The lexical and formal semantics of distributivity

LELIA GLASS (iD)

]u[ubiquity press

Abstract

Some predicates are distributive (true of each member of a plural subject: if two people *smile*, they each do). Others are nondistributive (if two people *meet*, they do so jointly rather than individually), or go both ways: if two people *open a door*, perhaps they each do so (distributive), or perhaps they do so jointly but not individually (nondistributive). This paper takes up the rarely-explored lexical semantics question of which predicates are understood in which way(s) and why, presenting quantitative evidence for predictions about how certain features of an event shape the inferences drawn from the predicate describing it. Causative predicates (*open a door*), and predicates built from transitive verbs more generally, are shown to favor a nondistributive interpretation, whereas experiencer-subject predicates (*love a movie*) and those built from intransitive verbs (*smile*) are mostly distributive. Turning to the longstanding formal semantics question about how distributivity should be represented compositionally, any such theory ends up leaving much of the work to lexical/world knowledge of the sort that this paper makes explicit.

CORRESPONDING AUTHOR:
Lelia Glass

School of Modern Languages, Georgia Institute of Technology, 613 Cherry St NW, Atlanta, GA 30313, US

lelia.glass@modlangs.gatech. edu

1 Introduction

Within semantics and pragmatics, where the aim is to understand the inferences drawn from (uses of) sentences, this paper zooms in on a particular class of inferences: those drawn from sentences with a plural subject (such as *Alice and Bob*) about how each member of the subject participates in the predicate of the sentence (Bartsch 1973; Scha 1981; Link 1983; Roberts 1987); see Winter & Scha (2015); Nouwen (2015); de Vries (2017); Champollion (2019; 2020) for recent overviews.

(1) conveys that Alice and Bob *each* smiled. *Smile* is therefore distributive: inferred to be individually true of (to distribute down to) each member of the plural subject. (Distributivity applies to all sorts of plurals, but I focus on conjoined names for clarity.)

(1)   Alice and Bob smiled.   **(distributive)**
         a.   ✓**Distributive:** Alice smiled, Bob smiled.
         b.   ✗**Nondistributive:** Alice and Bob smiled jointly but not individually.

In contrast, (2) does not convey that each person met – at least, not unless one imagines some sort of implicit object. Instead, *meet* is true of Alice and Bob together, not each one individually: nondistributive.[1]

(2)   Alice and Bob met.   **(nondistributive)**
         a.   ✗**Distributive:** Alice met, Bob met.
         b.   ✓**Nondistributive:** Alice and Bob met jointly but not individually.

Whereas *smile* is distributive and *meet* is nondistributive, (3) can be interpreted in both ways: it can describe a situation in which Alice and Bob *each* opened the door (distributive); or a situation in which Alice and Bob did not technically each open the door, because they did so by working together (nondistributive).

(3)   Alice and Bob opened {the/a} door.   **(can be understood both ways)**
         a.   ✓**Distributive:** Alice opened {the/a} door, Bob opened {the/a} door.
         b.   ✓**Nondistributive:** Alice and Bob opened {the/a} door jointly but not individually.

With an indefinite object (3), a predicate built from a transitive verb has the potential for covariation (Dotlačil 2010) – for the indefinite to covary with each member of the subject, as when (3) is interpreted to involve two different doors. In general, when a predicate can be interpreted as either distributive or nondistributive (3), and especially when its distributive interpretation would involve covariation, the nondistributive interpretation is favored even if both interpretations are available in principle (Brooks & Braine 1996; Frazier et al. 1999; Dotlačil 2010; Syrett & Musolino 2013; Dobrovie-Sorin et al. 2016).

This empirical picture raises two big questions, a formal semantics question which has been discussed widely, and a lexical semantics question which has largely remained open.

First, the widely discussed formal semantics question (Scha 1981; Link 1983; Dowty 1987; Roberts 1987; Landman 1989; Lasersohn 1995; Schwarzschild 1996; Winter 1997; Landman 2000; Winter 2002; Champollion 2010; de Vries 2015; Champollion 2016; 2017): How should sentences like (1)–(3) be represented formally? To what extent should the inferences drawn from these sentences manifest transparently in their semantic representation? In particular, how do we capture the two distinct interpretations available to (3) – in terms of a semantic ambiguity (Roberts 1987; Landman 1989; Lasersohn 1995; Champollion 2010), or in terms of an underspecified meaning compatible with multiple different situations (Schwarzschild 1996; Kratzer 2007)? If (3) is ambiguous, why are (1) and (2) unambiguous?

Second, the much less-discussed lexical semantics question: Which other predicates behave like *smile*, like *meet*, or like *open the door* – and why? Uncontroversially, the inferences drawn from these predicates are shaped by our knowledge about how events of smiling, meeting,

---

[1]   Nondistributive interpretations are also called *collective* (Scha 1981; Link 1983; Landman 1989), a term which may evoke elusive inferences about joint responsibility and collaboration (Landman 2000) and a contentious distinction between "collective" versus "cumulative" interpretations (Landman 2000; Kratzer 2007; Champollion 2010). To avoid those issues, I simply contrast distributive interpretations with non-distributive ones (Roberts 1987; Schwarzschild 1996; Link 1998).

and door-opening take place in the world (Dowty 1987; Roberts 1987; Winter 1997; 2000; Champollion 2010; de Vries 2015). *Smile* is distributive (1) because people have their own faces and thus cannot *smile* jointly without also doing so individually. *Meet* is nondistributive (2) because it describes an inherently social action that cannot be undertaken unilaterally. *Open the door* can be understood in both ways (3) because it can be carried out individually or jointly.

Prior work has illuminated various elements of the relation between lexical semantics and plural predication, including the interpretation of adjectives (Scontras & Goodman 2017; Glass 2018a), reciprocity (Kruitwagen et al. 2017; Poortman et al. 2018; Winter 2018), whether a predicate applied to a plural must apply to every single member of it (Yoon 1996), different types of non-distributive predicates (Corblin 2008; Kuhn 2020), interactions with negation (Löbner 2000; Križ 2016), and the distribution of the modifier *all* (Dowty 1987; Löbner 2000; Winter 2000; Brisson 2003). But there is still a need for a predictive theory of which predicates are interpreted as distributive and/or nondistributive and why, in view of lexical/world knowledge about the events that they describe.

There is an ongoing "dictionary versus encyclopedia" debate about what knowledge should be tied to particular lexical items versus one's extralinguistic knowledge of the world (Fillmore 1969; Pustejovsky 1995; Harley & Noyer 1999; Peeters 2000; McNally 2005). The noncommittal term *lexical/world knowledge* is intended to sidestep that issue. Here, the aim is to systematize the knowledge relevant for distributivity, without deciding whether that knowledge is lexical or encyclopedic or both.

This paper takes on the lexical semantics question. §2 motivates a series of predictions about the behavior of various types of predicates, generalizing the intuitive analysis of predicates such as *smile* and *open the door* to a larger scale. To preview:

(4)   **Transitive/Intransitive Asymmetry:** Predicates built from many intransitive verbs (*smile, laugh, arrive, die*) are only distributive, whereas predicates built from many transitive verbs (*open a door, eat a pizza*) can be nondistributive.

(5)   **Mind Prediction:** Because individuals have their own minds, predicates describing the subject's mental processes (*believe it, love a movie, meditate, see a photo, worry*) are distributive.

(6)   **Causative Prediction:** Because the nature of **causation** allows that multiple individuals' contributions may be jointly sufficient but individually insufficient to cause a result, predicates built from **causative** verbs (describing an event where the subject causes the object to change, such as *annoy a neighbor, break a vase, destroy a family, open a door*) can be nondistributive as well as distributive.

§3 presents distributivity judgments from online annotators for over one thousand English predicates (intransitive verbs, and transitive verbs with corpus-motivated objects). For each verb, the features predicted to shape its distributivity potential are labeled using FrameNet (Baker et al. 1998), a lexical database that records inferentially relevant features of events described by verbs. §4 presents a statistical analysis of those annotations, finding evidence consistent with (4)–(6). The observed asymmetry between transitive and intransitive verbs (4) is explained using the Causative Prediction (6): many transitive verbs (even, I argue, those not strictly categorized as "causative") describe events in which the subject affects (causes a change upon an object), so that the structure of causation gives them a nondistributive interpretation.

Turning to the formal semantics question, §5 reviews the literature to emphasize that any semantic representation of distributivity must be complemented by a predictive analysis, like the one offered here, of which predicates are interpreted in which ways and why.

Broadly (§6), this paper aims to explore distributivity at a large scale; and to show that distributivity is productively handled not just as a formal semantics topic, but as a lexical semantics one.

2 Predicting distributivity across the lexicon

This section motivates a series of predictions about the types of predicates that are interpreted as distributive (like *smile*), nondistributive (like *meet*), or in both ways (like *open the/a door*).

In general, most predicates *can* be interpreted as distributive, because most predicates – all the ones that make sense with an atomic subject – describe actions that can be carried out by a single individual (*Alice smiled, Alice opened the door*). The only exceptions are (i) reciprocal predicates like *meet*, which describe inherently multilateral actions; and (ii) predicates with definite objects describing actions that cannot be repeated on the same object (*break the vase*; the same vase generally cannot be broken repeatedly). Because most predicates can be interpreted as distributive, it is most informative to distinguish between the predicates that can *only* be distributive (*smile*), versus those that allow a nondistributive interpretation in addition to a distributive one (*open the/a door*).

I focus on the predictions (§2.1–§2.3) that are supported in the annotation study reported below (§3, §4), before sketching (§2.4) some other predictions that did not reach statistical significance there.

2.1 The Transitive/Intransitive Asymmetry

Nearly forty years ago, Link (1983) observed that a predicate's distributivity potential is related to its argument structure:

(7)   **The Transitive/Intransitive Asymmetry:** Predicates built from many intransitive verbs (*smile, laugh, arrive, die*) are only distributive, whereas predicates built from many transitive verbs (*open a door, eat a pizza*) can be nondistributive.

After observing that *carry the piano* (built from a transitive verb) can be both distributive and nondistributive, Link writes: "Common nouns and intransitive verbs like *die*, however, seem to admit only atoms in their extension. I call such predicates *distributive*" (Link 1983: 132). He reiterates (Link 1983: 141): "Most of the basic count nouns like *child* are taken as distributive, similarly IV [intransitive verb] phrases like *die* or *see*."

Of course, there are counter-examples: *love a movie* is built from a transitive verb and is only distributive (presumably because people have their own emotional attitudes); *meet* is intransitive and nondistributive. But as a tendency, (7) is plausible. To use introspective evidence, all the intransitive verbs in (8) behave like *smile* in that if Alice and Bob carry out these actions, then they each do so (distributive).

(8)   arrive, blush, die, disappear, faint, fall, laugh, meditate, pray, run, swim, walk, wink, …
        ✓distributive, **✗nondistributive**

In contrast, all of the predicates built from transitive verbs in (9) behave like *open the/a door* in that if Alice and Bob carry out these actions, they may do so jointly rather than individually (nondistributive). (The predicates in (9) can also be interpreted as distributive, with or without covariation depending on whether the action described by the verb can be repeated on the same object; but the important point is that they can be interpreted as nondistributive.)

(9)   create a controversy, eat a pizza, score a point, send a letter, write a book, …
        (✓distributive), **✓nondistributive**

Unlike the other predictions proposed below, (7) has no obvious theoretical motivation; if it is manifested, we face a deeper question of why it would be so. To preview, I suggest below that many transitive verbs describe events of causation, independently shown to favor nondistributivity.

2.2 The Mind Prediction

Love a movie is distributive because *loving* is a mental attitude, which people experience individually. The same reasoning should extend to other predicates describing the mental processes of an experiencer, such as perception, emotion, and thought. This intuition is inspired

by Roberts (1987), who observes that predicates describing self-willed actions are inherently distributive:

> "The fact that a particular lexical item is a group predicate or a distributive predicate doesn't really need to be specified independently: it follows from the sense of the predicate itself. [...] What is it to *be a pop star* or to *walk* or to *die*? The actions or states denoted by these verbs can generally only be performed or endured by an individual with a single will and consciousness. It is for this reason that we think of them as distributive."—Roberts (1987): p. 124

In other words:

(10)   **Mind Prediction:** Because individuals have their own minds, predicates describing the subject's mental or emotional processes (*believe it, hear a sound, love a movie, worry*) are distributive.

2.3 The Causative Prediction

It is less obvious why *open the/a door* prefers to be nondistributive, or which other predicates should pattern with it.

My proposal is that *open* is a causative verb (Smith 1970; Fillmore 1970; Dowty 1979), describing an event in which the subject causes the object to change in openness. By definition, causatives describe events of causation. I argue that this truism predicts the distributivity potential of such predicates: as a general fact about causation, captured by any adequate analysis of it (Swanson 2012; Menzies 2014; Copley & Wolff 2014), it is possible for the actions of multiple individuals to be jointly-but-not-individually sufficient (Mackie 1965) to bring about a result.

Illustrating with the influential counterfactual analysis of causation from Hume (1748), revitalized by Lewis (1973) and synthesized with distributivity by Dowty (1987), a sentence such as *Alice and Bob opened the door* is analyzed to mean that *a* and *b* (Alice's action and Bob's action) cause a result *d* (the opening of the door). Perhaps *a* caused *d* and *b* caused *d* (distributive), meaning that Alice's action caused the door to open, and Bob's action caused the door to open too (11a). But perhaps Alice's action and Bob's action (*a* and *b*) were jointly but not individually sufficient to cause the door to open: if Alice or Bob had acted alone, the door would still not be open (11b). Because two events may be jointly but not individually sufficient to cause a result, we predict that when a causative is predicated of a plural subject, the sentence may be interpreted as nondistributive (in addition to a distributive interpretation, which depends on the repeatability of the action and the definteness of the object). Perhaps Alice unlocks the door, and Bob pushes it open, so that the door would not have opened but for Alice's action and Bob's action together.

(11)   Alice and Bob opened {the/a} door.
    a.   (✓**Distributive:** They each opened {the/a} door.)
    b.   ✓**Nondistributive:** They opened {the/a} door jointly without each individually doing so.
      (Alice unlocks it, Bob pushes it open.)

To generalize, this discussion leads to a prediction:

(12)   **Causative Prediction:** Because the nature of **causation** allows that multiple individuals' contributions may be jointly sufficient but individually insufficient to cause a result, predicates built from **causative** verbs (describing an event where the subject causes the object to change, such as *annoy a neighbor, break a vase, destroy a family, open a door*) should allow a nondistributive interpretation (in addition, perhaps, to a distributive one).

2.4 Other predictions (which turned out not significant)

I turn to some other predictions which, while intuitively motivated, did not reach statistical significance in the annotation study (§3) reported below.

Smile is distributive because it describes a facial action which people can only carry out individually. The same reasoning should extend to other predicates describing the actions of an individual body, including actions of the face, voice, and self-propelled motion (Roberts 1987; de Vries 2015). Thus:

(13)   **Body Prediction:** Because individuals have their own bodies, predicates describing the actions of an individual body (*chew, faint, jump, laugh, sing, smile, shrug, walk*) are distributive.

Some predicates describe an event where an object, called an incremental theme (Dowty 1991), is affected in tandem with the progress of the event of affecting it (Tenny 1987; Krifka 1992). *Eat a pizza* describes an event that is half over when a pizza is half-eaten, and fully over when it is fully eaten. Such events are not necessarily causative; the progress of a *read a book* event maps incrementally to the parts of the book, but does not describe a caused change therein (Rappaport Hovav 2008).

If two people *eat a pizza*, perhaps they each eat one (distributive), or perhaps they each eat a different portion of a single pizza, adding up to a whole pizza between them (nondistributive). Informally, it is always possible for multiple individuals to each carry out the event described by the verb on a different portion of an incremental object, only jointly adding up to the whole. To generalize:[2]

(14)   **Incremental Prediction:** Because individuals may each affect a different portion of an incremental object, only jointly affecting the whole, predicates with incremental objects (*build a house, eat a pizza, paint a wall, read the book, write a letter*) are predicted to allow a nondistributive interpretation (in addition, perhaps, to a distributive one).

(15) can be understood in both ways (distributive and nondistributive), presumably because buying is a commercial transaction that can involve both individuals and larger parties.

(15)   Alice and Bob bought a car.   **(can be understood both ways)**
    a.   ✓**Distributive:** Alice bought a car, Bob bought a car.
    b.   ✓**Nondistributive:** Alice and Bob bought a car jointly but not individually.

The modern legal system allows property and commercial transactions to be shared as well as individualized. Thus:

(16)   **Commercial Prediction:** Because money and property can be possessed collectively, predicates describing commercial transactions (*buy/sell a car, lease/rent a room, pay a bill, owe a debt, donate a library, own a boat*) are predicted to allow a nondistributive interpretation (in addition to a distributive one).

Intuitively, *meet* is nondistributive because it describes an inherently multilateral action which individuals cannot carry out alone. If an action requires multiple participants, then an individual person (*Alice*) cannot carry out that action alone (Carlson 1998; Siloni 2012). Therefore, predicates describing such actions cannot be distributive, but can only be nondistributive.[3] To generalize:

---

2   More formally, this prediction can be derived from a widespread theoretical assumption (Krifka 1992; Kratzer 2007; Champollion 2010) that verbs and thematic roles are "cumulative" in the sense of being closed under sum formation. A verb such as *eat* can be analyzed as a set of eating events, as in (i) (where events are represented as tuples consisting of a label for the event and its thematic roles). Then, for any two events $e1$ and $e2$ in this set, the cumulativity assumption requires that their sum $e1 \oplus e2$ is also in this set. The sum of two *eat* events is also an *eat* event; its agent is the sum of the agent of $e1$ and the agent of $e2$, and its theme is the sum of the theme of $e1$ and the theme of $e2$. This setup guarantees the natural result that if Alice eats half the pizza and Bob eats the other half, then Alice and Bob eat the full pizza between them.

(i)   ⟦eat⟧ = {⟨$e1$, *agent* = *Alice, theme* = *half the pizza*$_1$⟩,
             ⟨$e2$, *agent* = *Bob, theme* = *half the pizza*$_2$⟩,
             ⟨$e1 \oplus e2$, *agent* = *Alice* $\oplus$ *Bob, theme* = *half the pizza*$_1$ $\oplus$ *half the pizza*$_2$⟩}

3   There are apparent exceptions to (17), such as Lasersohn's example, *The committees met* (Lasersohn 1988), which can be distributive (each committee meets alone). But this exception actually proves the rule; committees can meet individually in a way that individual humans cannot.

(17)   **Multilateral Prediction:** Because individuals cannot carry out inherently multilateral actions alone, predicates describing such actions (*coexist, collaborate, cooperate, meet, share a pizza, tango*) are predicted to be nondistributive.

Note that (17) is the only prediction about when nondistributivity is required; all the others predict when it is allowed.

2.5 Section summary

For certain predicates, one can identify an intuitive explanation for how they are understood (as distributive, nondistributive, or in both ways) when applied to a plural subject, based on the real-world event described by the predicate. This section has expanded such intuitive explanations into a series of predictions about the distributivity potential of various classes of predicates.

3 Distributivity annotations

To test these predictions, this section presents a dataset of 1020 predicates (intransitive verbs, and transitive verbs with corpus-motivated objects), annotated for distributivity using Amazon's Mechanical Turk service.

3.1 Study design

Annotators encountered past-tense predicates applied to two conjoined human names, and answered questions such as (18)–(19) – thus annotating the predicate as either distributive ("technically *each* PRED") or nondistributive ("*jointly* PRED without technically *each* doing so").

(18)   Nora and Ralph walked.
         From this sentence, one most likely infers that Nora and Ralph …

> technically **each** walked.

> **jointly** walked without technically **each** doing so.

(19)   Kendall and Taylor reduced a risk.
         From this sentence, one most likely infers that Kendall and Taylor …

> technically **each** reduced a risk.

> **jointly** reduced a risk without technically **each** doing so.

For each predicate, the FrameNet database is used to label features of the event predicted (§2) to shape its distributivity potential.

The questions (18)–(19) elicit a binary judgment about whether to interpret the predicate as distributive (*each*) or nondistributive (*jointly*). For predicates where only one interpretation makes sense (*walk, smile*), annotators are expected to choose the only sensible answer. For predicates where both interpretations make sense in principle (*reduce a risk, open a door*), annotators are expected to choose either answer, but with a bias towards the nondistributive interpretation in light of the finding (Brooks & Braine 1996; Frazier et al. 1999; Dotlačil 2010; Syrett & Musolino 2013; Dobrovie-Sorin et al. 2016) that nondistributive interpretations are preferred when they are available. Thus, predicates that only make sense as distributive (*smile*) should be annotated as distributive; predicates that only make sense as nondistributive (*meet*; by far the smallest class) should be annotated as nondistributive; and predicates that can receive both interpretations (*open a door*) should tend to be annotated as nondistributive. Of course, the task is rather abstruse and annotators may interpret it in idiosyncratic ways, so we should realistically expect these predictions to manifest as tendencies rather than absolutes.

While (18)–(19) elicit a single binary judgment about how annotators *actually* interpret the sentence, prior work (Glass 2018b) asked two hypothetical questions, using a five-point Likert scale, about how annotators *could* interpret it: (a) "Does it follow that Nora and Ralph *each* walked?" and (b) "Could it be that Nora and Ralph didn't technically *each* walk, because they did so *together*?" The current formulation was chosen because it is simpler (asking about one's actual interpretation rather than hypothetical ones, using a binary scale rather than a Likert

scale for what is really a binary distinction); it eliminates the confusing redundancy of asking two inversely related questions; and it avoids the notoriously polysemous word *together,* which can evoke both nondistributivity and socio-spatial coordination (Moltmann 2004). But, as expected, the 2018 data are strongly correlated with the new data reported here,[4] meaning that both formats probe the same phenomenon.

3.2 Choosing corpus-motivated verbs

The verbs to be annotated were chosen using a corpus of comments from Reddit, a United States-based online discussion platform. Reddit is organized into sub-communities with more or less specialized interests (r/bicycling, r/movies); here, comments were taken only from r/AskReddit, one of the largest communities, dedicated to general-interest topics (recently popular: *What is something about yourself that sounds totally made up but is 100% real?*, and: *People who shoved their school papers in their backpack with no binder/folder etc, where are you now?*). Reddit is a massive, freely available dataset of contemporary English, using fairly standard orthography but with a register close to that of spoken English (Herring et al. 2013).

The AskReddit comments from January 2014 were downloaded from the PushShift repository[5] and processed to remove all information about individual users, discussion thread structure, and upvotes/downvotes, as well as hyperlinks and comments by self-identified bots. In total, the comments comprise 110 million words.

Next, the comments were run through SpaCy (Honnibal & Johnson 2015), a natural language processing pipeline which tokenizes sentences, lemmatizes words, tags parts-of-speech, and parses the syntactic dependencies of each sentence. I counted all occurrences of each part-of-speech-tagged verb lemma in the data, and kept the verbs (excluding crude ones) with a per-million-word frequency of 2 or more. (Some of the least-frequent verbs in the data, with a per-million-word frequency of 2, include *assist, await, bolt,* and *chuck*; the most-frequent include *get, make, say, want,* and *know*, each with a per-million-word frequency of over 2000).

To create sentences such as (18)–(19) to be annotated, each verb also has to be classified as transitive (in which case it is given an object, using a process described below), or intransitive. Although many verbs can appear in both transitive and intransitive argument structures (*I ate lunch; I ate*; see, e.g., Levin 1993), this dataset annotates each verb only once, as either transitive or intransitive. Using the dependency parse from SpaCy, I computed the percent of the time that the verb appeared with a "dobj" (direct object) dependency, as a fraction of its overall occurrences. As a general rule, verbs were classified as transitive if they have a direct object more than 30% of the time, intransitive otherwise.[6]

3.3 Choosing corpus-motivated objects for transitive verbs

To create sentences to be annotated as in (19), each transitive verb must be given an object. The object of a transitive verb – both its grammatical properties and its referent – plays an important role in shaping the distributivity potential of a full predicate.

Grammatically, it matters whether the object is singular or plural. A predicate with a plural object can always be interpreted as nondistributive ("cumulative"; Scha 1981): if two people *open two doors* or *see two photos,* perhaps they do so by each opening/seeing one, adding up to two doors/photos between them (Krifka 1992; Champollion 2010). Singular objects were used to avoid that confound.

---

4   In a linear regression predicting the percentage of distributive annotations for a predicate as a function of the mean z-scored 2018 "each" rating of a predicate built from that same verb, $\beta = 0.12$, $p < 0.001$. Using the mean z-scored 2018 "together" rating as a predictor instead, $\beta = -0.13$, $p < 0.001$.

5   *https://files.pushshift.io/reddit/comments/.*

6   There were some exceptions to this general rule; among verbs that rarely have a direct object, some were still classified as transitive if their intransitive argument structure does not make sense when applied to a human subject. *Tend* rarely has a direct object (its complement is usually a nonfinite clause), but was classified as transitive because *Alice and Bob tended a bar* is more sensible than *Alice and Bob tended.*

As previewed above (§1), a predicate's potential for distributivity also depends on whether the object is definite or indefinite, which in turn interacts with whether the action described by the verb can be repeated on the same object (Champollion 2020).

(20)   Alice and Bob opened {the/a} door.
   a.   ✓**Distributive:** They each opened {the same, a different} door.
   b.   ✓**Nondistributive:** They opened {the/a} (single) door jointly without each individually doing so.

(21)   Alice and Bob broke {the, a} vase.
   a.   {???/✓} **Distributive:** They each broke {??the same, a different} vase.
   b.   ✓**Nondistributive:** They broke {the/a} (single) vase jointly without each individually doing so.

Because the same door can be opened more than once, (20) allows both interpretations regardless of whether its object is indefinite or definite. But because the same vase normally cannot be broken more than once, an indefinite object allows *break a vase* (21) to have a (covarying) distributive interpretation which is unavailable with a definite object. Thus, indefinite objects were used to abstract away from whether the action described by the verb can be repeated on the same object.

A predicate's distributivity potential is also affected by the referent of its object. *Open an eye* is distributive, based on the knowledge that people have their own eyes. *Open a book* and *open a vault* can both go both ways, but may differ because it is easier to open books than vaults.

For this study, it is important to choose objects for verbs using a method that systematically controls for these issues. Particularly if the focus is verbs, we do not want the choice of object to confound the data. But we cannot give every verb the same object (*open a door* vs. *#eat a door*); and a generic object such as *thing* would be unnatural. Instead, the AskReddit corpus data were used to find, for each transitive verb, a list of its most-frequent lemmatized direct objects according to SpaCy's dependency parse. (The list automatically excludes pronouns; demonstratives such as *this*; wh-words such as *who* and *whatever*; quantifiers such as *anyone*; partitives such as *piece* and *lot*; the highly bleached words *other, way,* and *thing*; and all vulgar words). By default, each transitive verb was given its most common lemmatized object, as a singular indefinite. I then went through by hand and identified any objects that did not make sense as a singular indefinite (mass nouns such as *water*, intensifiers such as *hell*, relational nouns such as *end*). In such cases, one of the next-most-common objects was chosen; for *reduce*, the object *risk* was chosen, because the more-common objects (*amount, chance, number*) would need further context to make sense.

(22)   **Most common lemmatized objects for the verb *reduce*, and their counts.**
         amount(64), chance(48), number(41), **risk**(37), cost(32), rate(29), stress(19), level(15), price(13), pain(12)

The noun *person* was the most-common object for so many verbs that the next-most-common object, if it made sense as a singular indefinite, was chosen for balance.

This process yields objects that are naturalistically motivated, minimally shaped by researcher bias, and sensible as singular indefinites.

3.4 Labeling predicate features with FrameNet

Each predicate must also be labeled for the features predicted (§2) to shape its potential for distributivity. Of course, if the researcher labeled these features, the study might be vulnerable to confirmation bias – the researcher might choose labels consistent with their own beliefs about the predicate's potential for distributivity, and then circularly use these labels to predict distributivity.

Therefore, labels were chosen in an automatic manner using the FrameNet database[7] (Baker et al. 1998), which is built upon the theory of Frame Semantics from Fillmore (1976). Frame Semantics brings together the idea of thematic roles (the roles played by each argument of a verb in the event that it describes; Gruber 1965) with the idea that humans understand language using rich background knowledge – called frames, scripts, or schemas (Schank & Abelson 1977) – about stereotypical events.

FrameNet is a machine-readable database of such frames, built by semanticists and lexicographers. The lexical unit *walk.v* evokes the SELF-MOTION frame:

(23)   SELF-MOTION: "The **Self-Mover**, a living being, moves under its own direction along a **Path**. Alternatively or in addition to **Path**, an **Area**, **Direction**, **Source**, or **Goal** for the movement may be mentioned."

Each underlined word constitutes a Frame Element, to which each argument of the verb *walk* can be mapped. *Reduce.v* evokes the CAUSE-CHANGE-OF-POSITION-ON-A-SCALE frame:

(24)   CAUSE-CHANGE-POSITION-ON-A-SCALE: "An **Agent** or a **Cause** affects the position of an **Item** on some scale (the **Attribute**) to change it from an initial value (**Value1**) to an end value (**Value2**). The direction of the change (**Path**) can be encoded as well as the magnitude of the change (**Difference**)."

Frames are related to other frames through various Frame-Frame relations. The SELF-MOTION frame "inherits" (is a more specific instance of) the MOTION frame. The CAUSE-CHANGE-POSITION-ON-A-SCALE frame (also evoked by related verbs such as *add*, *double*, and *raise*) serves as the "causative-of" the CHANGE-POSITION-ON-A-SCALE frame (which, in turn, is the "inchoative-of" the CAUSE-CHANGE-POSITION-ON-A-SCALE frame).

FrameNet was used – specifically, the version integrated into the Natural Language Toolkit (NLTK; Loper & Bird 2002) by Schneider & Wooters (2017) – to label predicates for the features predicted (§2) to shape their distributivity potential.

A predicate was labeled as a "mind" predicate if it evokes or inherits the frames EXPERIENCER-FOCUS (for verbs with experiencer subjects, such as *love*); PERCEPTION, EMOTIONS-OF-MENTAL-ACTIVITY, COGITATION, AWARENESS, MEMORY, and MENTAL-ACTIVITY; and/or if it requires a COGNIZER among its core Frame Elements. Because the prediction is about the subjects of mind verbs rather than their objects, verbs were excluded from this classification if they evoke the EXPERIENCER-OBJECT frame, describing the mental experience of the syntactic object (*astonish*; Grafmiller 2013) rather than the subject. In total, 127 predicates were labeled as "mind" predicates (112 transitives, 15 intransitives), including:

(25)   admire a person, believe a story, care, crave a cigarette, dread a class, dislike a movie, feel a pain, grieve, hear a story, find a job, expect a tip, imagine a scenario, envy a friend, listen, perceive a threat, pity a fool, …

A predicate was labeled as "causative" if it involves a transitive verb (because causatives, as defined here, describe events in which a subject causes a change upon an object) and evokes or inherits the frames EXPERIENCER-OBJ (for "psych" verbs such as *annoy*, describing events in which a stimulus subject causes an emotion in an experiencer object); CAUSATION, or KILLING; if it evokes or inherits any frame with the CAUSE- prefix; if is related to any other frame through the "causative-of" frame relation; or if it requires a CAUSE among its core Frame Elements. In total, 314 predicates were labeled as causative (all transitive), including:

(26)   activate a card, annoy a friend, arrest a person, baffle a doctor, bake a cake, butcher an animal, cast a spell, chill a drink, calm a child, develop a skill, dissolve a plastic, discourage a child, fry a chicken, melt a cheese, plant a seed, reduce a risk, rip a shirt, …

---

7   FrameNet can be explored through its web demo: *https://framenet.icsi.berkeley.edu/*.

Any predicate was excluded from the study if its verb is absent from FrameNet (which has some odd gaps; *blush, dream, edit, greet,* and *relax* are absent). Even among the predicates that appear in FrameNet, quite a few of them do not receive any of the labels just described; for example, *refuse an offer* is labeled as neither "mind" nor "causative" nor any other label.[8]

Predicates were labeled before gathering any distributivity annotations, and the data to be annotated were pre-registered through the Open Science Framework (*https://osf.io/ena5r/*).

3.5 Data collection

In total, 1020 predicates were assembled, 161 intransitive verbs and 859 transitive verbs with objects, all labeled using FrameNet for the features predicted to shape their distributivity potential. These 1020 predicates were randomly split into 20 lists of about 50 predicates each.[9] Each list of about 50 predicates was used to generate an annotation survey on the Qualtrics platform (using the "Loop and Merge" function to iterate over a list of predicates). Each predicate, in the past tense, was combined with a random conjunction of two names and placed in a question modeled after (18)–(19).

Using Amazon's Mechanical Turk, 215 annotators were recruited[10] with a goal of collecting (at least) nine annotations for each of the twenty lists of ~50 predicates. Annotators using United States I.P. addresses were paid $3.00 for what amounted to between seven and fifteen minutes of work. Two hundred and one (201) annotators were included in the analysis; fourteen were excluded because they either did not complete the study or they said, after being advised that they would be paid regardless of their answer, that their native language was not English.

Table 1 shows an excerpt of the data for the first three annotators. Subj1 rated the predicate *boot a computer* as distributive ("*each* booted a computer"); this predicate was also labeled as causative by the FrameNet procedure described above.

---

8   As for the labels that turned out not to be significant, a predicate was labeled as a "body" predicate if it evokes or inherits the frames Self-Motion, Body-Movement, Sleep, Death, Making-Faces, or Experience-Bodily-Harm. In total, 103 predicates were labeled as "body" predicates (69 transitives, 34 intransitives), including:

(i)   blink, back a claim, dance, duck, hop, hurry, jump, jog, chase a car, close a door, hit a wall, march, move, nod, reach a goal, shake a bottle, shrug a responsibility, stub a toe, walk, …

Some predicates may seem to be mis-labeled (*back a claim, shrug a responsibility* do not really seem to involve the body), but *back* evokes the Self-Motion frame (e.g., *back up*) and *shrug* inherit the Body-Movement frame, so they are labeled as "body" predicates. In general, automatic labeling is rarely perfect, but cannot be corrected by hand without risking bias from the researcher.

A predicate was labeled as "commercial" if it evokes or inherits the frames Giving, Possession, Bringing, Sending, Commerce-Buy, or Commerce-Sell. In total, 43 predicates were labeled as "commercial" (all transitive), including:

(ii)   donate a dollar, gift a car, lend a car, mail a check, own a gun, pay a bill, provide an example, sell a car, supply a drug, …

A predicate was labeled as "incremental" if it involves a **transitive** verb (because incremental predicates, as defined here, describe events in which a subject incrementally affects an object) and evokes or inherits the frames Ingestion or Intentionally-Create. In total, 42 predicates were labeled as "incremental" (all transitive), including:

(iii)   bake a cake, consume an alcohol, drink a beer, draw a picture, ingest a pill, produce a result, sign a contract, write a book, …

A predicate was labeled as "multilateral" if it evokes or inherits the Reciprocity or Come-together frames. (In some cases, only the intransitive frame of the verb actually describes a reciprocal relation between members of a plural subject, as in *they met*, while the transitive frame describes such a relation between the subject and and object, as in *they met me*; but there are other cases where even the transitive frame of the verb describes a reciprocal relation between members of a plural subject, as in *they exchanged an email*.) In total, 21 predicates were labeled as "multilateral" (15 transitive, 6 intransitive), including:

(iv)   chat, differ, exchange an email, meet a friend, share a story, trade a stock, talk, unite a tribe, vary, …

9   A twenty-first list was also added, for five predicates that had mistakenly been left out of the original twenty lists.

10   Initially, 90 annotators were run in May 2020; an additional 125 were added in October 2020, for 215 total. This study was declared officially exempt from the IRB by my institution's IRB board.

ID	pred	annotation	labeled features
Subj1	booted a computer	distributive	causative
Subj1	failed a test	distributive	–
Subj1	negotiated a price	nondistributive	–
(...)	(...)	(...)	(...)
Subj2	cared	distributive	mind
Subj2	dissolved a plastic	nondistributive	causative
Subj2	hurried	distributive	body
(...)	(...)	(...)	(...)
Subj3	crashed a car	nondistributive	causative
Subj3	fell	distributive	–
Subj3	imagined a scenario	distributive	mind

Table 1 For the first three annotators, this table shows their (distributive, nondistributive) annotations for some predicates that they encountered, as well as the features of the predicate (hypothesized to predict distributivity) labeled using FrameNet.

Figure 1 records a histogram of the percentage of distributive annotations for all 1020 predicates; *Figure 2* shows examples of some predicates along with the percent of distributive annotations thereof; for example, nine of the ten annotations for *admired a person* rate it as distributive (consistent with the Mind Prediction).
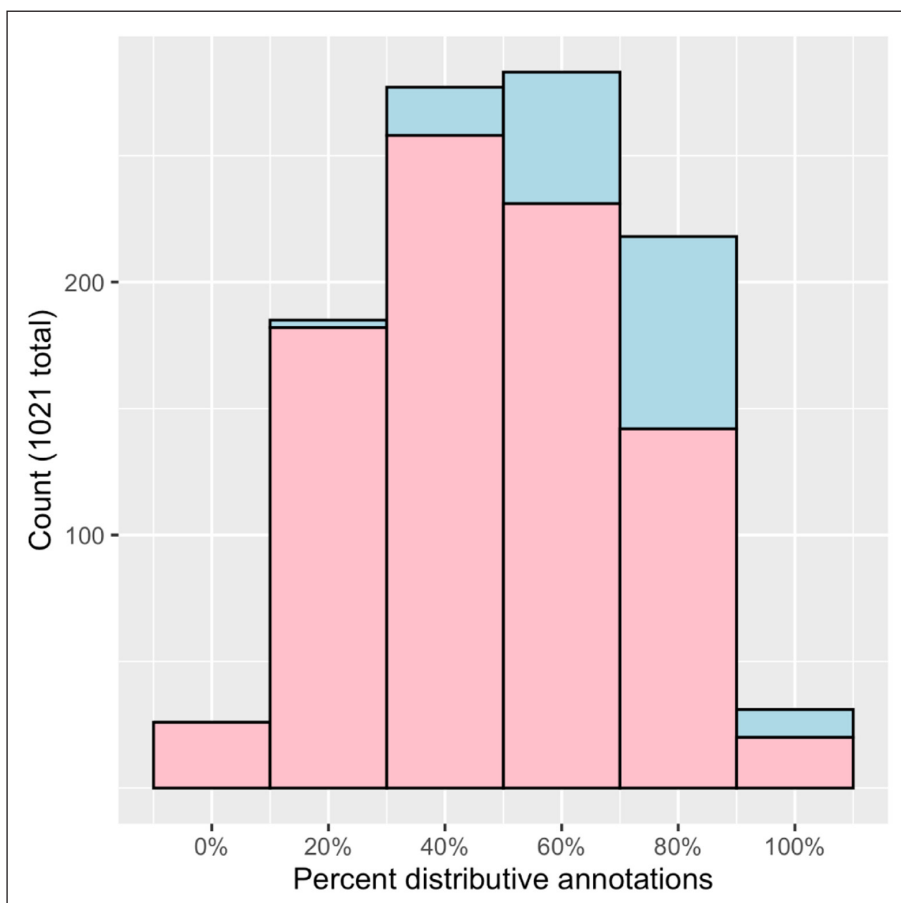
Figure 1 Histogram of the percentage of distributive annotations.

4 Testing predictions about predicates' distributivity potential

The next step is to use the annotations (§3) to test predictions (§2) about the distributivity potential of different types of predicates.
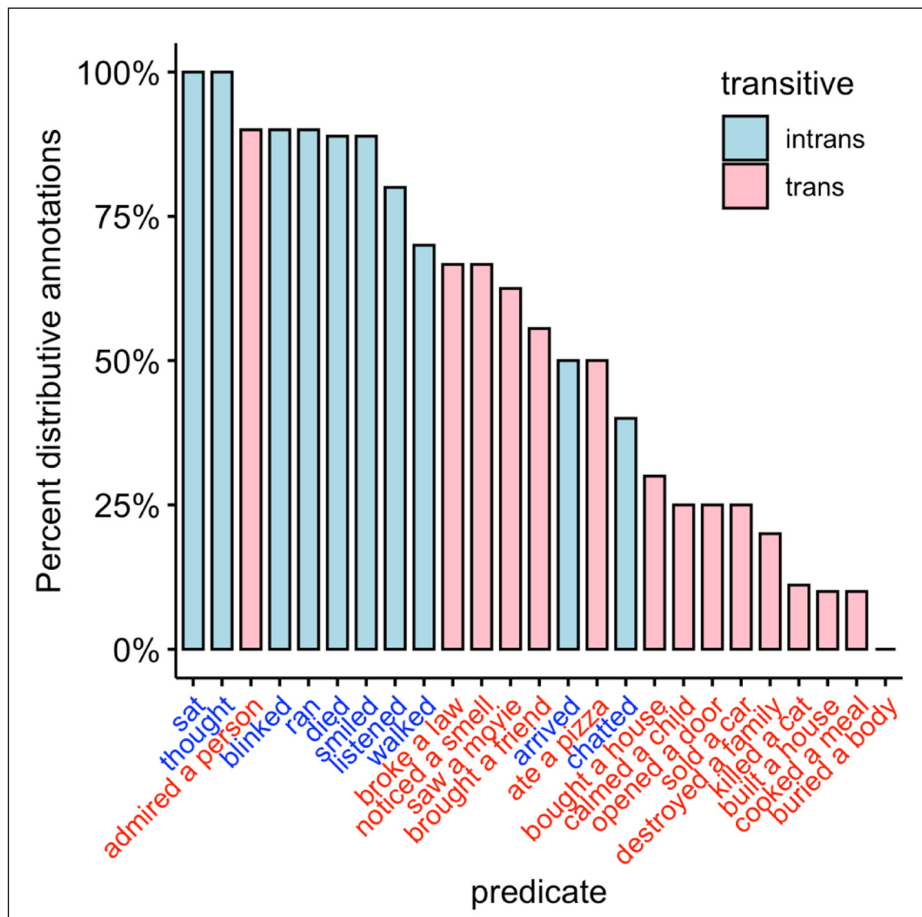
4.1 Statistical analysis

Data were analyzed with mixed-effects logistic regression models in R (the `glmer` function; Bates et al. 2015; R Core Team 2012, using the `bobyqa` optimizer of Powell 2009 to help them converge). A logistic regression predicts a binary dependent variable (here, an annotation of either distributive or nondistributive) as a function of one or more continuous or categorical independent variables. A mixed-effects model (Winter 2013) uses random effects to factor out systematic differences – between individual annotators or items – unrelated to the hypothesis being tested.

A series of models was built, using every hypothesized independent variable (§2) as well as subsets and combinations (additions and interactions) thereof. Models used random intercepts for each predicate and tried both random intercepts and random slopes for each annotator (Barr et al. 2013). Models were then compared using Analysis of Variation (anova), which rewards models for a balance of parsimony and data coverage. According to the anova, the best (most parsimonious and explanatory) model uses random intercepts for each predicate, random slopes and random intercepts for each annotator, and predicts the binary annotation outcome (distributive or nondistributive) from the independent variables of *transitive, causative,* and *mind* (each coded as a binary yes/no factor):

(27)   glmer(annotation ~ transitive + caus + mind + (transitive | SubjId) + (mind | SubjId) + (caus | SubjId) + (1 | pred), data = d, family = binomial)

The independent variables in (27) remained significant across all models.

Table 2 illustrates the effect sizes, standard errors, and p values for each independent variable, and presents the model's predicted probability (calculated using `plogis`) of each type of predicate being annotated as distributive.

Table 3 illustrates the extent to which these independent variables overlap with one another. For example, all causatives as defined here inherently involve transitive verbs; 37% of transitive

verbs (314 of 859) are labeled as causative. But while these independent variables overlap, a Variance Inflation Factor test shows that they are not too collinear.[11]

The statistical model (27) (*Table 2*) shows evidence consistent with certain predictions about the distributivity potential of various predicates (§2).

	Estimate	P(dist)	Std error	z	Pr(>|z|)
(Intercept=intrans)	1.29	78%	0.13	10.23	<0.001***
transitive	−1.22	52%	0.13	−8.85	<0.001***
mind	0.52	86%	0.12	4.51	<0.001***
causative (& transitive)	−0.26	45%	0.08	−3.28	<0.01**

	trans	intrans	mind	causative	overall
trans	**859 (100%)**	0 (0%)	112 (88%)	314 (100%)	859 (84%)
intrans	0 (0%)	**161 (100%)**	15 (12%)	0 (0%)	161 (16%)
mind	112 (13%)	15 (9%)	**127 (100%)**	11 (3%)	127 (12%)
causative	314 (37%)	0 (0%)	11 (9%)	**314 (100%)**	314 (30%)
total	**859**	**161**	**127**	**314**	**1020**

4.2 Evidence consistent with the Causative Prediction

Causatives were predicted (28) (repeated from above) to allow a nondistributive interpretation.

(28)   **Causative Prediction:** Because the nature of **causation** allows that multiple individuals' contributions may be jointly sufficient but individually insufficient to cause a result, predicates built from **causative** verbs (describing an event where the subject causes the object to change, such as *annoy a neighbor, break a vase, destroy a family, open a door*) should allow a nondistributive interpretation (in addition, perhaps, to a distributive one).

This prediction is indeed manifested statistically (27). *Figure 3* compares the average percentage of distributive annotations for causative predicates versus predicates built from other, non-causative transitive verbs. (All causatives are transitive, and the model finds a striking effect of transitivity to be explored below, so it is most illuminating to compare causatives to other transitives rather than to all verbs). A regular transitive verb has about a 52% chance of being annotated as distributive, while a causative transitive has about a 45% chance.

Causation is known to be grammatically and inferentially important (Smith 1970; Fillmore 1970; Dowty 1979; Levin 1993; Levin & Rappaport Hovav 1994; Rappaport Hovav & Levin 2010). Causative verbs are grammatically unique in that they are the only ones to participate in the causative-inchoative alternation of Smith (1970) (*I opened the door/the door opened*). They are inferentially unique in that they entail a change of state in their object/patient argument, and don't specify exactly how the agent acted to bring it about. This paper identifies one more inferential consequence of causation: when applied to a plural subject, causative predicates systematically favor a nondistributive interpretation.

---

11   Code from T. Florian Jaeger (*https://hlplab.wordpress.com/2011/02/24/diagnosing-collinearity-in-lme4/*) was used to calculate the Variance Inflation Factor (VIF) for each independent variable, as a test for collinearity. VIF measures the extent to which one independent variable is correlated with others (too much collinearity is a problem, indicating that one variable is perhaps redundant with another). The VIF scores are:

(i)   a.   transitive: 1.05
        b.   mind: 1.03
        c.   causative: 1.07

A VIF score around 1 indicates minimal collinearity with another independent variable. Thus, while all causatives are transitive, (i) shows that these two variables are still not too collinear.
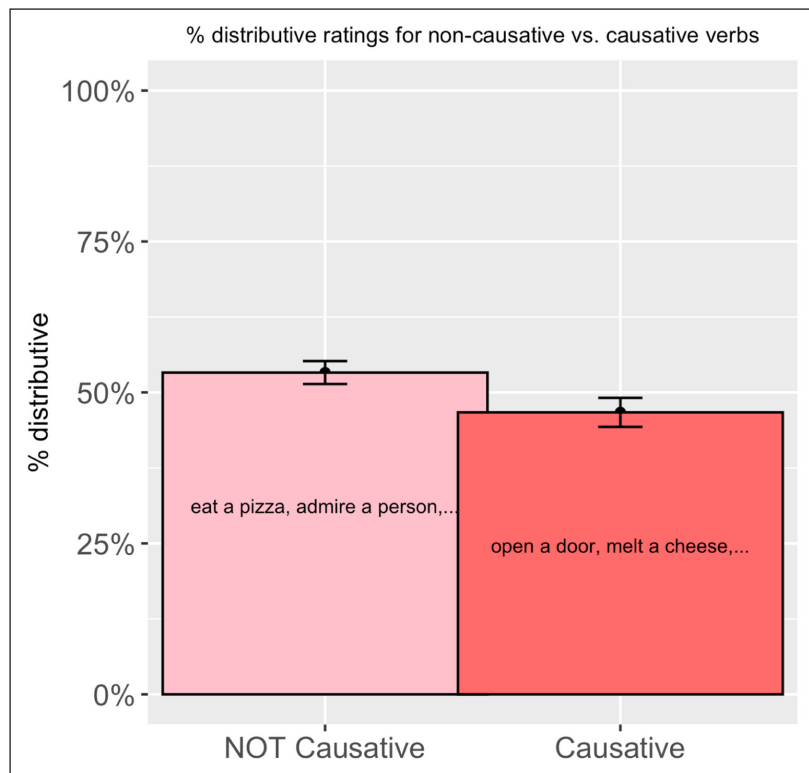
Figure 3 Average percentage of distributive annotations for transitive non-causative versus transitive causative verbs.

4.3 Evidence consistent with the Mind Prediction

Predicates describing mental actions were predicted (29) (repeated from above) to be distributive.

(29)   **Mind Prediction:** Because individuals have their own minds, predicates describing the subject's mental processes (*believe it, love a movie, meditate, see a photo, worry*) are distributive.

This prediction is indeed manifested (*Figure 4*). Across both transitives and intransitives, mind verbs (*admire a person, think*) favor a distributive interpretation in comparison to other verbs, consistent with (29).
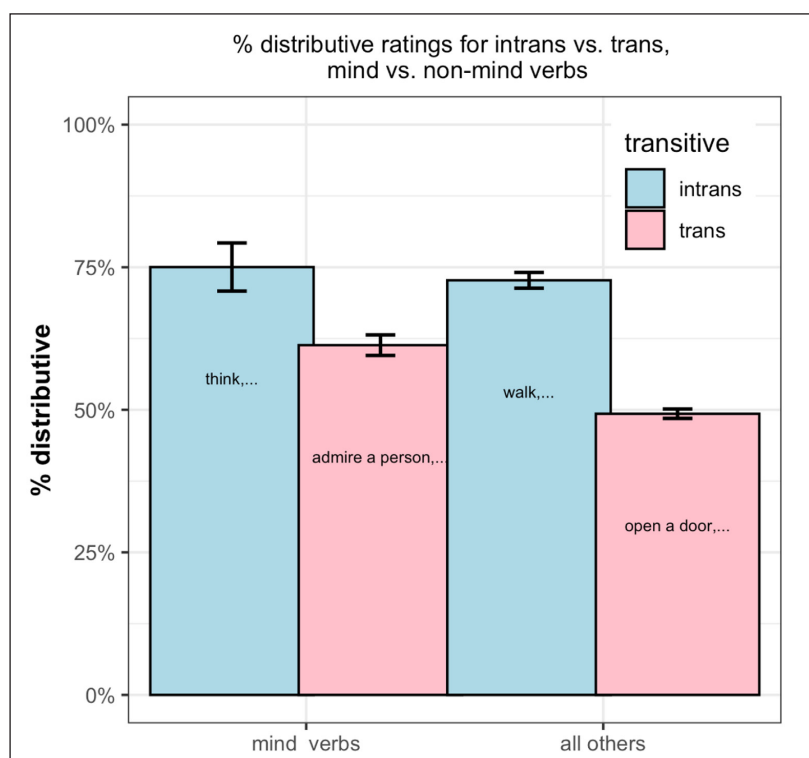
Figure 4 Average percentage of distributive annotations for mind verbs vs. other verbs, considering both intransitives and transitives.

Strictly speaking, (29) might predict that mind verbs should all be annotated as distributive, without exception; but *Figure 4* shows a tendency rather than an absolute, showing that some (confused, inattentive, or imaginative) annotators were willing to use the adverb *jointly* to describe situations in which two people share the same mental state.

Although the model comparison finds that mind verbs have an additive effect rather than a significant interaction with transitivity, *Figure 4* shows that this effect is clearest among transitive mind verbs (*love a movie*). Intransitive mind verbs (*think*) are not much different from other intransitive verbs (*walk*), all favoring a distributive interpretation. In contrast, transitive mind verbs (*admire a person*) are strikingly more distributive than other transitive verbs (*open a door*).

Most transitive verbs describe events in which a subject affects an object (Hopper & Thompson 1980) but transitive mind verbs (those with experiencer subjects, such as *see, love,* and *hate*) are unique because their objects bring about a perceptual or emotional experience in their subjects (Belletti & Rizzi 1988; Dowty 1991). This paper identifies one more inferentially unique facet of mind verbs: when applied to a plural subject, mind verbs systematically favor a distributive interpretation.

To contextualize this finding, it is important to explore how transitive verbs differ from intransitive verbs more generally.

4.4 Explaining the Transitive/Intransitive asymmetry

The distinction between transitive and intransitive verbs (30) (repeated from above) has the largest effect size. *Figure 5* illustrates the average percentage of distributive annotations for intransitive verbs (~75%) compared to predicates built from transitive verbs (~50%).
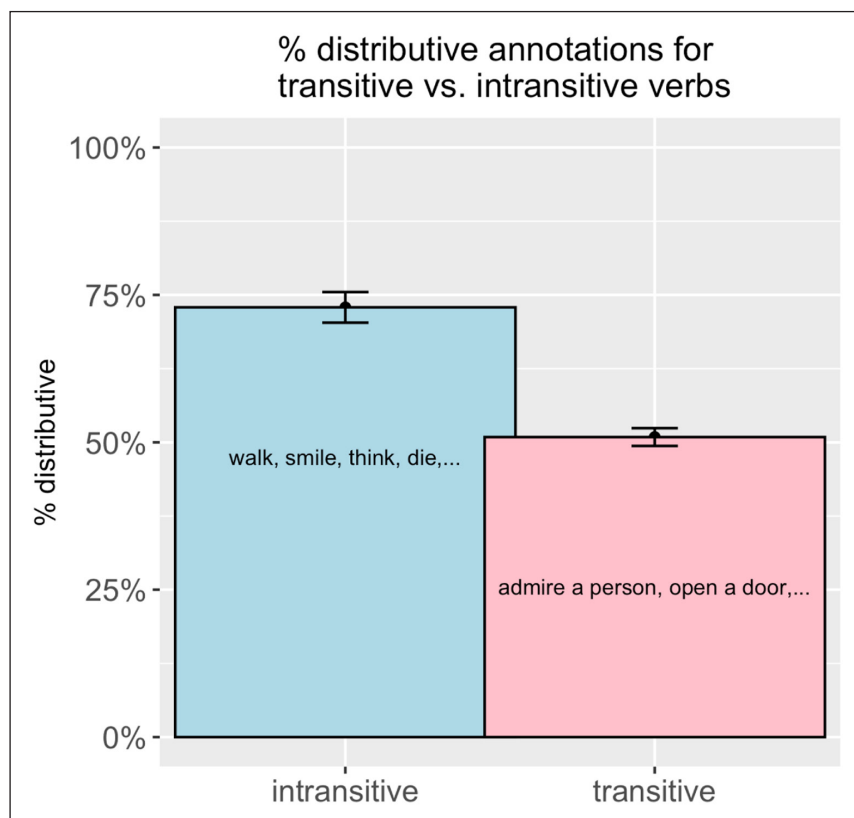

Figure 5 Average percentage of distributive annotations for intransitive verbs vs. predicates built from transitive verbs.

(30)   **Transitive/Intransitive Asymmetry:** Predicates built from many intransitive verbs (*smile, laugh, arrive, die*) are only distributive, whereas predicates built from many transitive verbs (*open a door, eat a pizza*) can be nondistributive.

But it may seem ironic that the prediction with the largest effect size has the least obvious theoretical motivation (§2). Why would a predicate's potential for distributivity be related to its syntax?

We have seen that causatives favor nondistributive interpretations, and that transitive verbs are the only ones that can be causative in the sense of describing an event in which a subject causes a change on an object. I attempted a mediation analysis (Baron & Kenny 1986), testing whether the effect of transitivity is lessened when causation is included as well (on this analysis, transitivity would predict causation, which would in turn predict nondistributivity). But the effect of transitivity is scarcely lessened by including causation in the model, so the effect of transitivity is not much mediated by causation.[12]

Thus, even controlling for causation, transitive verbs are still starkly more likely to be annotated as nondistributive compared to intransitive verbs. Why are even the non-causative transitive verbs so much less distributive than intransitive verbs?

We find a clue among examples of the "non-causative" predicates built from transitive verbs that are still most often annotated as nondistributive (31):

(31)   **Predicates built from transitive verbs, *not* labeled as causative, annotated as nondistributive by >80% of annotators**
afford a car, announce a plan, build a house, bury a body, expose a flaw, free a country, negotiate a price, protect a child, seal a deal, steal a car, support a family, train a dog…

None of the predicates in (31) are labeled as "causative", because none of these verbs inherits or evokes any Causation-related frame in FrameNet, nor serves as the "causative-of" any other frame. Nor do they undergo the causative-inchoative alternation (Smith 1970; Levin 1993) – *I opened the door/the door opened* – which serves as a sufficient-but-not-necessary diagnostic for causation.

In contrast, consider the "non-causative" predicates built from transitive verbs that are annotated as distributive by at least 70% of annotators (32):

(32)   **Predicates built from transitive verbs, *not* labeled as causative, annotated as distributive by >70% of annotators**
cross a road, don a hat, flee a country, forgive a person, hear a story, interpret a statement, learn a lesson, light a cigarette, lose a job, manifest a symptom, ponder a question, practice a religion, ride a bike, shed a tear, use a phone, violate a rule, …

Comparing (31) and (32), we observe that the mostly-nondistributive predicates in (31) tend to describe events in which the object is relatively more affected, while the mostly-distributive ones in (32) describe events in which the subject is more affected. A person who buries a body changes its location (object-affecting), while a person who *crosses a road* changes their own location (subject-affecting).

To generalize, we can draw on ideas from Dixon (1979); Hopper & Thompson (1980); Comrie (1989); Dowty (1991); Gropen et al. (1991); DeLancey (1991); Naigles & Kako (1993); Levin & Rappaport Hovav (2005); Næss (2007); Beavers (2011); Croft (2012) to arrange predicates along a spectrum (33) from those where the object is most affected to those where the subject is most affected. At the end of the spectrum where the object is most affected, we find the verbs defined strictly as causative (*open a door*) – those that participate in the causative/inchoative alternation, evoke a causation-related frame in FrameNet, and entail a change of state in their object; all the verbs at this end of the spectrum must be transitive because only transitive verbs have an object.

In the intermediate portion of the spectrum, we find different degrees of object affectedness (Beavers 2011), from those entailing a specific change in the object (*open a door*) to those conveying a potential for change (*train a dog, scrub a pot, hit a window*).

At the end of the spectrum where the subject is most affected, we find transitive verbs describing events where the subject rather than the object undergoes a change, including subject-experiencer mind verbs (*I noticed a problem*), and all intransitive verbs, which have no object.

---

12   A model that considers both transitivity and causation predicts a (non-causative) transitive verb to have a 51% chance of being annotated as distributive; a model that considers only transitivity predicts it to have a 49% chance of being annotated as distributive. Please see my full R code, available on the Open Science Framework (*https://osf.io/ena5r/*), for the full mediation analysis.

(33)   ← **Object most affected** ……………… ………………**Subject most affected** →
         open a door > bury a body > train a dog > notice a problem, flee a country, fall

To explain the Transitive/Intransitive Asymmetry (30), we can begin by exploring differences *within* transitive verbs. Within transitives (33), a nondistributive interpretation is available for those describing events in which the subject affects the object (*open a door, bury a body, train a dog*). Whenever the object changes as a result of such an event (the door opens, the body's location changes, the dog's behavior changes), the subject causes that change. Any time a subject causes a change upon an object, the Causative Prediction would predict that the structure of causation should allow a nondistributive interpretation, whereby the actions of multiple individuals are jointly but not individually sufficient to cause a result. From this perspective, the Causative Prediction should apply not just to the verbs that meet the strict criteria for causatives according to FrameNet, but to all verbs describing an event in which a subject causally affects an object, including not just the pole of (33) but the whole left portion, including predicates such as (31).

In contrast, among transitive verbs describing events in which the subject is more affected (*flee a country*), a distributive interpretation is preferred. There is no way for the structure of causation to give rise to a nondistributive interpretation, because the subject does not affect an object; instead, it is the subject which is affected. This explanation encompasses both the subject-affecting predicates in (32) as well as the transitive mind verbs with experiencer subjects handled by the Mind Prediction (*love a movie*), all of which strongly favor a distributive interpretation.

As for intransitive verbs (*smile, fall*), all of them describe events affecting the subject. Just like subject-affecting transitive verbs, they cannot describe events in which a subject affects an object, so they cannot get a nondistributive interpretation from the structure of causation. As a result, they behave as distributive, unless they describe events that are inherently multilateral (*meet*).

To explain the Transitive/Intransitive Asymmetry, I therefore propose that:

(34)   **Proposed explanation for the Transitive/Intransitive Asymmetry**
         a.   Many transitive verbs describe events in which a subject affects (causes
                a change in) an object, and thus can describe an event in which multiple
                individuals' joint contributions are jointly sufficient but individually
                insufficient to bring about a result – thus, are likely to be interpreted as
                nondistributive.
         b.   Intransitive verbs by definition cannot describe events in which a subject
                affects an object, so they cannot get a nondistributive interpretation from the
                structure of causation – thus, are likely to be interpreted as distributive.

This explanation brings together all of the main findings of the paper. It relies upon the Causative Prediction, because the structure of causation allows that the contributions of multiple individuals may be jointly but not individually sufficient to cause a result. It also comprises the Mind Prediction; mind verbs are distributive because they describe events in which the subject rather than the object is affected. And it explains not only the Transitive/Intransitive Asymmetry, but also the differences within different types of transitive verbs (31)–(32). (Transitive) verbs describing object-affecting events get a nondistributive interpretation from the nature of causation, inherent to affecting change in an object. (Transitive or intransitive) verbs describing subject-affecting events tend to receive a distributive interpretation, because causation cannot give them a nondistributive interpretation.

4.5 Further evidence that object-affectedness predicts nondistributivity

(34) can be further validated using the data of White et al. (2016), who annotate inferences (Dowty 1991) about the noun-phrase arguments of various verb tokens in the English Web Treebank. In the sentence *Katrina devastated refineries in Louisiana and Mississippi*, annotators rated on a 5-point Likert scale the extent to which the direct object *refineries* "was/were altered

or somehow changed during or by the end of the *devastating*." Such annotations capture the affectedness of a direct object without requiring the verb to count as strictly causative.

For each transitive verb, the average "change-of-state" Likert rating of its direct object was gathered (mean = 2.93 across all tokens and annotators; note that only 401 of my 859 transitive verbs appear in these data). Among all transitive verbs, a verb's mean change-of-state rating is a strong negative predictor of the verb being annotated as distributive (predicting 'annotation' in a logistic regression as a function of change-of-state rating, with random intercepts for annotators and predicates, $\beta = -0.21$, $p < 0.001$), and the effect persists even when limiting the data to transitive verbs that are not labeled as causative.

In other words, even among transitive verbs that are not labeled as causative, the ones that describe object-affecting events are least likely to be annotated as distributive. I take these findings to be consistent with the claim (34) that even some not-strictly-causative transitive verbs describe events in which a subject affects (causes a change upon) an object, and that these transitive verbs favor a nondistributive interpretation just as the strictly-causative ones do.

4.6 Other predictions that turned out not significant

Some other independent variables were predicted (§2) to influence distributivity but had no statistically noticeable effect: body predicates, incremental predicates, commercial predicates, and multilateral predicates. We cannot draw strong inferences from the absence of a statistical effect. But to speculate, perhaps these predictions failed because each of these classes was quite small (none comprised more than 105 verbs, most less than 50). The incremental prediction and the commercial prediction apply exclusively to transitive verbs and predict them to favor nondistributivity – but any such effect may be washed out by the fact that most transitive verbs favor nondistributivity already. From the available evidence, it remains open whether these predictions should be re-thought, or whether they are just empirically drowned out by other factors.

4.7 Section summary

This section has found evidence consistent with several theoretically motivated predictions about how a predicate's distributivity potential depends on the nature of the event it describes.

I have argued that the potential for distributivity crucially depends on whether the subject or the object of the verb is affected. Verbs describing object-affecting events get a nondistributive interpretation from the structure of causation, whereas verbs describing subject-affecting events cannot receive a nondistributive interpretation through these means. This explanation encompasses the Transitive/Intransitive Asymmetry (only transitive verbs can describe object-affecting events), the Causative Prediction (causation is what gives object-affecting verbs a nondistributive interpretation), the Mind Prediction (mind verbs as defined here are all subject-affecting and distributive), and differences within transitive verbs (the object-affecting ones can be nondistributive, even those that are neither causatives nor mind verbs).

Many questions remain open. Why are some predictions (about body, incremental, and multilateral predicates) not manifested? In addition to the effect of a given verb, what is the effect of its particular object on the distributivity of a full predicate? But this section at least charts a path for exploring distributivity across the lexicon.

5 Semantic representations of distributivity

Turning to the formal semantics question of how distributive and nondistributive interpretations should be represented, I show that any available formal analysis must be complemented by a theory, like the one offered here, of which predicates are interpreted in which ways.

5.1 Distributivity as plurality

Landman (1989; 2000) aims to unify distributivity with plurality. For him, *smile* is semantically singular, like a singular count noun (*child*); it is lexically restricted to only apply to "atomic" individuals such as *Alice*. To apply to a plural subject such as *Alice and Bob*, *smile* must be

simultaneously made plural and distributive using the ⋆ operator (closure under sum) from Link (1983).[13] Just as pluralized *children* (⋆*child*) is true of the plural *Alice* ⊕ *Bob* if singular child is true of each one, pluralized ⋆*smile* is true of the plural *Alice* ⊕ *Bob* if singular, un-pluralized *smile* is individually true of *Alice* and of *Bob*. Among both nouns and verbs, plurality and distributivity are derived in unison from ⋆.

(35)   ⟦*child*⟧ = {*Alice, Bob*}

(36)   ⟦⋆*child*⟧ = {*Alice, Bob, Alice* ⊕ *Bob*}

(37)   *child*(*a*) ∧ *child*(*b*) ↔ ⋆*child* (*a* ⊕ *b*)

(38)   ⟦*smile*⟧ = {*Alice, Bob*}

(39)   ⟦⋆*smile*⟧ = {*Alice, Bob, Alice* ⊕ *Bob*}

(40)   *smile*(*a*) ∧ *smile*(*b*) ↔ ⋆*smile*(*a* ⊕ *b*)

Since distributive predication is synonymous with plural predication on Landman's view, then collective (roughly, non-distributive) predication must equal singular predication. For Landman, *meet* is lexically restricted to only apply to "groups," semantically singular but conceptually composite entities such as *committee*, which can be formed from regular plurals by Link's group-forming ↑ operator. *Meet* is true of the group ↑ (*Alice* ⊕ *Bob*), but not individually true of each member.

(41)   Alice and Bob met.
         meet (↑ (*a* ⊕ *b*))

As for predicates that can be interpreted as both distributive and nondistributive, such as *open the door,* these are lexically allowed to apply both to atomic individuals such as *Alice*, and to groups such as ↑ (*Alice* ⊕ *Bob*). On its distributive interpretation, open the door becomes both plural and distributive via ⋆ and applies individually to Alice and to Bob as atoms; on its nondistributive interpretation, it is singular and applies to the group ↑ (*Alice* ⊕ *Bob*).

(42)   Alice and Bob opened the door.
         a.   **Distributive:** ⋆open the door (a ⊕ b)
         b.   **Collective:** open the door (↑ (a ⊕ b))

Landman's analysis faithfully represents the inferences drawn from *smile, meet,* and *open the door,* but does not explain or predict which predicates are understood in which ways. *Smile* is said to be lexically restricted to atoms, *meet* to groups; *open the door* can apply to both atoms and groups. These facts, which derive the distributivity potential of such predicates, presumably depend on lexical/world knowledge about the events they describe (i.e., the fact that people have their own faces and so can only *smile* individually), in ways open to be explored.

For Landman, therefore, the current study helps explain which further predicates lexically apply to atoms, groups, or both.

5.2 Meaning postulates and a D operator

The literature's most common approach to distributivity (Roberts 1987; Dowty 1987; Link 1991; Lasersohn 1995; Link 1998; Winter 2000; Champollion 2010; de Vries 2015; Champollion 2017; de Vries 2017) is two-pronged, involving both meaning postulates (Carnap 1952; Scha 1981) and a silent version of each known as the *D* operator (Link 1991, originally written in the 1980s; Roberts

---

13   ⋆*P* is the closure under sum of a set *P;* if *Alice* and *Bob* are in the unpluralized set of individuals who *smile*, then their sum *Alice* ⊕ *Bob* is in the pluralized ⋆*smile*. Landman further assumes that un-pluralized *smile* applies only to individual atoms, and that the pluralizing *star* applies only to predicates that in their singular form are restricted to atoms. Thus, if the sum *Alice* ⊕ *Bob* is in the denotation of pluralized ⋆*smile*, it follows that the atoms *Alice* and *Bob* are members of the un-pluralized *smile*, and vice versa.

1987).[14] Meaning postulates are stipulated restrictions on the models entertained in a model-theoretic framework, used to capture lexical/world knowledge. *D* is an optional, silent, scope-taking operator, ambiguously present or absent, which guarantees distributivity when present.

To illustrate with the influential version of Champollion (2010), smile is distributive because a meaning postulate requires us to only consider models where every member of a plural who smiles does so individually: whenever a group G smiles, its members do so too.

(43)   Alice and Bob smiled.
         smile(Alice ⊕ Bob)
         Meaning postulate: $smile(G) \rightarrow \forall x[x \in G \rightarrow smile(x)]$

Meet is nondistributive because it has no such meaning postulate (and perhaps also thanks to the group-forming ↑ operator of Link 1983, which some authors in this tradition invoke in addition to other tools).

(44)   Alice and Bob met.
         meet(Alice ⊕ Bob)
         (or, if using ↑:) *meet(↑(Alice ⊕ Bob))*

Open the door is understood in both ways because it is ambiguous between a representation with the *D* operator (45a) (silent *each*) and one without (45b). The nondistributive version, without *D,* might or might not also be analyzed to include the group-forming ↑ operator.

(45)   Alice and Bob opened the door.
         a.   **Distributive:** Alice and Bob *D*(opened the door).
         b.   **Nondistributive/Collective:** ↑(Alice and Bob) opened the door.

All inferences about distributivity are derived formally from a combination of meaning postulates, *D*, and possibly also ↑.

To clarify some terminology: distributive inferences attributed to meaning postulates are also termed "P(redicate)-distributivity" (Winter 1997; de Vries 2015; 2017) or "lexical distributivity" (Champollion 2010; 2017) because these inferences are pinned to the meaning of a particular predicate or lexical item, and because the prototypical examples (*smile*) consist of a single lexical item; such inferences are predicted to be consistent and non-optional because the lexical item requires them. In contrast, distributive inferences attributed to *D* are termed "Q(uantificational)-distributivity" (Winter 1997; de Vries 2015; 2017) or 'phrasal distributivity' (Champollion 2010; 2017), because a predicate combined with a (quantificational) operator constitutes a syntactically complex phrase, and because the prototypical examples (open a door, build a raft) involve syntactically complex phrases; such inferences are optional because *D* itself is optional. (As for non-prototypical examples – such as win, a one-word "lexical" predicate which can be both distributive and nondistributive; or *see the photo*, a consistently distributive "phrasal" predicate – the labels of lexical and phrasal distributivity are harder to assign.)[15]

In sum, *smile* is required to be distributive by a meaning postulate; *meet* is not; *open the door* is ambiguous because *D* might or might not be present. It is left open which meaning postulates are needed and why, as well as with which predicates the distributive operator *D* and the collective operator ↑ would be redundant, consequential, or incompatible. Presumably these questions depend on lexical/world knowledge about the events described by such predicates, in ways that remain to be explored.

The current study thus would help explain which further predicates should have a distributive meaning postulate, and which ones should ambiguously combine with *D* or not. Moreover,

---

14   Some authors subsume *D* under the pluralizing ⋆operator of Landman (1989; 2000); but other authors keep *D* separate from ⋆. Particularly, some researchers (Kratzer 2007; Champollion 2010) assume that all verbs and thematic roles are closed under sum formation ("cumulative"), and use ⋆ to represent that assumption – but they do not intend this use of ⋆ to convey distributivity.

15   The distinction between one-word and multi-word predicates also comes up in the literature on collectivity (Winter 2000; Kuhn 2020), where one-word collective predicates (*gather*) are found to differ from multi-word collective predicates (*form a good team*), for reasons open to be explored:

(i)   a.   (All) the students gathered.
       b.   (?All) the students form a good team.

the Transitive/Intransitive asymmetry also grounds the observation, fundamental to the two-pronged approach, that most "lexical" predicates built from intransitive verbs are consistently distributive (smile), whereas many "phrasal" predicates built from transitive verbs (*open a door*) have both interpretations available.

5.3 Covers

On a third type of analysis (Higginbotham 1981; Gillon 1987; Schwarzschild 1996), a predicate applied to a plural is individually true of each cell of a contextually supplied cover – set of subparts – of the subject. Covers were initially used to deal with so-called non-atomic distributivity (Gillon 1987; Lasersohn 1995; 1998; Wohlmuth 2019), when a predicate distributes down to plural sub-groups of a plural subject, as in *the shoes cost $*50 (Lasersohn 1998) where *cost $50* is interpreted so that each pair of shoes occupies its own cell of the cover. But the idea of covers can handle all distributive and nondistributive interpretations of sentences, atomic as well as non-atomic.

When the sentential subject comprises two conjoined names (*Alice and Bob*), there are two possible cover settings: one placing each member of the subject in its own cell of the cover (distributive, because the predicate is true of Alice and of Bob); and one placing both of them into the same cell (nondistributive, because the predicate is true of Alice and Bob together but not each one individually).[16] This analysis treats *smile, meet,* and *open the door* in a uniform way: each predicate is true of each cell of some contextually supplied cover of the subject. Different inferences are drawn from *smile, meet,* and *open the door* because different covers are entertained for each predicate, given what is known about the events they describe.

For *smile*, the only sensible cover is one placing each member of the subject into its own cell (distributive), given that individuals have their own faces and cannot *smile* jointly. As for the notation, *Cov(Alice ⊕ Bob)* represents the set of cells of the contextually supplied cover of the plural *Alice and Bob*. *Smile(e) ∧ agent(e, x)* indicates that *e* is a smiling event whose agent is *x*, using the neo-Davidsonian event semantics of Higginbotham (1985) and Parsons (1990), building on Davidson (1967). (46) ensures that Alice and Bob are each the agent of their own smiling event.

(46)   Alice and Bob smiled.
        $\forall x[x \in Cov(Alice \oplus Bob) \rightarrow \exists e[smile(e) \wedge agent(e, x)]]$
    a.   ✓**Distributive:** they each smiled
          Cov = { {a }, {b} }

    b.   ✗**Nondistributive:** they smiled jointly but not individually
          Cov = { {a, b} }

For *meet,* the only sensible cover is one placing both members of the subject in the same cell (nondistributive), given that individuals cannot *meet* individually. (47) describes a single *meet* event, with Alice and Bob together as its agent.

(47)   Alice and Bob met.
        $\forall x[x \in Cov(Alice \oplus Bob) \rightarrow \exists e[meet(e) \wedge agent(e, x)]]$
    a.   ✗**Distributive:** they each met
          Cov = { {a }, {b} }

    b.   ✓**Nondistributive:** they met jointly but not individually
          Cov = { {a, b} }

Finally, for *open the door,* both available covers are sensible – one placing each member of the subject into their own cell (distributive), one placing them into the same cell (nondistributive) – given that people can open doors individually or jointly.

---

16   The chosen cover should also be the tightest-fitting one – one where no cover with more fine-grained cells would be accurate. Without this stipulation, (46a) and (46b) might both be equally good covers in a situation where Alice and Bob each smiled – (46a) because each of them smiled, and (46b) because, if we adopt a widespread assumption that verbs and thematic roles are closed under sum formation ("cumulative"; Krifka 1992, Kratzer 2007, Champollion 2010), then if there is a smiling event by Alice and a smiling event by Bob, there is also a larger smiling event by *Alice ⊕ Bob*. By requiring the tightest-fitting Cover, (46a) is chosen over (46b) when Alice and Bob *each* smiled.

(48)   Alice and Bob opened the door.
         $\forall x[x \in Cov(Alice \oplus Bob) \rightarrow \exists e[open(e) \wedge agent(e, x) \wedge theme(e, \iota y[door(y)])]]$
    a.   ✓**Distributive:** they each opened it
          Cov = { {a }, {b} }
    b.   ✓**Nondistributive:** they opened it jointly but not individually
          Cov = { {a, b} }

On this proposal, all three predicates – *smile, meet,* and *open the door* – are given the same semantics: true of each cell of a contextually supplied cover of the subject. Where they differ is in their pragmatics: different covers are entertained for each predicate, given what is known about these events. Like all the others, this formalism tells only part of the story:

> "This [analysis in terms of pragmatically determined covers] leaves us with […] a pragmatic theory of distributivity, which, along with other pragmatic phenomena, requires further analysis both in and outside of linguistics." – Schwarzschild 1996: 101

On this approach, the current study would help to explain which covers are chosen for which predicates.

5.4 Section summary

There are various ways to formalize the inferences drawn from *smile, meet,* and *open the door*. But none of them explains which other predicates will behave like *smile*, like *meet*, like *open the door*, or why. We also need to explain, as this paper has tried to, what inferences we want to formalize: which interpretations are available for which predicates.

6 Conclusion

To explain how people understand sentences with plural subjects, researchers face two questions:

 i.   *The lexical semantics question:* Which predicates are interpreted as distributive and/or nondistributive, and why?

 ii. *The formal semantics question:* How should distributivity be represented formally?

Addressing the lexical semantics question, the paper has motivated some predictions about the distributivity potential of various predicates, and shown that these are manifested in a large dataset: the Causative Prediction and the Mind Prediction. Using the notion of object-affectedness, the paper has also offered an explanation of the Transitive/Intransitive Asymmetry – the observation that predicates built from transitive verbs favor a nondistributive interpretation, whereas those built from intransitive verbs tend to be distributive. It is argued that object-affecting transitive verbs favor nondistributivity because they describe events in which a subject causes a change upon an object; the structure of causation allows that multiple individuals' contributions may be jointly sufficient but individually insufficient to bring about a result.

More generally, any time a semantic phenomenon depends on lexical/world knowledge, the challenge is to explain what such knowledge matters and why. This paper has aimed to take on that challenge to offer a more predictive view of this phenomenon.

As for the formal semantics question, the paper has argued that any formal analysis ends up leaving the explanatory work to lexical/world knowledge about how members of the subject can participate in the event described by the predicate, highlighting the need for an answer to the lexical semantics question.

Zooming out, distributivity has traditionally been studied as a topic for formal semantics, aiming to explain a small group of clear-cut examples. Here, I have treated it as a topic for lexical semantics, still illustrating with a handful of clear-cut examples but also aiming to explain a wider range of data. This approach aims to take up the challenge set out by Winter & Scha (2015):

> "We would like to reiterate the importance that we see for a rigorous theory about the lexicon and the pragmatics of plurals, especially in relation to […]

distributivity […]. More general and precise theories of these lexical and pragmatic domains will also surely shed more light on the compositional semantics of plurality."
– Winter & Scha (2015): 35

Distributivity is defined by the observation that different predicates (*smile, meet, open the door*) act different from one another, making it a lexical semantics topic from the start. I hope to have shown that it is illuminated when treated as one.

Additional file

The additional file for this article can be found as follows:

- **Appendix:** Mechanical Turk/FrameNet annotations and statistical analysis in R available on the Open Science Framework. DOI: *https://doi.org/10.17605/OSF.IO/ENA5R*

Ethics and consent

Annotators on Mechanical Turk participated in the study after agreeing to a consent form written in consultation with the Georgia Tech Institutional Review Board. Annotators all used United States I.P. addresses and were paid $3.00 for what amounted to between seven and fifteen minutes of work. Because the annotators were anonymous and provided no personal data, this study received an official exemption from the Georgia Tech Institutional Review Board.

Competing interests

The author has no competing interests to declare.

Author affiliation

Lelia Glass ⓘ *orcid.org/0000-0003-0428-7785*
School of Modern Languages, Georgia Institute of Technology, 613 Cherry St NW, Atlanta, GA 30313, US

References

Baker, Collin F., Charles J. Fillmore & John B. Lowe. 1998. The Berkeley FrameNet project. In *Proceedings of the 17th international conference on computational linguistics*, 86–90. Association for Computational Linguistics. DOI: *https://doi.org/10.3115/980845.980860*

Baron, Reuben M. & David A. Kenny. 1986. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of personality and social psychology* 51(6). 1173–1182. DOI: *https://doi.org/10.1037/0022-3514.51.6.1173*

Barr, Dale J., Roger Levy, Christoph Scheepers & Harry J. Tily. 2013. Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language* 68(3). 255–278. DOI: *https://doi.org/10.1016/j.jml.2012.11.001*

Bartsch, Renate. 1973. The semantics and syntax of number and numbers. In John Kimball (ed.), *Syntax and semantics* 2. 51–93. New York: Seminar Press. DOI: *https://doi.org/10.1163/9789004368804_003*

Bates, Douglas, Martin Mächler, Ben Bolker & Steve Walker. 2015. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software* 67(1). 1–48. DOI: *https://doi.org/10.18637/jss.v067.i01*

Beavers, John. 2011. On affectedness. *Natural Language & Linguistic Theory* 29(2). 335–370. DOI: *https://doi.org/10.1007/s11049-011-9124-6*

Belletti, Adriana & Luigi Rizzi. 1988. Psych verbs and θ-theory. *Natural Language and Linguistic Theory* 6(3). 291–352. DOI: *https://doi.org/10.1007/BF00133902*

Brisson, Christine. 2003. Plurals, 'all', and the nonuniformity of collective predication. *Linguistics and Philosophy* 26(2). 129–184. DOI: *https://doi.org/10.1023/A:1022771705575*

Brooks, Patricia J. & Martin D. Braine. 1996. What do children know about the universal quantifiers *all* and *each*? *Cognition* 60(3). 235–268. DOI: *https://doi.org/10.1016/0010-0277(96)00712-3*

Carlson, Greg. 1998. Thematic roles and the individuation of events. In Susan Rothstein (ed.), *Events and grammar*, 35–51. Dordrecht: Kluwer Academic Publishers. DOI: *https://doi.org/10.1007/978-94-011-3969-4_3*

Carnap, Rudolf. 1952. Meaning postulates. *Philosophical studies* 3(5). 65–73. DOI: *https://doi.org/10.1007/BF02350366*

Champollion, Lucas. 2010. *Parts of a whole: Distributivity as a bridge between aspect and measurement.* Philadelphia: University of Pennsylvania dissertation.

Champollion, Lucas. 2016. Covert distributivity in algebraic event semantics. *Semantics and Pragmatics* 9. DOI: *https://doi.org/10.3765/sp.9.15*

Champollion, Lucas. 2017. *Parts of a whole: Distributivity as a bridge between aspect and measurement.* Oxford: Oxford University Press. DOI: *https://doi.org/10.1093/oso/9780198755128.001.0001*

Champollion, Lucas. 2019. Distributivity in formal semantics. *Annual Review of Linguistics* 5. DOI: *https://doi.org/10.1146/annurev-linguistics-011718-012528*

Champollion, Lucas. 2020. Distributivity, collectivity, and cumulativity. In Daniel Gutzmann, Lisa Matthewson, Cécile Meier, Hotze Rullmann & Thomas Ede Zimmermann (eds.), *Wiley blackwell companion to semantics*, Hoboken: Wiley Blackwell. DOI: *https://doi.org/10.1002/9781118788516*

Comrie, Bernard. 1989. *Language universals and linguistic typology,* second edition. Chicago, IL: University of Chicago Press.

Copley, Bridget & Phillip Wolff. 2014. Theories of causation should inform linguistic theory and vice versa. In Bridget Copley & Fabienne Martin (eds.), *Causation in grammatical structures*, 11–57. Oxford: Oxford University Press. DOI: *https://doi.org/10.1093/acprof:oso/9780199672073.003.0002*

Corblin, Francis. 2008. Des prédicats non-quantifiables: les prédicats holistes. *Langages* 1. 34–56. DOI: *https://doi.org/10.3917/lang.169.0034*

Croft, William. 2012. *Verbs: Aspect and causal structure.* Oxford: Oxford University Press. DOI: *https://doi.org/10.1093/acprof:oso/9780199248582.001.0001*

Davidson, Donald. 1967. The logical form of action sentences. In Nicholas Rescher (ed.), *The logic of decision and action*, 81–95. Pittsburgh, PA: University of Pittsburgh Press. DOI: *https://doi.org/10.1093/0199246270.003.0006*

de Vries, Hanna. 2015. *Shifting sets, hidden atoms: The semantics of distributivity, plurality and animacy.* Utrecht: Utrecht University dissertation.

de Vries, Hanna. 2017. Two kinds of distributivity. *Natural Language Semantics* 25(2). 173–197. DOI: *https://doi.org/10.1007/s11050-017-9133-z*

DeLancey, Scott. 1991. Event construal and case role assignment. In Laurel A. Sutton, Christopher Johnson & Ruth Shields (eds.), *Berkeley linguistics society (BLS)* 17. 338–353. Ann Arbor: Braun-Brumfield, Inc. DOI: *https://doi.org/10.3765/bls.v17i0.1610*

Dixon, R. M. W. 1979. Ergativity. *Language* 55(1). 59–138. DOI: *https://doi.org/10.2307/412519*

Dobrovie-Sorin, Carmen, Emilia Ellsiepen & Barbara Hemforth. 2016. Why are distributive readings dispreferred? In Ernestina Carrilho, Alexandra Fiéis, Maria Lobo & Sandra Pereira (eds.), *Romance languages and linguistic theory 10: Selected papers from 'going romance' 28*, 83–102. Amsterdam: John Benjamins. DOI: *https://doi.org/10.1075/rllt.10.05dob*

Dotlačil, Jakub. 2010. *Anaphora and distributivity: A study of same, different, reciprocals and others.* Utrecht: Utrecht University dissertation.

Dowty, David R. 1979. *Word meaning and Montague grammar.* Dordrecht: Reidel. DOI: *https://doi.org/10.1007/978-94-009-9473-7*

Dowty, David R. 1987. A note on collective predicates, distributive predicates, and 'all'. In Fred Marshall, Ann Miller & Zheng-sheng Zhang (eds.), *Eastern states conference on linguistics (ESCOL)* 3. 97–116. Columbus: The Ohio State University.

Dowty, David R. 1991. Thematic proto-roles and argument selection. *Language* 67(3). 547–619. DOI: *https://doi.org/10.1353/lan.1991.0021*

Fillmore, Charles J. 1969. Types of lexical information. In Ferenc Kiefer (ed.), *Studies in syntax and semantics*, 109–137. Dordrecht: Reidel. DOI: *https://doi.org/10.1007/978-94-010-1707-7_6*

Fillmore, Charles J. 1970. The grammar of hitting and breaking. In Roderick Jacobs & Peter Rosenbaum (eds.), *Readings in english transformational grammar*, 120–33. Washington: Georgetown University Press.

Fillmore, Charles J. 1976. Frame semantics and the nature of language. In *Annals of the New York Academy of Sciences: Conference on the origin and development of language and speech* 280. 20–32. DOI: *https://doi.org/10.1111/j.1749-6632.1976.tb25467.x*

Frazier, Lyn, Jeremy M. Pacht & Keith Rayner. 1999. Taking on semantic commitments, ii: Collective versus distributive readings. *Cognition* 70(1). 87–104. DOI: *https://doi.org/10.1016/S0010-0277(99)00002-5*

Gillon, Brendan S. 1987. The readings of plural noun phrases in English. *Linguistics and Philosophy* 10(2). 199–219. DOI: *https://doi.org/10.1007/BF00584318*

Glass, Lelia. 2018a. Deriving the distributivity potential of adjectives via measurement theory. In Patrick Ferrell (ed.), *Linguistic society of america (LSA)*, 3. Washington, DC: Linguistic Society of America. DOI: *https://doi.org/10.3765/plsa.v3i1.4343*

Glass, Lelia. 2018b. *Distributivity, lexical semantics, and world knowledge*. Stanford University dissertation. *http://ling.auf.net/lingbuzz/004050*.

Grafmiller, Jason. 2013. *The semantics of syntactic choice: An analysis of english emotion verbs*. Stanford University dissertation.

Gropen, Jess, Steven Pinker, Michelle Hollander & Richard Goldberg. 1991. Affectedness and direct objects: The role of lexical semantics in the acquisition of verb argument structure. *Cognition* 41(1). 153–195. DOI: *https://doi.org/10.1016/0010-0277(91)90035-3*

Gruber, Jeffrey S. 1965. *Studies in lexical relations*. Cambridge, MA: Massachusetts Institute of Technology dissertation.

Harley, Heidi & Rolf Noyer. 1999. State-of-the-article: Distributed morphology. *Glot International* 4(4). 3–9. DOI: *https://doi.org/10.1515/9783110890952.463*

Herring, Susan C., Dieter Stein & Tuija Virtanen. 2013. Introduction to the pragmatics of computer-mediated communication. In Susan C. Herring, Dieter Stein & Tuija Virtanen (eds.), *Pragmatics of computer-mediated communication*, 3–32. Berlin: Mouton De Gruyter. DOI: *https://doi.org/10.1515/mc-2015-0016*

Higginbotham, James. 1981. Reciprocal interpretation. *Journal of Linguistic Research* 1(3). 97–117. DOI: *https://doi.org/10.1515/tlir.1981.1.1.41*

Higginbotham, James. 1985. On semantics. *Linguistic Inquiry* 16(4). 547–594.

Honnibal, Matthew & Mark Johnson. 2015. An improved non-monotonic transition system for dependency parsing. In *Proceedings of the 2015 conference on Empirical Methods in Natural Language Processing*, 1373–78. DOI: *https://doi.org/10.18653/v1/D15-1162*

Hopper, Paul J. & Sandra A. Thompson. 1980. Transitivity in grammar and discourse. *Language* 56(2). 251–99. DOI: *https://doi.org/10.2307/413757*

Hume, David. 1748. *Enquiries concerning the human understanding: And concerning the principles of morals*. Oxford: Clarendon Press (1902). DOI: *https://doi.org/10.1093/oseo/instance.00046349*

Kratzer, Angelika. 2007. On the plurality of verbs. In Johannes Dölling, Tatjana Heyde-Zybatow & Martin Schäfer (eds.), *Event structures in linguistic form and interpretation*, 269–300. Berlin: De Gruyter. DOI: *https://doi.org/10.1515/9783110925449.269*

Krifka, Manfred. 1992. Thematic relations as links between nominal reference and temporal constitution. In Ivan A. Sag & Anna Szabolcsi (eds.), *Lexical matters*, 29–54. Stanford, CA: CSLI (Center for the Study of Language and Information) Publications.

Križ, Manuel. 2016. Homogeneity, non-maximality, and 'all'. *Journal of Semantics* 3(33). 493–539. DOI: *https://doi.org/10.1093/jos/ffv006*

Kruitwagen, Imke, Eva B. Poortman & Yoad Winter. 2017. Reciprocal verbs as collective predicate concepts. In Andrew Lamont & Katerina Tetzloff (eds.), *North east linguistic society (NELS)*, 47. Amherst: Graduate Linguistics Student Association of the University of Massachusetts.

Kuhn, Jeremy. 2020. Gather/numerous as a mass/count opposition. *Natural Language Semantics,* 1–29. DOI: *https://doi.org/10.1007/s11050-020-09163-x*

Landman, Fred. 1989. Groups, I. *Linguistics and Philosophy* 12(5). 559–605. DOI: *https://doi.org/10.1007/BF00627774*

Landman, Fred. 2000. *Events and plurality: The Jerusalem lectures*. Dordrecht: Kluwer Academic Publishers. DOI: *https://doi.org/10.1007/978-94-011-4359-2*

Lasersohn, Peter. 1988. *A semantics for groups and events*. Columbus: The Ohio State University dissertation.

Lasersohn, Peter. 1995. *Plurality, conjunction and events*. Dordrecht: Kluwer Academic Publishers. DOI: *https://doi.org/10.1007/978-94-015-8581-1*

Lasersohn, Peter. 1998. Generalized distributivity operators. *Linguistics and Philosophy* 21(1). 83–93. DOI: *https://doi.org/10.1023/A:1005317815339*

Levin, Beth. 1993. *English verb classes and alternations*. Chicago: University of Chicago Press.

Levin, Beth & Malka Rappaport Hovav. 1994. A preliminary analysis of causative verbs in English. *Lingua* 92. 35–77. DOI: *https://doi.org/10.1016/0024-3841(94)90337-9*

Levin, Beth & Malka Rappaport Hovav. 2005. *Argument realization*. Cambridge: Cambridge University Press. DOI: *https://doi.org/10.1017/CBO9780511610479*

Lewis, David. 1973. Causation. *The Journal of Philosophy* 70(17). 556–567. DOI: *https://doi.org/10.2307/2025310*

Link, Godehard. 1983. The logical analysis of plurals and mass terms: A latticetheoretical approach. In Rainer Bäuerle, Christoph Schwarze & Arnim von Stechow (eds.), *Meaning, use and interpretation of language*, 127–146. Berlin: De Gruyter. DOI: *https://doi.org/10.1515/9783110852820.302*

Link, Godehard. 1991. Plural. In Arnim von Stechow & Dieter Wunderlich (eds.), *Semantik: Ein internationales Handbuch der zeitgenoessischen Forschung [Semantics: An international handbook of contemporary research]*, Berlin: De Gruyter. DOI: *https://doi.org/10.1515/9783110126969.6.418*

Link, Godehard. 1998. *Algebraic semantics in language and philosophy*. Stanford: CSLI (Center for the Study of Language and Information) Publications.

Löbner, Sebastian. 2000. Polarity in natural language: Predication, quantification and negation in particular and characterizing sentences. *Linguistics and Philosophy* 23(3). 213–308. DOI: *https://doi.org/10.1023/A:1005571202592*

Loper, Edward & Steven Bird. 2002. NLTK: The natural language toolkit. In *Proceedings of the association for computational linguistics (acl)*. DOI: *https://doi.org/10.3115/1118108.1118117*

Mackie, John L. 1965. Causes and conditions. *American philosophical quarterly* 2(4). 245–264.

McNally, Louise. 2005. Lexical representation and modification within the noun phrase. *Recherches Linguistiques de Vincennes* 34. 191–206. DOI: *https://doi.org/10.4000/rlv.1395*

Menzies, Peter. 2014. Counterfactual theories of causation. In Edward N. Zalta (ed.), *The stanford encyclopedia of philosophy*, Metaphysics Research Lab, Stanford University spring 2014 edn.

Moltmann, Friederike. 2004. The semantics of 'together'. *Natural Language Semantics* 12(4). 289–318. DOI: *https://doi.org/10.1007/s11050-004-6453-6*

Næss, Åshild. 2007. *Prototypical transitivity*. John Benjamins Publishing. DOI: *https://doi.org/10.1075/tsl.72*

Naigles, Letitia & Edward T. Kako. 1993. First contact in verb acquisition: Defining a role for syntax. *Child Development* 64(6). 1665–1687. DOI: *https://doi.org/10.2307/1131462*

Nouwen, Rick. 2015. Plurality. In Paul Dekker & Maria Aloni (eds.), *Cambridge handbook of semantics*, 267–284. Cambridge: Cambridge University Press. DOI: *https://doi.org/10.1017/CBO9781139236157.010*

Parsons, Terence. 1990. *Events in the semantics of English: A study in subatomic semantics*. Cambridge, MA: MIT Press.

Peeters, Bert. 2000. Setting the scene: Some recent milestones in the lexiconencyclopedia debate. In Bert Peeters (ed.), *The lexicon-encyclopedia interface*, 1–52. New York: Elsevier.

Poortman, Eva B., Marijn E. Struiksma, Nir Kerem, Naama Friedmann & Yoad Winter. 2018. Reciprocal expressions and the maximal typicality hypothesis. *Glossa* 3(1). DOI: *https://doi.org/10.5334/gjgl.180*

Powell, Michael J. D. 2009. The bobyqa algorithm for bound constrained optimization without derivatives. *Cambridge NA Report NA2009/06, University of Cambridge,* Cambridge, 26–46.

Pustejovsky, James. 1995. *The generative lexicon*. Cambridge: MIT Press. DOI: *https://doi.org/10.7551/mitpress/3225.001.0001*

R Core Team. 2012. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. *http://www.R-project.org/*. ISBN3-900051-07-0.

Rappaport Hovav, Malka. 2008. Lexicalized meaning and the internal structure of events. In Susan Rothstein (ed.), *Theoretical and crosslinguistic approaches to the semantics of aspect*, 13–42. Amsterdam: John Benjamins. DOI: *https://doi.org/10.1075/la.110.03hov*

Rappaport Hovav, Malka & Beth Levin. 2010. Reflections on manner/result complementarity. In Edit Doron, Malka Rappaport Hovav & Ivy Sichel (eds.), *Syntax, lexical semantics, and event structure*. Oxford: Oxford University Press. DOI: *https://doi.org/10.1093/acprof:oso/9780199544325.001.0001*

Roberts, Craige. 1987. *Modal subordination, anaphora, and distributivity*. Amherst: University of Massachusetts dissertation.

Scha, Remko. 1981. Distributive, collective and cumulative quantification. In Jeroen Groenendijk & Martin Stockhof (eds.), *Formal methods in the study of language*, 483–512. Amsterdam: Mathematical Center Tracts. DOI: *https://doi.org/10.1515/9783110867602.131*

Schank, Roger C. & Robert Abelson. 1977. *Scripts, plans, goals, and understanding: An inquiry into human knowledge structures*. Hillsdale, NJ: Lawrence Erlbaum Associates. DOI: *https://doi.org/10.4324/9780203781036*

Schneider, Nathan & Chuck Wooters. 2017. The NLTK FrameNet API: Designing for discoverability with a rich linguistic resource. In *Proceedings of the conference on empirical methods in natural language processing: System demonstrations*. Copenhagen, Denmark: Association for Computational Linguistics. DOI: *https://doi.org/10.18653/v1/D17-2001*

Schwarzschild, Roger. 1996. *Pluralities*. Dordrecht: Kluwer Academic Publishers. DOI: *https://doi.org/10.1007/978-94-017-2704-4*

Scontras, Gregory & Noah Goodman. 2017. Resolving uncertainty in plural predication. *Cognition* 168. 294–311. DOI: *https://doi.org/10.1016/j.cognition.2017.07.002*

Siloni, Tal. 2012. Reciprocal verbs and symmetry. *Natural Language and Linguistic Theory* 30(1). 261–320. DOI: *https://doi.org/10.1007/s11049-011-9144-2*

Smith, Carlota S. 1970. Jespersen's 'move and change' class and causative verbs in English. In Mohammad A. Jazayery, Edgar C. Polomé & Werner Winter (eds.), *Linguistic and literary studies in honor of archibald a. hill*, vol. 2: Descriptive Linguistics, 101–109. The Hague: Mouton. DOI: *https://doi.org/10.1515/9783110800432.101*

Swanson, Eric. 2012. The language of causation. In Delia Graff Fara & Gillian Russell (eds.), *The Routledge companion to the philosophy of language*, 716–712. London: Routledge.

Syrett, Kristen & Julien Musolino. 2013. Collectivity, distributivity, and the interpretation of plural numerical expressions in child and adult language. *Language Acquisition* 20(4). 259–291. DOI: *https://doi.org/10.1080/10489223.2013.828060*

Tenny, Carol L. 1987. *Grammaticalizing aspect and affectedness*. Cambridge: Massachusetts Institute of Technology dissertation.

White, Aaron Steven, Dee Ann Reisinger, Keisuke Sakaguchi, Tim Vieira, Sheng Zhang, Rachel Rudinger, Kyle Rawlins & Benjamin Van Durme. 2016. Universal decompositional semantics on universal dependencies. In *Proceedings of the 2016 conference on empirical methods in natural language processing (EMNLP)*, 1713–1723. Austin, Texas. DOI: *https://doi.org/10.18653/v1/D16-1177*

Winter, Bodo. 2013. Linear models and linear mixed effects models in r with linguistic applications. University of California, Merced, tutorial. Available at *http://arxiv.org/pdf/1308.5499.pdf*.

Winter, Yoad. 1997. Choice functions and the scopal semantics of indefinites. *Linguistics and Philosophy* 20(4). 399–467. DOI: *https://doi.org/10.1023/A:1005354323136*

Winter, Yoad. 2000. Distributivity and dependency. *Natural Language Semantics* 8(1). 27–69. DOI: *https://doi.org/10.1023/A:1008313715103*

Winter, Yoad. 2002. Atoms and sets: A characterization of semantic number. *Linguistic Inquiry* 33(3). 493–505. DOI: *https://doi.org/10.1162/002438902760168581*

Winter, Yoad. 2018. Symmetric predicates and the semantics of reciprocal alternations. *Semantics and Pragmatics* 11. DOI: *https://doi.org/10.3765/sp.11.1*

Winter, Yoad & Remko Scha. 2015. Plurals. In Shalom Lappin & Chris Fox (eds.), *Handbook of contemporary semantic theory*, 77–113. New York: Wiley 2nd edn. DOI: *https://doi.org/10.1002/9781118882139.ch3*

Wohlmuth, Kata. 2019. *Atomicity and distributive reference*. Barcelona: Universitat Pompeu Fabra dissertation.

Yoon, Youngeun. 1996. Total and partial predicates and the weak and strong interpretations. *Natural Language Semantics* 4(3). 217–236. DOI: *https://doi.org/10.1007/BF00372820*

]u[ᓚ