



Original Articles

Lexical distributional cues, but not situational cues, are readily used to learn abstract locative verb-structure associations[☆]Katherine E. Twomey^{a,b}, Franklin Chang^{b,c,*}, Ben Ambridge^{b,c}^aLancaster University, UK^bESRC International Centre for Language and Communicative Development (LuCID), UK^cUniversity of Liverpool, UK

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ABSTRACT

Children must learn the structural biases of locative verbs in order to avoid making overgeneralisation errors (e.g., **I filled water into the glass*). It is thought that they use linguistic and situational information to learn verb classes that encode structural biases. In addition to situational cues, we examined whether children and adults could use the lexical distribution of nouns in the post-verbal noun phrase of transitive utterances to assign novel verbs to locative classes. In Experiment 1, children and adults used lexical distributional cues to assign verb classes, but were unable to use situational cues appropriately. In Experiment 2, adults generalised distributionally-learned classes to novel verb arguments, demonstrating that distributional information can cue abstract verb classes. Taken together, these studies show that human language learners can use a lexical distributional mechanism that is similar to that used by computational linguistic systems that use large unlabelled corpora to learn verb meaning.

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1. Introduction

Language acquisition is a complicated business. With little explicit teaching from adults, children rapidly learn words and grammatical structures. Critically, children must acquire language-specific links between verbs and structures (Levin & Hovav, 2005); for example, in English *fill* can appear in *the woman filled the bucket with water*, but not **the woman filled water into the bucket*. At around five years of age, children sometimes make overgeneralisation errors such as **I'm going to cover a screen over me* (4;5; Bowerman, 1982) where a verb is paired with a structure that is not appropriate in the language that they are learning. Such errors show that children understand the verb's meaning and can produce the structure, but they have not yet learned the correct verb-structure link. Over time, however, children stop making

these errors. This *retreat from overgeneralisation* occurs as children learn adult-like verb-structure links (Pinker, 1989).

The English locative alternation (e.g., *I sprayed water onto the wall*) involves events where a *theme* (e.g., water) moves to a *location* (e.g., wall) and the location is changed by the action (e.g., wall becomes wet). Locative events can be described with two structures, which differ as to whether the verb is followed by the location or the theme: the location-theme (LT) structure, as in *the woman sprayed the wall with paint*, and the theme-location (TL) structure, as in *the woman sprayed paint onto the wall*. Not all locative verbs can appear in both structures, however. Specifically, LT-biased verbs appear predominantly in the LT structure, for example *deluge*, *inundate* and *flood* (e.g., *I deluged the flowerbed with water* vs. **I deluged water onto the flowerbed*). TL-biased verbs such as *dribble*, *drip* and *pour* appear mainly in the TL structure (e.g., *I dribbled water onto the flowerbed* vs. **I dribbled the flowerbed with water*). Finally, alternating verbs like *spray*, *load* and *pack* appear in both structures (e.g., *I sprayed water onto the flowerbed/I sprayed the flowerbed with water*). Linguistic analyses explain these associations between verbs and structures in terms of verb classes: clusters of verbs with common semantic and syntactic properties (Levin, 1985; Levin & Hovav, 2005). For example, verbs in the “cover-type” class (e.g., *deluge*, *inundate* and *flood*; Ambridge, Pine, & Rowland, 2012; Pinker, 1989) have the semantic property “a layer completely covers a surface”, which highlights the surface location

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over the theme argument. The greater salience of the location in these actions means they tend to be described with utterances that place the location earlier in sentences (e.g., *he flooded the floor with water*). If verbs incorporate this relative salience information into their meaning representation (Levin, 1993), then the structural preferences of the verb can be determined from the meaning (e.g., location-salient verbs tend to appear in LT structures).

One potential solution to the problem of learning verb-structure mappings would be for children to learn conservatively, memorising the verb-structure mappings in their input. This could be implemented with statistical learning mechanisms such as entrenchment (e.g., Braine & Brooks, 1995) and preemption (e.g., Goldberg, 1995). Here, the occurrence of a particular verb in grammatical constructions (e.g., *I dribbled water onto the flowerbed*) constitutes probabilistic evidence for the mappings in the input and against the grammaticality of unwitnessed combinations (e.g., **I dribbled the flowerbed with water*). Although these proposals enjoy some support, including in this particular domain (Ambridge et al., 2012; Bidgood, Ambridge, Pine, & Rowland, 2014) and can help to explain the retreat from overgeneralisation errors, they are not on their own sufficient, as they do not directly explain why children make errors in the first place.

An influential account of why children overgeneralise is that of Pinker (1989), who suggested that from the outset children possess innate *broad range* rules that link alternating structures which can be used to describe the same action. In the locative, the broad range rule connects two construals of a locative action – one in which the focus is the location's change of state and the other in which the focus is the manner of motion of the theme. When the location's change of state is highlighted (e.g., a wall becomes completely covered with paint), the LT structure is preferred since it places the location earlier in the sentence (e.g., *the girl sprayed the wall with paint*). When the manner of motion is highlighted (e.g., the paint moves in a distributed manner under pressure), the TL structure is preferred, since it places the theme earlier in the sentence (e.g., *the girl sprayed the paint onto the wall*). On Pinker's account, the semantic information in the scene (e.g., thematic roles) can be used to activate a broad range rule that allows children and adults to take a verb that has been heard only in one structure and use it with the other structure. This is desirable for many low-frequency alternating verbs which may only have been in a single structure in the input (e.g., *strew the flowerbed with seeds* → *strew seeds onto the flowerbed*), but it can also lead to overgeneralisations if a verb is only acceptable in one structure (e.g., **I filled the water into the bath*).

Pinker (1989) explains the retreat from overgeneralisation through the acquisition of semantic verb classes. In this theory, children assign verbs to semantic verb classes which link to structures via *narrow range* rules and these rules allow children to retreat from the overgeneralisations licensed by the broad range rules. In particular, the salience and consistency of the components of an action across different instances determines its verb class (Gropen, Pinker, Hollander, & Goldberg, 1991a). For example, LT-biased *cover* is used to describe an action where the location changes state from being visible to being obscured (e.g., a blanket covers a bed). While the state change is salient and consistent across different cover actions, the movement of the theme can take place in various ways (e.g. the blanket can be dragged, thrown, dropped, etc.). Likewise, TL-biased *pour* describes a liquid moving in a continuous stream to the location (e.g., water flowing out of a hose), but the change of state of the location can be variable (e.g., the bucket can be partially or fully filled; the water could be poured onto the floor, etc.). A range of empirical evidence supports the idea that for both adults and children, verbs' syntactic behaviour is governed by these semantically constrained classes (Ambridge et al., 2012; Bidgood et al., 2014; Brooks & Tomasello,

1999; Brooks, Tomasello, Dodson, & Lewis, 1999; Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989; Gropen, Pinker, Hollander, & Goldberg, 1991b; Gropen et al., 1991a; Pinker, Lebeaux, & Frost, 1987).

Pinker's account of verb class acquisition focuses on semantic information that can be extracted from the situations that verbs are heard in. Gropen et al. (1991a) provided evidence in support of this *situational* approach in a series of verb learning experiments in which they taught children and adults novel verbs (e.g., *look, this is keating*) alongside novel actions. Each action included either a salient location change of state (e.g., a colour change, Exp 2) or a salient theme manner (e.g., moving a matchbox in a zigzagging motion, Exp 1). After training with these novel verb/action pairs, participants were prompted at test to describe the same action using a full locative structure. Participants used more LT locatives after training scenes with a salient location component, and more TL locatives after training scenes with a salient manner component. However, although this study appears to show situational effects on verb-structure learning, this is not the only possible account of Gropen et al.'s results, because their test actions were biased in the same way as their training items. For example, if in training participants saw the theme move towards the location in a zigzag motion with no change to the location, they saw the same event again at test. Participants' choice of structure could therefore have been determined by placing the salient argument (location/theme) earlier in the sentence; importantly, this could take place without reference to verb-specific semantics (this experiment provided verb-independent constructional meaning; Goldberg, 1995; Twomey, Chang, & Ambridge, 2014). More generally, since most studies that show semantic effects on structural choice manipulate the test situation (Ambridge et al., 2012; Bidgood et al., 2014; Brooks & Tomasello, 1999; Brooks et al., 1999; Gropen et al., 1989, 1991a), it is not clear whether learners can recall situational information previously associated with a verb and use that information in later structural choices. In Experiment 1, we examine whether verb-specific situational training information can influence structural choices at a later test.

A potential problem for situational learning is that the relevant situational information may only rarely be present: speakers do not generally narrate events as they unfold. Instead learners may acquire a considerable amount of information regarding a verb's meaning from its linguistic context, as proposed under the *syntactic bootstrapping* hypothesis (Fisher, Gertner, Scott, & Yuan, 2010; Gleitman, 1990). For example, Naigles (1990) demonstrated that children correctly associated sentences containing novel verbs with causative visual scenes based on the transitive syntactic frame in which the verbs were presented. Specifically, children mapped the transitive sentence *the duck is gorging the bunny* to a scene in which a duck made a bunny squat by pushing on the bunny's head (i.e., a causative action). In contrast, children associated a scene in which a duck and a bunny simultaneously made arm gestures (i.e., a non-causative action) with intransitive sentences such as *the duck and the bunny are gorging* (Naigles, 1990) or *the duck is gorging with the bunny* (Hirsh-Pasek & Golinkoff, 1999; Kidd, Bavin, & Rhodes, 2001). The results of syntactic bootstrapping studies have been explained with a range of distinct mechanisms. One involves the number of arguments in a phrase; for example, two arguments would signal a causative meaning (Fisher, 1996). Another account is that learners use syntactic structures to establish elements of verb meaning; for example, the sequence of syntactic categories NP VERB NP might bias towards the causative (Fisher, Gleitman, & Gleitman, 1991; Gleitman, 1990). A third account is that the post-verbal noun may signal its thematic role; for example, patient nouns may indicate the causative (e.g., Rappaport Hovav & Levin, 2002). In addition to these syntactic mechanisms, it has been suggested that lexical mechanisms could

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