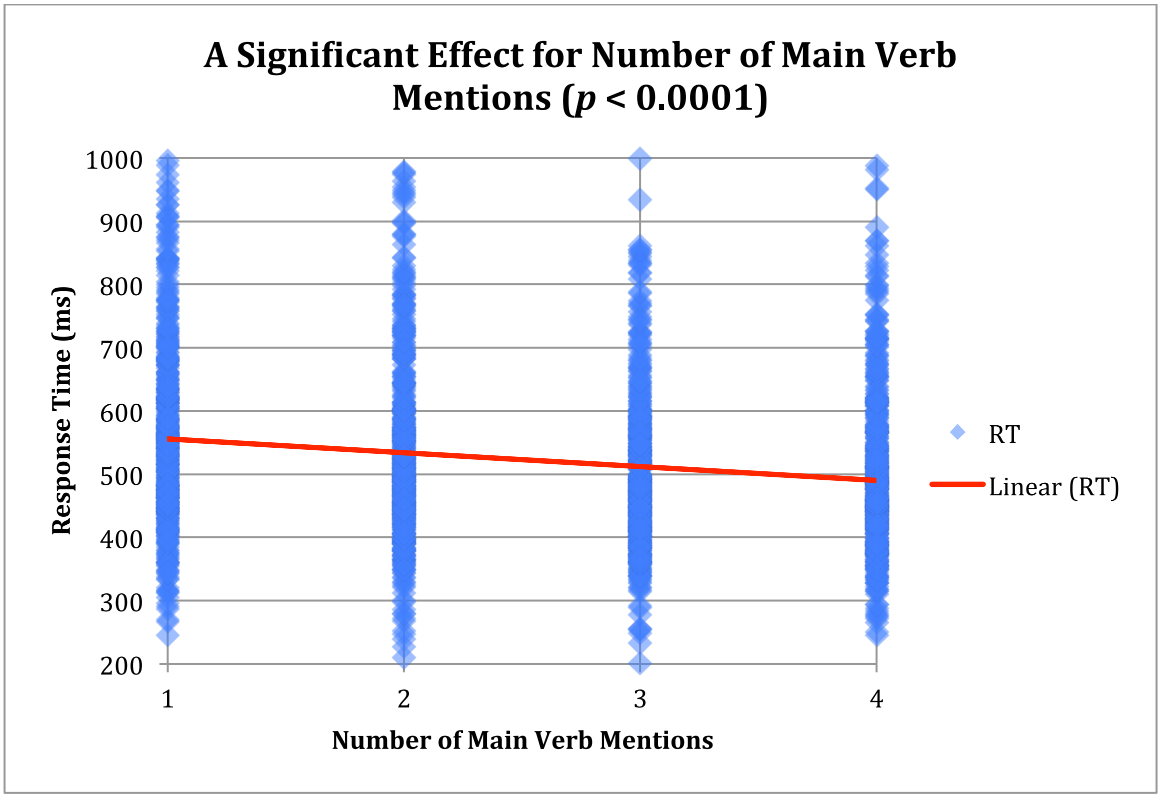
Crucially, however, as this experiment was driven by participants' assessments of grammaticality, only critical sentences in which participants pressed down the green button—and were ***expected*** to press down the green button—were accepted as part of the data pool. Thus, of a total of 2,240 critical trial responses, 105 (or 4.7%) were not used.

5. Results

Responses that took less than 200 ms or more than 1,000 ms were removed from the data. Of the 2,135 trials collected in which participants hit the correct response key, zero were less than 200 ms, and 97 (4.5%) were greater than 1000 ms, leaving a total of 2,038 trials used in the statistical analysis. A mixed models analysis with crossed random effects for participant and item was performed. This analysis yielded one significant main effect, two additional main effects that approached significance, and three significant interaction terms. Each of these findings will be briefly highlighted below, and then treated more thoroughly in the Discussion section.

The significant main effect involved the number of main verb mentions in this experiment (Wald $\chi^2(1, \boldsymbol{n} = 40) = 101.46$, $\boldsymbol{p} < 0.0001$): as number of mentions increases (each verb was seen a total number of four times), reaction time decreases. This effect is illustrated in Figure 2.

Fig. 2: A significant effect for short-term frequency (number of main verb mentions), where participant response time decreases as number of mentions increases



Although the above result is highly significant, it is likely a product of habituation effects rather than simulation effects, as participants become more acclimated to the experimental task (and thus complete individual trials more rapidly) as experimental trials progress.

As noted above, two additional main effects were observed to approach significance in the data. These were participant age[8] ($\chi^2(1, \boldsymbol{n} = 40) = 3.13$, $\boldsymbol{p} = 0.08$) and sentence congruity (congruent versus incongruent) ($\chi^2(1, \boldsymbol{n} = 40) = 2.88$, $\boldsymbol{p} = 0.09$). The main effect for sentence congruity (button-press-is-congruent versus button-press-is-not-congruent), which approached significance, is illustrated in Figure 3.

[8] We observed a direct (albeit statistically insignificant) correlation between age and response time, where average response time increases with age. Such a result is most likely a product of an age-related mild slowing of reflexes, and likely not related to simulation effects.

Fig. 3: Average participant response times for congruent and incongruent button press conditions

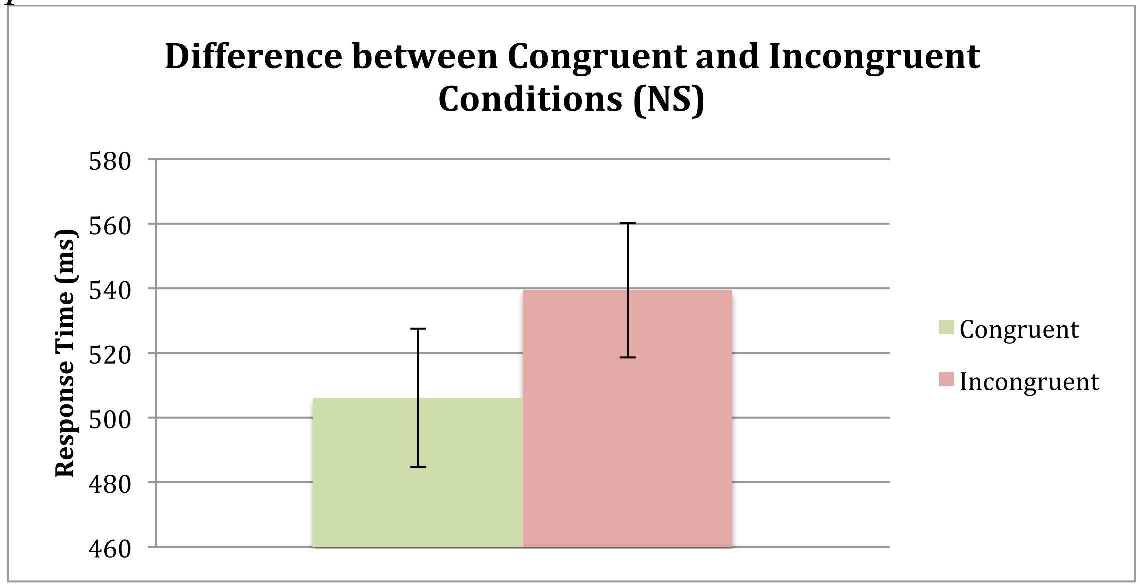
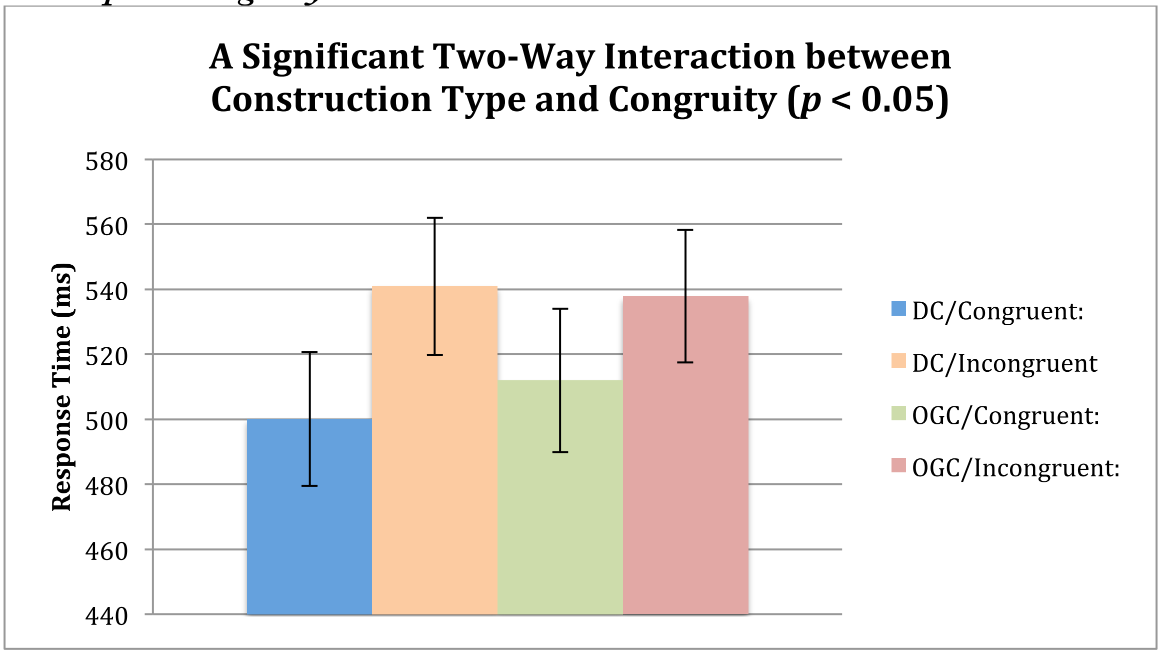


Figure 3 shows the relationship between congruent and incongruent conditions. In particular, trials in which the button press location is congruent with sentence meaning (i.e. the button is located farther away from the body) are observed to require, on average, 506 ms, while trials in which the button press location is incongruent with sentence meaning (i.e. the button is located closer to the body) are observed to require, on average, 539 ms. Given that close button press filler trials were observed to require 569 ms on average, and far button press filler trials were observed to require 530 ms on average, we can cautiously portray the above results as a combination of a mild interference effect and a strong facilitation effect. Again, while this result is not statistically significant, several higher-order interaction terms contain sentence-to-button-press congruity as one of their items, and, in light of the character of those interaction terms (where some predication types generated much weaker motor simulation effects than others), the above result is not entirely surprising. This point will be discussed more thoroughly in the following section.

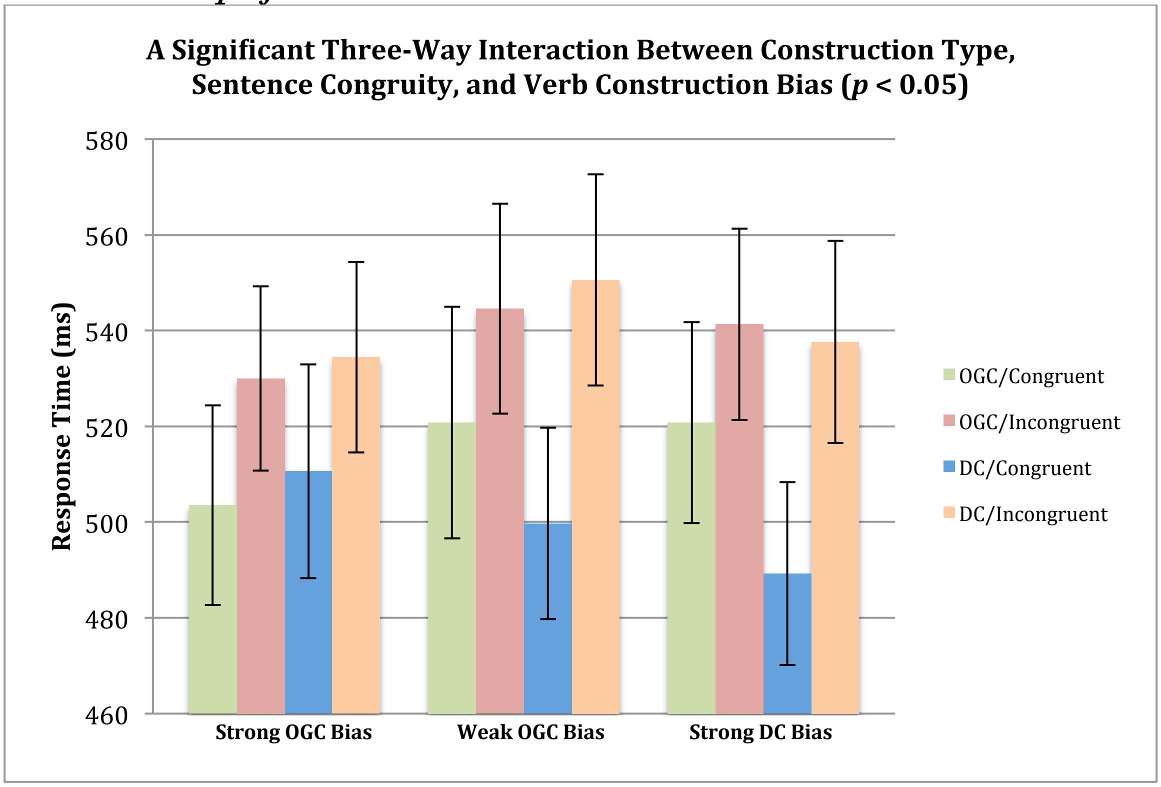
We now turn to the three significant interaction terms. The first is a significant two-way interaction between construction type and sentence congruity ($\chi^2(1, \boldsymbol{n} = 40) = 4.29, \boldsymbol{p} < 0.05$): the incongruent condition was observed to generate longer response times, while the congruent condition was observed to generate shorter response times. However, in this instance, a notable difference between the DC and the OGC was observed, where the DC generated stronger motor simulation effects than the OGC (Figure 4). In Figure 4, the first and second columns represent congruent and incongruent conditions (respectively) for stimulus sentences instantiating the DC. Correspondingly, the third and fourth columns represent congruent and incongruent conditions (respectively) for stimulus sentences instantiating the OGC.

Fig. 4: A significant interaction between construction type and sentence-to-button press congruity



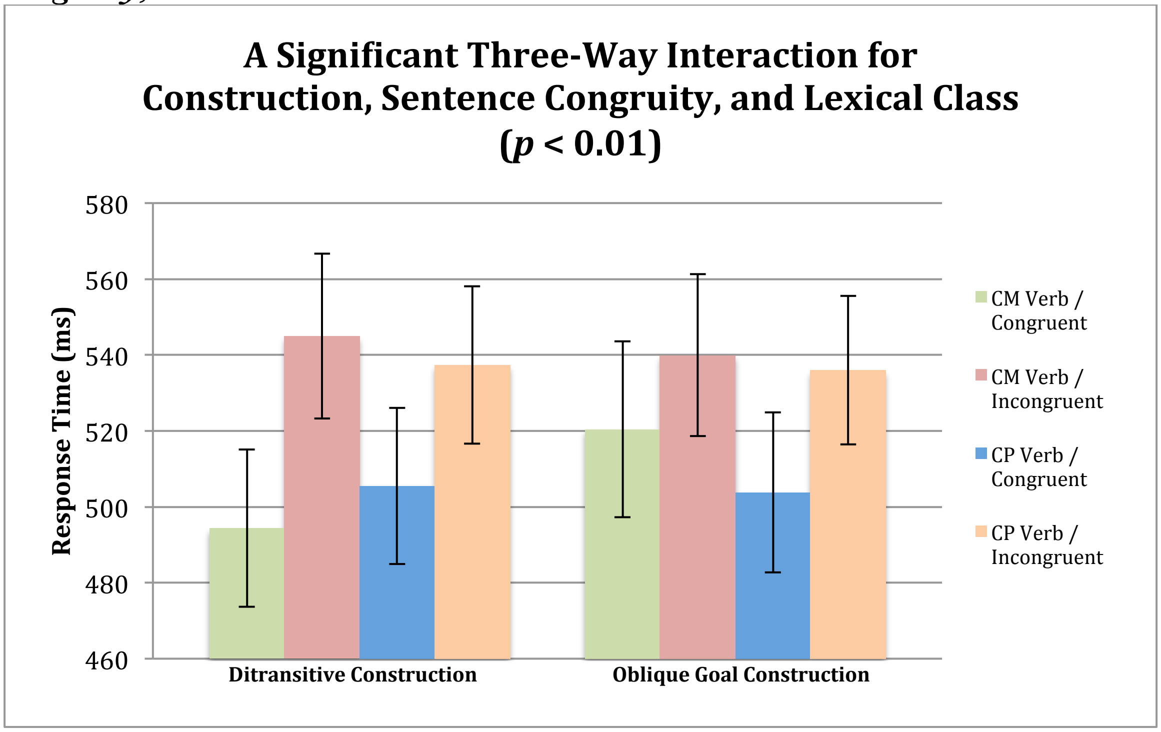
The second significant interaction term is a three-way interaction is between construction type, verb constructional bias, and sentence congruity ($\chi^2(1, \boldsymbol{n} = 40) = 3.85, \boldsymbol{p} < 0.05$). This complex interaction reveals that constructional bias does indeed modulate motor simulation effects, and that verbs appearing in their 'preferred' construction generate stronger effects overall. Although in our statistical model verb construction bias is treated as a continuous variable, the following chart (Figure 5) presents it as a categorical variable in order to make this complicated three-way interaction somewhat easier to digest. In Figure 5, the first group, ***Strong OGC Bias***, is composed of those verbs whose DC:OGC ratio in the BNC was less than 0.55. These verbs were ***lob***, ***send***, ***toss***, ***lend***, and ***pass***. The second group, ***Weak OGC Bias***, is composed of those verbs whose DC:OGC ratio in the BNC was between 0.56 and 0.99. These verbs were ***fling***, ***flip***, ***slide***, ***throw***, and ***hand***. The third group, ***Strong DC Bias***, is composed of those verbs whose DC:OGC ration in the BNC was greater than 1. These verbs were ***give***, ***loan***, ***offer*** and ***show***.

Fig. 5: A three-way interaction between construction type, congruity, and constructional preference



The third and final significant interaction term is a three-way interaction between construction type, sentence congruity, and lexical class ($\chi^2(1, \boldsymbol{n} = 40) = 8.61, \boldsymbol{p} < 0.01$). This significant of this interaction term suggests that Rappaport Hovav & Levin's (2008) transfer verb classes work in combination with the DC and OGC in order to predict motor simulation effects (Figure 6). In Figure 6, we see eight colored columns. Columns 1-4 represent all categories of the DC, while columns 5-8 represent all categories of the OGC. Caused motion verbs are shown in columns 1, 2, 5, and 6, while caused possession verbs are shown in columns 3, 4, 7, and 8. Finally, columns 1, 3, 5, and 7 represent button-press-congruent trials, while columns 2, 4, 6, and 8 represent button-press-incongruent trials.

Fig. 6: A three-way interaction between construction type, button-press congruity, and lexical class



The interaction results described above will be explored in detail in the Discussion section below.

6. Discussion

As detailed in the Results section above, this study produced several significant results, all of which have potential ramifications for theories of simulation-based linguistic representation. As mentioned above, the data yielded a significant main effect for short-term frequency (as well as two other main effects that approached significance). This effect, however, is attributable to habituation effects; it did not significantly interact with other factors in the statistical model. In short, the significant main effect for short-term frequency tells us very little about the manner in which this type of frequency may modulate motor simulation effects. There are, however, three other significant findings that do bear on the general theory of mental simulation assumed in this article. These will be discussed in turn below.

6.1 Construction Type Significantly Predicts Motor Simulation Effects

Before addressing the two predictions made in Section 3 above, we discuss a more general finding that is relevant to both: a significant two-way interaction between sentence congruity and construction type (Figure 4). A two-way interaction is observed because the character of the relationship between the simulation results elicited by congruent and incongruent stimulus sentences changes based on the construction seen by participants. In particular, it appears that simulation effects elicited by the DC are, on the whole, slightly stronger than those elicited by the OGC. This is readily observable in both congruent and incongruent conditions, as the average participant response time in the DC is both faster in the congruent condition and slower in the incongruent condition.

This difference in the character and magnitude of the simulation effects generated here may arise from the semantics of the constructions used. The DC entails change of possession while the OGC does not: oblique-goal sentences may express ***either*** change of possession ***or*** causation of motion, depending on the entailments of the verb. When language users see an instance of the DC, they may therefore unambiguously simulate a scene in which transfer occurs, whereas language users encountering the OGC may not do so.

6.2 Frequency-Based Concord Significantly Predicts Motor Simulation Effects

Having established that the DC and OGC significantly differ with regard to their characteristic motor facilitation and interference effects, we now turn to our first prediction, involving the effects of frequency-based concord on motor simulation: a verb will generate stronger simulation effects when appearing in its preferred construction. This prediction is confirmed by a significant three-way interaction between construction type, sentence congruity, and main verb construction 'preference,' detailed in Figure 5.

We can observe several distinct patterns in Figure 5. First, it is clear once again that the DC generates stronger motor simulation effects than the OGC does; however, in the case of verbs that have a strong OGC bias, the difference between the DC and OGC is nullified. Second, frequency-based concord appears to be moderately predictive of motor simulation effects: when a verb favors a particular construction in the English dative alternation ***and*** appears in that favored construction, it appears to generate stronger motor simulation effects, on average, than it does when it appears in its dispreferred pattern. In other words, the greatest difference between congruent and incongruent conditions for stimulus sentences appearing in the OGC can be observed in verbs that have the strongest OGC bias, and the greatest difference between congruent and incongruent conditions for stimulus sentences appearing in the DC can be observed in verbs that have the strongest DC bias. This effect is much more pronounced in the case of DC verbs. As noted in the previous section, we believe that constructional semantics account for this difference. The DC entails change of possession, but the OGC does not. This suggests that the DC allows for unambiguous simulation of transfer scenes, while the OGC does not, owing to its variable entailments.

6.3 Lexical-Semantic Concord Significantly Predicts Motor Simulation Effects

According to our second prediction, the effect of constructional context on motor simulation will differ according to whether the verb's array of participant roles matches that of the construction. When the DC enriches a CM verb up to a CP verb, we will see enhanced simulation effects relative to the OGC context. This prediction is confirmed by a significant three-way interaction effect between construction type, sentence directional congruity and lexical class. To make sense of this interaction, we must recall Rappaport Hovav and Levin's lexical-class-driven theory of the dative alternation, discussed in the Background section above. The authors propose that two major classes of verbs participate in the English dative alternation: verbs having only a caused possession sense regardless of constructional environment (CP verbs), and verbs having either a caused motion or a caused possession sense, depending on constructional environment (CM verbs). When a verb from either of these verb classes appears in the DC, the CP-CM distinction becomes irrelevant, as all verbs appearing in the DC necessarily entail change of possession. In the OGC environment, by contrast, there remains a distinction between those causative verbs that entail a change of possession and those that do not, such that lexical class is a relevant factor. Our findings support this model. We find no construction-driven differences in simulation effects observed for CP verbs, because all CP verbs have the same (change of ownership) meaning regardless of the construction in which they appear. At the same time, there are construction-driven differences in simulation effects observed for CM verbs, because these verbs, according to Rappaport Hovav and Levin (2008) have distinct entailments depending on the construction in which they appear: in the DC, these verbs evoke a caused possession sense, while in the OGC, these verbs evoke only a caused motion sense. Figure 6 illustrates this distribution.

As discussed, we posited that CP verbs would trigger the same motor simulation effects whether appearing in the DC or the OGC. Looking at columns 3, 4, 7, and 8, we can see that CP verbs do indeed pattern virtually identically in the two syntactic contexts. In the case of CP verbs appearing in the DC, we see average response times of 505 ms in the congruent condition, and 537 ms in the incongruent condition. Similarly, these same verbs appearing in the OGC generate average response times of 504 ms in the congruent condition and 536 ms in the incongruent condition. In short, there is virtually no difference between these conditions, as predicted.

Turning to CM verbs, let us recall that these verbs should exhibit significantly different patterns in the DC versus the OGC. We expect this divergence because CM verbs are presumed to have a caused possession reading in the former construction, but a caused motion reading in the latter construction. As the caused possession scenario is presumed more likely to trigger motor simulation effects, we anticipated that motor simulation effects should be the strongest in the DC. Looking at columns 1, 2, 5, and 6, we see that this is indeed the case. Specifically, strong motor simulation effects are seen for CM verbs in the DC context, where average response times are 494 ms in the congruent condition and 545 ms in the incongruent condition. Conversely, in the OGC context, the differences between congruent and incongruent conditions are the smallest of any congruent/incongruent pair in the experiment (520 ms and 540 ms, respectively).

Our findings suggest that verb-construction conflict, rather than 'derailing' interpreters, provides a cue during meaning construction. By recognizing that construction meaning and verb meaning make distinct and potentially conflicting contributions to sentence meaning (Michaelis 2004), we can make sense of an initially counterintuitive result. Although CP verbs evoke reliable motor simulation effects in both the DC and OGC contexts, CM verbs evoke, on average, even stronger simulation effects in the DC than CP verbs do. The difference between incongruent and congruent conditions for CM verbs in the DC is roughly 50 ms, while this same difference is roughly 32 ms for CP verbs in the two constructions. How can we explain this finding while preserving the claim that a scenario involving transfer of possession is more readily simulated than one involving causation of motion? The answer involves lexical-semantic concord, or the lack of it. In a predication characterized by both DC form and a CP verb, constructional effects are simply neutralized by lexical-class semantics: a predication containing a CP verb entails change of possession irrespective of constructional context.

By contrast, a predication containing a CM verb entails change of possession only when verb meaning and construction meaning are in conflict. CM verbs are 'mismatched' to the DC context; in order to resolve verb-construction conflict, the interpreter must construe the verb's goal argument as a recipient in particular. Here we suggest that Gricean manner-based inference comes into play: the interpreter reasons that the user of this sentence had a good communicative rationale for using the DC pattern, as opposed to the more semantically congruent pattern for CM verbs, the OGC pattern. During this reasoning, the change-of-possession scenario is likely to be more salient to the interpreter than it might be in concord (CP-DC) contexts.

In sum, frequency-based concord and lexical-semantic concord appear to exert opposing influences on simulation effects. Frequency-based concord facilitates mental reenactment of the denoted event: a verb in its preferred construction generates stronger simulation effects than one in a dispreferred construction. We presume that this difference is attributable to the manner in which interpretive resources are allocated during sentence understanding: when the verb is highly predictable in the context, verb and construction need not be retrieved separately, and the interpreter can expend more energy on mental reenactment. In light of the foregoing, it is somewhat surprising that lexical-semantic concord in fact ***dampens*** motoric simulation: a CM verb in the 'mismatched' DC context generates stronger simulation effects than one in the concordant OGC context. Overall, the strongest differences between motor simulation effects in congruent and incongruent trials were seen in DC sentences, which uniformly entail a change of ownership (unlike OGC sentences). We suggest that this asymmetry exists because coordinated actions like transfer of possession have more predictable mental reenactments than 'single-party' actions like instigation of motion.

7. Conclusion

Knowing a verb means knowing some things that are extrinsic to that verb: what semantic entailments it shares with other verbs, the constructions with which it prefers to combine and the contribution it makes to meaning construction. We find that simulation-based differences among verbs arise not only from lexical-class differences (divergent entailments), but also from the syntactic environments in which members of those lexical classes appear. The results of this experiment suggest not only that certain syntactic environments (the DC and OGC) are associated with differing simulation effects, but also that lexical-class semantics may diminish or possibly negate these effects, as in the case of CP verbs occurring in the OGC context. These findings suggest that those looking for evidence of embodied representations in language comprehension should attend not only to lexeme distinctions, lexical-class distinctions and constructional meaning differences, but also to the interplay between lexeme and construction.

As mentioned earlier, the findings reported here have ramifications for methodological and experimental design within simulation semantics. The effects of both frequency-based concord and lexical-semantic concord should be taken into account in the design of stimuli. Thus, if one were to design a study similar to the one described here, but using only verbs that heavily favor the OGC, it is likely that OGC and DC would not diverge with respect to motor simulation effects. Similarly, because CP verbs have the effects they have regardless of constructional context, if one were to examine the motor simulation effects of OGC and DC using only CP verbs, simulation-based differences between the two constructions might not be apparent.

Finally, this study suggests that proponents of an embodied view of linguistic cognition can achieve an accord with those who correctly observe that a theory of language understanding based solely on sensorimotor representation cannot account for abstract aspects of language understanding. It may be, as suggested by Zwaan (2014), that interpreters rely on symbolic representations (e.g., frame-semantic meanings of lexical items) during semantic composition, although these representations activate grounded representations. The present study suggests that various forms of linguistic representation—from verbs to verb classes to constructions—form a hierarchy of abstraction, ultimately grounded in embodied action. While all of the sentences featured in this experiment depicted concrete instances of transfer, the argument arrays used in the stimuli (footballs, packages, and the like) accounted for only one level of semantic representation. There were, of course, two other levels of semantic representation that were shown to significantly modulate simulation results: (1) constructional meaning, and (2) lexical class membership. Although it would be inappropriate to categorize either form of semantic representation as purely abstract, it seems clear that they have been ***abstracted*** from concrete meanings. As Goldberg (2006) points out, children initially use constructions like the DC to describe literal instances of transfer of possession, after which they begin to generalize these syntactic configurations to contexts beyond those in which they were first encountered. In this process, constructions become more semantically abstract and generalizable, but retain vestiges of embodied meaning that are detectable into adulthood.

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Appendix A: Critical Stimuli Used in the Study

Slide Text	Construction	Verb Bias (Ditransitive/ Oblique Goal)	Verb Class
You are flinging Amy the frisbee.	Ditransitive	0.8125	Caused Motion
You are flinging Amy the plate.	Ditransitive	0.8125	Caused Motion
You are flipping Cathy the card.	Ditransitive	0.666666667	Caused Motion
You are flipping Cathy the matchbook	Ditransitive	0.666666667	Caused Motion
You are lobbing Lucas the bottle.	Ditransitive	0.4	Caused Motion
You are lobbing Lucas the egg.	Ditransitive	0.4	Caused Motion
You are sending Jason the package.	Ditransitive	0.47160789	Caused Motion
You are sending Jason the shoebox.	Ditransitive	0.47160789	Caused Motion
You are sliding Jenna the glass.	Ditransitive	0.851851852	Caused Motion
You are sliding Jenna the tray.	Ditransitive	0.851851852	Caused Motion
You are throwing Julie the football.	Ditransitive	0.980769231	Caused Motion
You are throwing Julie the orange.	Ditransitive	0.980769231	Caused Motion
You are tossing Erin the apple.	Ditransitive	0.545454545	Caused Motion
You are tossing Erin the hat.	Ditransitive	0.545454545	Caused Motion
You are flinging the frisbee to Curtis.	Oblique Goal	0.8125	Caused Motion
You are flinging the plate to Curtis.	Oblique Goal	0.8125	Caused Motion
You are flipping the card to Caleb.	Oblique Goal	0.666666667	Caused Motion
You are flipping the matchbook to Caleb.	Oblique Goal	0.666666667	Caused Motion

You are lobbing the bottle to Sophie.	Oblique Goal	0.4	Caused Motion
You are lobbing the egg to Sophie.	Oblique Goal	0.4	Caused Motion
You are sending the package to Wanda.	Oblique Goal	0.47160789	Caused Motion
You are sending the shoebox to Wanda.	Oblique Goal	0.47160789	Caused Motion
You are sliding the glass to Nicole.	Oblique Goal	0.851851852	Caused Motion
You are sliding the tray to Nicole.	Oblique Goal	0.851851852	Caused Motion
You are throwing the football to Ashley.	Oblique Goal	0.980769231	Caused Motion
You are throwing the orange to Ashley.	Oblique Goal	0.980769231	Caused Motion
You are tossing the apple to Kathleen.	Oblique Goal	0.545454545	Caused Motion
You are tossing the hat to Kathleen.	Oblique Goal	0.545454545	Caused Motion
You are giving Carla the gift.	Ditransitive	2.980433055	Caused Possession
You are giving Carla the money.	Ditransitive	2.980433055	Caused Possession
You are handing Steven the ball.	Ditransitive	0.615735462	Caused Possession
You are handing Steven the shirt.	Ditransitive	0.615735462	Caused Possession
You are lending Sally the key.	Ditransitive	0.498108449	Caused Possession
You are lending Sally the phone.	Ditransitive	0.498108449	Caused Possession
You are loaning Carmen the notebook.	Ditransitive	1.352941176	Caused Possession
You are loaning Carmen the pencil.	Ditransitive	1.352941176	Caused Possession
You are offering Jackie the basket.	Ditransitive	1.649122807	Caused Possession
You are offering Jackie the cake.	Ditransitive	1.649122807	Caused Possession
You are passing Lisa the folder.	Ditransitive	0.494163424	Caused Possession
You are passing Lisa the scissors.	Ditransitive	0.494163424	Caused Possession
You are showing Patrick the picture.	Ditransitive	4.134706815	Caused Possession
You are showing Patrick the wallet.	Ditransitive	4.134706815	Caused Possession
You are giving the gift to Francis.	Oblique Goal	2.980433055	Caused Possession
You are giving the money to Francis.	Oblique Goal	2.980433055	Caused Possession
You are handing the ball to Walter.	Oblique Goal	0.615735462	Caused Possession
You are handing the shirt to Walter.	Oblique Goal	0.615735462	Caused Possession
You are lending the key to Ernie.	Oblique Goal	0.498108449	Caused Possession

You are lending the phone to Ernie.	Oblique Goal	0.498108449	Caused Possession
You are loaning the notebook to Laurie.	Oblique Goal	1.352941176	Caused Possession
You are loaning the pencil to Laurie.	Oblique Goal	1.352941176	Caused Possession
You are offering the basket to Paula.	Oblique Goal	1.649122807	Caused Possession
You are offering the cake to Paula.	Oblique Goal	1.649122807	Caused Possession
You are passing the folder to Gerald.	Oblique Goal	0.494163424	Caused Possession
You are passing the scissors to Gerald.	Oblique Goal	0.494163424	Caused Possession
You are showing the picture to Jerry.	Oblique Goal	4.134706815	Caused Possession
You are showing the wallet to Jerry.	Oblique Goal	4.134706815	Caused Possession

Appendix B: Non-Critical Stimuli Used in the Study

Slide Text	Construction Type
You are agreeing Jimmy the menu.	Ditransitive
You are agreeing the menu to Charlie.	Oblique Goal
You are apologizing Betty the email.	Ditransitive
You are apologizing the email to Kyle.	Oblique Goal
You are appearing Geoffrey the restaurant.	Ditransitive
You are appearing the restaurant to Daryl.	Oblique Goal
You are arriving Janice the station.	Ditransitive
You are arriving the station to Rosie.	Oblique Goal
You are collapsing Alex the floor.	Ditransitive
You are collapsing the floor to Wilson.	Oblique Goal
You are colliding Ralphie the fence.	Ditransitive
You are colliding the fence to Trisha.	Oblique Goal
You are dancing Morgan the scene.	Ditransitive
You are dancing the scene to Layla.	Oblique Goal
You are disappearing Joelle the note.	Ditransitive
You are disappearing the note to Sandra.	Oblique Goal
You are emerging Jacob the artist.	Ditransitive
You are emerging the artist to Vinny.	Oblique Goal
You are existing Sadie the child.	Ditransitive
You are existing the child to Harold.	Oblique Goal
You are falling Kelsey the ice.	Ditransitive
You are falling the ice to David.	Oblique Goal
You are happening Miles the surprise.	Ditransitive

You are happening the surprise to Mary.	Oblique Goal
You are having Douglas the conversation.	Ditransitive
You are having the conversation to Edward.	Oblique Goal
You are lasting Kaley the bicycle.	Ditransitive
You are lasting the bicycle to Mickey.	Oblique Goal
You are laughing Michael the story.	Ditransitive
You are laughing the story to Yvette.	Oblique Goal
You are living Hunter the conversation.	Ditransitive
You are living the conversation to Olga.	Oblique Goal
You are looking Alan the child.	Ditransitive
You are looking the child to Nadine.	Oblique Goal
You are lying Randy the tale.	Ditransitive
You are lying the tale to Sigmund.	Oblique Goal
You are occurring Harper the idea.	Ditransitive
You are occurring the idea to Asher.	Oblique Goal
You are remaining the scraps to Peter.	Oblique Goal
You are remaining Vicky the scraps.	Ditransitive
You are responding Katie the question.	Ditransitive
You are responding the question to Terry.	Oblique Goal
You are rising Reggie the morning.	Ditransitive

You are rising the morning to Trevor.	Oblique Goal
You are searching Tammy the liquid.	Ditransitive
You are searching the liquid to Percy.	Oblique Goal
You are sitting Krista the table.	Ditransitive
You are sitting the table to Pierre.	Oblique Goal
You are sleeping Curtis the pillow.	Ditransitive
You are sleeping the pillow to Hazel.	Oblique Goal
You are sneezing Heather the story.	Ditransitive
You are sneezing the story to Lawrence.	Oblique Goal
You are snoring Jeffrey the whistle.	Ditransitive
You are snoring the whistle to Christian.	Oblique Goal
You are standing Lindsey the chair.	Ditransitive
You are standing the chair to Donald.	Oblique Goal
You are staying Bobby the room.	Ditransitive
You are staying the room to Celia.	Oblique Goal
You are swimming Esther the ocean.	Ditransitive
You are swimming the ocean to Andy.	Oblique Goal
You are vanishing Bella the rabbit.	Ditransitive
You are vanishing the rabbit to Ellie.	Oblique Goal
You are waiting Elaine the taxi.	Ditransitive
You are waiting the taxi to Freddie.	Oblique Goal

Appendix C: BNC Corpus Counts

Verb	Class	DC Count	OGC Count	Ratio
Fling	CM	26	32	0.813
Flip	CM	4	6	0.667
Lob	CM	2	5	0.4
Send	CM	1,578	3,346	0.472
Slide	CM	23	27	0.852
Throw	CM	204	208	0.981
Toss	CM	24	50	0.545
Give	CP	30,007	10,068	2.98

Hand	CP	540	877	0.616
Lend	CP	395	793	0.498
Loan	CP	23	17	1.353
Offer	CP	2,548	1,539	1.649
Pass	CP	254	514	0.494
Show	CP	2,609	631	4.135

Summary of significant effects in alternative statistical model without ***flip*** and ***lob*** included:

Significant Effects	Model with ***Flip*** and ***Lob***		Model without ***Flip*** and ***Lob***	
	$\chi^2(1, n = 40)$	***p***	$\chi^2(1, n = 40)$	***p***
Number of Mentions	101.46	< 0.0001	86.42	< 0.0001
Construction Type ***x*** Congruity	4.29	= 0.038	3.56	= 0.059
Construction Type ***x*** Congruity ***x*** Ratio	3.85	= 0.049	3.30	= 0.069
Construction Type ***x*** Congruity ***x*** Verb Class	8.61	= 0.003	8.11	= 0.004

The increased ***p***-values in the model without ***flip*** and ***lob*** are almost certainly attributable to the loss of statistical power incurred by removing one seventh of our data from the model. Given that all of the coefficients in this model follow the same overall trend as the coefficients in the model with ***flip*** and ***lob*** included, we feel that it remains appropriate to include these lexemes in the main analysis provided here.