



Breaking and Entering: Verb Semantics and Event Structure

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Breaking and Entering:
Verb Semantics and Event Structure

A DISSERTATION PRESENTED

BY

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Breaking and Entering:
Verb Semantics and Event Structure

Abstract

Any event can be construed from a variety of perspectives. While this flexibility is fundamental to human ingenuity, it poses a challenge for language learners who must discern which meanings are encoded in their language and by which forms. The papers in this dissertation focus on verbs encoding directed motion (e.g., a girl runs into a house) and caused change-of-state events (e.g., a boy blows out candles). Both classes of events can be expressed by verbs that lexicalize different components of the event, namely Manner-of-motion (e.g., *run*) or Path (e.g., *enter*), and Means (e.g., *blow*) or Effect (e.g., *extinguish*), respectively.

Papers 1 and 2 examine the representation of higher-order generalizations about the meanings of directed motion and caused change-of-state verbs. Both studies use a novel verb-learning paradigm to manipulate the meanings of verbs in the input and then assess how learners interpret subsequently encountered novel verbs (measure *lexicalization bias*). The results indicate that learners rapidly use semantic regularities to form expectations about verb meaning.

In Paper 1, adults taught Manner verbs construed new directed motion verbs as lexicalizing Manner more often than those taught Path verbs. Moreover, changes in verb learning bias were accompanied by shifts in visual attention: Manner-verb learners fixated on Manner-related elements of visually-presented events more than Path-verb learners. These results indicate that previously observed cross-linguistic differences in verb lexicalization

biases are unlikely to stem from the restructuring of semantic representations along language-specific lines and more likely reflect the operation of a flexible, inferential learning mechanism that monitors the input and updates beliefs accordingly.

Likewise, in Paper 2, adults taught Means verbs interpreted unknown verbs for caused change-of-state events as encoding the Means more often than those taught Effect verbs. Unlike directed motion verbs, the encoding of these events is not characterized by marked typological variation and the availability of Means and Effect verbs does not appear to vary appreciable within or across languages. These results suggest that the formation of higher-level generalizations about meaning is a fundamental property of the processes that undergird lexical acquisition.

Paper 3 focuses on the representation of the event concepts that underlie verb meanings. Specifically, we examine the possibility that Manner of motion and Means are actually instances of a broader semantic category, MANNER, whereas Path and Effect are instances of a different semantic category, RESULT. Adults were taught novel verbs for either directed motion or caused change-of-state events and subsequently presented with novel verbs from the other semantic class. The results revealed that adults transfer newly-learned higher-order generalizations about the meanings of directed motion verbs to caused change-of-state verbs (and vice versa), providing support for the psychological reality of superordinate event concepts.

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This thesis is dedicated to my Amma.

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“*LITOST* is a Czech word with no exact translation into any other language. It designates a feeling as infinite as an open accordion, a feeling that is the synthesis of many others: grief, sympathy, remorse, and an indefinable longing. The first syllable, which is long and stressed, sounds like the wail of an abandoned dog.

Under certain circumstances, however, it can have a very narrow meaning, a meaning as definite, precise, and sharp as a well-honed cutting edge. I have never found an equivalent in other languages for this sense of the word either, though I do not see how anyone can understand the human soul without it.

Let me give you an example. One day the student went swimming with his girlfriend. She was a top-notch athlete; he could barely keep afloat. He had trouble holding his breath underwater, and was forced to thrash his way forward, jerking his head back and forth above the surface. She was madly in love with him and tactfully kept to his speed. But as their swim was coming to an end, she felt need to give her sporting instincts free rein, and sprinted to the other shore. The student tried to pick up his tempo too, but swallowed many mouthfuls of water. He felt humiliated, exposed for the weakling he was; he felt resentment, the special sorrow which can only be called *litost*. He recalled his sickly childhood---no physical exercise, no friends, nothing but Mama's ever-watching eye---and sank into utter, all-encompassing despair. On their way back to the city they took a shortcut through the fields. He did not say a word. He was wounded, crestfallen; he felt an irresistible desire to beat her. 'What's wrong with you?' she asked him, and he went into a tirade about how the undertow on the other side of the river was very dangerous and he had told her not to swim over there and she could have drowned---then he slapped her face. The girl burst out crying, and when he saw the tears running down her face, he took pity on her, and his *litost* melted into thin air.

Or take an instance from the student's childhood: the violin lessons that were forced upon him. He was not particularly gifted, and his teacher would stop him and point out his mistakes in a cold, unbearable voice. It humiliated him, he felt like crying. But instead of trying to play in tune and make fewer mistakes, he would make mistakes on purpose. As the teacher's voice became more and more unbearable, enraged, he would sink deeper and deeper into his bitterness, his *litost*.

Well then, what is *litost*?

Litost is a state of torment caused by a sudden insight into one's own miserable self"

-Milan Kundera, *The Book of Laughter and Forgetting*

Introduction

Consider a simple event, such as a cat chasing a mouse. We can convey many kinds of information about such an event, at multiple levels of granularity. For example, we can express the Manner and Path of the movement of the mouse (*The mouse is running away from the cat*) or of the cat (*The cat is running after the mouse*). Alternatively, we can describe their goals, *fleeing* and *chasing* (or *hunting*), respectively. We can describe their emotions (*The mouse fears the cat; The swift mouse frustrates the cat*) or desires (*The mouse wants to escape and live; The cat wants to gobble up the mouse*). We can also focus on more fine-grained details, such as the cat raising its paw in an attempt to swat at or grab the mouse or use metaphorical language (*The mouse is flying across the field*). Each of these perspectives may be expressed in different ways in other languages.

As this example illustrates, the ability to think about and describe events from a myriad of perspectives is one of the foundations of linguistic creativity. This flexibility, however, also raises fundamental problems for the cognitive sciences. As speakers, how do we represent and convey multiple different construals of the same event? As listeners, how do we reconstruct the intended meaning of an utterance? As language learners, how do we determine the ways in which our language packages components of events into words and phrases to become competent adult speakers and listeners?

Over the past decades, the cognitive sciences have refined our understanding of the conceptual primitives that underlie mental representations of events and the way that these primitives are packaged in language. On one hand, developmental and comparative psychology have provided evidence for systems of *core knowledge*: encapsulated, culturally invariant, early developing, and evolutionarily ancient systems that represent basic

conceptual structures such as objects, actions, number, and space (Carey & Spelke, 2004; Spelke, 1990, 2004; for review, see Carey, 2009; Spelke & Kinzler, 2007). Each of these systems is selectively sensitive to certain kinds of perceptual input and able to generalize in specific, domain-appropriate ways.

On the other hand, work on the meaning of words, especially verbs, has revealed that the linguistic system is sensitive to conceptual distinctions similar to those proposed as core-knowledge systems. This research has revealed that verbs with similar syntactic behaviors can be grouped into semantic classes composed of hierarchical event-structures whose atomic components map onto these conceptual primitives (e.g., Motion, Path, Cause and Effect; Croft, 1990; Fillmore, 1968; Gruber, 1976; Gusserel, Hale, Laughren, Levin, & White, 1985; Grimshaw, 2005; Hale & Keyser, 1993; Jackendoff, 1983; 1990; Levin & Rappaport Hovav, 1995; Pinker, 1989; Rappaport Hovav & Levin, 1998). Research in cognitive psychology and neuroscience confirms the psychological reality of many of these semantic primitives (Kemmerer, Catillo, Talavage, Patterson, & Wiley, 2008; Wu, Morganti, & Chatterjee, 2008; for review of evidence that pre-linguistic infants are sensitive to semantically relevant dimensions of events, see Göksun, Hirsh-Pasek, & Golinkoff, 2010).

Taken together, these various strands of research lead to a picture where event representations are computed compositionally from a core set of primitive predicates, such as ACT, CAUSE, and BECOME (see Pinker, 2007, on “the language of thought”), whose meanings can be sometimes be grounded in core-knowledge representations.

This emerging picture explains both how we can flexibly represent an infinite set of events (thanks to compositionality), and why certain conceptual primitives have privileged linguistic status. These universal primitives, however, may be combined in many ways and

languages differ in how they typically package event components into words and phrases. These differences pose a problem for the learner who must adduce the relevant forms, meanings and mappings between the two in their native language. Fortunately, languages prefer particular ways of construing events and these language-specific lexicalization biases (preferences about the meanings encoded in a word) are psychologically real, higher-order generalizations: mature speakers of a language know the lexical and statistical properties of their language and use this knowledge to guide verb learning (discussed in more detail below; Naigles & Terrazas, 1998). This raises fundamental questions about the representation of higher-order generalizations about verb meaning. Are cross-linguistic differences in the encoding of event components represented as changes in the organization of conceptual or semantic representations or as generalizations about linkages between forms and meanings? What is the exact format and generality of particular conceptual primitives, such as Path or Manner?

The goal of this dissertation is to address some of these basic questions about event structure and its encoding in verbs. Papers 1 and 2 ask how higher-order statistical generalizations about verb meanings are represented. Paper one examines whether cross-linguistic differences in the allocation of attention during verb processing reflect differences in semantic representations by examining directed motion verbs. Cross-linguistic differences in the lexicalization of directed motion events and in the verb lexicon are pronounced and these differences have inspired the proliferation of theories that espouse some form of linguistic relativity; broadly, these theories contend that cross-linguistic variation is represented as changes in semantic or conceptual space. Our results indicate that this is unlikely as learning rapidly shifts biases in verb construal and visual attention to event

components.

The question asked in Paper 2 naturally follows from the results of Paper 1. If cross-linguistic differences are not represented in the shape of semantic representations, then they must be instantiated as generalizations about linkages between forms and meanings. Paper two extends the study of the acquisition of verb lexicalization biases to verbs for caused change-of-state event. Our results revealed that, despite the lack of appreciable lexical disparities in the English caused change-of-state verb lexicon, adults rapidly learn verb lexicalization biases for caused change-of-state verbs (as with directed motion verbs in Paper 1). This indicates that learners continue to attend to lexical-statistical information (even when information value is uncertain), and importantly, that the learning mechanism is inherently driven to uncover higher-order generalization about category structure. Papers 1 and 2 differ primarily in the class of verb examined and the results can, be interpreted similarly. These papers complement one another and bolster the generalizability of the results obtained. The framing of Papers 1 and 2 however, differ greatly, as they are situated within two distinct theoretical frameworks, each emphasizing a slightly different aspect of the problem of representation.

Paper three steps back and examines a fundamental question about conceptual primitives themselves: are event concepts that have been proposed as being relevant for specific subsets of verbs, such as Manner, Path, Means and Effect, really instances of more general conceptual categories? Our results indicate that these are subcategories of event-general concepts, as newly formed generalizations about the meanings of verbs from one semantic field (either directed motion events or caused change-of-state events) influenced the construal of novel verbs from the other semantic field.

In the remainder of this chapter, I provide context for these papers by discussing relevant theoretical issues and reviewing prior research. First, I describe the encoding of directed motion and caused change-of-state events, drawing attention to commonalities and differences within and across languages. Then, for each paper, I discuss the conceptual issues and theories that emanate from typological observations, review relevant empirical evidence, and highlight unanswered questions that are addressed by the research presented in this dissertation.

The encoding of directed motion and caused change-of-state events

Decades of linguistic and psycholinguistic research have revealed both significant cross-linguistic consistencies in the kinds of event information encoded by verbs and significant cross-linguistic variability in the particular ways in which languages package these event components. The encoding of directed motion events is a well-studied case of such typological stability and variability (Aske, 1984; Beavers, Wei Tham, & Levin, 2010; Jackendoff, 1972, 2006; Slobin & Hoitling, 1994; Slobin, 1997, 2000, 2006; Talmy, 1989, 1991, 2000; *inter alia*).

Consider the following sentences in English and Spanish:

(1) Directed motion events

- a. He ran out of the house
- b. Él salió de la casa corriendo
'He exited the house, running'

In English, the verb, *ran*, encodes the *Manner of motion* (the way a movement is carried out) and the particle, *out*, encodes *Path* (the movement of the *Figure* with respect to a stationary object, the *Ground*). In contrast, in Spanish, the verb, *salió*, encodes Path and the gerund, *corriendo*, encodes Manner. This difference between English and Spanish is exemplary of a

much more general pattern observed across the world's languages. Talmy (1991) demonstrated that languages characteristically express Path, the element central to motion events, either in the main verb (*verb-framed languages*) or in a *satellite*, a clause-internal morpheme (e.g., case-markers, affixes, adpositions; *satellite-framed languages*).¹ Since then, Talmy's typology has been extended to include a third class, *equipollent-framed languages* (e.g., Mandarin, Thai) that express Manner and Path in grammatically similar forms within the same clause (Slobin, 2006).² Note that Manner and Path verbs are found in all languages—typological classifications represent statistical generalizations about the way meanings are distributed across surface-level forms.

This broad satellite-/verb-framed language distinction is correlated with two important properties. First, satellite-framed languages have more Manner verbs than Path verbs in the lexicon as well as larger numbers of Manner verbs (note that equipollent-framed languages pattern like satellite-framed languages) than verb-framed languages.³ The reverse generalization, that verb-framed languages have a greater number of Path verbs, is also true, but the trend is not nearly as pronounced.⁴ Second, in verb-framed languages only Path verbs can express events with definite end-points, that is, *telic* events (Aske, 1989; Papafragou &

¹ Satellite-framed languages (*run*-type) include Germanic languages (e.g., English, German), Slavic languages (e.g., Russian, Polish), Finno-Urgic languages, and Malayalam. Verb-framed languages (*enter*-type) include Romance languages (e.g., French, Spanish), Semitic languages (e.g., Hebrew, Arabic), Turkic languages (Turkish, Uzbek), Korean, and Japanese (from Slobin, 2002).

² The class of equipollent-framed languages includes serial verb languages like Mandarin in which a Manner and Path verb(s) appear in the same clause; bipartite languages in which the verb consists of a Manner and Path morpheme; and generic verb languages, in which one of 5 basic verbs with deictic or aspectual functions ('go', 'come', 'fall', 'hit', 'do') is combined with a Manner and a Path 'coverb' (satellite-like elements).

³ There are approximately 300 manner verbs in English but only 75 in Spanish (Slobin, 2002).

⁴ Russian may only have one Path verb, *vozvrashchatsya / vernutsya*, the equivalent of 'return' (Beavers, Levin & Wei Tham, 2010).

Selimis, 2010; Slobin & Hoiting, 1994).⁵ In such cases, Manner can be encoded using an adjunct (e.g., *corriendo*, “running”) but speakers of verb-framed languages often omit Manner information in favor of simpler syntactic structures—particularly when it is easily recovered from extra-linguistic or discourse context. Speakers of satellite-framed languages (*run*-type) regularly express both Path and Manner but the forms used to express Path vary, including adpositions (*into* and *out*), verbal prefixes like *vy-* ‘out’ (Russian), case markers (Finish), or compound verb constructions (Mandarin).

Beavers, Wei Tham, and Levin (2010) propose a reconceptualization of cross-linguistic patterns observed in the encoding of motion events. They contend that cross-linguistic variation (deviations from core typologies) stems from differences in the lexical and morpho-syntactic resources available in a language (e.g., casemarkers, prepositions, verbal affixes) and cross-linguistic stability (what manifests as a distinction between satellite-framed, verb-framed, and equipollent-framed languages) stems from two crucial properties related to the verb: (i) does the clausal verb tend to encode the Manner or the Path of motion; and (ii) can morphemes encoding Manner and Path both appear together in the same clause. Beavers et al. also observe that languages that tend to encode Path in the main clausal verb typically do not allow both Path and Manner in that clause. That is, the choice with regards to (i) affects the choice with regards to (ii). Verb-framed languages are those which tend to encode Path in the main verb, and only allow this primitive to appear in the main clause – Manner must be specified in an additional clause (e.g., a subordinate or small clause).

⁵ This is often referred to as a constraint on events conceptualized as crossing a boundary (Aske, 1989; Slobin & Hoiting, 1994). Slobin (2004) equates boundary crossing with change of state, such that Path verbs are required for enter, exit, and cross events, but Manner verbs are allowed for high-energy actions that can be construed as punctual events (e.g., the equivalent of ‘plunge’). This pattern is characteristic of Romance languages but languages like Greek require Path verbs for telic events; thus, ‘fly to’/‘fly from’ are ungrammatical in Greek (Papafragou, Hulbert, & Trueswell, 2008).

Satellite-framed languages tend to encode Manner in the main verb, but come in two varieties: those that allow also Path verbs in the main clause (equipollent languages) and those that do not (satellite-framed languages, proper).⁶

Importantly, Beavers et al. (2010) argue that their account of motion typologies is easily generalized to other classes of events (see also Talmy, 1991, 2000). In particular, semantic primitives that are similar to Manner-of-motion and Path follow similar constraints to those just outlined. This generalization is exemplified by the encoding of caused change-of-state events. Consider the English and Spanish sentences in (2).

(2) Caused change-of-state events

a. He blew the candle out

b. Él apagó la vela soplando

‘He extinguished the candle, blowing’

In English, the verb, *blew*, encodes the *Means*, (the way an action is carried out), and *out* encodes the *Effect* (the change in state of an entity, caused by that action). In contrast, the verb, *apagó*, encodes Effect and the gerund, *soplando*, encodes Means. The typological patterns (satellite-framed/verb-framed and equipollent-framed languages) observed in the encoding of directed motion events can be generalized to the encoding of caused change-of-state events, such that Means behaves like Manner, and Effect behaves like Path. Notably, verb-framed languages (*enter-type*) apply a clause-level constraint that prohibits Manner and Path or Means and Effect information to be jointly specified in the main clause. For example, (atelic) Manner-of-motion and Means verbs cannot combine with resultative phrases to describe scenarios with definite endpoints (telic events)—rather, to describe telic

⁶ Note that although the terms satellite-framed, verb-framed, and equipollent-framed are used in this discussion, under the theory proposed by Beavers et al. (2010), these classes are epiphenomenal, arising from the two central properties related to the verb.

events, a Path or Effect verb must be used (Aske, 1989; Slobin & Hoiting, 1994). Thus, the English sentences in (3) would be ungrammatical in verb-framed languages (but many satellite-framed languages have comparable constructions):

(3) Examples of Manner/Path and Means/Effect in the same clause

- a. The woman hobbled in from the back. [Directed motion]
- b. She scrubbed the floor clean. [Caused change of state]

Many other theorists have also studied similar parallels between changes in location and changes in state (Beavers, 2011, 2011a; Gropen, Pinker, Hollander, & Goldberg, 1991; Jackendoff, 1983; Pinker, 1989; Rappaport-Hovav and Levin, 1998, 1999, 2010; Talmy, 1991, 2000). These similarities and their significance will be discussed in more detail when reviewing background for Paper 3.

At present, I would like to consider one additional, important detail. Despite the similarities just discussed, the composition of directed motion and caused change-of-state lexicons often differ notably within and across languages. While languages tend to have strong tendencies to encode either Path (*enter, arrive*) or Manner (*run, meander*) in the motion-verb lexicon, all languages have substantive repertoires of Means verbs (*hit, hammer*) and Effect verbs (*break, smash*) and cross-linguistically languages do not tend to strongly prefer one kind of verb or the other (but see Weinold, 1995; Snell-Hornby, 1983).

The Studies Presented in this Thesis: Papers 1 and 2

Papers 1 and 2 examine how higher-order statistical generalizations about verb meanings are represented by using a novel verb-learning and extension paradigm to examine whether English-speaking adults can learn higher-order lexicalization biases for directed motion verbs (which are characterized by conspicuous cross-linguistic variability) and caused change-of-state verbs (which are characterized by the lack of appreciable lexical disparities),

respectively.

Paper 1

Paper 1 examines whether cross-linguistic differences in motion verb lexicalization biases and visual attention reflect differences in semantic representations. There is wealth of evidence that speakers of satellite-framed and verb-framed languages differ in the way they allocate attention to Manner-of-motion and Path information during sentence processing and these differences are apparent from an early age (Berman and Slobin, 1994; Cifuentes-Férez & Gentner, 2005; Maguire, Hirsh-Pasek, Golinkoff, Imai, Haryu, et al., 2010; Naigles, Eisenberg, Kako, Highter, & McGraw, 1998; Naigles & Terrazas, 1998; Papafragou, Massey, & Gleitman, 2006; Papafragou & Selimis, 2010; Slobin, 1996, 2000, 2006). For example, 14- to 17-month-old English-speaking infants orient more to Manner of motion when events are labeled by a novel verb (Pulverman, Brandone, & Salkind, 2004). Moreover, by the second year of life, English-speaking infants with higher vocabularies focus more on the Manner of motion than their low vocabulary peers whereas high vocabulary Spanish-speaking infants attend less to Manner-of-motion related information than their low vocabulary peers—in non-linguistic contexts (Pulverman, Sootsman, Golinkoff, & Hirsh-Pasek, 2003; for evidence of similar changes in attention to relational components of events, see Göksun et al., 2010). Such differences raise the question of what cognitive systems represent language-specific biases for verb lexicalization.

One class of theories attributes cross-linguistic variability to *semantic reorganization*. Generally speaking, these theories posit that the initial salience of the perceptual correlates of semantic primitives such as Path and Manner is not universally fixed, and that semantic space “reorganizes” as a result of learning the inventory of verbs (and other words) in a

language (Bowerman, 1996; Choi & Bowerman, 1991; Gentner, 1982; Gentner & Boroditsky, 2001; Lucy, 1993, 1996; Slobin, 1996, 2001). As the child acquires language, non-linguistic perceptual and conceptual primitives are bundled together into the more abstract event-structure primitives encoded by lexical items:⁷

“...universal perceptual constructs are reorganized to match the expressional tendencies of one’s native tongue. Language, in this case, would have the function of orienting...attention to some relations in events over others” (Göksun et al., 2010, p.34).

Changes in semantic space alter the salience of corresponding perceptual features.⁸ That is, language-specific demands on attention to particular components of events during language use and learning become automatized (what Slobin, 1996, 2000, calls “thinking for speaking”); consequently, particular ways of construing events become ‘privileged’ during online language production, comprehension and learning and these biases also affect non-linguistic processes, such as perception and memory, during contexts of language use (Billman & Krych, 1998; Billman, Swilley, & Krych, 2000; Slobin, 1996 2000, 2006; Göksun et al., 2010; but see Papafragou, Hulbert, & Trueswell, 2008; Trueswell & Papafragou, 2010). Under stronger versions of semantic reorganization, the linguistic system has more pervasive and permanent effects on non-linguistic representations, resulting in cognitive asymmetries between speakers of different languages (Haun, Rapold, Janzen, &

⁷ Slobin (2001) suggests that the granularity of initial primitives may be more fine-grained than semantic notions in most linguistic theories; he proposes the following possible primitives: contrasts between containment and support, tight and loose fit; first-person agency, control act, manipulated object, change of state; or fine-grained motor features of different hand positions, directions, elbow joint motions, and force.

⁸ As Clark (2004) states, “Just as semantically irrelevant phonetic details are ‘ignored’ during speech perception yet available to the acoustic system... a similar relation probably holds for conceptual versus linguistic representations: we become so used to ‘thinking for speaking’ that we generally ignore conceptual information that is not needed for speaking. But this information remains available and can be invoked under the appropriate circumstances.”

Levinson, 2011; Majid, Bowerman, Kita, Haun, & Levinson, 2004).

In contrast with semantic reorganization theories, *flexible linkage theories* contend that language learning only affects the mappings between semantic categories (which are universal) and linguistic forms (Gillette, Gleitman, Gleitman, & Lederer; Gleitman, 1990; Gropen, Pinker, Hollander, & Goldberg, 1991ab; Fisher, 1996; Gennari, Sloman, Malt, & Fitch, 2001; Jackendoff, 1990, 1996; Naigles, 1990, 1996; Papafragou, Massey, & Gleitman, 2002; Papafragou & Selimis, 2010; Pinker, 1989; Shafto, Havasi, & Snedeker, 2014). Under these theories, cross-linguistic differences in the allocation of attention reflect differences in expectations about the likelihood that a particular dimension is to be encoded in a form, rather than differences in the lower-level organization of the perceptual correlates of the dimension itself. For example, English speakers (a satellite-framed language) learn that fine-grained distinctions in Manner of motion are encoded in English verbs and, consequently, during verb processing, predictively allocate more attention to Manner-related perceptual features in order to more efficiently evaluate the meaning of a sentence.

In Paper 1, we examined the viability of semantic-reorganization theories by assessing the stability of biases in verb construal and attention to events components. If semantic space reorganizes over development, changing the salience of conceptual dimensions, then language-specific preferences should be stable. To address this question, we taught English-speaking adults either Manner or Path verbs. Then we assessed whether adults learned biases that reflected the input by measuring whether, on later trials, they preferred to construe novel verbs as Manner or Path verbs (see also, Shafto, Havasi, & Snedeker, 2014). We also tracked fixations to Manner and Path components of events as in Papafragou, Hulbert and Trueswell (2008). The meanings of newly learned verbs influenced verb

lexicalization preferences and visual attention indicating that cross-linguistic differences in attention are not the product of representational changes. Adults learning Path verbs acquired Path biases whereas those learning Manner verbs strengthened their Manner biases. Additionally, Path-biased adults were more likely to attend to the Path components of events than Manner-biased adults, mirroring previously observed cross-linguistic differences in attention between Greek (Path language) and English speakers (Papafragou et al., 2008). These results are inconsistent with semantic reorganization theories under which habitual deployment of attention to linguistically ‘privileged’ ways of construing events become automated and are spontaneously activated from the onset of message formulation (even before lexical items are selected). It is, however, consistent with flexible linkage theories that expect biases about the meanings conflated into verbs (or form-meaning mappings more generally) to be stable insofar as the context supports such expectations.

Paper 2

Paper 2 extends the study of learning verb lexicalization biases, or expectations about the components of meaning conflated into the verb, from verbs for directed motion events to verbs for caused change-of-state events. Leveraging the fact that caused change-of-state verb lexicons do not display strong Means or Effect biases in English, we can investigate whether the learning mechanism tracks input statistics and generates higher-order generalizations about verb meaning even in cases where the utility of such lexical statistical knowledge is questionable.

This idea is tested by teaching English-speaking adults either novel Means verbs (e.g., *hammer*, *bat*) or novel Effect verb (e.g., *break*, *cut*) and assessing how adults construed novel caused change-of-state verbs encountered on later trials. The data revealed that

learning rapidly influences verb construal: adults learning Means verbs reliably preferred Means interpretations of new novel verbs whereas adults learning Effect verbs reliably preferred Effect interpretations. The results of Paper 2 mirror those in Paper 1 despite differences in the composition of the directed motion and caused change-of-state verb lexicons in English. This data pattern indicates that the learning mechanism inherently forms higher-order generalizations about category structure that are then used to constrain the hypotheses entertained by the learner in verb learning contexts (see Paper 2 for discussion regarding the acquisition of inductive constraints in noun learning).

Together, Papers 1 and 2 provide evidence that learners rapidly form higher-order generalizations over the meanings of individual verbs in the input. As these papers examine verbs for classes of events that differ perceptually and exhibit distinct lexical statistical properties, convergence across studies indicates that the same learning mechanism undergirds the acquisition of verbs from different event classes and that this mechanism inherently forms abstractions at multiple levels of generality. Further, flexibility in verb construal for directed motion and caused change-of-state verbs further militates against theories of semantic reorganization and supports theories under which verb lexicalization biases are expectation-driven inferences about form-meaning mappings. Lastly, in Papers 1 and 2 the novel verb-learning paradigm set up a new context and provided adults with input that they could use to acquire new higher-order knowledge. These experimental properties fostered a situation in which learners could relax expectations based on their knowledge of the English lexicon. Many studies examine the acquisition of inductive constraints in word or concept learning either within naturalistic (developmental) contexts or using entirely novel or artificial categories—in either case, learning involves the formation of new higher-order

generalizations for an unknown domain. In contrast, adults in the studies in Papers 1 and 2 acquired new semantic biases for a ‘familiar’ semantic domain, that is, an area for which learners already have experiential knowledge about its organization. These findings, then, highlight the importance of understanding higher-order generalizations, such as lexicalization biases for verbs of directed motion and caused change-of-state, among others, as contextually grounded. This also offers a plausible way to understand how biases so flexible in nature may nevertheless play an important role in verb learning (discussed in further detail in Paper 2). As a final note, even though Papers 1 and 2 are entirely complementary in nature, the papers are framed within two distinct theoretical frameworks that emphasize different aspects of the problem of representation.

Paper 3

Paper 3 considers the status of event primitives like Path, Manner, Means, and Effect, specifically, whether these primitives are actually instances of more abstract concepts that apply across these different semantic fields.

The possibility that such superordinate event concepts exist has, at least implicitly, been a part of many theories about lexical-semantic structure and verb acquisition (Gropen et al., 1991a; Gruber, 1965; Jackendoff, 1972, Pinker, 1989; Rappaport-Hovav & Levin, 1985, as described in Pinker, 1989; 1998; Talmy, 1991), but has been stated most explicitly by Rappaport-Hovav & Levin (2010, hereafter RHL; see also Beavers et al., 2010, for extension to language typology), who propose a generalization that runs across the entire verbal lexicon and applies across the world’s languages.

These theorists have proposed the existence of two higher-order semantic primitives: MANNER, which encompasses Manner of motion and Means, and RESULT, which encompasses

Path and Effect.⁹ As illustrated earlier, across languages, similar constructions are used to encode Manner and Means and similarly, Path and Effect. Moreover, verb-framed languages disallow both Manner and Means verbs to express telic events. The case for MANNER and RESULT is bolstered by additional analyses revealing that both Manner and Means verbs can appear in a wide range of sentential contexts but both Path and Effect verbs are licensed in a relatively restricted set of syntactic contexts (Rappaport-Hovav & Levin, 1998). Moreover, these restrictions are semantically motivated, stemming from a rule linking the affected entity in an event¹⁰ to the direct object position (Gropen, Pinker, Hollander, & Goldberg, 1991a; Rappaport-Hovav & Levin, 1998, 2010). More generally, Path and Effect verbs have been associated with both notions of scalar change and affectedness (for review and theory reconciling these notions, see Beavers et al., 2011).

There is also experimental evidence indicating similarities in the acquisition of lexical items which encode Manner-of-motion/Means and Path/Effect. Across languages, these concepts are among children's earliest expressions but they are encoded in different forms. For example, Path and Effect terms are initially expressed in available satellites (e.g., particles, affixes, case markers) in satellite-framed languages but in verbs in verb-framed languages (Berman & Slobin, 1994; Choi & Bowerman, 1991; Smiley & Huttenlocher, 1995; Naigles, Eisenberg, & Kako, 1992). Bowerman and Choi (2001) demonstrated that the emergence of motion expressions in English- and Korean-speaking children is characterized by universal and language-specific influences. Children in both languages expressed Path in

⁹ I follow RHL in using the terms MANNER and RESULT but will be circumscribing their application to include only Manner/Means and Path/Effect verbs, respectively.

¹⁰ Typically, 'affectedness' is construed as an observable change in an entity, either in location or state, but Beavers (2011) presents a definition of affectedness that also captures the relationship between Path verbs and the Ground (expressed as the direct object)

single-word utterances, expressed Manner a few months later, and produced Manner and Path expressions last (Bowerman & Choi, 2001). From the beginning, children expressed terms in the forms preferred by their language (English-speaking children produced Path in satellites and Manner in verbs whereas Korean-speaking children produced Path in verbs and Manner in adjuncts), and English-speaking children produced Manner and Manner + Path expressions earlier, reflecting both the relative frequency and complexity of these expressions in English and Korean (Bowerman & Choi, 2001).

Production studies also provide evidence of parallels across directed motion and caused-change-of-state fields. Young English-speaking children produce more Manner-of-motion and Means verbs than Path (unless *come* and *go* are included) or Effect verbs in spontaneous speech (Bowerman & Choi, 1991; Gentner, 1978; Huttenlocher et al., 1983). Moreover, English-speaking adults and preschoolers (3- and 5-year-olds) prefer to use Means verbs than Effect verbs to describe caused change-of-state events (Behrend, 1990) just as they prefer Manner-of-motion over Path verbs (Berman & Slobin, 1994).

Papafragou and Selimis (2010) reveal parallel cross-linguistic differences between adult and five-year-old speakers of English (satellite-framed language; *run*-type) and Greek (verb-framed language, *enter*-type) in elicited production and verb learning, further supporting the idea that there are semantic similarities between Manner-of-motion and Means and between Path and Effect. When asked to describe directed motion events (Experiment 1), English speakers more often used Manner-of-motion verbs (e.g., *run*) whereas Greek speakers more often used Path verbs (e.g., *enter*) and, similarly, when asked to describe caused change-of-state events (Experiment 2), English speakers typically used Means verbs (e.g., *push*) whereas Greek speakers typically used Effect verbs (e.g., *send*).

When the same events were described using novel motion verbs (and presented to different groups of English and Greek speakers), a similar pattern emerged: novel verbs for directed motion events were reliably interpreted as Manner-of-motion verbs by English speakers but as Path verbs by Greek speakers (Experiment 1); similarly, English speakers were more likely than Greek speakers to interpret novel caused motion verbs as Means verbs—but speakers of both languages preferred Effect interpretations (Experiment 2). Greek speakers’ preferences were consistent across production and verb learning tasks; in contrast, English speakers rarely produced Effect verbs yet preferred Effect interpretations of novel verbs (used to describe the same events).¹¹

In Paper 3, we examined the hypothesis that Manner-of-motion verbs like *run* and Means verbs like *hammer* encode changes of one kind (MANNER) and that these classes of events are distinct from those encoded by Path verbs like *enter* and Effect verbs like *flatten*, which encode changes of a different kind (RESULT). Using the paradigm in Papers 1 and 2, we manipulated English-speaking adults’ biases for directed motion or caused change-of-state verbs. Then, we assessed whether newly learned biases were generalized across semantic fields. In all three experiments, adults taught novel motion verbs with Manner (*run*) or Path (*enter*) meanings differed in their conjectures for new directed motion verbs (generalization within the same event class) and novel caused change-of-state verbs (generalization across event classes). Similarly, adults taught novel Means (*hammer*) and novel Effect (*flatten*) verbs differed in their interpretation of new caused change-of-state

¹¹ Interestingly, Behrend (1990) similarly found that English-speaking adults and toddlers preferred to describe novel caused change-of-state events using Means verbs (e.g., *hammer*, *hit*) but preferred to construe novel verbs describing those events as *Effect* verbs (e.g., *break*). Moreover, even though instrumental Manner-of-motion verbs were frequently used to describe events, but adults and children rarely considered the instrument as part of the lexicalized meaning of a novel caused-change-of-state verb (Behrend, 1990).

verbs and novel directed motion verbs (Experiments 2 and 3). These results indicate that higher-order generalizations were formed over dimensions shared by directed motion and caused change-of-state events—had that not been the case, learning should only have influenced the interpretation of novel verbs used to describe events from the same class as those in the learning input. The data pattern obtained in Paper 3 provides evidence for MANNER and RESULT categories that range over classes of verbs for directed motion and caused change-of-state events but whether MANNER and RESULT extend across other semantic fields as indicated by prior research (or as RHL propose, across the entire verbal lexicon) remains an open question.

Summary

The universality of event concepts, such as Manner, Path, Means, and Effect, paired with systematic cross-linguistic variation in how these concepts are encoded raises important questions about representation and learning. The papers in this thesis investigate whether language-specific preferences in verb construal and attention emanate from reorganization of semantic space, whether the acquisition of verb meanings can be supported by mechanisms of higher-order generalization, and whether primitive event concepts are tied to specific classes of events or are more abstract, unifying perceptually dissimilar events.

Paper 1: The Flexibility of Event Encoding:
Evidence for Rapid Learning of Semantic Generalizations

Amy C. Geojo & Jesse Snedeker

Languages vary in how they characteristically encode events. When describing motion events, English more often encodes the Manner of motion in the verb (*meander*) while Greek more often encodes the Path of motion (*enter*). Language-specific ways of expressing events influence how speakers interpret new verbs and how they attend to components of events. But do these lexicalization biases represent a reorganization of semantic components to match their expression in language? If so, adults should not be able to learn new higher-order generalizations about verb meaning; thus biases in verb learning and visual attention should be stable. In two experiments, we demonstrate that English-speaking adults learning Manner verbs strengthened their bias to interpret new verbs as encoding Manner while those learning Path verbs developed a bias to interpret new verbs as encoding Path. Additionally, learning shaped how adults allocated attention to events when they first encountered a novel verb, before they were asked to generalize it. Adults learning Path verbs looked more at the object defining Path, while those learning Manner verbs looked more at the object specifying Manner. We conclude that language-specific semantic biases likely reflect the acquisition of context-specific, higher-order inferences about mappings between semantic components and linguistic forms rather than the reorganization of semantic or conceptual space.

Introduction

A single event can be construed and categorized in multiple ways. Consider, for example, a man throwing a frisbee across a field. This simple motion event can be classified along many dimensions. You can describe it in terms of the cause of motion (*throw*), the Manner of motion (*fly* or *glide*), or the Path of motion (*crossing the field*). Languages differ in how they preferentially package, or conflate, these different aspects of events into words and phrases. Talmy (1985) notes that every motion event is comprised of (at least) four parts: a Figure, moving in a particular Manner, along a Path defined with reference to the Ground (a stationary object). While all languages can express these elements, they systematically differ in how they lexicalize Manner and Path (Talmy, 1985, 1991; Slobin, 2001, 2006, 2008). Path (or Verb-framed) languages (e.g., Greek, Spanish) more often encode Path in the verb (e.g., *enter*, *ascend*) and optionally express Manner in gerunds, adpositions, or adverbials whereas Manner (or Satellite-framed) languages (e.g., English) more often encode Manner in the verb (e.g., *skip*, *run*) and express Path in adpositions, particles, or verbal affixes. These language-specific lexicalization preferences are reflected in adult speech and even in the speech of young children (Berman & Slobin, 1994; Cifuentes-Férez & Gentner, 2005; Naigles, Eisenberg, Kako, Hightner, & McGraw, 2008a). For example, to describe an event in which a bottle moves atop water into a cave, speakers of Path languages, like Spanish, characteristically select a Path verb (1) while speakers of Manner languages, like English, typically select a Manner verb (2; Talmy, 1985, pp. 69):

(1) Spanish: La botella entró a la cueva (flotando)
the bottle moved-in to the cave (floating)

(2) English: The bottle floated into the cave

Furthermore, such lexicalization biases represent psychologically real generalizations: when a novel verb is used to describe a motion event (e.g., a girl running out of a house), speakers of Manner languages like English typically assume it encodes Manner (e.g., run) whereas speakers of Path languages like Greek typically assume it encodes the Path (e.g., exit; Maguire et al., 2010; Naigles & Terrazas, 1998; Papafragou & Selimis, 2010). These language-specific lexicalization biases (higher-order expectations about verb meaning) emerge between five and seven years of age (Hohenstein, 2005; Maguire et al., 2010; Papafragou & Selimis, 2010; Shafto, Havasi & Snedeker, 2014). However, to date, very little evidence has been adduced regarding the flexibility of these higher order biases themselves. Specifically, can speakers override or reverse their verb-general language-specific bias for Path- or Manner- constructions in certain contexts? In this paper, we provide evidence that adults speakers of English, a Manner language, develop lexicalization biases that reflect the distribution of meanings of novel motion verbs in our experimental manipulation: adults taught novel Manner verbs strengthened their Manner biases while adults taught novel Path verbs developed Path biases. Furthermore, differences in lexicalization bias are accompanied by differences in visual attention to Manner and Path components of events.

The present research bears on a dimension in which theories of lexical acquisition vary. One class of theories, which I will refer to as semantic reorganization theories, proposes that learning how language carves up events and parcels conceptual components of events into verbs (and other relational terms) sharpens children's sensitivity to certain semantic distinctions while dampening their sensitivity to others (McDonough, Choi, & Mandler, 2003), explaining why language users become more attentive to some dimensions of meaning. In other words, these theories propose that language input induces fundamental

changes to the organization of the learner's semantic representations (Choi, 2006; Clark, 2003, 2004; Gentner & Boroditsky, 2001; Göksun, Hirsh-Pasek, & Golinkoff, 2010; Hespos & Spelke, 2004, 2009; Majid, Bowerman, Kita, Haun, & Levinson, 2004; McDonough et al., 2003; Slobin, 2008). Learning how motion events are characteristically expressed, for example, makes Manner more salient to English speakers and Path more salient to Greek speakers (Göksun et al., 2010; Pulverman et al., 2006; Slobin, 2000), ultimately resulting in differences in how English and Greek speakers allocate attentional resources (Papafragou, Hulbert, & Trueswell, 2008; also see, Berman & Slobin, 1994, p. 612; Slobin, 2000).

These theories often make an analogy with the development of speech perception (Göksun et al., 2010). In the phonological domain, over the first year of life children hone their ability to discriminate phonetic distinctions that are contrastive in their language and lose their ability to discriminate phonetic contrasts that are not contrastive in their language (Kuhl et al., 2006; Werker & Tees, 1984, 2002; see Werker & Tees, 2005 for review). For example by 10 months of age, English-speaking infants no longer distinguish differences in the “d” in “this doll” and “your doll”, a phonetic contrast between a dental [d̪] and a retroflex [ɖ], respectively, but Hindi speakers continue to differentiate this contrast (example from Werker, Yeung, & Yoshida, 2012, p.221). It is often suggested that the failure of older children and adults to perceive non-native contrasts is the result of the reorganization of perceptual resources, rather than being merely a consequence of higher-level linguistic categorization of the outputs of perceptual systems (Kuhl, 2000).

The analogy with verb learning is, of course, imperfect, since speakers of both Path and Manner languages retain the ability to comprehend and learn novel instances of both types of verbs. Furthermore, such theories typically do not cash out the representations and

mechanisms underlying semantic reorganization. Nevertheless, semantic reorganization theories suggest that changes in the salience of Path and Manner ensue from the reorganization of semantic resources through processes akin to that underlie the reorganization of perceptual resources in speech development—with one significant exception, namely that reorganization in semantic development refers to the acquisition of a hierarchy of preferences rather than loss of the ability to distinguish properties of events that are not grammatically distinguished (Göksun et al., 2010; Haun, Rapold, Janzen, & Levinson, 2011; Majid, Bowerman, Kita, Haun, & Levinson, 2004).

By contrast, another class of theories, which I will refer to as flexible linkage theories, assumes that basic conceptual and semantic resources vary minimally in adults cross-linguistically (Shafto, Havasi, & Snedeker, 2014). Under these theories, lexicalization-bias driven differences in attention must be attributed to expectation-driven inferences about the linking between forms and meanings in a language. Greek speakers do not look to the Path-related aspects of a scene more due to differences in the salience or representation of Path, but because they know that verbal roots in their language tend to encode Path, and therefore privilege attending to Path-related information in order to facilitate the comprehension or production of Greek verbs. From a developmental perspective, flexible linkage theories emphasize that language acquisition is largely a problem of learning linking patterns between forms and meanings—while conceptual or semantic resources may change during childhood for other reasons (e.g., biological maturation), cross-linguistic variation in the way words package information is not considered a significant factor.

As mentioned above, speakers of Path- and Manner-biased languages can and do learn both types of verbs. Nevertheless, this does not provide strong evidence against

semantic-reorganization theories. Lexicalization biases may represent a mixture of a single higher-order generalization (i.e., “rule”) that links the dominant lexicalization pattern to the semantically privileged category of meaning, while other lexical items are represented by idiosyncratic, verb-specific mappings to potentially unprivileged semantic representations. However, if adult speakers can reverse their higher-order biases in certain contexts (i.e., learn the opposite “rule”)—temporarily becoming speakers of the opposite kind of language—this would provide stronger evidence for conceptual uniformity.

1.1 The Present Proposal

The present paper addresses this question by examining whether the lexicalization biases of adults are sensitive to changes in the semantic content of the words they encounter. This question is, however, impossible to examine within naturalistic linguistic contexts because adults have already acquired the lexicalization preferences of their linguistic community and will continue to draw upon that knowledge. Instead, we created an artificial context to encourage adults to suspend their knowledge about the English verb lexicon by asking adults to participate in a novel word learning task in a laboratory setting. Specifically, English-speaking adults were taught ten novel verbs that all encoded either Manner or Path. As they encountered each verb, we assessed their lexicalization biases, using the paradigm employed by Naigles and Terrazas (1998). If semantic development induces stable reorganization, participants should continue to assume that each new verb encodes Manner, regardless of the other verbs they have learned in the study. In contrast, if lexicalization biases are data-driven higher-order inferences about form-meaning mappings, participants

should update their expectations on the basis of the input that they receive, respectively forming Path-biases in the Path condition and Manner-biases in the Manner condition.

To obtain an implicit measure of lexicalization bias, one less susceptible to conscious reasoning, we drew upon an event description study by Papafragou, Hulbert, and Trueswell (2008) that revealed that language-specific verb encoding preferences are reflected in attentional biases; specifically, they found that adult speakers of Greek, a Path language, initially fixated on Path-relevant components of motion events more than English-speaking adults. As participants encountered new verbs, we tracked their eye-movements to measure spontaneous attention to the Manner and Path components of events. This method enabled us to examine whether verb learning affects event apprehension and to what extent attention and verb construal are linked. This also provides a strong test of semantic reorganization theories because they predict that reorganization of semantic components results in changes in the salience of perceptual correlates of semantic components within linguistic contexts.

EXPERIMENT 1

Method

1.1 Participants

Thirty native English speakers participated. Additional participants were excluded because of excessive track loss in their eye-movement record (N=5) or failure to learn eight or more of the ten verbs (N=2).

1.2 Materials and Procedure

Stimuli consisted of six-second animated motion events that depicted an agent moving in a salient Manner and Path relative to a reference object (e.g., a man driving into a garage). Manners of motion involved the use of vehicles or instruments (e.g., driving). Ten Manners of motion and ten Paths were selected as the intended meanings of novel verbs. Path meanings were: around, behind, between, down to, in front of, into, over, through, under, and up to. Manner meanings were: hot-air ballooning, biking, camel-riding, driving, flying, sailing, roller-skating, skiing, and sledding. Novel verbs were phonologically well-formed English nonsense words presented in sentences consisting of a subject, the progressive form of the verb, and a prepositional phrase encoding the Path (e.g., “The man is krading into the house”). Participants were presented with 10 verb-learning trials, each composed of four phases: the Ambiguous-phase, Bias-phase, Training-phase, and Test-phase. See Table 1.1.

Table 1.1 Four-phase structure of each novel verb learning trial.

Trial Phase	Target Manner Concept: <i>skate</i>	Target Path Concept: <i>(go) under</i>
Ambiguous	skate under arch	
Bias: manner-match	<u>skate</u> in front of fishtank	
Bias: path-match	ride hot-air balloon <u>under</u> rainbow	
Training: 3 exemplars	Manner Condition: skate	Path Condition: (go) under
	skate over book skate behind dog skate into barn	ride magic carpet under table bike under slide drive under sign
Test: manner-match	<u>skate</u> between lamp posts	
Test: path-match	camel <u>under</u> flags	

Each Manner concept was arbitrarily paired with a Path concept. Across conditions, the stimuli for the paired verbs differed only in the events seen during the Training-phase. The 10 verb pairs were randomly ordered and half of the participants in each condition were tested with trials in the reverse order. Participants were randomly assigned to the Manner or the Path condition and learned 10 verbs with Manner or Path meanings, respectively.

The Ambiguous-phase introduced a novel verb in a written sentence which described the subsequently presented a motion event. The video seen during this phase will be referred to as the Ambiguous-event as the novel verb could encode either the Manner or Path of motion. During the Bias-phase, two events that differed from the Ambiguous event either in Manner or in Path (but not both) were sequentially presented and, after each, participants judged whether the novel verb could be used to describe the event (“Does this show Verbing?”). If a participant extends the novel verb to the Manner-match event but not the Path-match event, this indicates that the participant believes that the verb encodes Manner; the reverse response pattern indicates that the participant believes the verb encodes Path. The Training-phase disambiguated the meaning of the word by presenting participants with three motion events, each described by a sentence containing the novel verb. Participants learning Manner verbs viewed events depicting the same Manner as the Ambiguous-event but varying in Path. The reverse was true for participants learning Path concepts. The Test-phase assessed whether participants acquired the intended verb concept by presenting them with another extension test parallel to the Bias-phase. The order in which the Manner-match and Path-match videos were presented during Bias- and Test-phases was counterbalanced across trials. Participants were informed that they would be learning new words by watching videos and answering questions. Throughout the experiment, participants’ visual fixations were

recorded using a Tobii T60 eye-tracker. Eye-tracking data was coded by defining spatial regions corresponding to Path and Manner using the same criteria as Papafragou et al. (2008). Manner was defined as the area occupied by the instrument enabling the agent's motion, excluding the space occupied by the agent. Path was defined as looks to the reference object that defined the Path, rather than looks to all points along the agent's trajectory.

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Results and Discussion

Participants in both conditions successfully acquired novel verb meanings although performance on Manner verbs was marginally higher than performance on Path verbs ($M_{\text{Manner Condition}} = .95$, $M_{\text{Path Condition}} = .91$, Wilcoxon $W=155$, $p = .07$). Because we are interested in examining whether learning alters adults' hypotheses about the meaning of subsequently encountered verbs and attention to event components, our primary analyses examine differences between conditions during the Ambiguous- and Bias-phases of Trials 3-10 (after participants learned two verbs).

Responses to Bias-phase questions were coded in the following manner; for each trial, participants received a score of 1 if they only accepted the Manner-match video, 0 if they only accepted the Path-match video, and 0.5 if they accepted or rejected both videos. The first novel verb was construed as a Manner verb by 62% of participants ($M_{\text{Manner}} = .60$; $M_{\text{Path}} = .63$). As illustrated in Figure 1.1, verb learning resulted in the development of lexicalization biases consistent with the meanings of novel verbs in the learning input; specifically, the proportion of Manner-biased responses significantly differed across Manner and Path verb learning conditions. ($M_{\text{Manner}} = .98$; $M_{\text{Path}} = .21$; Wilcoxon $W = 225, p < .001$).

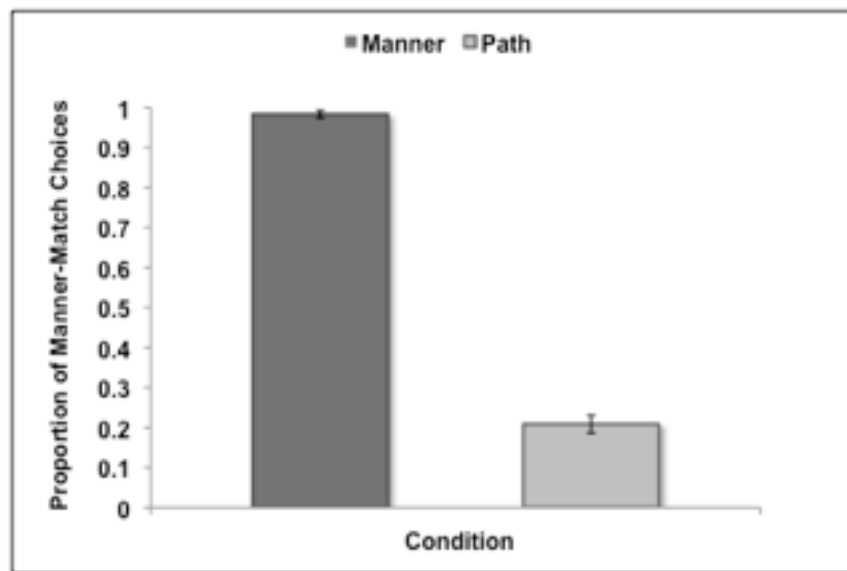


Figure 1.1. Lexicalization Bias for Manner and Path conditions in Experiment 1 plotted as the proportion of Manner-match choices over all responses during the Bias-phase of Trials 3-10. Error bars depict standard errors.

Following Papafragou et al. (2008), we defined a critical time window between 200 and 1300 milliseconds after the onset of the Ambiguous-event. For each frame, fixations to the Manner object were coded “1” and fixations to the Path object “0” and for each trial we computed the proportion of frames in which the participant attended to Manner. Thus frames in which the participant looked at neither object were excluded from analysis. Participants

learning Manner verbs attended to the Manner object significantly more than participants learning Path verbs ($M_{\text{Manner}} = .63$, $M_{\text{Path}} = .41$, Wilcoxon $W = 196$, $p < .01$). See Figure 1.2.

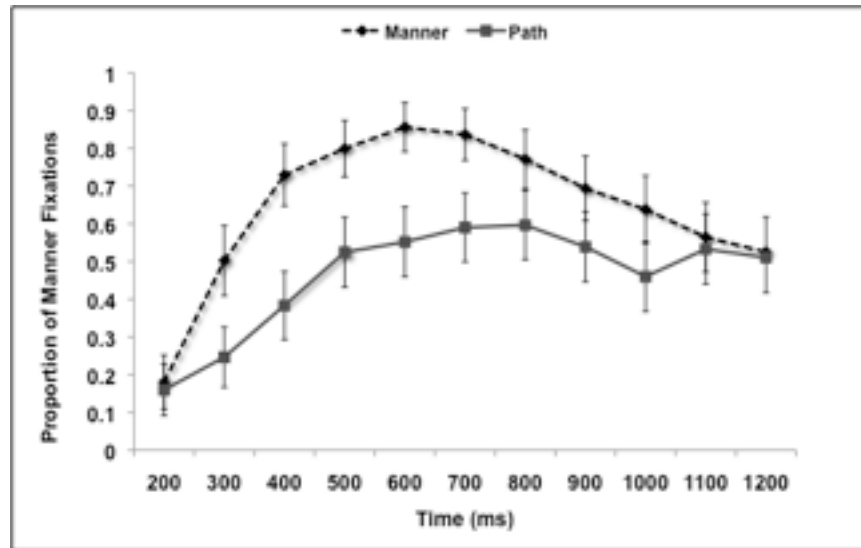


Figure 1.2. Eye-movement results for Trials 3-10 of Experiment 1 plotted as the proportion of fixations to Manner and Path components from 200 to 1300 ms after the onset of the Ambiguous-video. Error bars depict standard errors.

Our results indicate that learning markedly shaped participants' expectations for the meanings of novel verbs. Moreover, the observed shifts in bias do not appear to simply reflect late strategic processes as learning influences visual attention to event components within the first second of the Ambiguous-phase—before participants are asked to extend the novel verb to new events. It is, however, possible that participants in the Manner and Path condition diverged in their visual attention because of low-level perceptual differences in the stimuli presented during training. For each verb, participants in the Path condition viewed three events that depicted a constant Path with respect to an object; this predictable perceptual similarity may have biased participants to focus on the reference object during subsequent learning trials. In contrast, only the vehicle remained constant across videos in

the Manner condition, which may have led participants to focus relatively more on this object. In Experiment 2, we controlled for perceptual experience by presenting the same set of events in both conditions

EXPERIMENT 2

Methods

2.1 Participants

Thirty-two native English speakers participated. Two additional participants were excluded for failing to learn at least eight verbs.

2.2 Materials and Methods

The stimuli, procedure and coding were identical to Experiment 1 with the following exception. During the Training-phase, participants in both conditions watched the same 6 videos; three maintained the same Manner as the Ambiguous-event and three maintained the same Path. Participants in the Manner condition were taught that only Manner-match events could be described by the novel verb whereas participants in the Path condition were taught that only Path-match events depicted the novel verb.

Results and Discussion

Analyses of Test-phase responses revealed that target verb concepts were acquired 97% of the time and performance did not differ across Manner and Path conditions ($M_{\text{Manner}} = .97$, $M_{\text{Path}} = .97$; Wilcoxon $W = 143.5$, n.s.). On the first trial, 68% of participants preferred Manner interpretations ($M_{\text{Manner}} = .72$, $M_{\text{Path}} = .63$) but analyses of trials 3-10 revealed that they quickly developed lexicalization biases consistent with previously acquired verb meanings ($M_{\text{Manner}} = .98$; $M_{\text{Path}} = .10$; $W = 256$, $p < .001$). See Figure 1.3.

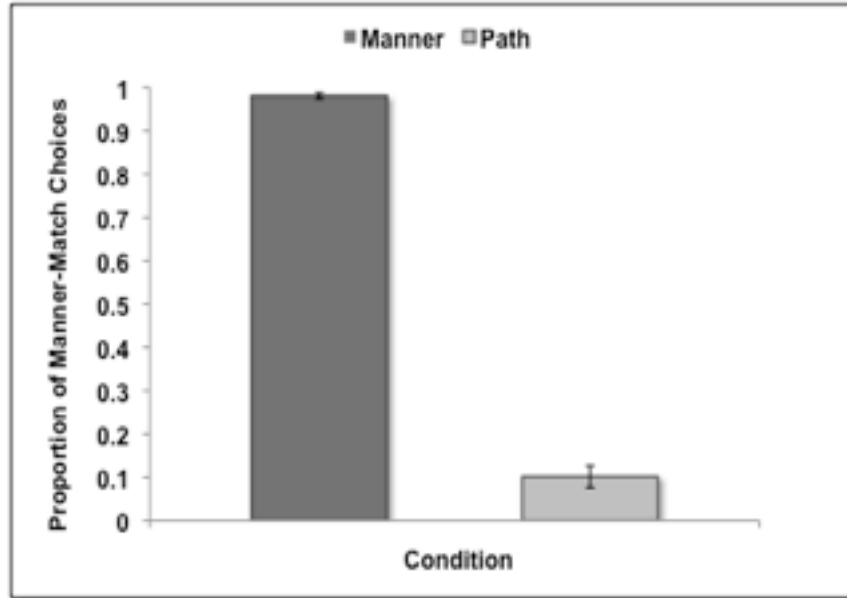


Figure 1.3 : Lexicalization Bias for Manner and Path conditions of Experiment 2. Plotted as the proportion of Manner-match choices over all responses during the Bias-phase of Trials 3-10. Error bars depict

Analysis of eye-tracking data revealed that 200 to 1300msec after the onset of the Ambiguous-event, participants' attention to event components differed by condition ($M_{\text{Manner}} = .63$, $M_{\text{Path}} = .41$, Wilcoxon $W = 237$, $p < .001$). See Figure 1.4.

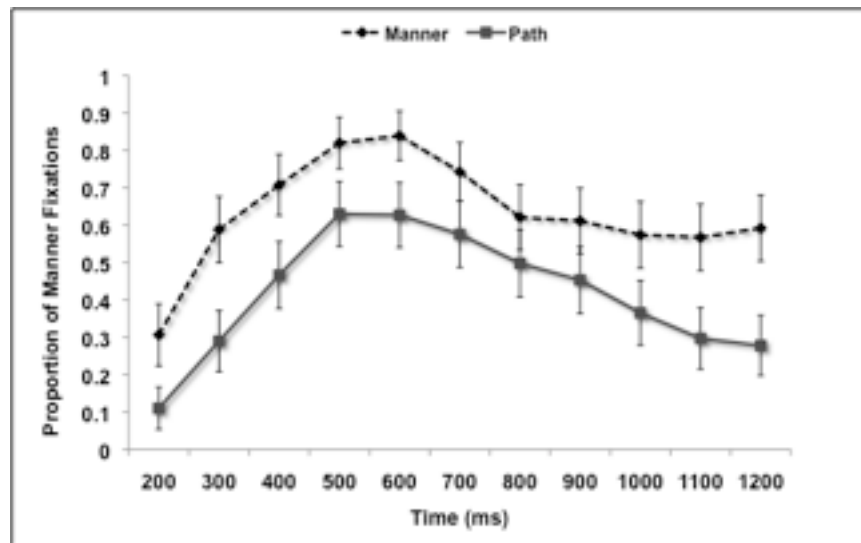


Figure 1.4. Eye-movement results for Trials 3-10 of Experiment 2. Plotted as the proportion of fixations to Manner and Path components from 200 to 1300 ms after the onset of the Ambiguous-video. Error bars depict standard errors.

As in Experiment 1, learners' lexicalization biases and visual attention were strongly shaped by previously acquired verb meanings. Because all participants in Experiment 2 viewed the same events, low-level perceptual factors cannot fully account for these differences.

GENERAL DISCUSSION

This paper examined the plausibility of semantic-reorganization theories of lexical-semantic development. These theories propose that language-specific differences in the distribution of event components across lexical items cause permanent reorganization of semantic spaces in adult language users. Furthermore, reorganization of semantic components is posited to increase the salience of corresponding event components and the deployment of attention to facilitate language production and comprehension.

In two experiments, we demonstrate that higher-order motion-verb lexicalization biases are flexible, changing with minimal linguistic input. Adults interpret a new novel motion verb as a Path verb (e.g., go in front of) after learning just a handful of verbs encoding Path (e.g., go under) but as a Manner verb (e.g., camel-riding) after learning a few Manner verbs (e.g., hot-air-ballooning). These results converge with recent findings that demonstrate that adults and five-year old children (range 4;6 to 5;6) use the meanings of motion verbs in the input to update their biases (Shafto, Havasi, & Snedeker, 2014).¹² Analyses of visual fixations revealed that verb learning also influenced visual attention to event components even after controlling for perceptual information (Experiment 2). Path-verb learners attended less to the Manner component of events compared to Manner-verb

¹² Child participants in Shafto, Havasi, & Snedeker (2014) had not yet acquired the Manner biases typical of English-speaking adults but changes in bias in respect to the data were comparable to those of adult participants. This suggests that adults learned new higher-order biases using the same learning mechanisms that facilitated the acquisition of language-specific verb lexicalization biases in childhood.

learners. This pattern parallels differences in visual attention between Greek and English speakers observed in a production study conducted by Papafragou et al., (2008). This suggests that participants actively engage linguistic representations, and are not using purely meta-linguistic strategies in this task. Furthermore, from the onset of an event, the adults focus on the physical objects that define a specific Manner or Path revealing a tight temporal and spatial link between verb construal and visual attention and suggesting that the processes that extract and package event components lexicalized in a verb are similar in comprehension and production.

The present results are more consistent with flexible linkage theories under which attention is allocated due to expectations about the meaning of verbs (encoded in lexicalization biases). Since expectations do not result from changes in semantic representations but are inferences about form-meaning mappings, they may be conditioned upon other reliable information sources and thus freely vary across contexts. For example, participants in a dance class may quickly surmise that Manner is likely to be important for any novel verbs they encounter, while people who are getting directions about how to navigate around a new city may be more likely to interpret novel verbs as encoding Path. Similarly, when the biases of the verbs in the present study began diverging from the input statistics of English, our participants may have implicitly realized that they were drawn from a different distribution and thus must reflect a new form of discourse.

Conclusion

The present results demonstrate that adults can learn new higher order generalization about the meanings of motion verbs that are context dependent. English-speaking adults taught novel Manner verbs substantially strengthened existing Manner biases while adults

taught Path verbs reversed their biases, construing subsequent novel verbs as Path verbs 79% of the time—a rate that deviates from the use of Path-verb framed constructions and the statistical properties of the motion verb lexicon in English. The flexibility of language-specific lexicalization biases indicates that lexical-semantic development does not change the availability of conceptual or semantic resources. Rather, the present findings suggest that individuals may adaptively learn narrow, higher-order generalizations that are context dependent, varying across sentential and pragmatic contexts and tuned to the patterns of speech that are characteristic of the diverse environments and people that are a part of the individual's experience.

Paper 2: Acquiring context-based inductive biases for caused change-of-state verbs

Amy C. Gejo & Jesse Snedeker

To learn a word the learner must generalize over the finite set of instances encountered to infer the attributes of the concept encoded. One way that learners can differentiate valid from invalid generalizations about word meanings is by forming higher-order generalizations, or overhypotheses, about the structure of different categories of words. There is substantial evidence that children form inductive biases in noun learning (e.g., shape bias) and this data has been crucial in the development of overhypothesis models of word learning. But do the mechanisms that underlie noun learning also facilitate the acquisition of verbs? Identifying the referent event is not sufficient to adduce the event components a verb encodes. For instance, a caused change-of-state event can be described by a Means verb like *hit* or an Effect verb like *break*. Moreover, neither class is more prominent in the lexicon. In the present paper, we demonstrate that adults rapidly learn a higher-order bias about caused change-of-state verbs by generalizing over novel verbs in the experimental input. Adults taught Means verbs developed reliable Means biases whereas adults taught Effect verbs developed reliable Effect biases and in both condition, acquired biases deviated from those of naïve English speakers. These findings underscore the importance of indicates that developing models of overhypothesis formation that take contextual factors into account. We suggest that the present results are an exaggerated facsimile of the way speakers regularly learn and use different context-based generalizations across different environments, speakers, and topics.

Introduction

Learning the meaning of a word is solving a complex inductive problem. By attending to consistencies across contexts of a particular word's use, a learner can narrow in on the aspects of meaning that are lexically encoded and subsequently judge the applicability of that word in new situations. But learners also form inferences above the level of individual word categories—they form overhypotheses (Goodman, 1955), or generalizations about the features that are relevant to specific classes of categories (Colunga & Smith, 2005; Kemp, Perfors & Tenenbaum, 2007). These often manifest as biases or preferences to extend words along particular dimensions.

In the remainder of the introduction, I motivate the present study investigating overhypothesis learning of *lexicalization biases* (beliefs about the semantic elements encoded in a word) for verbs expressing externally caused change-of-state events (e.g., a child breaks a vase with a bat). The first sections consider key findings from research on the acquisition of higher-order inductive biases in noun learning and theories emanating from this literature, which propose that the learning mechanism uses statistical regularities in the input to form inferences at multiple levels of abstraction. After illuminating the paucity of comparable research outside the domain of noun learning, section four considers one exception— a well-documented case of overhypothesis learning in the acquisition of directed motion verbs. The goal of this paper is to broaden the scope of this line of research and examine whether learners can acquire a lexicalization bias for a new class of verbs, namely change-of-state verbs. Thus, the final sections review linguistic and psycholinguistic research on verbs for externally caused change-of-state events before delving into the details of the present experiment.

1.1 Higher-order generalizations in noun learning

Evidence that word-learners construct higher-order generalizations about category structure is primarily derived from noun learning studies. By age two, children begin to extend newly learned words in systematic ways (Markman, 1989; Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002). Biases in word extension have primarily been studied through the use of a novel word learning task: first a novel exemplar object is labeled and then participants are asked to extend the label to items that differ from the exemplar in one property (e.g., shape, color, material/texture etc.; Imai & Gentner, 1997; Jones & Smith, 2002; Landau, Smith, & Jones, 1988). Studies using this paradigm have demonstrated that 2- and 3- year olds prefer to extend novel labels for solid objects by shape and prefer to extend labels for non-solids (substances) by similarity in material composition; moreover, these shape and material biases are stronger for nouns in count and mass syntax, respectively (Imai & Gentner, 1997; Landau et al., 1988; Soja, Carey & Spelke, 1991). These preferences reflect the category structure of early learned nouns: Samuelson & Smith (1999) found that a majority of the 312 most common nouns in the productive vocabularies (of children between 18- and 30-months¹³) appear in count syntax and label solid objects that are well organized by shape (according to adult judgments). They concluded that early lexicons provide sufficient evidence to justify higher-order inferences about the relevance of shape (and less so material) for nouns encountered by children at this developmental stage.

The presence of regularities that support overhypotheses, such as the shape bias, does not *per se* indicate that learners can acquire these overhypotheses, for example, shape may be a conceptually privileged dimension or a proxy for kind membership (Cimpian & Markman,

¹³ These are the most common words according to the MacArthur Communicative Developmental Inventory (Fenson, Dale Reznick, Bates, Thal, & Pethick, 1994).

2005; Diesendruck & Bloom, 2003; Soja et al., 1991). A longitudinal study conducted by Smith and colleagues (2002), however, demonstrated that 1.5 year olds can learn the shape bias from regularities in the input. Smith et al. (2002) found that children trained on four lexical categories organized by shape later extended nouns for novel items to new instances by shape and acquired more object names outside of the laboratory than children in the baseline condition. Subsequent studies probing the relationship between category structure and noun learning have revealed that learners form more specific generalizations as their vocabularies expand, for example, that color is a better cue for the extension of categories of food than shape (Booth & Waxman, 2002; Booth, Waxman, & Huang, 2005; Colunga & Smith, 2005; Jones & Smith, 2002; Macario, 1990; Markson, Diesendruck, & Bloom, 2008), and that higher-order generalizations can be generated rapidly, even from sparse data and over arbitrary features (Sim, Yuan, & Zu, 2011; Yuan, Perfors, Tenenbaum, & Xu, 2011).

1.2 Mechanisms for the acquisition of higher-order abstractions

The studies just reviewed indicate that learners continuously fine-tune knowledge about the dimensions organizing particular nominal categories by exploiting regularities in the input and use these in word extension and object categorization. These findings underlie proposals that contend that children can discover category-specific hypotheses when learning words (Colunga & Smith, 2005; Kemp et al., 2007; Perfors, Tenenbaum, Griffiths, & Xu, 2011; Xu, Dewar, & Perfors, 2009). These theories stress that inductive constraints on a higher order of generalization can be learned from input data if they are available in the hypothesis space. If such mechanisms are responsible for lexical acquisition, learners should be able to acquire overhypotheses about the dimensions lexicalized by words other than nouns—for instance, by different classes of verbs.

1.3 The problem of induction in verb learning

The acquisition of verb meanings presents many of the same—if not more formidable—challenges as noun learning (Gleitman, 1990; Pinker, 1984, 1989). The learner must determine the appropriate referent state or event out of a multitude of possibilities. Imagine a cat chases a mouse up a hill. This event can be described from the perspective of the cat (*chasing* the mouse) or the mouse (*fleeing* from the cat). Alternatively, the speaker can focus on the Path of motion (*ascending* the hill) or the Manner of motion (*run*, *bolt*) or even select verbs, like *play* or *exercise*. The learner must also ascertain the dimension along which a verb is generalized. Directed motion verbs, such as *run* and *dash* are extended on the basis of Manner but direction-of-motion verbs, such as *ascend* and *enter* are extended on the basis of Path. Yet, few studies have assessed whether learners use semantic regularities in the input to generate higher order inferences about the dimensions organizing specific verb classes (hereafter, *verb lexicalization biases*) akin to noun learning biases,¹⁴ and evidence that learners form such generalizations is persuasive only in the case of directed motion verbs.

1.4 The typology of motion events

All languages construe motion events (e.g., a child running into a house) as the translocation of a *Figure* (the child) with respect to a stationary object, the *Ground* (house). These elements as well as *Manner* and *Path* (the trajectory of the figure relative to the ground) can be expressed in all languages but how these elements are characteristically mapped onto lexical and grammatical structures differs (Jackendoff, 1990; Slobin, 1997, 2004, 2006; Talmy, 1985, 1991, 2000). Motion events can be expressed by a Path-verb framed construction in which Path is lexicalized in the clausal verb (e.g., *enter*) and Manner

¹⁴ What has not been examined is whether lexicalization biases can be learned.

optionally expressed using adverbials, gerundives etc. or by a Manner-verb framed construction in which Manner is lexicalized in the clausal verb (e.g., *run*) and Path expressed using particles (*out*), affixes (German prefixes *raus-* ‘out’ as in *rause-rennen* ‘run out’), adpositions (e.g., *into the house*) etc.¹⁵ Languages are classified as Path languages (*enter-type*) or Manner languages (*run-type*) depending on which construction is more common (Talmy, 1985, 1991; Slobin 2006¹⁶). Languages also vary along other dimensions, such as the number and semantic specificity of Manner and Path verbs in the lexicon and the extent to which Manner verbs can compose with a diversity of Path phrases (Aske, 1989; Slobin, 1989; Slobin & Hoiting, 1994). These are independent factors but Path languages typically have fewer Manner verbs than Manner languages. Moreover, many Path languages do not permit Manner verbs to combine with Path phrases encoding culminated events; this restriction is not characteristic of Manner languages (Beavers, Levin, & Wei Tham, 2010).

1.5 Learners form lexicalization biases about the meaning of motion verbs

Three kinds of data provide convergent evidence for the acquisition of motion verb lexicalization biases: cross-linguistic studies demonstrating the effect of language typology on the interpretation of unknown verbs, evidence that visual attention reflects language-specific lexicalization patterns, and bias generalization studies demonstrating that learners update lexicalization biases by forming generalizations over individual verbs in the input.

¹⁵ Talmy (1991) distinguished constructions (and languages) as Verb-framed and Satellite-framed. In this paper, the terms Path-verb framed and Manner-verb framed will be used instead to make this distinction more transparent.

¹⁶ Slobin (2006) proposes a third class of languages, Equi-pollentally framed languages, to accommodate languages in which Manner and Path appear to receive equal weight as neither component can be unequivocally distinguished as more central to the clause via morphosyntax.

1.5.1 Language typology shapes motion verb lexicalization biases and visual attention

Verb learning studies modeled after the noun learning extension task (section 1.1) indicate that typological differences influence how adults and older children initially construe unknown verbs. When a novel verb is used to describe a particular scenario, speakers of Path languages (*enter-type*; e.g., Spanish, Greek, Turkish) typically assume it encodes the Path of motion whereas speakers of Manner languages (*run-type*; e.g., English, Russian, Mandarin) typically assume it encodes the Manner of motion (Cifuentes-Férez & Gentner, 2006; Naigles & Terrazas, 1998; Hohenstein, 1995; Papafragou & Selimis, 2010; Maguire et al., 2010). Language-specific lexicalization biases emerge between five and seven years of age (Hohenstein, 2005; Maguire et al., 2010; Papafragou & Selimis, 2010; Shafto, Havasi & Snedeker, 2014), suggesting that younger children do not know enough Motion verbs to form the relevant generalizations (Colunga & Smith, 2005; Shafto, Havasi, & Snedeker, 2014).

An additional source of evidence that learners form lexicalization biases over Manner and Path dimensions comes from a study revealing cross-linguistic differences in visual attention. Papafragou, Hulbert, and Trueswell (2008) found that English (Manner language) and Greek (Path language) speakers differed in how they attended to Manner and Path elements in a linguistic task: adults initially attended to the event component typically encoded in verbs in their native language. This effect emerged in telic contexts alone, that is, for events with endpoints.¹⁷ Because restrictions on the use of Manner verbs for these kinds of scenarios are characteristic of Path languages (*enter-type*), including Greek, but not Manner languages (*run-type*), like English (section 1.4.1), this further indicates that attentional differences are linguistic in nature.

¹⁷ Each event had a telic and atelic variant. Both depicted the same manner-of-motion and trajectory of movement but in the telic version, a goal object marked the end of the figure's path.

1.5.2 Learners rapidly form generalizations about motion verb semantics

A series of bias generalization studies, modeled after Smith et al. (2002) training study,¹⁸ revealed that learners rapidly (within a few trials) form motion verb lexicalization biases using the semantic content of words in the input. English-speaking adults and five-year-olds taught novel Manner verbs were more inclined to construe unknown motion verbs encountered on subsequent verb learning trials as encoding Manner than their Path-verb learning counterparts (Geojo & Snedeker, 2009; Geojo & Snedeker, Paper 1 of thesis; Shafto, Havasi, & Snedeker, 2014). Moreover, Geojo and Snedeker (Paper 1) contend that verb-learning induced changes in lexicalization bias emanate from linguistic processes rather than the use of explicit analytic strategies because verb learning affects how learners visually inspect scenes: English-speaking adults taught Path verbs initially attend to the Path component of events more than English-speaking adults taught Manner verbs (reminiscent of cross-linguistic differences observed in Papafragou, Hulbert, & Trueswell, 2008).

1.6 Expanding the scope of lexicalization bias research to caused state change verbs

In the domain of noun learning, learners distinguish a variety of nominal kinds by the dimensions that are relevant to their extension (e.g., shape for artifacts, material for substances, color for food, etc.). If similar mechanisms undergird verb learning, learners should be able to form higher-level generalizations over dimensions of event structure similar, but not limited, to Manner and Path. This paper extends research on the acquisition of verb lexicalization biases to the change-of-state domain. We examine prototypical caused change-of-state scenarios that involve an agent using some implement to directly manipulate

¹⁸ A major difference from Smith et al. (2002) is that the learning phase consists of only 8-12 consecutive verb-learning trials presented over the course of one session.

and alter the physical characteristics of an object (e.g., a monster breaks a record by hitting it with a bat).

Linguistic analyses reveal abstract parallels in the encoding of changes in location and changes of state (Gruber, 1965; Jackendoff, 1972; Pinker, 1989; Rappaport-Hovav & Levin, 2010; Beavers, Levin, & Wei Tham, 2010). Like motion events, change-of-state events are encoded by two distinct classes of verbs—Means verbs that specify how an agent acts (e.g., *hit*, *bat*) and Effect verbs that specify the result of that action, often a change in the physical characteristics of the affected entity (e.g., *break*). Means and Effect, like Manner and Path, are dimensions of event structure that play a critical role in determining form-meaning mappings (Croft, 1990; Jackendoff, 1990; Lakoff & Jackendoff, 1980; Levin, 1985; Pinker, 1984; Slobin, 1997).

Verbs for change-of-state events also differ from directed motion verbs in non-trivial ways. First, cross-linguistic differences in the size and composition of motion verb vocabularies (particularly in the availability of Manner verbs) are conspicuous and well documented (section 1.4.1) but appreciable differences in the number of Means and Effect verbs (either within or across languages) have not been noted (but see Snell-Hornby, 1983; Wienold, 1995; see also Matsumoto, 2003). Second, particular Means are frequently coupled with particular Effects in real-world scenarios (e.g., *scrub-clean* and *hit-break*; Rappaport-Hovav & Levin, 2010). The prototypicality of Means-Effect co-occurrences may make it more difficult to disentangle the lexically entailed aspects of meaning and form lexicalization biases.¹⁹ This conjecture is supported by errors in verb construal observed during the early

¹⁹ While Manner of motions are circumscribed by properties of the Figure and Paths are delimited by the geometry of Grounds (a *through* Path requires an entrance and exit), particular Manners of motion do not appear to be associated with particular Paths as strongly as particular Means are with particular Effect (cf. *run* and *into* versus *pour* and *fill*).

stages of language acquisition, for example, English-speaking children frequently misrepresent verbs like *fill* as *pour* (Bowerman, 1982; Gropen, Pinker, Hollander, & Goldberg, 1991a, 1991b).²⁰

1.6.1 Psycholinguistic research on externally caused change of state verbs

The present experiment investigates the acquisition of lexicalization biases for prototypical change-of-state verbs. Because we are interested in the conceptualization of Means and Effect and these dimensions are relevant to causative events, the research reviewed in this section encompasses verbs for externally caused changes more broadly.²¹ We include studies of locative verbs, which describe the transfer of an Figure to a Ground (surface or container) that causes the Ground to undergo a state change, and caused motion verbs that describe caused changes in location.

Evidence from three lines of research bear upon the psychological reality of Means and Effect and learners' capacity to form generalizations over these dimensions: (1) developmental studies examining semantic errors in the interpretation of known verbs; (2) a novel verb learning study investigating semantics-syntax linkages; and (3) novel verb extension studies using production and comprehension methods to assess lexicalization bias.

Semantic errors in the interpretation of familiar verbs in English-speaking children are evident in spontaneous speech (Bowerman, 1982) and experimental studies that ask participants to judge the applicability of words in different contexts (Gentner, 1978; Gropen et al., 1991a,b). Generally speaking, Means verbs are learned quite early but many common

²⁰ Comparable problems with Manner and Path verbs have not, to the best of our knowledge, been observed.

²¹ This includes any event in which an entity is forced to change state because of an external force or event. Such events have complex event structures comprised of causally linked subevents: a Means subevent (representing the way a change is produced) and an Effect subevent (representing the coming about of a specific result-state) (Beavers & Koontz-Garboden, 2012).

Effect verbs are misrepresented and errors persist into the elementary school years. Often, an Effect verb is interpreted as lexicalizing a Means commonly associated with that Effect. Gentner (1978) discovered that five- to seven-year-old children (but not seven- to nine-year-olds or adults) fail to distinguish appropriate from inappropriate uses of *mix* (an Effect verb that specifies ‘an increase in homogeneity’) — applying it to situations involving *stir*-like actions with mixable substances (salt and water) and non-mixable substances (cream) alike. Specific Means verbs, *stir*, *beat*, and *shake*, however, were distinguished with ease.

Gentner (1978) proposed that English-speaking children are Means-biased, at least in the context of verb learning. Convergent evidence comes from a study by Gropen et al. (1991b), which found that 3- to 6-year-olds (but not 6- to 8-year-olds or adults) expect pouring to be a lexically entailed part of the meaning of the Effect verb *fill*; similarly, dumping is misconstrued as a necessary component of *empty*. An alternative account for these errors is suggested by experimental evidence revealing that Mandarin-speaking children often make the opposite error, interpreting Means verbs as entailing a prototypically associated Effect and linguistic analyses demonstrating that these cross-linguistic differences reflect typological differences in the lexicalization of change-of-state events (Chen, 2004). These findings indicate that ambiguities in the mapping between events and verbs rather than biases for particular conceptual dimensions explain why young children misrepresent verb meanings (Chen, 2004). Semantic error studies, however, examine knowledge about known verbs so errors may stem from difficulty discerning the particular properties comprising the Effect encoded by the verb tested rather than from semantic biases as abstract as Means and Effect.

Gropen et al. (1991a) present evidence that English-speaking adults and children distinguish novel locative verbs that encode the Means²² by which an entity is caused to change location (e.g., *pour*) from those that lexicalize the Effect of the translocative event (a change in one of the attributes of a ground object) (e.g., *fill*; p.158ff.). These classes of verbs differ in object realization. Pour-type verbs express the theme as the direct object *pour water into the glass* while fill-type verbs express the ground as the direct object *fill the glass with water*. Gropen et al. taught adults and children aged 3;5 to 9;4 one locative verb with a *pour*-type meaning “cause X to move to Y in a zigzagging manner” and one with a *fill*-type meaning, “cause Y to change color by placing X on it”. Participants successfully used context to acquire intended verb meanings and associated learned verbs with semantically appropriate argument structures: the moving figure was more often expressed as the direct object with the *zigzagging* verb whereas the ground was more often expressed as the direct object with the *color-change* verb. This data pattern reveals that Means and Effect are represented as independent components of events and that learners can classify individual verbs as one or the other. These findings do not, however, indicate that higher-order generalizations over Means and Effect can be learned or used to constrain future learning.

Novel verb extension studies reveal that learners prefer Means or Effect interpretations of novel change-of-state events in particular contexts but whether these biases reflect the acquisition of knowledge about the organization of the change-of-state verb lexicon remains unclear. Behrend (1990) examined how English-speaking 3- and 5-year-olds construed novel verbs used to describe caused change-of-state events by measuring how

²² Locative verbs classified as Means verbs in this paper (e.g., *pour*, *dump*) encode the Means subevent, a location change event. These verbs specify the way an entity is transferred to a ground object (lexicalize the manner of caused motion) rather than the how it impinges upon an object. Means verbs for ‘prototypical’ change-of-state events lexicalize the way an agent or force acts upon the affected entity (e.g., *hit*, *hammer*).

often the verb was used to describe new events that differed along one dimension. Sample events depicted an agent using an instrument to change the state of an object, for example, a person collecting tangled yarn with a spaghetti server. Variants differed from the sample event in either the instrument (ratchet), the action (scoop) or the end-state (yarn is left dangling). Behrend (1990) found that children often used the novel verb to describe events with new instruments but rarely used the verb to describe events with new end-states (for evidence that children between 1;8 and 2;2 rarely use familiar verbs to describe novel events with new Effects, see Forbes & Poulin-Dubois, 1997). This finding indicates that children prefer to interpret novel verbs describing change-of-state events as Effect verbs. It also reveals that children rarely consider the instrument as a necessary part of verb meaning.

Lexicalization biases, however, vary across morpho-syntactic contexts indicating that lexical and structural factors inform verb construal. Behrend, Harris, and Cartwright (1995) found that verb form influenced how English-speaking preschoolers (3- and 5-year-olds) and adults interpret novel verbs. Novel change-of-state verbs with progressive endings (*-ing*) elicited more Means interpretations than those with the past ending (*-ed*). This effect was robust in adults but weaker and more variable in children.²³ This finding may indicate that learners form overhypotheses about verb meaning that condition lexicalization biases on factors, such as morpho-syntax. Alternatively, participants may have formed direct mappings between particular verb forms and particular event structures. For example, from knowing that *-ing* expresses the progressive tense, learners can infer that the verb in question denotes an ongoing activity and limit their hypotheses accordingly. They may consider verbs with

²³ Inflectional morphology had a weak effect on 3-year-olds' biases in experiment 1 but a strong effect in experiment 2. Five-year-olds' biases were influenced by verb inflection in experiment 1 but not 2.

activity event structures like *hit* or *bat* but not verbs with achievement or accomplishment event structures like *break* or *finish* (because Effect verbs express culminated events).

Language background also affects verb-learning biases. Papafragou and Selimis (2010, Experiment 2) examined how English- and Greek-speaking adults and five-year-olds initially construed novel caused motion verbs (e.g. Means verbs like *push*, and Effect verbs like *send*²⁴). On each trial, participants were presented with a sample event depicting either an agent or natural force moving an object to a new location. This event was labeled by a novel verb in transitive syntax. For example, an event, which consisted of a man pushing a snowball, resulting in the snowball rolling downhill, was described as “The man sneered the snowball”. Then participants were asked to extend the novel verb to new events that were similar to the sample event along either the Means (push) or the Effect dimension (send downhill).

Papafragou and Selimis (2010) found that English speakers were more likely than Greek speakers to interpret novel verbs as Means verbs (English M = 42%; Greek M = 30%) but speakers of both languages preferred to interpret novel verbs as Effect verbs (encoding a change in location). This cross-linguistic difference for caused motion verbs is surprising. Unlike the case of directed motion verbs, the lexical statistical properties of English and Greek caused motion vocabularies do not differ greatly (but see Snell-Hornby, 1983; Wienold, 1995). Therefore, this result indicates that learners are using some other form of knowledge. One possibility proposed by Papafragou and Selimis (2010) is that lexicalization

²⁴ Caused motion verbs classified as Effect verbs encode a caused location change. All other Effect verbs, including those in the present experiment, encode change-of-state events. On many theories, achieved location and state changes are subtypes of result (Gropen et. al, 1991a:159; Rappaport-Hovav & Levin, 2010:28).

biases for directed motion verbs are generalized to caused motion verbs.²⁵ It is also possible that learners are using higher-order knowledge of more abstract classes or that cross-linguistic differences reflect language-general properties; for example, the transitive is closely linked to Effect verbs in both languages but the magnitude of this association may differ because of availability of other grammatical devices for encoding events (Beavers, Wei Tham, & Levin, 2010).

1.7 The present proposal

The goal of the present study is to investigate overhypothesis learning of lexicalization biases for verbs encoding externally caused change-of-state events (e.g., a monster breaks a record by hitting it with a bat). These events can be described by Means verbs (e.g., *bat*), which specify the action that produced a change or by Effect verbs (e.g., *break*), which specify the resulting change in state in the affected entity. The present study investigates whether English-speaking adults can use semantic regularities in the input (the distribution of Means and Effect verbs), to update lexicalization biases for novel change-of-state verbs by using a verb learning and bias assessment paradigm (see Paper 1; Gejojo & Snedeker, 2009; Shafto, Havasi, & Snedeker, 2014). Participants were randomly assigned to either the Means or the Effect verb-learning condition and taught eight novel change-of-state verbs with either Means or Effect meanings, respectively. For each novel change-of-state verb, we assessed adults' lexicalization bias before providing unambiguous evidence about which component it encoded.

²⁵ This proposal presumes that Manner-of-motion and Means verbs are members of one broad semantic category (MANNER verbs) and that they differ from Path and Effect verbs, which are members of a different superordinate category (RESULT verbs) (see Rappaport-Hovav and Levin, 2010).

If adults can learn overhypotheses about the relevance of these dimensions to the meaning of change-of-state verbs, they should form lexicalization biases that match the meanings of verbs in the experimental input. Specifically, adults in the Means condition, who consistently learn means verbs, should interpret novel change-of-state verbs encountered on later trials as Means verbs more often than adults in the Effect condition, who consistently learn Effect verbs. This data pattern would resemble the acquisition of inductive constraints in noun learning and motion verb lexicalization biases.

Alternatively, the processes that enable verb learning may be tailored to account for language-specific ways of encoding particular semantic fields (Childers, 2009). If so, the methods that work best for learning directed motion verbs may not be suitable for learning change-of-state verbs. Consequently, participants may acquire the meanings of individual verbs yet fail to develop input-contingent lexicalization biases (or at least not within the span of eight verb learning trials).

Methods

2.1 Participants

Participants were 105 English-speaking adults recruited using Amazon Mechanical Turk. Additional participants were excluded because they failed to follow directions ($N = 7$) or because they were unable to see stimuli on at least 6 trials due to browser related streaming issues ($N = 7$). Participants were randomly assigned to one of the two conditions (defined below): Means ($N = 53$) and Effect ($N = 52$).

2.2 Stimuli and Procedure

Participants viewed animations of externally caused change-of-state events. Each animation depicted a green monster using an instrument to produce a change in the physical

appearance of a unique object. Participants were randomly assigned to either the Means or Effect conditions and learned eight novel Means verbs or eight novel Effect verbs, respectively. Means verbs encoded the instrument used by the agent, viz.: *bat, comb, crowbar, hammer, knife, pliers, poker, and trowel*. Effect verbs expressed the affected object's change-of-state, viz.: *break, rip, open, crush, cut, bend, empty, and flatten*. Each trial included an introductory phase, lexicalization bias assessment phase, learning phase, and test of verb- learning phase.









Table 2.1 Stimuli for ambiguous and bias phases of novel caused change-of-

Sample change-of-state event	Same Effect	Same Means
1. break record with bat	break cookies with comb	flatten cupcakes with bat
2. rip armchair with comb	rip kite with bat	open book with comb
3. open grill with crowbar	open door with trowel	rip pillow with crowbar
4. crush strawberries with hammer	crush candy canes with pliers	empty container with hammer
5. cut bread with knife	cut curtain with poker	bend fork with knife
6. bend candle with pliers	bend sunflower with hammer	cut pizza with pliers
7. empty trash with poker	empty goblet with knife	crush car with poker
8. flatten sand pile with trowel	flatten doughnut with crowbar	break flower pot with trowel

To create the Means and Effect conditions we paired a Means verb meaning with an Effect verb meaning such that both members of the pair had the same introductory phase, bias phase and test phase but differed in the stimuli presented during the learning phase. This allowed us to compare bias and test responses across the two conditions. Table 2.1 depicts the sample event viewed during the introductory phase followed by the Means-match and Effect-match variants seen during the bias assessment phase

On each trial, a single novel caused change-of-state verb was learned. Each trial was composed of four phases: an introductory phase, bias assessment phase, learning phase, and test of verb learning phase. These phases will be described with reference to the stimuli seen during the sample Means verb learning trial in Figure 2.1. The corresponding Effect verb trial differed only in the stimuli seen during the learning phase (Figure 2.2).

Figure 2.1. The four-phase structure of a *single* novel verb learning and extension trial in Part 1 (Trials 1-8). This example depicts training stimuli for a Means verb learning trial: *blicking* is associated with the concept 'bat'.

Phase		
Introduction		
The monster is blicking the record.		
Bias Assessment		
(Means-match)		Does this show blicking?
(Effect-match)		Does this show blicking?
Training		
<i>Means Verb: bat</i>		
The monster is blicking the bagel.		
The monster is blicking the grocery bag.		
The monster is blicking the peanuts.		
Test of Verb Learning		
(Effect-match)		Does this show blicking?
(Means-match)		Does this show blicking?

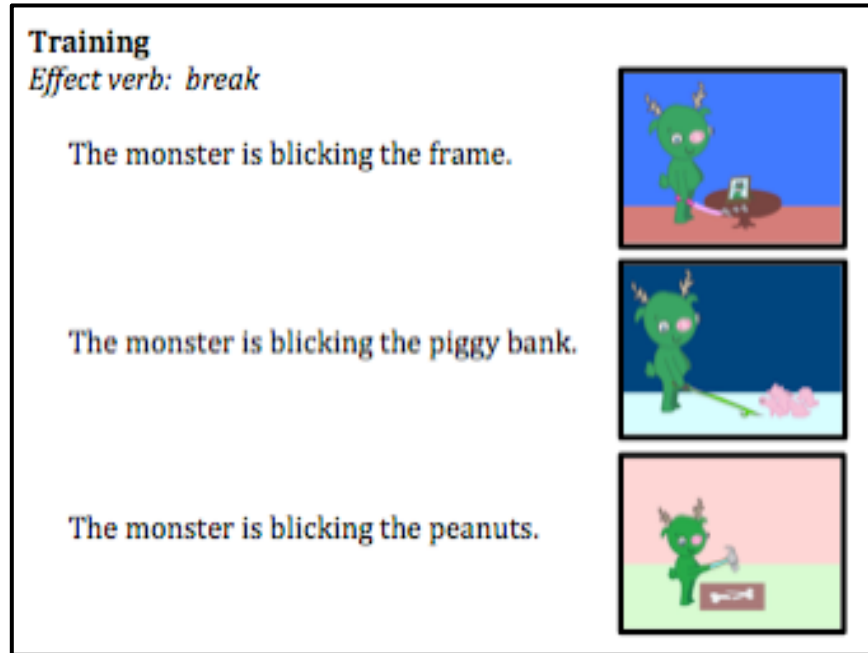


Figure 2.2: Example of Training phase stimuli for an Effect verb (break) learning trial. The Introduction, Bias Assessment and Test phases for this novel verb, blicking, are shared with its Means verb counterpart (see Figure 2.1).

During the *introductory phase*, participants read a sentence containing a novel verb (e.g., “The monster is *krading* the record”) and then viewed the event it labeled (a monster uses a bat to break a record).

During the *bias assessment phase*, participants viewed two events, presented sequentially. In the Means-match variant, the same instrument was used to produce a new Effect (e.g., a *bat* was used to flatten a cupcake). In the Effect-match variant, the same Effect was produced using a new instrument (e.g., a comb was used to *break* cookies). The order of presentation was counterbalanced across trials. After each variant, participants judged whether the event could be labeled using the novel verb (e.g., “Does this show *krading*?”). Responses during the bias phase were used to assess lexicalization bias. If adults believe that the novel verb (here, *krading*) lexicalizes Means, they should accept the Means-match variant *and* reject the Effect-match variant. If adults believe the verb lexicalizes Effect, they should

reject the Means-match event *and* accept the Effect-match event. Participants also had the option of rejecting or accepting both variants but this response pattern was rarely observed.

During the *learning phase*, participants viewed three new events. Each event was preceded and described by a sentence containing the novel verb heard during the previous two phases (e.g., “The monster is *krading* the bagel”). The stimuli presented during the learning phase differed across conditions. Participants in the Means condition viewed three Means-match events (Learning phase in Figure 2.1); those in the Effect condition viewed three Effect-match events (Figure 2.2). Cross-situational consistency in either the Means or Effect component of events provided sufficient evidence to disambiguate the meaning of the novel verb (e.g., *krading*) as a Means verb for adults in the Means condition (e.g., *bat*) but as an Effect verb for adults in the Effect condition (e.g., *break*).

Finally, in the test of *verb learning test phase*, acquisition of the target verb concept was assessed. This phase was structurally identical to the bias assessment phase. Participants viewed two videos that match the sample event presented during the introductory phase in either the Means or Effect component but not both. If a participant in the Means condition accurately represents the meaning of the novel verb, he/she should *only* accept the Means-match variant (e.g., a *bat* is used to open a baby bottle). In contrast, a successful verb learner in the Effect condition should *only* accept the Effect-match variant (e.g., pliers are used to *break* eye-glasses). Other response patterns are indicative of failure to acquire the target verb concept. As in the bias phase, the order in which the Means and Effect variants were presented was counterbalanced across trials. After participants completed the test of verb learning phase for one verb, they started the next verb trial (beginning with the *introductory* scene). The order of the eight verb trials was randomized across participants. Linguistic

stimuli were visually presented and reading was self-paced.

Each verb learning trial consisted of eight unique videos, each presented twice. The last frame of each video displayed a '+' sign. To determine whether the entire video streamed, we asked participants if they saw this sign. For a trial to be included in the analysis, the participant must have seen at least one of the two presentations of each of the unique videos. Participants were included if they had at least six valid trials. Based on these criteria, 70 (0.083%) of 840 trials and seven participants were excluded. Twenty-seven of the invalid trials belonged to included participants while the remaining 43 were from excluded participants.

Results

3.1 *Verb learning accuracy*

During the test of verb learning phase of each novel change-of-state verb learning trial, participants provided two yes/no responses. Each trial was given a score of '1' if the target novel verb was acquired and a score of '0' if it was not.

As depicted in Figure 2.3, participants in both conditions acquired target Means and Effect verb meanings ($M_{\text{Means}} = .73$, $SE = .04$; $M_{\text{Effect}} = .86$, $SE = .02$; Wilcoxon $V = 1136.5$, $p < .001$ (two-sided); Wilcoxon $V = 1274$, $p < .001$ (two-sided), respectively). A logistic regression with condition as a fixed effect and subjects and items as random effects revealed that Means verbs were marginally harder to learn than Effect verbs ($\beta = -.63$, $p = .047$). This was confirmed using a Wilcoxon rank sum nonparametric test (Wilcoxon $W = 1136$, $p = .12$).

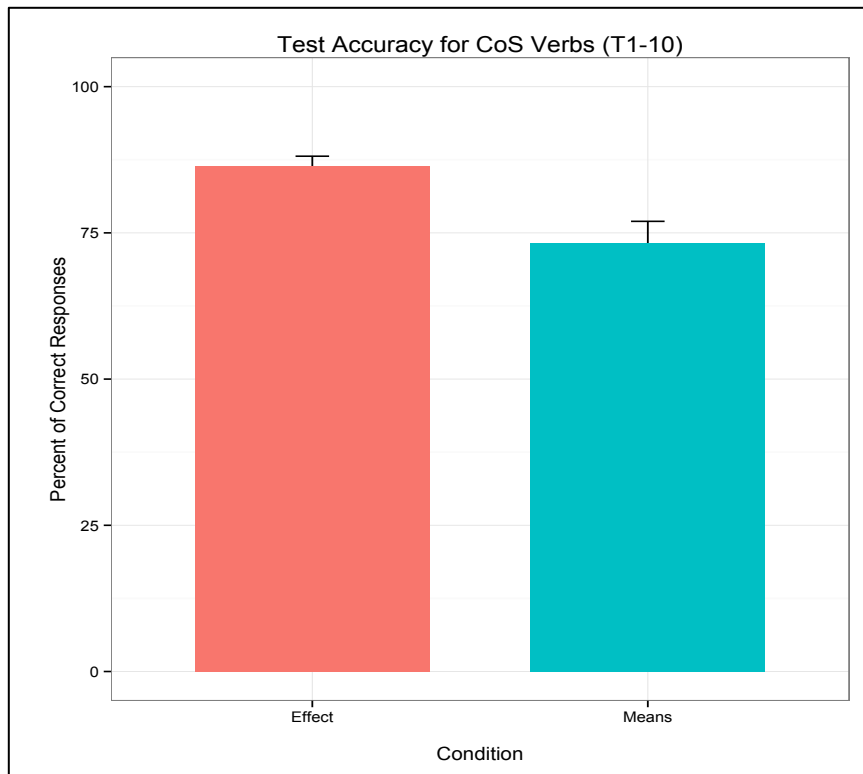


Figure 2.3. The percentage of accurate responses during the Test of Verb Learning Phase by condition

3.1 Assessment of Lexicalization bias

A participant's initial conjecture about the meaning of a novel verb was assessed by his/her willingness to extend a novel change-of-state verb to new events with either the same Means *or* the same Effect (after viewing a *single* event labeled by the novel verb during the introductory phase). On each trial, a participant could accept one, both or neither of these variants. A Means preference score was computed for each trial: a score of '1' was assigned if the Means-match variant was accepted and the Effect-match variant rejected; the reverse response pattern was assigned a score of '0'. Acceptance or rejection of both variants was scored '0.5'.

The first novel change-of-state verb (trial 1) was interpreted as a Means verb by 37%

of participants ($M_{\text{Means}} = .37$, $M_{\text{Effect}} = .37$). Analyses of Means choices during trials 3-8 using a mixed effects logistic regression with condition as a between-subjects factor and subjects and items as random effects revealed that verb learning significantly influenced conjectures about the meanings of subsequent novel change-of-state verbs ($\beta = 5.06$, $p < .001$). The effect of condition was confirmed using a Wilcoxon rank sum test ($W = 2495.5$, $p < .001$). As illustrated in Figure 2.4, participants in the Means condition reliably offered Means guesses for novel change-of-state verbs ($M_{\text{Means}} = .62$, $SE = .05$; $V = 929$, $p = .01$) whereas adults in the Effect condition consistently preferred Effect interpretations ($M_{\text{Effect}} = .10$, $SE = .02$; $V = 0$, $p < .001$).

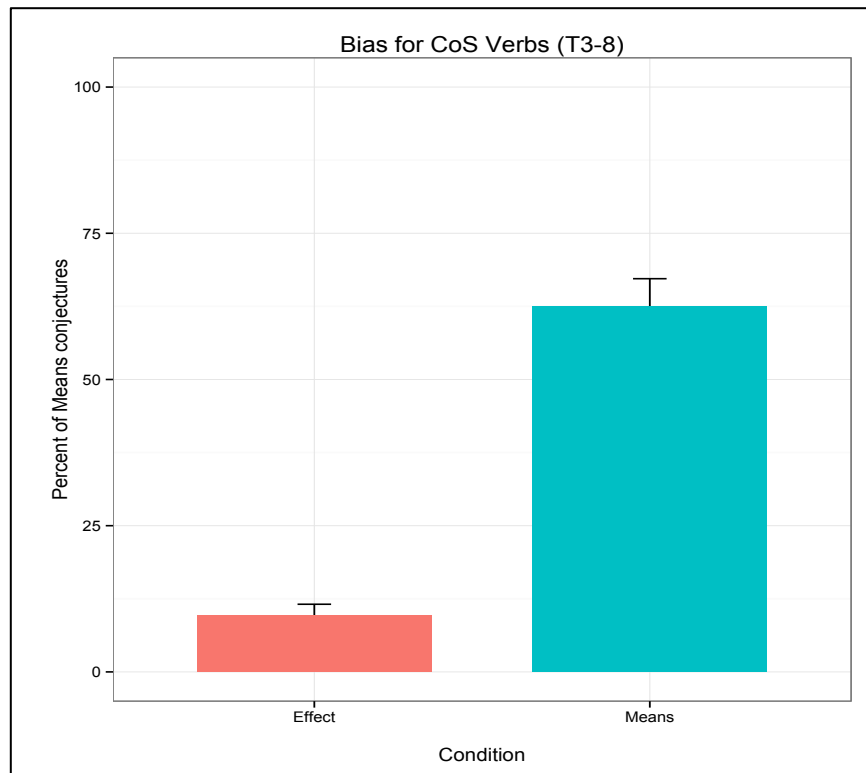


Figure 2.4. The percentage of Means conjectures offered during the Lexicalization Bias Assessment phase by participants in the Means and Effect conditions.

In both conditions, learning-induced shifts in lexicalization bias significantly differed from baseline, or untrained, biases for these novel verbs. A measure of baseline preference was obtained from a norming study²⁶ that assessed lexicalization bias (for the novel verbs in the present study) in the absence of a learning manipulation.

3.3 Does translatability affect verb construal?

One concern with the present method is that adults may be translating novel verbs into existing English verbs. In the present study, the meanings of novel Effect verbs exist in English, but the meanings of many Means verbs do not or are lower in frequency. We examined whether this partly explains why adults were better at learning Effect verbs than Means verbs (86% vs. 73% accuracy, respectively) and why adults were initially (before training) inclined towards Effect interpretations (64% of adults construed the first novel verb as an Effect verb). We compared performance on Means verbs without synonyms (e.g., *poker*, *plier*, *comb*), with low-frequency synonyms (e.g., *crowbar*, *trowel*) and with more common synonyms (e.g., *bats*, *hammer*, *knife*). Neither the acquisition of Means verbs ($M_{\text{High-Syn}} = .73$, $SE = .04$; $M_{\text{Low-Syn}} = .75$, $SE = .04$; $M_{\text{No-Syn}} = .72$, $SE = .04$) nor baseline preferences for Means interpretations of novel change-of-state verbs²⁷ ($M_{\text{High-Syn}} = .3$, $SE = .04$; $M_{\text{Low-Syn}} = .31$, $SE = .05$; $M_{\text{No-Syn}} = .32$, $SE = .04$) differed across items with common synonyms, low-frequency synonyms, and without synonyms indicating that responses are not driven by implicit labeling of events using existing verbs (for similar conclusions, see Papafragou & Selimis, 2010).

²⁶ The norming study consisted solely of the ambiguous and bias phases of the present experiment. As in the present study, participants were English-speaking adults recruited from Amazon Mechanical Turk (N = 54). Note that in the present study only the first trial reflected baseline lexicalization bias.

²⁷ Untrained, or baseline lexicalization biases were obtained from a norming study.

Discussion

This experiment examined whether English-speaking adults can learn lexicalization biases for externally caused change-of-state verbs by generalizing over individual Means or Effect verbs. The results reveal that adults rapidly form higher-order generalizations about the semantic content of these verbs and use this knowledge to interpret novel verbs encountered later. Adults who were taught Means verbs (e.g., *hammer*) developed reliable Means biases (62% of responses) while adults who were taught Effect verbs (e.g., *break*) developed reliable Effect biases (only 10% of responses in the Effect condition were Means-oriented). Moreover, responses in both conditions differed significantly from the conjectures of untrained English-speaking adults (who offered Means-oriented responses only 30% of the time).²⁸ The impact of verb learning is evident within the first few trials (even after learning just two verbs), indicating that the learning mechanism swiftly incorporates semantic information in the input, categorizing individual verbs as Means or Effect verbs and adjusting overhypotheses about lexicalization biases accordingly. The flexibility of Means/Effect biases mirrors that of Manner/Path biases observed in prior studies using the same paradigm (Geojo & Snedeker, 2009; Geojo & Snedeker, Paper 1; Shafto, Havasi & Snedeker, 2014) despite differences in the structure of the motion and change-of-state verb lexicons (Childers, 2009). Adults adapted their lexicalization bias in this experiment even though the baseline proportion of Means and Effect verbs in English does not differ appreciably, indicating that these biases are learned via a mechanism that quickly and spontaneously computes higher-order generalizations.

How can we account for this plasticity? One possibility is that the mechanisms of overhypothesis formation used in our task and those underlying speakers' beliefs about the

²⁸ Ibid.

English lexicon are partially or wholly unrelated. For example, participants may have employed general problem solving strategies, rather than mechanisms used in normal linguistic processing. There are, however, a number of reasons to believe that the shifts in lexicalization bias observed in this study are linguistic in nature. First, Shafto, Havasi and Snedeker (2014) demonstrated syntactic context, mediates adults' use of semantic information in the input to form lexicalization biases for motion verbs. Second, Gejo & Snedeker (Paper 1) demonstrated that changes in motion verb lexicalization biases are accompanied by changes in visual attention. Specifically, Path-verb learners attended less to the Manner component of events compared to Manner-verb learners. This pattern parallels differences in visual attention between Greek and English speakers observed in a production study conducted by Papafragou et al., (2008). This suggests that participants actively engage linguistic representations, and are not using purely meta-linguistic strategies in this task.

Another possibility is that adults were translating novel verbs into English verbs but this seems unlikely because the existence of an English synonym did not affect the acquisition of novel Means verbs or baseline²⁹ lexicalization biases for change-of-state verbs (see also Papafragou & Selimis, 2010). This suggests that the difference in the availability of English synonyms is unlikely to explain why Effect verbs were more easily learned or why untrained adults (trial 1, norming study) were Effect biased. This 'Effect advantage' may arise from the presentation of novel verbs in transitive frames (for similar proposals, Naigles & Terrazas, 1998; Papafragou & Selimis, 2010; Shafto, Havasi & Snedeker, 2014) because transitivity and causativity are tightly linked across languages (Dowty, 1979; Jackendoff, 1990; Levin & Rappaport Hovav, 1995); alternatively, Effects may have been more salient in

²⁹ Baseline bias was obtained from a norming study that assessed lexicalization bias but did not involve a verb learning manipulation. Trial 1 of the present study is the only unbiased estimate of bias.

the stimuli used or more perceptually similar across events (and thus easier to categorize).

Furthermore, if adults used a translation strategy, Manner- and Path-verb learners' lexicalization biases should reflect knowledge of the English lexicon—that is, resemble the preferences of untrained English-speaking adults. Instead, adults in the Manner and Path condition learn different higher-order generalizations and, the lexicalization biases of adults in both conditions significantly differed from those of untrained adults.

4.1 *Implications of verb lexicalization biases for models of overhypothesis learning*

The present findings are broadly consistent with two prominent theories of overhypothesis formation: the Attentional Learning Account (Colunga & Smith, 2005) and the Rationalist Constructivist View (Kemp, Perfors, & Tenenbaum, 2007).³⁰ Both theories emphasize that learners form abstractions at multiple levels of generality and that bottom-up learning is constrained by higher-order knowledge. Despite these similarities, these approaches propose very different mechanisms for the formation of overhypotheses.

The Attentional Learning Account relies upon series of associative processes that build generalizations bottom-up. First, children learn generalizations over the meanings of individual words (e.g., that *ball* maps onto ball-shaped things). Then, by detecting correlations between “cues and categories”, such as the relationship “between being solid and being in a category that is organized by shape” (Colunga & Smith, p.351), they form higher-order generalizations (e.g., object nouns are organized by shape).

The Rationalist Constructivist View characterizes overhypothesis formation via a hierarchical Bayesian model in which the learning mechanism (i.e., probabilistic conditioning) uses each data point to simultaneously update all hypotheses (Kemp, Perfors,

³⁰ This view is espoused by a number of researchers (including Perfors, Tenenbaum, Griffiths, & Xu, 2011; Xu, Dewars, & Perfors, 2009) and is similar to other hierarchical Bayesian models.

& Tenenbaum, 2007). For example, each instance of a ball encountered changes beliefs about both word-level hypotheses (e.g., the hypothesis that *ball* maps onto similarly shaped things while decreasing the weight of other hypotheses, such as *ball* denotes square things) and beliefs about higher-order hypotheses (e.g., the hypothesis that similarly shaped objects are given the same name; Perfors, Tenenbaum, & Xu, 2011).

A critical feature that distinguishes the Rational Constructivist View (and other hierarchical Bayesian models) from the Attentional Learning Account (and other neural network models/connectionist models) is that biases at different levels of abstraction are acquired simultaneously and, in fact, higher-order generalizations can be acquired before lower-level ones,³¹ allowing for the rapid acquisition of biases from limited and sparse data (Kemp et al., 2007).

Both the Rational Constructivist and Attentional Learning theories provide general mechanisms by which high-order generalizations can be learned from input data; however, there is a remaining difficulty for both models with the results reported in this paper. Under both models, the novice learner may form higher-order generalizations from a relatively small amount of data, but as knowledge accumulates, new data points have less influence on hypotheses. The learner may continue to tweak hypotheses in response to experience, but large-scale changes are. In this respect, the present findings cannot be captured by either model in their simplest forms since our results indicate that adults--who have formed stable high-order generalizations over the English lexicon--can also rapidly change these biases in the context of our experimental manipulation.

One possible solution is suggested by a study by Gallistel, Krishan, Liu, Miller, &

³¹ Higher-level generalizations may precede lower-level ones if the input consists of many categories but few instances within each category (Kemp et al., 2007)

Latham (2014) that demonstrated that adults implicitly detect changes in the distribution, and know when samples are drawn from a new population. Participants in our study may have similarly sensed that the distribution of Means and Effect verbs in the experimental context deviated from their distribution in the English change-of-state lexicon and accordingly, re-set their priors, and attended to verbs in the input to learn a new higher-order generalization about the structure of the change-of-state lexicon in the present context. If so, introducing additional distributional changes in the frequency of Means and Effect verbs should compel adults to learn additional overhypotheses about change-of-state verbs. This context-based explanation also accords with our intuition that adults' bias on the first trial (or better yet, the biases of untrained participants from the norming study) would better predict how our participants would interpret unknown change-of-state verbs encountered outside of the experimental setting.

Presently, there are a few overhypothesis models of learning that generate context dependent overhypotheses (George & Hawkins, 2009; Hasson, Yang, Vallines, Heeger, & Rubin, 2008; Kiebel, Daunizeau, Friston, 2008; Saeedi, O'Donnell, Gershman, & Mansinghka; in prep). These richer models detect changes in the causal structure of the domain in which categories are being learned by noting abrupt changes in the distribution and structure of categories in the input. When these models discern abrupt changes in the distribution and structure of categories in a particular domain, they posit that they are in a new context where the causal structure of the domain differs from the previous context. Learners then construct new overhypotheses that reflect the organization of the domain in this new context.

The present study contributes to the literature on overhypothesis models of word

learning in two ways. First, we extend the investigation of the acquisition of higher-order inductive biases, which has primarily been studied in the context of nouns, to the verbal domain. We found that despite the imperceptibility of lexical disparities in the English caused change-of-state lexicon, adults continue to attend to lexical statistical information, indicating that the learning mechanism is inherently driven to uncover overhypotheses about category structure. Second, the results of the present study reveal that adults, who clearly possess knowledge about the lexicalization of change-of-state events in English, flexibly acquire new and recognizably different biases in the same domain (for similar findings from the motion domain, Paper 1 of thesis; Geojo & Snedeker, 2009; Shafto, Havasi & Snedeker, 2014). Our findings highlight the importance of incorporating context-based learning into overhypothesis models of lexical acquisition. More generally, they suggest that learners continue to track lexical distributions because such knowledge is not a static reflection of the English dictionary but a dimension that changes continuously across registers, environments (work vs. home), conversational partners, topics of discussion etc. and speakers even adapt rates of word use over the context of a conversation.

Paper 3: Verb learning biases extend across semantic fields

Amy C. Geojo & Jesse Snedeker

This work explores how our concepts for events are organized and how this affects verb learning. Verbal roots encode certain categories of event concept. For instance, directed motion verbs in English either encode the Path of motion (*enter the house*) or the Manner of motion (*run into the house*). Similarly, caused change-of-state verbs encode either the Means (*hammer the metal*) or the Effect (*flatten the metal*) of the state change. Following earlier work, Rappaport-Hovav and Levin (2010) proposed that these (and other) event concepts are special cases of two superordinate categories: MANNER, which unifies Means and Manner of motion, and RESULT, which unifies Path and Effect.

In three experiments, we test the psychological reality of these superordinate event concepts. We manipulated English-speaking adults' expectations about verb meaning by teaching them 8 verbs for change-of-state or directed motion events, all from the same class. Afterwards, we assessed whether biases formed for verbs from one semantic class influenced the interpretation of verbs from the other class in ways that respect superordinate class lines. In Experiment 1, we only found evidence that biases were generalized from motion to change-of-state verbs. We hypothesized that transfer from change-of-state to motion was overridden by strong baseline preferences for Manner of motion. Experiments 2 and 3 reduced Manner-of-motion biases by using instrumental Manners (e.g., *skate*) and by presenting motion verbs in transitive frames, respectively. In both experiments, biases transferred in both directions. We conclude that MANNER and RESULT are conceptually salient, superordinate event concepts that cut across the boundaries of specific classes of verbs.

Introduction

A basic question in cognitive science is what kinds of concepts we have and how they are related. The present paper focuses on the nature of concepts that underlie verb meanings, providing evidence for a superordinate categorization of verb stems that generalizes across verb-class specific categories.

Decompositional approaches to lexical semantics decompose verb meanings into two components: an *event structure*, composed from a finite set of eventive predicates (e.g., cause for causation, act for action, and become for change) and a unbounded set of lexical-conceptual roots, which specify the idiosyncratic elements of verb meaning that differentiate verbs with the same event structure (Rappaport-Hovav & Levin, 1998; Pustejovsky, 1991; Pinker, 1998; Jackendoff, 1990; Beavers & Koontz-Garboden, 2012). For example, all change-of-state verbs share an event structure that includes the predicate become as in (1) below, but the meaning of individual verbs is differentiated by their lexical root as in (2a-b).

(1) [BECOME [y <*result-state*>]]

(2) (a) [BECOME [y <*melt*>]]

(b) [BECOME [y <*freeze*>]]

Verb roots belong to categories (e.g., State, Result-state, Thing, Stuff, Location, Manner), which determine the event structures into which they can be incorporated (e.g., Grimshaw, 2005; Jackendoff, 1990; Rappaport-Hovav & Levin, 1999; Ramchand, 2008).

Many categories of roots proposed in the literature are specific to particular classes of verbs. For example, Talmy (1985) distinguished three basic categories of motion verb roots, namely those that conflate Motion with one of the following components, respectively: (i) Manner of motion/Cause (e.g., *run*, *push*), (ii) Path (e.g., *enter*), and (iii) Figure (e.g. *rain*).

As another example, for verbs for caused change-of-state events (e.g., a man hammers metal flat), the Means of causing (e.g., *hit*, *hammer*) and the Effect (e.g., *flatten*) are considered basic constituents. The implicit assumption is that such categories are event-specific—that is, Path is not the relevant category for caused changes of state nor Effect for changes in location.

A number of theorists have, however, drawn attention to parallels in the semantic and syntactic behavior of verbs that encode different classes of events and, accordingly, suggested that we represent higher-order categories that span semantic fields (Beavers, 2011, 2011a; Gropen, Pinker, Hollander, & Goldberg, 1991; Jackendoff, 1983; Pinker, 1989; Rappaport-Hovav & Levin, 1985, as described in Pinker, 1989; 1998, 1999, 2010; Talmy, 1991, 2000). This idea has been most thoroughly developed by Rappaport-Hovav and Levin (2010; RHL hereafter), who propose that *all* non-stative verb roots are instances of one of two superordinate categories: MANNER, which encodes the way in which an action is performed, and RESULT, which encodes the end-result of an action. In motivating their proposal, RHL closely examine the encoding of directed motion and caused change-of-state events and, illuminating similarities in the expression of Means/Manner-of-motion on one hand, and Path/Effect on the other, argue that these are instances of different superordinate categories, — MANNER and RESULT, respectively (see Figure 3.1).

In the present paper, we explore the viability of this proposal by examining whether learners form generalizations about verb meaning that extend across directed motion and caused change-of-state verbs. To do so, we assess whether verb-learning biases acquired in the context of learning novel verbs for directed motion events influence the interpretation of

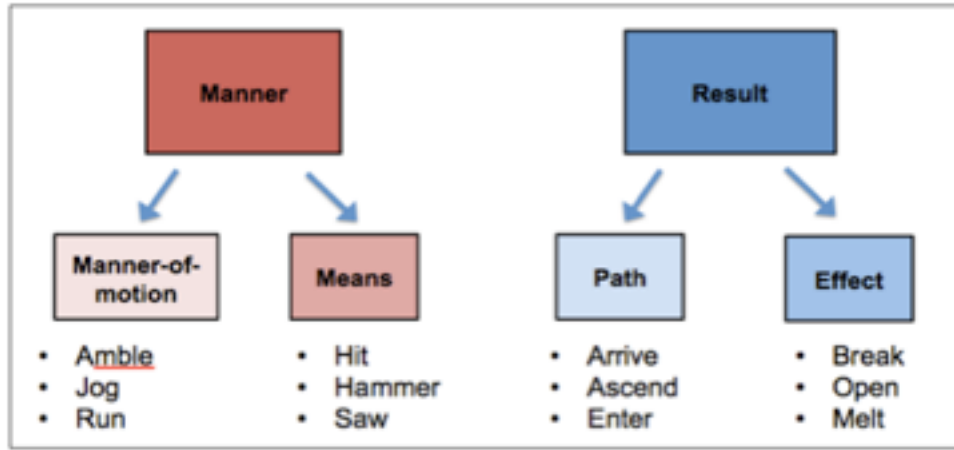


Figure 3.1 Representation of hierarchical relationship between MANNER and RESULT and event-specific components of directed motion and caused change-of-state events.

novel verbs for caused change-of-state events (and vice versa). In the following section, we elaborate upon RHL’s proposal to clarify the empirical and theoretical ideas behind the introduction of the superordinate categories MANNER and RESULT. Because the scope of present study is limited to demonstrating the reality of these generalizations across directed motion and caused change-of-state verbs, the final sections discuss linguistic and empirical evidence within this narrower context before presenting the details of the present proposal.

1.1 Rappaport-Hovav and Levin, 2010

Parallels in the meanings of verbs for directed motion and caused change-of-state events were foundational in the development the MANNER/ RESULT distinction, but under RHL’s proposal, these categories generalize across the non-stative verbal lexicon. Table 3.1 (from Levin, 2012) shows examples of MANNER and RESULT verbs from a number of different verb classes. RHL posit that MANNER and RESULT roots are associated with different positions in the event decomposition. MANNER verbs encode an event in which some entity (often an agent) performs some action (moving, contact, emitting a sound) and individual MANNER verbs specify about the way the entity acts (e.g., *race* vs. *gallop*; *slap* vs. *hit*; *scream* vs. *squeal*). Thus, MANNER roots are inserted into activity event templates as modifiers of an ACT

predicate, as in (3; after Levin, 2010). RESULT verbs are inherently complex, encoding an unspecified action that causes a specified change in state (e.g., caused change of state, of position, of motion); this is reflected in the sub-event structure composed of the predicate CAUSE which relates an activity event (3) and a change-of-state event (1) in which affected entity (the syntactic object) is argument of BECOME (4; after Levin, 2010).

(3) [x ACT <MANNER>]

(4) [[x ACT <MANNER>] CAUSE [BECOME [y <RESULT-STATE>]]]

Note that the structure of these categories is described in terms of a specific formal theory of verb-argument structure. This framework is crucial to RHL's broader proposal, which includes a constraint on lexicalization that states that all non-stative verb roots must encode either MANNER or RESULT, but not both. This hypothesis has aroused considerable controversy in the linguistic literature (see, e.g., Beavers & Koontz-Garbon, 2012). However, we emphasize that the present experiments do not address either the question of whether MANNER and RESULT generalize beyond motion and change-of-state verbs, or whether verbal roots can encode only one category.³² Furthermore, any theory of lexical semantics that captures these superordinate categories is consistent with our results.

RHL argue that the notions of RESULT and MANNER can be grounded in terms of a distinction between scalar and non-scalar changes (following Rappaport-Hovav, 2008). Verbs that lexicalize RESULT encode changes along an ordered scale (e.g., position, height, temperature, change-of-state). For example, the Effect verb, *dim*, lexicalizes a decrease along the dimension of illumination while *warm*, encodes an increase in temperature. In the motion domain, *ascend* denotes an increase along the dimension of height. In contrast, MANNER verbs

³² Nevertheless, to avoid potential confounds, we avoided creating experimental stimuli encoding both a MANNER and a RESULT meaning.

encode non-scalar changes, which involve neither directed change nor an ordering relation (Beavers, 2008; Beavers, 2011: 17; Levin & Rappaport Hovav, 2010; Rappaport Hovav, 2008; Tenny, 1994).

1.2 Verbs for directed motion and caused change-of-state events

Semantic and syntactic parallels in the encoding of directed motion and caused change-of-state events raise the possibility that Path and Effect are members one category, and Manner-of-motion and Means of another. For example, semantically, the notions of Path and Effect involve a scalar change—in position and state respectively (for review, see Rappaport-Hovav & Levin, 2010). As another example, changes in location and changes in state are unified under the semantic notion of “affectedness” and this property constrains syntactic behavior. This is illustrated by the contrast in the locative alternation between caused changes in location (*load the hay onto the wagon*) and caused changes in state by means of a change in location (*load the wagon with hay*); in these events, the moved hay and the changed wagon are “affected” and both are realized as the direct object (Gropen et al., 1991; Gruber, 1965; Jackendoff, 1972; Pinker, 1989, p.228-39; Rappaport & Levin, 1985, as described in Pinker 1989; 1988). Because of these semantic properties, Path and Effect verbs must express as the direct object the entity that defines the scale they lexicalize (‘the affected entity’³³), that is, the Ground (*enter the house*), and Patient (*break the vase*), respectively (Beavers, 2011). While Path/Effect verbs have limited argument realization options, Manner-of-motion verbs like *run* and Means verbs like *sweep* appear in a range of argument

³³ Affectedness is usually considered as a change in an *entity* and much research indicates that causative verbs must express the affected entity as the direct object (Dowty, 1991; Fillmore, 1970, Jackendoff, 1990; Pinker, 1989). For example, Effect verbs like *break* express the object caused to change state (*break the vase*). The entity that undergoes a change in location is not, however, the object of a Path verb. Beavers (2011) brings the notions of scalar change and affectedness into alignment, proposing that the semantic definition of “affectedness” is a relationship between an argument and a property scale.

expressions, each associated with subtle variations in meaning (examples from Rappaport-Hovav & Levin, 1998):

- a. Path ran
 - b. *Pat ran to the beach*
 - c. *Pat ran herself ragged*
 - d. *Pat ran her shoes to shreds*
 - e. *Pat ran clear of the falling rocks*
 - f. *The coach ran the athletes around the track*
-
- a. *Terry swept*
 - b. *Terry swept the floor*
 - c. *Terry swept the crumbs off the floor*
 - d. *Terry swept the leaves off the sidewalk*
 - e. *Terry swept the floor clean*
 - f. *Terry swept the leaves into a pile*

The expression of motion and change-of-state also patterns together cross-linguistically. Across languages, Path-encoding terms, such as *out* and *into*, are also used in change-of-state expressions, such as *John blew the candle out* and *Kelly slapped Sam into silence* (examples from Beavers, Wei Tham, & Levin, 2010; see also Aske, 1989; Talmy, 1991, 2000).³⁴ Similar extensions of Path affixes and case-markers to express RESULT states are common in other languages; for example, the Russian *vy-tjorla* ‘out-wiped’ is understood as ‘wiped clean’ because *vy-* ‘out’ is interpreted as the prototypical Effect when affixed to a Means verb (for detailed review, see Beavers, 2010). The systematic extension of goal-marking Path expressions to encode Effects across languages suggests that that these event concepts have similar conceptual structures. Additionally, languages like Greek and Spanish that prohibit the use of Manner-of-motion verbs with goal-marking Path phrases (*to*, *from*, *into*, and *out of*) also prohibit the use of Means verbs with Effect-encoding complements,

³⁴ More generally, Path terms that mark goals are often used to express result and aspect.

requiring instead the use of Path and Effect verbs, respectively.³⁵ The parallel restriction in both semantic fields suggests that it may operate over superordinate categories that cross event class boundaries (Aske, 1989; Rappaport-Hovav & Levin, 2010; Slobin & Hoiting, 1994; see Beavers, Wei Tham & Levin, 2010 for a more thorough discussion of this cross-linguistic phenomenon).

1.3 Prior experimental work

Thus far, we have motivated the notions of MANNER and RESULT based on parallels in the treatment of caused change-of-state and directed motion verbs (similarities between Means and Manner-of-motion verbs and between Path and Effect verbs) within a given language and patterns of cross-linguistic similarities and divergences. Abstract features of linguistic structure may, however, emerge from the interaction of various factors, such as general learning constraints, semantic or pragmatic factors, and diachronic change. If parallels in the syntax and semantics of motion and change-of-state verbs are non-accidental (see, e.g., Christiansen & Chater, 2008; Malt, 2010; Levinson, 2011, 2012) and MANNER and RESULT are conceptual categories that guide our construal and expression of events, this distinction should be reflected in language learning and cognitive processing. In this section, we review experimental findings that indicate that speakers distinguish one class of verbs that, under RHL's proposal, encodes MANNER from another class that encodes RESULT. In each study, the verb classes compared belong to the *same* semantic field but the semantic field under investigation varies across studies (e.g., verbs for caused state changes, locative events, and

³⁵ In such languages, whether a clause encodes an *atelic* (unbounded) or *telic* (culminated) event is determined by the verb alone. Consequently, this constraint precludes the expression of both of the respective components of directed motion and caused change-of-state events in a single clause.

spontaneous and caused motion events).³⁶ Because these studies (or, to the best of our knowledge, any empirical evidence to date) do not test generalization across semantic fields, we cannot determine whether common representations (broad semantic categories) underlie the distinctions speakers respect in different semantic fields. In each case, an equally valid interpretation of the data is that speakers' behavior reflects the operation of generalizations that are narrow in scope—that is, categories specific to the particular class of events examined (e.g. categories like Manner, Path, Means and Effect). Nevertheless, the pattern of results across studies provides convergent evidence consistent with RHL's theory—in each case, semantic fields are cut along dimensions that respect the MANNER/RESULT distinction and, as predicted, this distinction affects linguistic behavior.

First, if the manner-result distinction is grammatically relevant, learners should expect it to align with grammatical distinctions. Behrend, Harris, & Cartwright (1995) found that preschoolers' (3- and 5-year-olds) and adults' prefer to interpret novel verbs in the progressive (*-ing*) as Means verbs and in the past tense (*-ed*) as Effect verbs, a bias that mirrors a universal tendency for languages to mark actions/processes with progressive aspect (in English, *-ing*) and results with completive aspect (in English, *-ed*). These lexicalization biases may reflect mappings between these verb forms and MANNER and RESULT concepts and reflect a bias to associate the progressive with a MANNER verb, because these denote ongoing activities but not with RESULT verbs because they mark completed actions (Pinker, 1985, 2007).

Additionally, Gropen et al. (1991a) present evidence that English-speaking adults and children (ages 3;5 and 9;4) can use perceptual information across uses of a novel locative

³⁶ Because the terms used to label clusters of semantically related verbs also vary, alongside the event-specific labels used in particular studies, we will indicate whether the classes are classified as MANNER or RESULT verbs.

verb to detect semantic properties relevant to ‘affectedness’ (which is proposed to unite Path and Effect) and appropriately express the affected entity as the direct object. When speakers used the novel verb encoding a caused change in location (‘cause X to move to Y in a zigzagging manner’), the moved entity was expressed as the direct object more often than the surface onto which it was placed (which was not affected) but when they used the novel verb encoding a caused change in state by means of a change in location (‘cause Y to change color by placing X on it’), the changed surface was more often the direct object.

Papafragou & Selimis (2010) reveals parallels in cross-linguistic differences in verb lexicalization biases (expectations about the meaning encoded in a verb) for directed motion verbs and caused motion verbs. Specifically, Papafragou & Selimis (2010) demonstrated that adult and five-year-old speakers of English and Greek differed in their initial construal of novel verbs for directed motion events (*run/enter*) and for caused motion events (*push/send*). Participants were presented with either a directed motion event (Experiment 1) or a caused motion event (Experiment 2) that was labeled by a novel verb and then they were presented with new events and asked extend the novel verb to one of them. For example, the sample event may depict a girl pushing a snowball, which then rolls downhill. One could describe that using a Means verb like *push* or an Effect verb like *send*. Next, participants saw two new events, one with the same Means (*push*) but a new Effect and one with the same Effect (*send*) but a new Means. Participants are asked ‘which one shows ‘Verbing’; if they extend the novel verb to the Means-match event, it indicates that they are Means-biased but if they extend it to the Effect-match event, it indicates that they are Effect-biased. The study was the same with directed motion verbs except that one variant matched in Manner-of-motion and the other in Path.

Papafragou & Selimis found that English speakers were more likely than Greek speakers to interpret novel directed motion verbs as Manner-of-motion verbs (*run*) and novel caused motion verbs as Means verbs (*push*). They also found that all participants were reliably Effect biased. Cross-linguistic differences in motion verb lexicalization biases are well-documented in the verb learning literature (Naigles & Terrazas, 1998; Hohenstein, 2005; Papafragou & Selimis 2010) and reflect substantive differences in the availability of Manner-of-motion and Path verbs lexicons (Talmy, 1985, 1991, 2000; Slobin, 2001, 2004, 2008). Why English speakers are more Means-biased than Greek speakers is, however, not as obvious since prominent differences in caused motion verb lexicons across these (or other) languages have not been noted (but see Bowerman & Choi, 1991, Snell-Hornby, 1983; Wienold, 1995).

It is possible that parallels in cross-linguistic lexicalization biases reflect, as Papafragou and Selimis suggest, a generalization of biases developed for inherently directed motion verbs to verbs of caused motion. This cross-linguistic difference need not, however, arise from a common representation. Languages like English that typically use Manner-of-motion verbs to encode directed motion events also tend to use Means verbs to encode caused change-of-state events while those like Greek that characteristically use Path verbs also tend to use Effect verbs raising the possibility that languages have a preference to map either MANNER or RESULT onto the verb (Beavers, Levin, & Wei Tham, 2010). Thus, lexicalization biases for caused motion and inherently directed motion events may have been formed independently, such that responses in both cases reflect language-specific knowledge about the encoding of that particular class of events.

There is one more piece of evidence that is compatible with the proposal that these superordinate event concepts, MANNER and RESULT, exist. Specifically, adults taught novel motion verbs or novel change-of-state verbs, quickly learn new lexicalization biases about the meanings of new novel verbs from the same semantic field (Paper 1 of thesis; Geojo and Snedeker, 2009; Shafto, Havasi & Snedeker, 2014; for change-of-state, Paper 2 of thesis). Adults taught Manner-of-motion verbs (*run*-type) were more likely to construe new novel motion verbs as encoding Manner-of-motion concepts than adults taught Path verbs. Similarly, adults taught Means verbs (*hit*-type) were more likely to interpret new novel change-of-state verbs as encoding Means concepts than adults taught Effect verbs (*break*-type). Moreover, the trajectory of learning novel motion verbs and novel change-of-state verbs is very similar ways despite the presence of a significant lexical bias for Manner-of-motion verbs in the English directed motion lexicon but comparable numbers of Means and Effect verbs; in both cases, adults rapidly learn context-dependent verb lexicalization biases that deviate from the distribution of these verbs in English.

1.4 The present proposal

The experiments reported here make use of a novel paradigm to test the hypothesis that there is a basic conceptual distinction between MANNER and RESULT verbs, which cuts across semantic fields and is spontaneously available to language users, by determining whether adults construe Means (e.g., *hammer*) and Manner-of-motion (e.g., *run*) concepts as belonging to one category (MANNER verbs) and construe Path (e.g., *enter*) and Effect (e.g., *break*) concepts, as belonging to another category (RESULT verbs). All three experiments use the novel verb learning and extension paradigm described above (Paper 1 and 2 of thesis; Shafto, Havasi & Snedeker, 2014; Geojo & Snedeker, 2009) to manipulate the biases that

learners develop as they acquire verbs from one semantic field (either change-of-state or motion) and then test whether they transfer this bias to the other field. Participants were assigned to one of 4 conditions and learned 8 novel verbs, all encoding one of these concepts: Means, Effect, Manner-of-motion, or Path concepts. Next, we assessed whether motion verb learning impacted the construal of novel change-of-state verbs and whether change-of-state verb learning affected biases for novel motion verbs by using the novel verb extension task (Naigles & Terrazas, 1998; Hohenstein, 2005; Papafragou & Selimis, 2010). Evidence of bias transfer across semantic fields would indicate that there are commonalities in the conceptual dimensions that comprise motion and change-of-state events. If biases are limited to a single semantic field, this would indicate that the dimensions underlying verb meanings are event-specific and, accordingly, that verb learning biases are generalizations about language-specific ways of encoding a *particular* semantic field.

EXPERIMENT 1

Method

2.1 Participants

Participants were 147 English-speaking adults recruited using Amazon Mechanical Turk (AMT). Additional participants were excluded because they failed to follow directions (N = 25) or because they were unable to see stimuli on at least 6 trials in either part 1 (trials 1-8) or part 2 (trials 9-16) due to browser related streaming issues (N = 28). Participants were randomly assigned (without replacement) to one of four conditions (defined below): Manner-of-motion (N = 39), Path (N = 32), Means (N = 40) and Effect (N = 36).

2.2 Materials and Procedure

Stimuli consisted of animations of simple motion events and externally caused

change-of-state events. Motion events depicted the same agent (a blue monster) moving in a salient Manner-of-motion and Path relative to a unique reference object (e.g., somersaulting into a garage). Change-of-state events portrayed a green monster using an instrument to produce a change in the physical characteristics of a unique object (e.g., breaking record with a bat). Eight Manners-of-motion and eight Paths were selected as the intended meanings of novel motion verbs. Path meanings were *into*, *down to*, *up to*, *around*, *between*, *through*, *over*, and *in front of*. Manner-of-motion meanings were *crabwalk*, *crawl*, *flapwalk*, *hop*, *roll*, *stoopwalk*, *tiptoe*, and *walk*. Novel motion verbs were presented in sentences consisting of a subject, the progressive form of the verb, and a prepositional phrase encoding the Path of motion (e.g., “The monster is krading into the house”). Means verbs encoded the instrument used by the agent: *bat*, *comb*, *crowbar*, *hammer*, *knife*, *pliers*, *poker*, and *trowel*. Effect verbs expressed the affected object’s change-of-state: *break*, *rip*, *open*, *crush*, *cut*, *bend*, *empty*, and *flatten*. All change-of-state verbs were presented in transitive sentences (e.g., “The monster blicked the bone”). All novel verbs were phonologically well-formed English nonsense words.

We devised a paradigm to detect whether verb learners form broad semantic generalizations at the level of MANNER and RESULT by drawing on two paradigms that have been employed to examine lexicalization biases within a single event class. During trials 1-8, we used a novel verb learning and extension paradigm (Papers 1 and 2 of thesis; Gejo & Snedeker, 2009; Shafto, Havasi & Snedeker, 2014) to train adults to acquire a lexicalization bias for verbs in one semantic field (either change-of-state or motion). Trials 9-16 tested whether they generalized to the other field by using a novel verb extension task. Motion and change-of-state verb trials were blocked and the order in which they were presented was




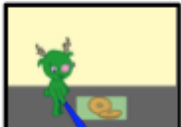
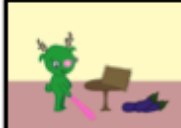



randomized across participants, allowing us to test for bias transfer from motion to change-of-state verbs and from change-of-state to motion verbs.

Part 1 (Trials 1-8): Novel verb learning and extension paradigm

The first eight novel verb learning trials (for motion and change-of-state verbs) included an introductory phase, lexicalization bias assessment phase, learning phase, and test of verb learning phase. We paired a Manner-of-motion concept with a Path concept to create Manner-of-motion and Path conditions, such that both members of a pair had the same introductory, bias assessment and test phases but differed in the stimuli presented during the learning phase. This allowed us to compare bias and test responses across the Manner-of-motion and Path conditions. Means and Effect meanings were similarly paired. The same procedure was used to create Means and Effect verb learning conditions.

On each trial, participants learned a single verb. Each trial consisted of four phases: an introductory phase, bias assessment, learning, and verb learning test phase. The phases will be described with respect to the change-of-state verb learning trials depicted in Figures 3.2 and 3.3 but the experimental structure is the same in the motion verb learning conditions. During the *introductory phase*, participants read a sentence containing a novel verb (e.g., “The monster is krading the record”) and then viewed the event it labeled (a monster uses a bat to break a record).

Figure 3.2. The four-phase structure of a *single* novel verb learning and extension trial in Part 1 (Trials 1-8). This example depicts training stimuli for a Means verb learning trial: *blicking* is associated with the concept 'bat'. The corresponding Effect verb learning trial differs only in the stimuli seen during the training phase (Figure 3.3)

Phase		
Introduction		
The monster is blicking the record.		
Bias Assessment		
(Means-match)		Does this show blicking?
(Effect-match)		Does this show blicking?
Training		
<i>Means Verb: bat</i>		
The monster is blicking the bagel.		
The monster is blicking the grocery bag.		
The monster is blicking the peanuts.		
Test of Verb Learning		
(Effect-match)		Does this show blicking?
(Means-match)		Does this show blicking?

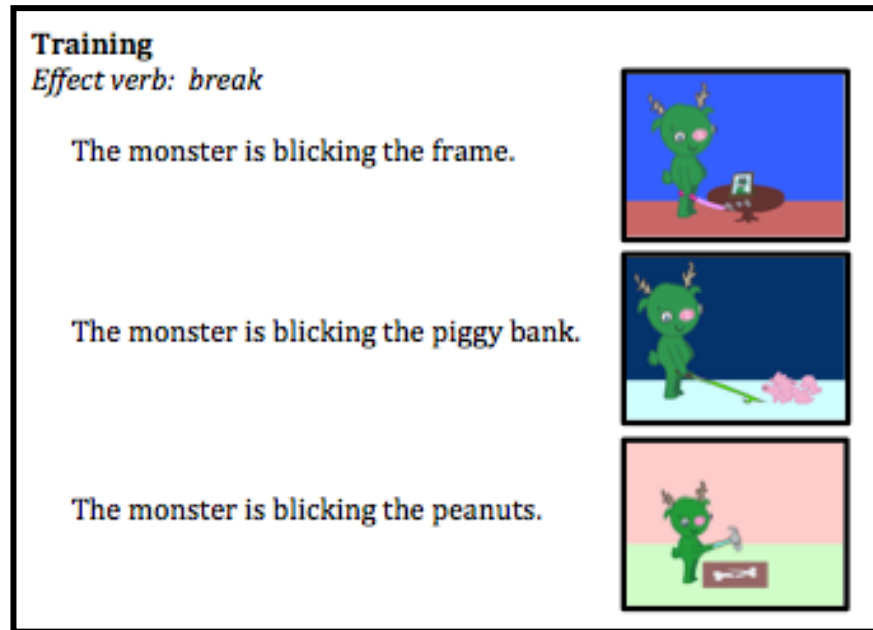


Figure 3.3. Example of training phase stimuli for an Effect verb (*break*) learning trial. The introductory, bias assessment and test phases for this novel verb, *blicking*, are shared with its Means verb counterpart (see Figure 3.2).

During the *bias assessment phase*, participants viewed two scenes, presented sequentially. In the Effect-match variant, the agent used a new instrument (new Means) to produce the same Effect (e.g., a comb is used to break cookies). In the Means-match variant, the same instrument was used to produce a new Effect (e.g., a bat is used to flatten a cupcake). Which variant was seen first was counterbalanced across trials. After each variant, participants judged whether the event could be labeled using the novel verb (e.g., “Does this show *krading*?”). Responses during the bias phase were used to assess lexicalization bias.

If participants believe that the novel verb (here, *krading*) lexicalizes Means, they should accept the Means-match variant and reject the Effect-match variant. On the other hand, if they believe the verb lexicalizes Effect, they should exhibit the opposite response pattern—that is, reject the Means-match event and accept the Effect-match event. Participants also had the option of rejecting or accepting both variants but those response

patterns were rarely observed.

During the *training phase*, participants viewed three new events. Each event was preceded and described by a sentence containing the novel verb heard during the previous two phases (e.g., “The monster is *krading* the bagel”). The stimuli presented during the training phase differed across conditions (compare Figure 3.2 and 3.3). Participants in the Means condition viewed three Means-match events (e.g., the monster cuts a bagel with a *bat*); those in the Effect condition viewed three Effect-match events (e.g., the monster uses a poker to *break* a piggybank). Cross-situational consistency in either the Means or Effect component of events provided evidence to disambiguate the meaning of the novel verb (e.g., *krading*) as a Means verb for adults in the Means condition (e.g., *bat*) but as an Effect verb for adults in the Effect condition (e.g., *break*).

Finally, during the *test of verb learning phase*, the acquisition of the target verb concept was assessed. This phase was structurally identical to the bias-phase. Participants viewed two videos that match the introductory video in either the Means or Effect component but not both. If a participant in the Means condition accurately represents the meaning of the novel verb, he/she should only accept the Means-match variant (e.g., a *bat* is used to open a baby bottle). In contrast, a successful verb learner in the effect condition should only accept the Effect-match variant (e.g., pliers are used to *break* eye-glasses). Other response patterns are indicative of failure to acquire the target verb concept. As in the bias phase, the order in which the Means and Effect variants were presented was counterbalanced across trials. After participants completed the verb-learning test for one verb, they started the next verb trial (beginning with the *introductory* scene). The order of the eight verb trials was randomized across participants. Linguistic stimuli were visually presented and reading was self-paced.

Motion verb learning trials differ only in content. The variants presented during the bias assessment and test phases matched the introductory motion event along either the Manner-of-motion dimension or the Path dimension. Responses were collected in the same way and interpreted as lexicalization bias and verb learning accuracy, respectively. Unlike change-of-state verbs, which were presented in transitive syntax, novel motion verbs appeared in intransitive sentences with Path-encoding prepositional complements (e.g., “The monster is krading the house”).

Part 2 (Trials 9-16): Experimental Structure of Novel verb extension task

During the second part of the study, adults in the Means and Effect conditions were asked to extend 8 novel motion verbs to variants that depicted either the same Manner-of-motion *or* the same Path (Table 3.1).

Table 3.1. Stimuli for novel verbs for directed motion event presented during part 2 (trials 9-16) to participants in the Means and Effect verb learning conditions.

Original motion event	Changed Manner-of-motion	Changed Path
1. crabwalk into garage	hop into cabin	crabwalk down to birdhouse
2. crawl down clown	flapwalk down to frog	crawl into cave
3. flapwalk up to cat	crawl up to swan	flapwalk around horse
4. hop around penguin	crabwalk around firehouse	hop up to the deer
5. roll between trees	walk between buildings	roll through tent
6. stoopwalk through flowers	tiptoe through lighthouse	stoopwalk between swings
7. tiptoe over cone	stoopwalk over haystack	tiptoe in front of snow plow
8. walk in front of elephant	roll in front of giraffe	walk over sand pile

Adults in the Manner-of-motion and Path conditions were asked to extend 8 novel change-of-state verbs to variants with either the same Means or the same Effect (Table 3.2).

Table 3.2. Stimuli for novel verbs for caused change-of-state events presented during part 2 (trials 9-16) to participants in the Manner-of-motion and Path verb learning conditions.

Original change-of-state event	Changed Means	Changed Effect
1. break record with bat	break cookies with comb	flatten cupcakes with bat
2. rip armchair with comb	rip kite with bat	open book with comb
3. open grill with crowbar	open door with trowel	rip pillow with crowbar
4. crush strawberries with hammer	crush candy canes with pliers	empty container with hammer
5. cut bread with knife	cut curtain with poker	bend fork with knife
6. bend candle with pliers	bend sunflower with hammer	cut pizza with pliers
7. empty trash with poker	empty goblet with knife	crush car with poker
8. flatten sand pile with trowel	flatten doughnut with crowbar	break flower pot with trowel

These novel verbs and associated stimuli were identical to those seen during the introductory and bias assessment phases by motion and change-of-state verb learners, respectively. The experimental procedure was also the same (Figure 3.5, above).

Each novel verb trial consisted of eight unique videos in part 1 and three unique videos in part 2, each presented twice. The last frame of each video displayed a ‘+’ sign. To determine whether the entire video streamed, we asked participants if they saw this sign. For a trial to be included in the analysis, the participant must have seen at least one of the two presentations of each of the unique videos. Participants were included if they had at least six valid trials in part 1 and six valid trials in part 2.

Results

Data from motion and change-of-state verb learners were analyzed separately. Each participant contributed two yes/no responses during the test of verb learning phase, the bias assessment phase and the novel verb extension task, respectively. Given the nature of our data, for each comparison, responses were entered into a mixed effects logistic regression with condition as a between subjects factor and subjects and items as random effects (betas

and p-values are reported).³⁷ The effect of condition was also analyzed using a (two-sample) Wilcoxon rank sum nonparametric test (*W* statistic). One-sample Wilcoxon rank sum tests (*V* statistic) were conducted for reasons discussed below.

Data from the test of verb learning phase (part 1, trials 1-8) was used to determine whether target meanings were acquired and whether this differed across conditions.

Data from the bias assessment phase was used to determine whether adults acquired lexicalization biases that reflected the meanings of verbs they were taught. To examine the influence of verb learning on lexicalization bias, we limited analyses to responses collected after participants learned two novel verbs (part 1, trials 3-8). These responses reflect the influence of verb learning on lexicalization bias for verbs from the same semantic field: we compared how novel motion verbs were initially construed by adults learning Manner-of-motion and Path verbs and how novel change-of-state verbs were interpreted by participants in the Means and Effect conditions.

Data from the verb extension task (part 2, trials 9-16) was used to determine whether adults generalized newly-learned lexicalization biases across semantic fields. Transfer from motion to change-of-state verbs was assessed by comparing how Manner-of-motion and Path verb learners initially interpreted novel change-of-state verbs. Transfer from change-of-state to motion verbs was assessed by comparing how Means and Effect verb learners initially construed novel motion verbs.

2.3 Verb Learning Accuracy (Trials 1-8)

Participants successfully used events presented during the training phase to acquire the intended meanings of novel verbs in the Manner-of-motion condition (Wilcoxon *V* =

³⁷ For each data set, we also split trials into two equal sized blocks to determine whether verb learning or lexicalization bias changed over time. Because performance did not differ across blocks, the results of these analyses are not reported.

741; $p < .001$ (two-tailed)), the Path condition (Wilcoxon $V = 464.5$; $p < .001$ (two-tailed)), the Means condition (Wilcoxon $V = 622.5$; $p < .001$ (two-tailed)), and the Effect condition (Wilcoxon $V = 666$; $p < .001$ (two-tailed)). Manner-of-motion verbs were easier to learn than Path verbs ($M_{MM} = .97$, $SE = .01$; $M_{Path} = .78$, $SE = .06$; $\beta = -4.09$, $p < .01$; Wilcoxon $W = 884.5$, $p < .001$ (two-tailed)). Means verbs were harder to learn than effect verbs ($M_{Means} = .74$, $SE = .05$; $M_{Effect} = .90$, $SE = .02$; logistic mixed effects regression, $\beta = -1.05$, $p < .05$; Wilcoxon $W = 549.5$, $p = .07$).

Assessment of Lexicalization bias (Phase 1: Trials 3-8): A participant's initial conjecture about a novel verb was measured by his/her willingness to extend the verb to two new events that matched the sample event (seen during the introductory phase)³⁸ along a single dimension. Events viewed during the bias assessment phase matched the exemplar event along either the Manner-of-motion (MANNER) or Path (RESULT) dimension for motion verb learners and either the Means (MANNER) or the Effect (RESULT) dimension for change-of-state verb learners. On each trial, a participant could accept one, both or neither of these variants. Responses from motion and change-of-state learners were coded in the same way. A MANNER (Manner-of-motion or Means) preference score was computed for each trial: a score of '1' was assigned if the MANNER-match (Manner-of-motion- or Means-match) variant was accepted and the RESULT-match (Path- or Effect-match) variant rejected; the reverse response pattern was assigned a score of '0'. Acceptance or rejection of both variants was scored '0.5'.

³⁸ On each novel verb trial, the sample event is the single positive example—an event paired with the novel verb—seen during the introductory phase, *before* participants are asked to extend the novel verb to new events.

Responses from motion and change-of-state learners were coded in the same way. A MANNER (Manner-of-motion or Means) preference score was computed for each trial: a score of ‘1’ was assigned if the MANNER-match (Manner-of-motion- or Means-match). Condition means (lexicalization bias) reported below should be interpreted as the proportion of responses that favored MANNER (Manner-of-motion or Means) conjectures.

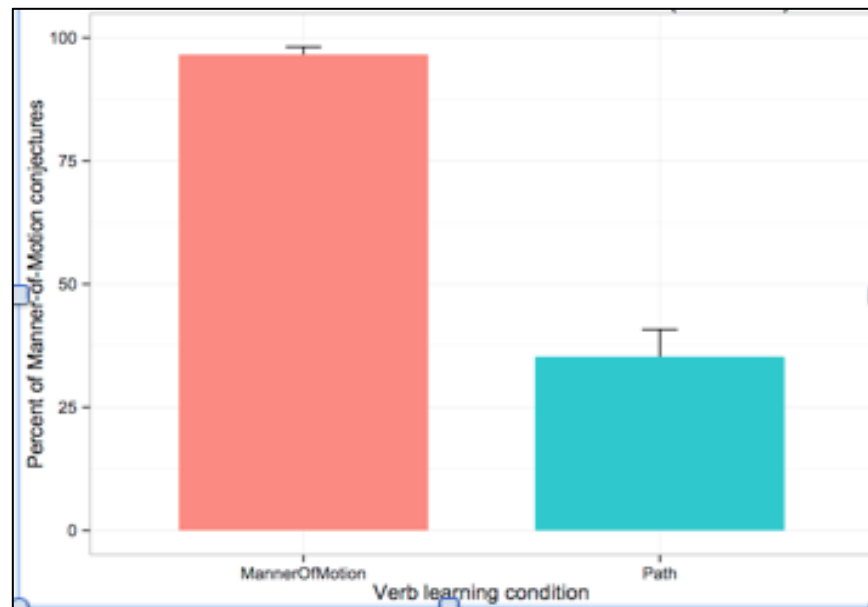


Figure 3.4. Lexicalization bias for novel verbs for directed motion events expressed as the percentage of Manner-biased responses offered by Manner- and Path-verb learners during trials 3-8.

Analyses of lexicalization bias for novel motion verbs across Manner-of-motion and Path conditions: Participants were initially Manner-of-motion biased (trial 1: $M_{MM} = .74$, $M_{Path} = .82$, $M_{Avg} = .79$) but analyses of lexicalization bias data from trials 3-8 revealed that verb learning influenced the construal of novel motion verbs encountered on later trials (mixed-effects logistic regression, $\beta = -7.42$, $p < .001$; Wilcoxon $W = 1168$, $p < .001$). As depicted in Figure 3.4, Path-verb learners ($M_{Path} = .35$, $SE = .06$) construed than adults in the Manner-verb learners ($M_{MM} = .97$, $SE = .02$). Additionally, the proportion of Manner guesses (trials 3-8) from each condition were separately entered into 2 one-sample, Wilcoxon rank-

sum tests and compared to chance. The results revealed that Manner-verb learners had a reliable preference for Manner-of-motion conjectures (Wilcoxon $V = 741$, $p < .001$) whereas Path learners had a reliable dispreference (hence, a Path bias; Wilcoxon $V = 136.5$, $p = .01$).

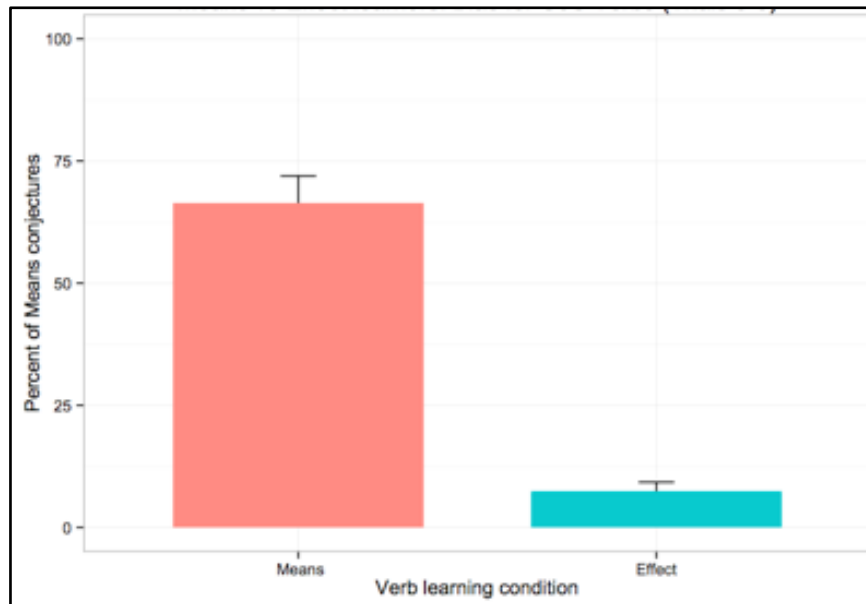


Figure 3.5. Lexicalization bias for verbs encoding caused changes in state expressed as the percentage of Means-biased responses offered by Means- and Effect-verb learners on trials 3-8.

Analyses of lexicalization for novel change-of-state verbs across Means and Effect conditions: About 40% of the time, the first novel change-of-state verb was interpreted as a Means verb ($M_{\text{Means}} = .38$, $M_{\text{Effect}} = .46$, $M_{\text{Avg}} = .42$). Analyses of the proportion of Means choices during trials 3-8 revealed that verb learning significantly influenced conjectures about the meanings of subsequently encountered novel change-of-state verbs ($\beta = 5.44$, $p < .001$; Wilcoxon $W = 1319.5$, $p < .001$). As illustrated in Figure 3.5, adults in the Means condition reliably offered Means conjectures ($M_{\text{Means}} = .66$, $SE = .06$; Wilcoxon $V = 471.5$; $p = .005$), and did so more often than adults in the Effect condition, who preferred Path interpretations ($M_{\text{Effect}} = .07$, $SE = .02$; Wilcoxon $V = 0$, $p < .001$).

Assessment of Verb Extension Preferences in Part 2 (Trials 9-16)

The collection, coding and analyses of lexicalization bias data are the same as in part 1. . Lexicalization biases for novel change-of-state verbs were from Manner- and Path-verb learners, and biases for novel directed motion verbs, from Means and Effect verb learners. As such, these analysis test whether biases are transferred across semantic fields.

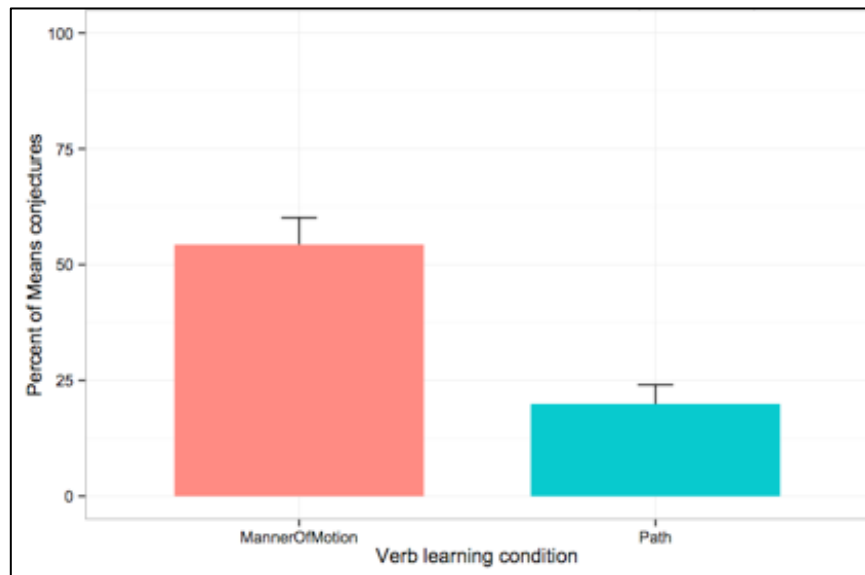


Figure 3.6. The percentage of Means biased responses for novel change-of-state verbs from Manner-of-motion and Path verb learners.

Analyses of lexicalization bias for novel caused change-of-state verbs on trials 9-16 across Manner-of-motion and Path conditions. As depicted in Figure 3.6, Means (MANNER) conjectures were offered significantly more often in the Manner-of-motion (MANNER) condition ($M_{MM} = .54$, $SE = .06$) than in the Path (RESULT) condition ($M_{Path} = .2$, $SE = .04$; $\beta = -2.85$, $p < .001$; Wilcoxon $W = 976$, $p < .001$). Comparison of performance in each condition to chance via two 1-sample Wilcoxon rank-sum tests yielded a reliable dispreference for Means interpretations (hence an Effect bias) in the Path condition (Wilcoxon $V = 25.5$; $p < .001$ (two-tailed)) but no preference for Means or Effect in the Manner-of-motion condition (Wilcoxon $V = 377.5$; $p = .24$ (two-tailed)). Lexicalization

biases did not change across trials 9-12 and trials 13-16 nor did time frame interact with learning condition, suggesting that generalized motion verb lexicalization biases do not rapidly decline.

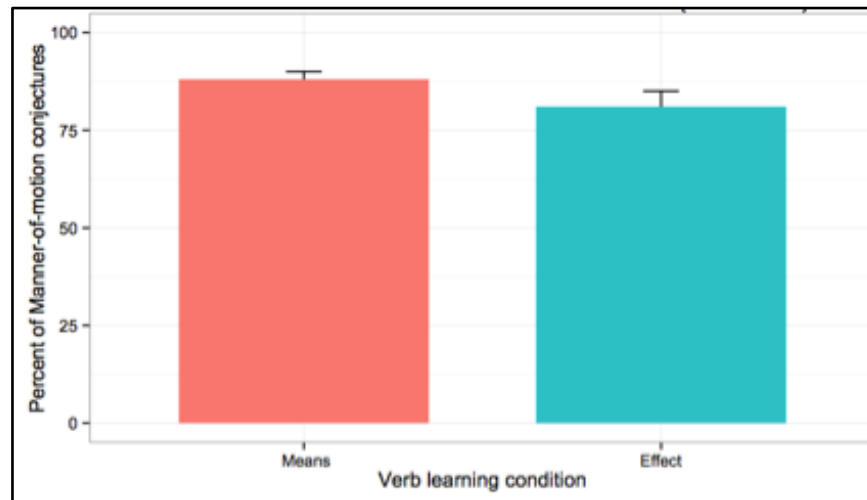


Figure 3.7. The percentage of Manner-of-motion biased responses for novel motion verbs from participants in the Means and Effect conditions.

Analyses of lexicalization bias for novel Motion verbs across Means and Effect verb learning conditions: As shown in Figure 3.7, lexicalization biases for novel motion verbs did not reliably differ between Means and Effect verb learners ($M_{\text{Means}} = .88$, $SE = .02$; $M_{\text{Effect}} = .81$, $SE = .04$; $\beta = .62$, $p = .31$; Wilcoxon $W = 792$, $p = .44$ (two-tailed). Adults with Means biases were as likely to interpret novel motion verbs as Manner-of-motion verbs as those with Effect biases. Participants in both conditions exhibited reliable Manner-of-motion biases ($V = 741$, $p < .001$ (two-tailed); and $V = 621$, $p < .001$ (two-tailed), respectively).

Discussion

The results of Experiment 1 demonstrate that adults form semantic generalizations over individual verbs in the experimental input and use this to guide future learning. First, we replicated previous findings that revealed an effect of verb learning on lexicalization biases for verbs within the same semantic field. As in prior studies, conjectures about the meanings

of novel motion verbs encountered during trials 3-8 were shaped by the semantic content of motion verbs in the training input. Adults in the Manner-of-motion condition strengthened their Manner-of-motion biases while those in the Path condition developed consistent Path biases (Paper 1; Gejo & Snedeker, 2009; Shafto, Havasi & Snedeker, 2014). Analyses of responses from trials 9-16 revealed that Manner-of-motion and Path verb learners also differed in their initial construal of novel verbs for caused change-of-state events. Adults in the Manner-of-motion condition consistently preferred Means interpretations of novel change-of-state verbs while those in the Path condition exhibited reliable Effect biases. This data pattern supports the proposal that Manner-of-motion and Means are MANNER concepts while Path and Effect are RESULT concepts. Evidence of bias transfer from motion verbs to change-of-state verbs indicates that learners are sensitive to the MANNER-RESULT distinction and form generalizations at this level of abstraction. Under this account, Manner-of-motion verb learners formed MANNER biases, which increased Manner-of-motion interpretations in part 1 and boosted Means conjectures in part 2; in contrast, Path verb learners formed RESULT biases that encouraged Path interpretations of novel motion verbs in part 1 and Effect interpretations of novel change-of-state verbs in part 2.

We also assessed whether biases transferred in the other direction—from change-of-state verbs to motion verbs. Analyses of lexicalization bias data from trials 3-8 indicated that conjectures about the meaning of new novel change-of-state verbs were consistent with the meanings of change-of-state verbs learned on earlier trials. Means verb learners preferentially interpreted new novel change-of-state verb as Means verbs and did so more frequently than Effect verb learners (replicating findings from Paper 2). We did not, however, find an effect of change-of-state verb learning on the construal of novel motion verbs in part 2. Participants

in the Means and Effect conditions exhibited robust Manner-of-motion biases (approximately 88% and 81% of the time, respectively) . We hypothesized that the asymmetry in bias transfer across semantic fields did not reflect true differences in the conceptualization of motion and change-of-state events but emerged because novel motion verbs elicited predominantly Manner-of-motion conjectures at baseline³⁹ whereas initial Means and Effect biases for novel change-of-state verbs were more evenly distributed. Strong preference for Manner-of-motion concepts may have overridden or masked the generalization of newly-learned biases from change-of-state to motion verbs.

In Experiment 2, we controlled for baseline Manner-of-motion/Path biases for novel motion verbs by using stimuli depicting instrumental manners-of-motion (e.g., *drive, skate*) rather than agentive ones (e.g., *tip-toe, somersault*) as in Experiment 1.

EXPERIMENT 2

Method

3.1 Participants

Participants were 139 English-speaking adults recruited using Amazon Mechanical Turk. Additional participants were excluded because they did not follow instructions (N = 19) or because they were unable to see stimuli on at least 2 trials in part 1 (trials 1-8) and 2 trials in part 2 (trials 9-16) due to browser related streaming issues (N = 31). Participants were randomly assigned to one of four conditions (defined below): Manner-of-motion (N = 32), Path (N = 35), Means (N = 33) and Effect (N = 39).

3.2 Materials and Procedure

³⁹ Baseline bias for novel motion verbs was computed as the average of Manner-of-motion conjectures collected from motion verb learners on trial 1. This is a reasonable measure of initial lexicalization bias for English-speaking adults as responses were collected before they learned novel verbs.

Stimuli for change-of-state verbs and experimental procedures were the same as in Experiment 1. Path concepts were the same as in Experiment 1: *into*, *down to*, *up to*, *around*, *between*, *through*, *over*, and *in front of* but Manner-of-motion concept now involve the use of vehicles or instruments. These instrumental Manners-of-motion were: *drive*, *carpet*, *sail*, *dog-sled*, *ski*, *fly*, *balloon*, and *camel*.⁴⁰ A particular Manner-of-motion was always performed by the same agent (e.g., a blond boy always sailed). Each instrumental Manner-of-motion was paired with a Path concept (e.g., *drive* and *into*) and Manner-of-motion and Path conditions were created as in Experiment 1 (Table 3.3).

Table 3.3. Stimuli for novel directed motion verbs in Experiment 3.2 are presented to motion verb learners during the introductory and bias phases of trials 1-8, and to change-of-state verb learners during trials 9-16.

Original motion event	Changed Manner-of-motion	Changed Path
1. drive into house	fly into spaceship	drive over cone
2. carpet down to lamp	skate down to seesaw	carpet between throne
3. sail up to swan	carpet up to monkey	sail down to seal
4. sled around penguin	bike around bird house	sled behind polar bear
5. ski between trees	camel between trees	ski into igloo
6. fly through clouds	drive through tunnel	fly under birds
7. balloon over eagle	ski over bush	balloon up to train
8. camel in front of pyramid	sled in front of bunny	camel around goat

Results

Data was coded and analyzed as in Experiment 1 and 2.

⁴⁰ Instrumental Manner-of-motion verbs often take their name from the vehicle that enables motion (e.g., *sail*; Levin, 2003: 267-8). Some of the concepts we chose have English equivalents but others do not: *carpet* corresponds to ‘flying on a magic carpet’, *balloon* to ‘flying using a hot-air balloon’, and *camel* to ‘riding on a camel’.

3.3 Verb learning Accuracy (Trials 1-8)

Participants successfully used events presented during the training phase to acquire the intended meanings of novel verbs in the Manner-of-motion condition (Wilcoxon $V = 525.5$; $p < .001$ (two-tailed)), the Path condition (Wilcoxon $V = 595$; $p < .001$ (two-tailed)), the Means condition (Wilcoxon $V = 359$; $p < .001$ (two-tailed)), and the Effect condition (Wilcoxon $V = 740$; $p < .001$ (two-tailed)). Unlike Experiment 1, verb learning accuracy did not differ across Manner-of-motion and Path conditions ($M_{MM} = .9$, $SE = .03$; $M_{Path} = .91$, $SE = .02$; $\beta = .33$, $p = .53$; Wilcoxon $W = 515$, $p = .56$ (two-tailed)). Performance was comparable to Experiment 1 for caused change-of-state verb learners: Means verbs were harder to learn than Effect verbs ($M_{Means} = .70$, $SE = .04$; $M_{Effect} = .89$, $SE = .02$; $\beta = -1.43$, $p < .05$; Wilcoxon $W = 364$, $p = .001$ (two-tailed)).

3.4 Assessment of Lexicalization bias (Phase 2: Trials 3-8)

Analyses of lexicalization bias for novel motion verbs across Manner-of-motion and Path conditions: At the outset of the study (trial 1), participants in the Manner-of-motion and Path conditions were unbiased ($M_{MM} = .52$, $M_{Path} = .53$; $M_{Avg} = .52$). As Figure 3.8 illustrates, during trials 3-8, adults in the Manner-of-motion condition reliably offered Manner-of-motion conjectures ($M_{MM} = .88$, $SE = .03$; Wilcoxon $V = 434$, $p < .001$), and did so significantly more than adults in the Path condition ($M_{Path} = .18$, $SE = .03$; $\beta = -6.49$, $p < .001$; Wilcoxon $W = 1112.5$, $p < .001$), who strongly preferred Path interpretations (Wilcoxon $V = 10.5$, $p < .001$).⁴¹

⁴¹ These analyses compared responses to chance (0.5). Because lexicalization bias was computed as the proportion of Manner-of-motion biased responses, ‘above chance’ indicates a reliable Manner-of-motion bias and ‘below chance’ indicates a reliable Path bias.

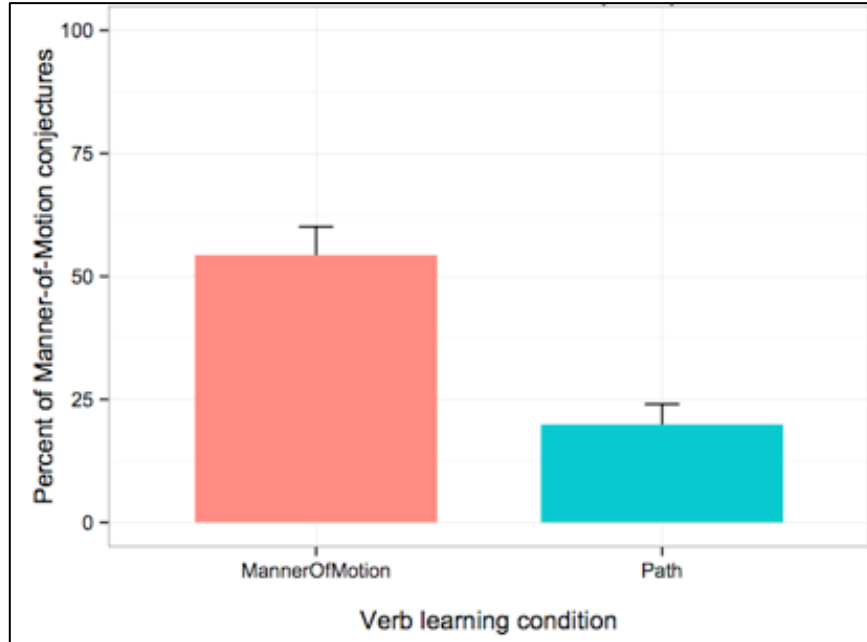


Figure 3.8. Percentage of Manner-of-motion biased responses from participants in the Manner-of-motion and Path conditions.

Analyses of lexicalization bias for novel change-of-state verbs across Means and Effect conditions: The first novel change-of-state verb was construed as a Means verb by 40% of participants ($M_{\text{Means}} = .40$, $M_{\text{Effect}} = .41$, $M_{\text{Avg}} = .40$). As depicted in Figure 3.9, participants in the Means condition offered significantly more Means conjectures for novel change-of-state verbs during trials 3-8 than Effect verb learners ($M_{\text{Means}} = .59$, $SE = .06$; $M_{\text{Effect}} = .08$, $SE = .02$; $\beta = 5.52$, $p < .001$; Wilcoxon $W = 1198.5$, $p < .001$). Adults in the Effect condition consistently construed novel change-of-state verbs as Effect verbs (Wilcoxon $V = 0$, $p < .001$); those in the Means condition exhibited were nearly consistent in offering Means conjectures (Wilcoxon $V = 273.5$, $p = .054$).

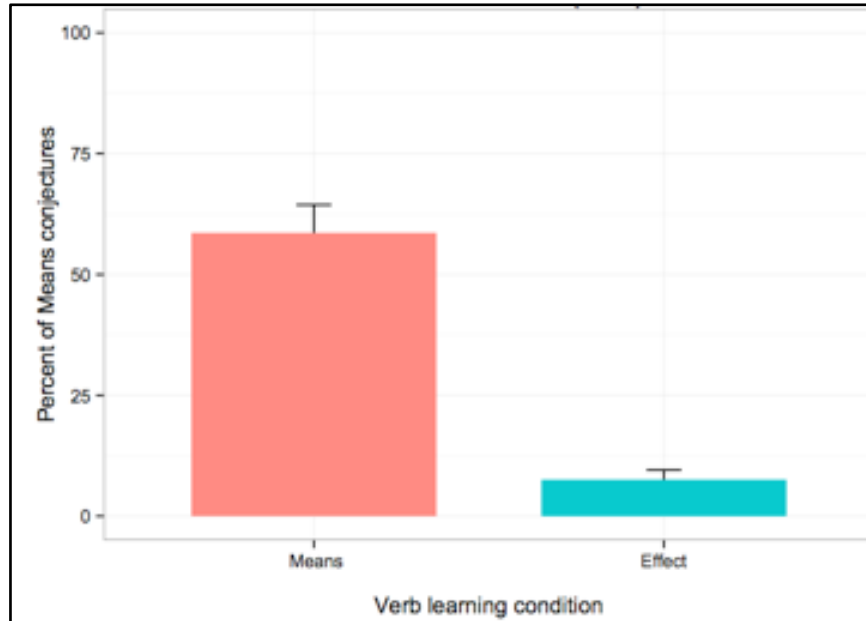


Figure 3.9 Percentage of Means-biased responses for novel change-of-state verbs in the Means and Effect verb learning conditions.

3.5 Assessment of Verb Extension Preferences in Part 2 (Trials 9-16)

Analyses of lexicalization bias for novel change-of-state verbs across Manner-of-motion and Path conditions: As illustrated in Figure 3.10, Manner-of-motion ($M_{MM} = .53$, $SE = .07$) and Path-verb learners ($M_{Path} = .21$, $SE = .03$) significantly differed in their expectations for the meanings of novel change-of-state verbs indicating that biases developed while learning motion verbs influenced the construal of unknown change-of-state verbs (mixed-effects logistic regression, $\beta = -2.57$, $p < .001$; Wilcoxon $W = 815$; $p = .001$). Adults in the Manner-of-motion condition did not exhibit an above chance preference to construe novel change-of-state verbs as Means verbs (Wilcoxon $V = 298$; $p = .16$) but those in the Path condition consistently preferred Effect interpretations (Wilcoxon $V = 8.5$, $p < .001$).

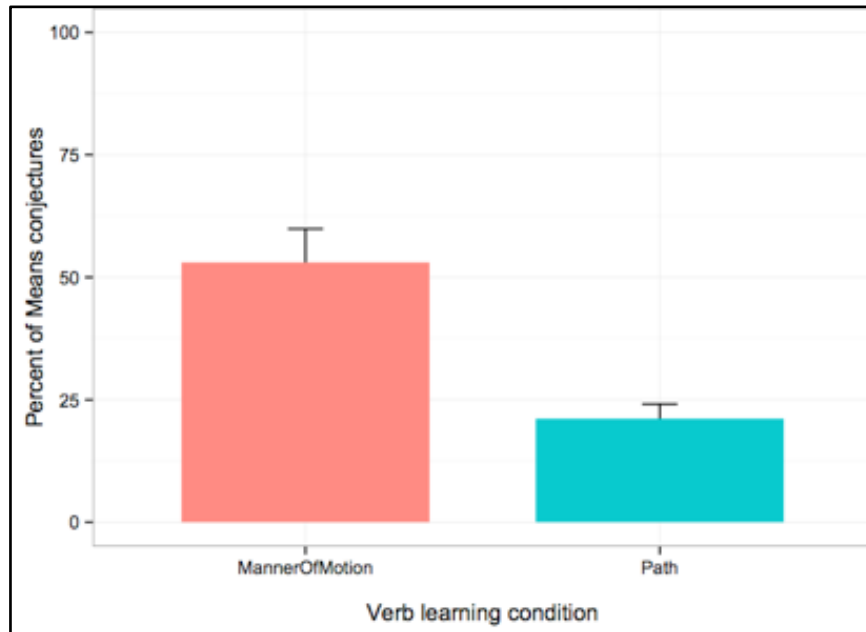


Figure 3.10. Percentage of Means-biased responses for novel caused change-of-state verbs from Manner-of-motion and Path-verb learners.

Analyses of lexicalization bias for novel motion verbs across Means and Effect verb learning conditions: As portrayed in Figure 3.11, Manner-of-motion interpretations of novel motion verbs were significantly higher in the Means condition ($M_{\text{Means}} = .63$; $SE = .06$) than the Effect condition ($M_{\text{Effect}} = .37$, $SE = .05$) indicating that adults generalized newly-learned biases for change-of-state verbs to motion verbs ($\beta = 2.81$, $p < .001$; Wilcoxon $W = 919$, $p = .002$). Adults in the Means condition consistently construed novel motion verbs as Manner-of-motion verbs (Wilcoxon $V = 373$, $p < .007$) while those in the Effect condition were reliably Path biased (Wilcoxon $V = 117.5$, $p = .004$).

Discussion

As in Experiment 1, we successfully manipulated participants' lexicalization biases for novel motion and change-of-state verbs during part 1. Unlike Experiment 1, we found evidence of bias transfer across semantic fields in both directions. Manner-of-motion and

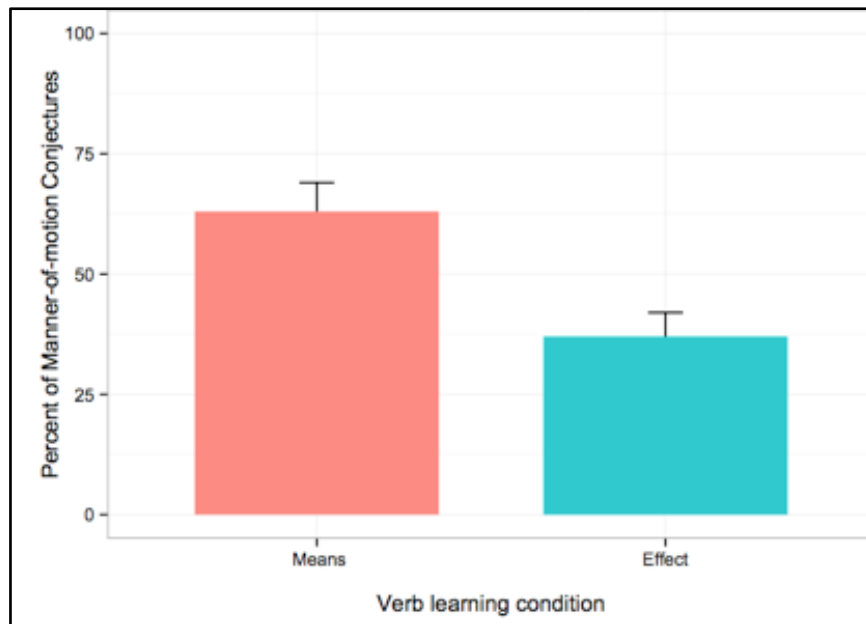


Figure 3.11. Percent of Manner-of-motion biased responses for novel verbs from Means and Effect-verb learners.

Path verb learners significantly differed in their construal of novel change-of-state verbs and did so in the predicted direction (Means conjectures were higher in the Manner-of-motion condition; or conversely, Effect preferences in the Path condition). Lexicalization biases also transferred from change-of-state to motion: Manner-of-motion conjectures were higher in the Means than Effect condition. This data pattern indicates that adults conceptualize Manner-of-Motion and Means as similar in underlying conceptual structure and distinct from Path and Effect, which are conceptualized as similar to one another.

Nevertheless, it is possible that some form of object priming underlies the generalization of lexicalization bias from change-of-state verbs to motion verbs. Instrumental Manner-of-motion and Means verbs frequently take their name from the object used to change location (*ski*) or produce change in the physical properties of an object (*hammer*), respectively. It is possible that this additional overlap in meaning—that both classes of verbs lexicalize *instrumental* Manner roots, is largely responsible for driving the difference

between conditions that mimics the data pattern expected if change-of-state verb learners developed MANNER/RESULT biases that influenced the construal of novel motion verbs.

A somewhat related explanation is that the acquisition of instrumental Means verbs raises the perceptual salience of objects in general. Adults in the Means condition may be more attentive to the vehicles facilitating Path traversal than those in the Effect condition and, therefore, more likely to interpret novel motion verbs (in part 2) as Manner-of-motion verbs. This could result in a difference between conditions that mimics the data pattern expected if change-of-state verb learners developed MANNER/RESULT biases that influenced the construal of novel motion verbs.

To rule out this possibility, in Experiment 3 we presented participants with motion events depicting agentive Manners-of-motion (from Experiment 1). Initial preference for Manner-of-motion interpretations of these novel motion verbs was reduced by presenting motion verbs in transitive frames, which prior research has revealed attenuates (or altogether eliminates) Manner-of-motion biases in English speakers (Naigles & Terrazas, 1998; Papafragou & Selimis, 2010; Shafto, Havasi, & Snedeker, 2014).

events depicting agentive Manners-of-motion (Figure 3.1). Baseline lexicalization biases for these stimuli were reduced by presenting motion verbs in transitive frames, which attenuates (or altogether eliminates) Manner biases in English speakers (Naigles & Terrazas, 1998; Papafragou & Selimis, 2010; Shafto, Havasi, & Snedeker, 2014).

EXPERIMENT 3

Method

4.1 Participants

Participants were 141 English-speaking adults recruited using Amazon Mechanical Turk. Additional participants were excluded for not following instructions ($N = 8$), or

viewing fewer than 6 trials on each part ($N = 27$).⁴² Participants were assigned to the Manner ($N = 37$), Path ($N = 33$), Means ($N = 42$) or Effect ($N = 29$) condition.

4.2 Materials and Procedure

Stimuli and procedures were the same as in Experiment 1 except that novel motion verbs appeared in transitive syntax (e.g., “The monster kraded into the house”) rather than intransitive sentences with Path modifiers.

Results

Data was coded and analyzed as in Experiments 1 and 2.

4.3 Verb learning Accuracy (Trials 1-8)

Verb learning accuracy was significantly above chance in the Manner-of-motion and Path conditions (Wilcoxon $V = 647.5$, $p < .001$; and Wilcoxon $V = 539$, $p < .001$, respectively) but Path verbs ($M = .93$, $SE = .04$) were easier to learn than Manner-of-motion verbs ($M = .83$, $SE = .03$; mixed-effects logistic regression, $\beta = 3.40$, $p = .003$; Wilcoxon $W = 364$, $p = .001$).

Means and Effect verb concepts were successfully acquired (Wilcoxon $V = 784$, $p < .001$; and Wilcoxon $V = 406$, $p < .001$, respectively) and performance did not differ across conditions ($M_{\text{Means}} = .74$, $SE = .04$; $M_{\text{Effect}} = .86$, $SE = .02$; $\beta = -6.9$, $p = .10$; Wilcoxon $W = 462.5$, $p = .08$).

⁴² See footnotes 18.

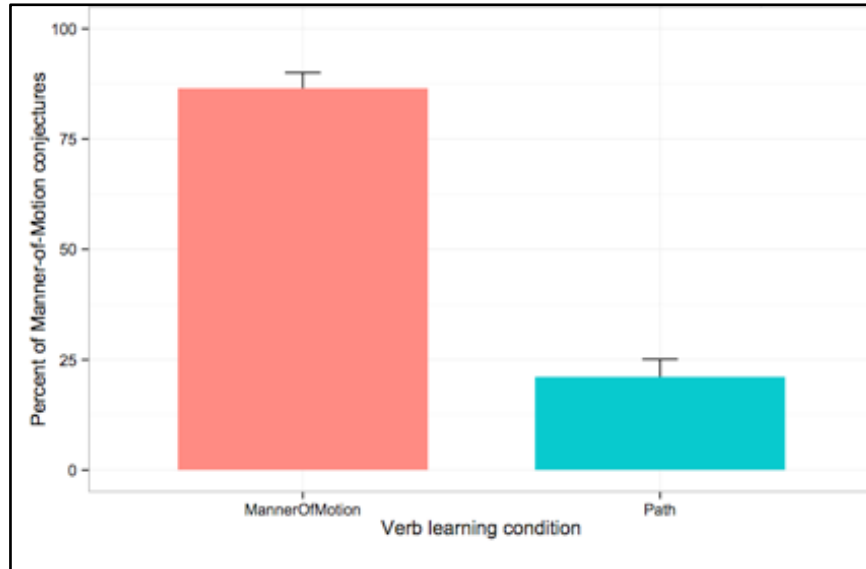


Figure 3.12. Percentage of Manner-of-motion biased responses offered by participants in the Manner and Path conditions.

4.4 Assessment of Lexicalization bias (Phase 1: Trials 3-8)

Analyses of lexicalization bias for novel motion verbs across Manner-of-motion and Path conditions. Approximately 40% of participants interpreted the first novel motion verb as a Manner-of-motion verb ($M_{Avg} = .41$; $M_{MM} = .38$, $M_{Path} = .45$) As Figure 3.12 illustrates, Path-verb learners ($M_{Path} = .21$, $SE = .04$) were significantly *less* likely to construe novel motion verbs on trials 3-8 as Manner-of-motion verbs compared to adults taught Manner verbs ($M_{MM} = .87$, $SE = .04$; $\beta = -5.80$, $p < .001$; Wilcoxon $W = 1160.5$, $p < .001$). Adults in the Manner condition were reliably Manner-of-motion biased ($V = 619.5$, $p < .001$) while those in the Path condition were Path biased ($V = 48$, $p < .001$).

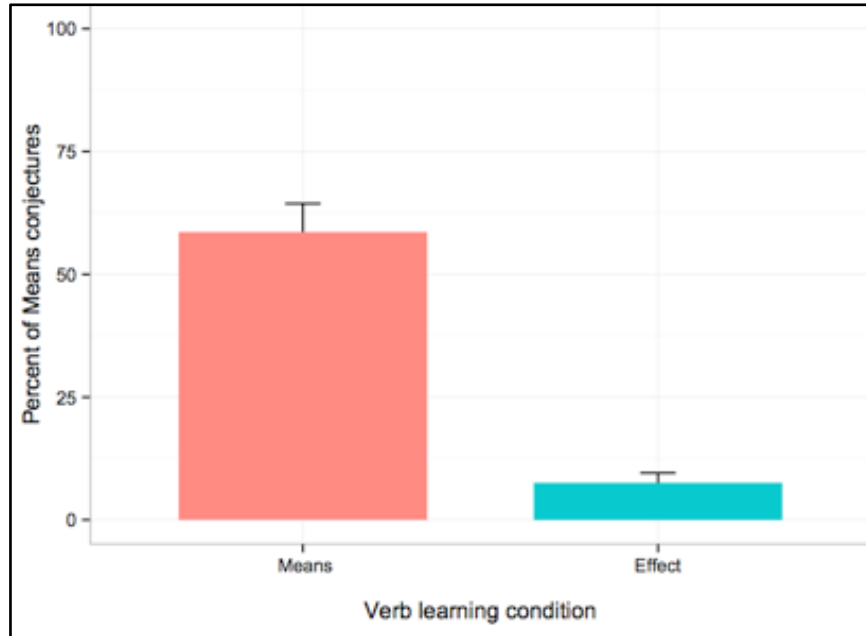


Figure 3.13. Percentage of Means-biased responses for novel change-of-state verbs in the Means and Effect conditions.

Analyses of lexicalization bias for novel change-of-state verbs across Means and Effect conditions: On the first trial, Means conjectures were offered about 40% of the time ($M_{\text{Means}} = .40$; $M_{\text{Effect}} = .43$; $M_{\text{Avg}} = .41$). As Figure 3.13 shows, learning had a marked effect on the interpretation of novel change-of-state verbs encountered later in the experiment ($\beta = 4.24$, $p < .001$; Wilcoxon $W = 1039$, $p < .001$ (two-tailed)). Adults in the Means condition ($M_{\text{Means}} = .60$, $SE = .06$) were more likely to interpret new change-of-state verbs as Means verbs compared to adults in the Effect condition ($M_{\text{Effect}} = .13$, $SE = .03$). Adults in the Means condition were reliably Means biased while those in the Effect condition were reliably Effect biased (Wilcoxon $V = 549.5$, $p = .03$, and Wilcoxon $V = 1$, $p < .001$, respectively).

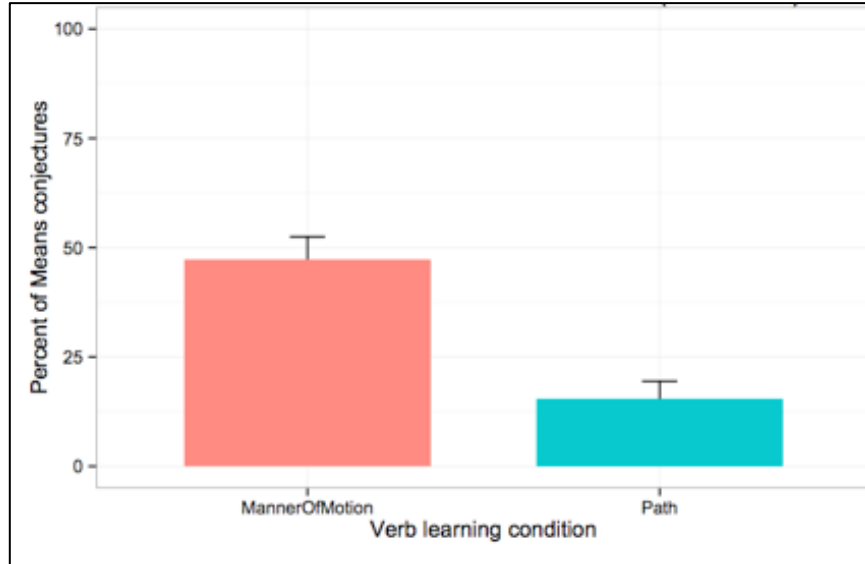


Figure 3.14. Percentage of Means-biased responses for novel change-of-state verbs in the Manner-of-motion and Path conditions.

4.5 Assessment of Verb Extension Preferences in Part 2 (Trials 9-16).

Analyses of lexicalization bias for novel Change-of-state verbs across Manner-of-motion and Path conditions: As depicted in Figure 3.14, lexicalization biases for change-of-state verbs differed across Manner-of-motion and Path conditions ($\beta = -2.73$, $p < .001$; Wilcoxon $W = 990.5$, $p < .001$) indicating that biases for motion verbs (experimentally induced during part 1) affected the construal of novel change-of-state verbs. Specifically, adults with Manner-of-motion biases were more likely to interpret novel change-of-state verbs as Means verbs, than adults with Path biases ($M_{MM} = .47$, $SE = .05$; $M_{Path} = .15$, $SE = .04$). Manner-of-motion verb learners did not offer Means conjectures at rates significantly different from chance (Wilcoxon $V = 305.5$, $p = .67$ (two-tailed)) whereas adults in the Path condition exhibited reliable Effect biases (Wilcoxon $V = 34.5$, $p < .001$ (two-tailed)).

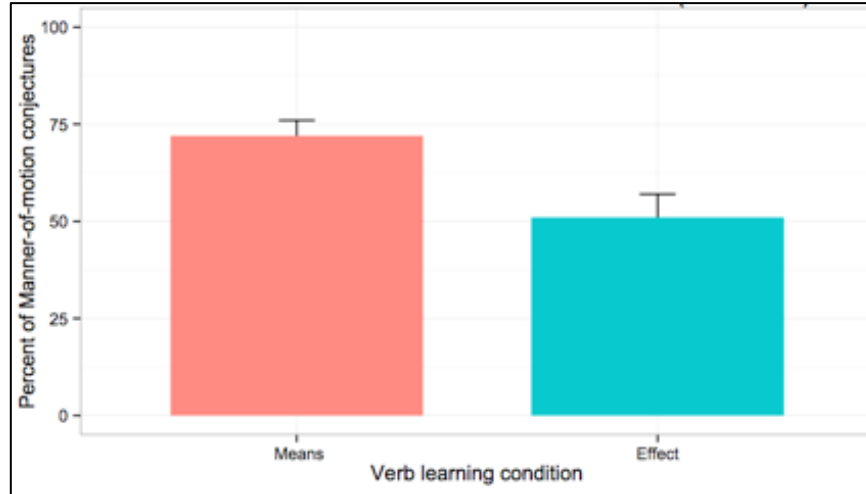


Figure 3.15. Percent of Manner-biased responses for novel motion verbs from participants in the Means and Effect conditions.

Analyses of lexicalization bias for novel motion verbs across Means and Effect verb learning conditions: As illustrated in Figure 3.15, participants who developed Means biases during part 1 were significantly more likely to interpret novel motion verbs as encoding Manner-of-motion compared to those who developed Effect biases ($M_{\text{Means}} = .72$, $SE = .04$; $M_{\text{Effect}} = .51$, $SE = .06$; $\beta = 1.56$, $p < .01$; Wilcoxon $W = 990.5$, $p < .001$). Adults in the Means condition were reliably Manner-of-motion biased (Wilcoxon $V = 752$, $p < .001$ (two-tailed)) but responses from adults in the Effect condition did not differ from chance (Wilcoxon $V = 186$, $p = .80$ (two-tailed))

Discussion

In Experiment 3, like Experiment 2 and unlike Experiment 1, lexicalization biases transferred across semantic fields in both directions supporting the hypothesis that MANNER and RESULT are psychologically-real, higher-order event concepts that transcend semantic field boundaries. Because MANNER verbs encoded agentive Manners-of-motions (as in Experiment 1) rather than instrumental ones (Experiment 2), the effect of change-of-state verb learning

on motion verb construal cannot be fully accounted for by some form of object-object priming with instrumental Means verbs.

GENERAL DISCUSSION

The present studies examined adults' representation of the concepts that underlie the meanings of motion verbs, such as *run* and *enter*, and caused change-of-state verbs, such as *hammer* and *flatten*. We examined the hypothesis that the lexical-semantic content encoded by Manner-of-motion verbs like *run* and Means verbs like *hammer* specify changes of one kind (MANNER changes), and that the events described by these classes of verb are distinct from events specified by Path verbs like *enter* and Effect verbs like *flatten*, which specify changes of a different kind (RESULT changes).

After learning novel motion verbs that encoded Manner-of-motion (*run*) or Path (*enter*), adults formed corresponding lexicalization biases that influenced the acquisition of subsequently encountered motion verbs and novel change-of-state verbs (Experiments 1, 2, and 3). Similarly, adults taught novel Means (*hammer*) and adults taught novel Effect (*flatten*) verbs differed in their conjectures for new novel change-of-state verbs and novel motion verbs (Experiments 2 & 3). This data pattern suggests that higher-order generalizations were formed over conceptual dimensions that are not specific to a particular kind of event (change-of-state or directed motion). Had lexicalization biases reflected preferences for event-specific concepts alone, learning should only have influenced the construal of novel verbs from the same semantic field. Another important finding is that the relationship between biases was the same regardless of the direction of influence (change-of-state to motion vs. motion to change-of-state): Manner-of-motion biases increased Means biases and vice versa; similarly, Path and Effect biases reinforced one another.

5.1 What does this tell us about event concepts underlying verb meanings?

Similarities in the lexicalization of directed motion events and caused change-of-state events and, in particular, the unification of Path and Effect as types of RESULTS figure prominently in many linguistic theories (Aske, 1984, Beavers, 2008, 2011; Beavers, Levin & Wei Tham, 2010; Slobin & Hoiting, 1994; Gropen et al., 1991ab, Pinker, 1989; Rappaport-Hovav & Levin, 1988, 1998, 2008; Talmy, 1991, 2000; Tenny, 1994) and are central to RHL's theory that the MANNER-RESULT distinction cuts across the verbal lexicon. Our results are consistent with this proposal. Transfer of bias across semantic fields elucidates that adults who form RESULT biases prefer to construe motion events as changes of location (Path) and change-of-state events as changes in state (Effect verbs). The data also indicate that participants formed generalizations over MANNER as they were biased to construe motion and change-of-state events in terms of Manner-of-motion and Means, respectively.

These findings challenge theories, which presume that location and result changes are conceptually and linguistically distinct (Jackendoff, 1990:94; Rappaport Hovav & Levin, 2002:10) but are consistent with theories under which these concepts are unified (Beavers, 2011; Gropen et. al, 1991; Rappaport-Hovav & Levin, 1998) or those that use multistratal representations to capture similarities and differences (e.g., "action" vs. "thematic" tiers from Jackendoff, 1990). The data also reveal that the impact of Path biases on Effect interpretations of novel change-of-state verbs is comparable to that of Effect biases on Path interpretations of novel motion verbs. This aspect of our data suggests that neither location change nor state change is semantically privileged and questions localist theories that conceptualize changes of state as instances of changes of location (Jackendoff, 1976, 1983).

The overall data pattern indicates that there are underlying commonalities between Path and Effect verbs and, similarly, between Means and Manner-of-motion verbs, but leaves open the question of what lexical-semantic and conceptual notions underlie these similarities. RHL identify RESULT with scalar change and use this concept to elucidate similarities between Paths and Effects. They contend that both types of verbs lexicalize a change in value of a particular attribute of an *affected* entity (in a particular direction) with possible values comprising the scale (see also Beavers, 2008, 2011; Rappaport-Hovav & Levin, 2008). On other proposals location changes and state changes are equated on the basis of similarities in aspect, affectedness and/or constraints on object realization (Dowty, 1991; Gropen et. al, 1991; Jackendoff, 1990, 1996; Rappaport-Hovav & Levin, 1998, 2002; Talmy, 2000; Tenny & Pustejovsky, 2000). The results obtained in the present studies support theories that unify location and state change on the basis of semantic (or grammatical) criteria but cannot adjudicate between specific proposals. Formulating more precise and independent criteria for distinguishing MANNER verbs from RESULT verbs, operationalizing notions of scalar/non-scalar change and affectedness (but see Beavers & Koontz-garden, 2012; Beavers, 2011) and examining whether learners use these notions to distinguish MANNER and RESULT verbs across semantic fields are crucial to gaining insight into the semantic and conceptual content of the basic concepts that underlie verb meanings.

5.2 Implications for linguistic structure across languages cross-linguistic variation

An important component of the RHLs proposal is that the MANNER-RESULT distinction is universal and grammatically relevant even though members of each class encode a variety of real-world scenarios (Table 1; see also Gropen et al., 1991). The present results lend experimental support to linguistic analyses that draw upon the MANNER/RESULT

distinction to account for systematic constraints on verb-argument structure patterns across semantic fields and languages (Levin, 2012). Because learners used perceptual information to form first-order generalizations over individual events and map event classes onto a novel verb, our results also indicate that MANNER and RESULT are conceptual dimensions—and hence, presumably available to speakers of all languages.⁴³ Participants in our study rapidly formed generalizations over these dimensions (after a few verb learning trials), suggesting that MANNER and RESULT are highly salient features and that we can flexibly conceptualize events as changes of either kind.

If the MANNER-RESULT dimension is a linguistic distinction that dichotomously classifies non-stative verbs across the world's languages, this would substantively constrain the organization of the lexicon and typological variation. Beavers, Wei Tham & Levin (2010) propose that typological variation in the distribution of MANNER and RESULT verbs in a language is a product of a language-wide preference to lexicalize MANNER or RESULT in the clausal verb (p.34), constraints on the lexicalization of both components in the VP, and event-independent factors, such as the availability of lexical and grammatical forms compatible with MANNER or RESULT meanings, *inter alia*. This theory predicts fairly stable typological patterns in the lexicalization of events across languages and, within a language, considerable systematicity in the encoding of different types of events.

⁴³ It does not follow that these are universal *semantic* notions. It is possible that these dimensions, while conceptually available, are not grammatically distinguished (e.g., evidentiality is marked in Turkish but not English).

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