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Supplementary Materials

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A Survey of child behavioral results

A.1 Child behavioral data

This is a synthesis of 38 behavioral acquisition studies relating to verb behaviors known by children by five years old. The specific verbs attested are used to identify which particular verbs ought (or ought not) to cluster together at different ages.

A.1.1 Passivizable, intransitive, & monotransitive.

A verb that’s passivizable is often one that can be used transitively (i.e., it allows an *object*). For example, *eat* is both passivizable (*It was/got eaten*) and (optionally) transitive (*I ate it*). However, verbs can also be used in the passive form even if they’re intransitive, because they can take an *indirect object*. We can see this with *sneeze*: *It was/got sneezed at* and *I sneezed at it*).

In terms of acquisition evidence, we should be able to look at studies that investigate comprehension of transitive verbs and transitive cues, as well as studies that investigate children’s comprehension of passives. Moreover, for passives, comprehension of a “short” passive (e.g., *It was/got eaten*) should be sufficient, rather than requiring comprehension of a “long” passive (e.g., *It was/got eaten by the cat*). Also, if children comprehend the long passive, they should be able to comprehend the short passive for that verb.

The ability to comprehend the passive usage of a verb correctly seems to come significantly after the cues to transitivity are recognized. For example, by two years old, English children recognize that the frame *She’s Xing the man* indicates X is a transitive verb and so expect a transitive meaning where one agent affects another; they also recognize the frame *She’s Xing* indicates X is an intransitive verb, and so expect an intransitive (e.g., unaccusative or unergative) meaning with only a single agent (Naigles, 1990, Naigles and Kako, 1993, Yuan and Fisher, 2009). At 28 months, they also recognize cues involving multiple frames to identify verbs as optionally transitive vs. unaccusative (Scott and Fisher, 2009).

Maratsos 1974. Maratsos (1974) finds that children can pass an act-out task with full passives using the verbs *bump* and *push* by age four and a half.

Maratsos et al. 1985. Maratsos, Fox, Becker and Chalkley (1985) found that children can comprehend long passives for these verbs by age 4: *find*, *hold*, *kick*, *kiss*, *push*, *wash*. They comprehend long passives for these verbs by age 5: *like*, *love*. They comprehend long passives for these verbs by age 9: *hate*, *remember*, *see*.

Gordon & Chafetz 1990. Gordon and Chafetz (1990) found that children can comprehend both short and long passives for these verbs by age 3: *drop*, *eat*, *carry*, *hold*, *hug*, *kick*, *kiss*, *shake*,

wash, watch. However, they fail to comprehend either long or short passives for these by age 3 to 4: *believe, forget, hate, hear, know, like, remember, see*.

O'Brien et al. 2006 & Nguyen et al. 2016. O'Brien, Grolla and Lillo-Martin (2006) found that children can comprehend long passives for these verbs by age 3 (and 4) when the pragmatic context makes the use of the passive more felicitous: *hug, chase, like, see*. However, Nguyen, Lillo-Martin and Snyder (2016) found that three- and four-year-olds only seem to comprehend long passives for *hug* and *chase*, though they comprehend short passives for all four verbs.

Hirsch & Wexler 2007. Hirsch and Wexler (2007) found that three-year-old children can comprehend long passives for these actional verbs at greater than chance rates in a two-choice sentence picture-matching task: *hold, kick, kiss, push*. In contrast, only seven-year-old children (and older) comprehend long passives for these psychological verbs at greater than chance rates: *hate, love, remember, see*.

Crain et al. 2009. Crain, Thornton and Murasugi (2009) report samples of elicited long passives from 9 three-year-olds, 22 four-year-olds, and one five-year-old. We can assume that if these children produce a passive structure, they have classified the verbs as passivizable. Based on the samples from the three-year-olds (3;4-3;11), by age three children should have grouped these verbs together: *bleed, crash, eat, hit, hurt, lick, knock, marry, punch, pick up, push, scratch, trip up, turn (over)*. Based on the samples from the four- and five-year-olds (4;1-5;0), by age four children should have additionally grouped these verbs together: *bite, hug, jump, kill, kick, kiss, knock, lick, ride, shoot*.

Messenger et al. 2009. Messenger, Branigan, McLean and Sorace (2009) found that children can comprehend long passives for these verbs by age 3-4: *frighten, shock, annoy, upset, surprise, scare, pat, bite, pull, hit, carry, squash*. However, they were unable to comprehend long passives at age 3-4 for these verbs: *see, hear, love, ignore, remember, hate*.

A.1.2 Ditransitive.

Corpus analysis and experimental work discussed below suggests that some verbs that allow (or require) two *objects* are identified by age three (Gropen, Pinker, Hollander, Goldberg and Wilson, 1989, Snyder and Stromswold, 1997, Campbell and Tomasello, 2001, Conwell and Demuth, 2007, Thoathathiri and Snedeker, 2008), though there may be some overgeneralizations where verbs are assumed to have the ditransitive behavior for awhile that shouldn't (ex: *say*).

Gropen et al. 1989. Gropen et al. (1989) conducted a corpus analysis of five children's productions (including Brown-Eve) and found that the double-object construction was often first produced between ages 1;8 and 3;3. Their corpus analysis showed that at least two of the five children had used the following verbs in both dative constructions, with the earliest age of use in parenthesis: *give (1;9), get (2;0), read (2;0), bring (2;3), buy (2;11), show (3;0), make (3;4), tell (3;4)*.

This same analysis showed that at least two of the five children had used the following verbs in the double-object dative construction, with the earliest age of use in parenthesis: *read* (1;8), *give* (1;9), *show* (1;9), *bring* (1;10), *get* (2;0), *buy* (2;11), *pour* (2;11), *tell* (3;0), *draw* (3;4), *make* (3;4), *teach* (3;6), *ask* (4;7).

This suggests that these verbs may have the ditransitive behavior by these ages: two = *read, give, show, bring, get*; three = *buy, pour, tell*; four = *draw, make, teach*; five = *ask*.

In addition, Gropen et al. (1989) also observed overproductive uses of the double-object construction at these ages for these verbs: *write* (2;3), *say* (2;8), *eat* (3;3), *keep* (3;8), *spend* (4;0), *put on* (4;1), *finish* (4;11), *fix* (5;2). So, the above clusterings may also include these errors (i.e., including these verbs at these ages). So, the groupings may look more like this for the ditransitive behavior: two = *read, give, show, bring, get*; three = *buy, pour, tell, write, say*; four = *draw, make, teach, eat, keep, spend*; five = *ask, put on, finish*; six = *fix*.

Snedeker & Huang 2015, Campbell & Tomasello 2001. Snedeker and Huang (2015), citing Campbell and Tomasello (2001), note that both constructions associated with the dative (i.e., *subject verb object_{indir} object_{dir}* [double-object]=*She gave him a penguin* and *subject verb object_{dir} preposition object_{indir}* [prepositional]=*She gave a penguin to him*) are acquired before age three. More specifically, Campbell and Tomasello (2001) conducted a corpus analysis of seven children in the CHILDES database and found that both dative constructions are first produced by age three (at the latest), and often before age two and a half (five of seven children). The specific verbs where the majority of children produced multiple dative construction types by age three are *bring, get, give, make, read, and show*. So, it is likely children should have grouped these verbs together by age three. Moreover, if we focus on the verbs that were used in the double-object construction specifically, these are grouped together: *bring, buy, get, give, make, read, show, tell*.

Huttenlocher et al. 2004. Huttenlocher, Vasilyeva and Shimpi (2004) found that four- and five-year-olds had structural priming for both dative constructions across these verbs: *bake, bring, buy, deliver, feed, give, serve, show, teach, throw*. This suggests these verbs have been clustered together by age four into a class that allows the double-object dative and the prepositional dative.

Conwell & Demuth 2007. Conwell and Demuth (2007) find that three-year-olds demonstrate abstract structural knowledge of both the double-object and prepositional dative constructions, using elicited repetition with novel verbs. In particular, three-year-olds will use the prepositional construction for a novel verb when it's been modeled in the double-object construction, suggesting they understand these are related. So, it is likely three-year-olds have a verb class that includes the double-object construction (i.e., the ditransitive behavior).

Thothathiri & Snedeker 2008. Thothathiri and Snedeker (2008) note that naturalistic production isn't definitive about categorization – in particular, children's productions could be simple imitations of their input rather than generalizations formed via a verb class. Thothathiri and Snedeker (2008) conduct priming studies with three- and four-year-olds children to determine whether class-level knowledge exists for dative constructions (double-object and prepositional). This presumably

also indicates which verbs belong to that class, as children who can generalize with a construction to a new usage are doing so because the verb belongs to the class.

In the first set of experiments, four-year-olds show both within-verb priming (with *give*) and across-verb priming (*show* priming *give* for the double-object construction, *bring* priming *give* for the prepositional dative). These results suggest that four-year-olds cluster together *show* and *give* for the double-object construction, and potentially also *bring* for datives in general.

In the second set of experiments, three-year-olds also show both within-verb and across-verb priming with these verbs: *bring*, *hand*, *pass*, *send*, *show*, *throw*, *toss*. The priming effect was stronger for the double-object construction, which suggests this class has definitely been formed. So, by three, children have likely clustered together these verbs (along with *give*) into a class that allows the ditransitive construction.

A.1.3 Unaccusatives and unergatives.

Both experimental evidence (Bunger and Lidz, 2004) and analysis of naturalistic productions (Déprez and Pierce, 1993, Snyder and Stromswold, 1997) suggest that English children have begun forming a class of unaccusative verbs by age two. Experimental evidence (Bunger and Lidz, 2008) additionally suggests that English children have begun forming a class of unergative verbs by age two.

Depréz & Pierce 1993. Déprez and Pierce (1993) investigated three English children's naturally produced speech between the ages of one and a half and two years old. They found that post-verbal *subjects* (i.e., VS order, like *going it*) occurred only with *be* and with unaccusatives such as *break*, *go*, *come*, and *fall*. This suggests that English children have grouped these unaccusatives together by age two (presumably noting the PATIENT-like role of the *subject*).

Snyder & Stromswold 1997. Snyder and Stromswold (1997) conducted a corpus analysis in the naturalistic productions of 12 English children to determine the age at which the verbs *break*, *come*, *fall*, *go*, *grow*, and *leave* were first produced in an "unaccusative context". This age range was found to be between 1;6 and 2;7. So, we might interpret this as children recognizing that these six verbs can be used unaccusatively by age two and clustering them together.

Gelman & Koenig 2001. Gelman and Koenig (2001) find that five-year-olds and adults use the animacy of a *subject* to determine how to interpret the verb *move* in intransitive uses such as *Was this X moving?* In particular, +animate *subjects* yield an unergative reading while -animate *subjects* yield an unaccusative reading. So, by five, children seemed to have created a distinction between the unergative and unaccusative classes that depends on the animacy of the subject. The three-year-olds in the study were trending towards this behavior, but their behavioral results weren't statistically significant.

Bunger & Lidz 2004, 2008. Bunger and Lidz (2004) demonstrate experimentally that 2-year-old English children are able to use syntactic distributional cues to determine that a verb is unac-

cusative. For example, when presented with “*The ball is pimming*” (sometimes accompanied with “*The girl is pimming the ball*”, 2-year-olds infer that *pim* refers to the “results-focused” action (like the ball bouncing) that unaccusatives have. This suggests that children have begun forming an unaccusative verb class by age two, and it has both syntactic and semantic cues associated with it.

Bunger and Lidz (2008) demonstrate experimentally that 2-year-old English children also are able to use both syntactic distributional cues and semantic role information to determine that a verb is unergative. For example, when presented with “*The boy is blicking*”, 2-year-olds infer that *blick* refers to the “means-focused” action (like pumping a bicycle pump to spin an attached flower) that unergatives have. This suggests that children have begun forming an unergative verb class by age two, and it has both syntactic and semantic cues associated with it.

A.1.4 Control object and raising object.

Kirby 2009, 2009, 2010 & Becker 2014. Becker (2014) discusses a set of experiments by Kirby (2009b) in which the raising object verbs *want* and *need* were investigated along with the control object verbs *ask* and *tell*. Kirby (2009b, 2011) found that four- and five-year-olds were able to correctly interpret raising object verb and control objects verb utterances when the embedded clause is active (e.g., “*He wanted Winnie the Pooh to kiss Patrick*”, “*He asked the farmer to comb the horse*”). Both ages of children are also able to interpret raising object utterances when the embedded non-finite clause is a passive (“*He wanted Tigger to be called by Elmo.*”). However, only five-year-olds were above chance on interpreting control objects with embedded non-finite passives (*She told the policeman to be sniffed by the dog.*”).

Additionally, as reported in Kirby (2009a, 2010), both four- and five-year-olds are sensitive to the animacy restrictions for control object verbs (and reject utterances like “*Elmo told the toys to be smaller*” as “weird” more often than chance). This behavior is different for raising object verbs (with utterances like “*The boy wanted the cake to be chocolate*”), where both ages of children were at chance for accepting the utterances as “okay”. Similarly, as also reported in Kirby (2009a, 2010), four- and five-year-olds treat control object and raising object verbs differently when judging the acceptability of expletive subjects in the embedded clause (e.g., control object: **The girl told it to be warm*, raising object: *The girl wanted there to be cookies in the bag.*). Adult-like judgments do vary by age: four-year-olds only have adult judgments for control object verbs and reject expletive subjects while five-year-olds only have adult judgments for raising object verbs and accept expletive subjects. Still, the main point is that they recognize that these types of verbs behave differently from each other but similarly to ones of the same kind (i.e., *want* patterns with *need* and *ask* patterns with *tell*).

This suggests five-year-olds have distinguished raising object from control object verbs, and four-year-olds may have as well. More specifically, we might expect four- and five-year-olds to group together *want* and *need* in one class and *ask* and *tell* in a separate class.

A.1.5 Control subject and raising subject.

Becker 2006. The experiment with children in Becker (2006) suggests that five-year-olds have adult-like judgments for verbs allowing inanimate *subjects*. In particular, they accept inanimate *subjects* only for subject raising verbs like *seem* and *appear* (e.g., *The flower seems to be pink*), and not for control subject verbs like *want* and *try* (e.g. *The flower wants to be pink*). In contrast, three- and four-year-olds allow all verbs to have inanimate *subjects* (and so have not differentiated *want* and *try* from *seem* and *appear* in this respect). For purposes of verb classification, this suggests that children place *want* and *try* together, separately from *seem* and *appear* by five years old.

Hirsch & Wexler 2007. The comprehension experiments in Hirsch and Wexler (2007), which involved children choosing which of two pictures matched a spoken utterance, suggest that children can correctly interpret instances of *seem* that don't involve raising (e.g., *It seems to Homer that Marge is pushing a cart*) as young as three. However, they struggle to comprehend *seem* instances that involve raising (e.g., *Homer seems to Maggie to be bowling a ball*). Because no other subject-raising verbs were tested, it is unclear if children would classify *seem* as being similar to other subject-raising verbs.

Becker 2007 and Becker 2009. The experiments in Becker (2007, 2009) suggests that three- and four-year-olds accept expletive subjects for *seem* and *appear* (e.g., *It seems to be windy*, *It appears to be warm*) either 83% (three-year-olds) or 91.7% (four-year-olds) of the time. This may indicate that they recognize that *seem* and *appear* are the same kind of predicate. However, these children also accepted expletive subjects for the control subject verbs *want* and *try* either 66.7% (three-year-olds) or 68.1% (four-year-olds) of the time. Becker (2009) suggests this is because children of both ages recognize the expletive subject as a cue for raising subject verbs – and so try to cast control subject verbs as raising subject verbs when they're used with expletive subjects (*It wants to be raining* = modal interpretation $\approx$ *It's going to rain*).

For the purposes of verb classification, only four-year-olds – but not three-year-olds – accepted raising subject verbs with expletive subjects more often than control subject verbs with expletive subjects. Becker (2009) suggests that three-year-olds are still determining the class membership for raising vs. control subject verbs. In particular, only four-year-olds recognize that *want* and *try* should be in a different class than *seem* and *appear* (the class that naturally allows expletive subjects).

Becker 2014. Becker (2014) discusses a pilot study (pp.206-207) with 5 five-year-olds, and finds that being used with an inanimate *subject* is a strong signal to expect that verb to also be used with the *there*-expletive (*Did there meeb to be a banana in the soup?*). So, five-year-olds have a strong sense of cues to raising verb analyses.

A.1.6 Subject-experiencer & object-experiencer verbs.

Experimental studies suggest that children are still in the process of learning how to interpret subject-experiencer verbs like *like*, *love*, and *hate* in all contexts, even though they use these words frequently in their naturalistic output and hear them often in their input (Hartshorne, Pogue and Snedeker, 2015). Five-year-olds, however, can interpret subject-experiencer verbs correctly above chance. In contrast, four-year-olds are better at sorting out object-experiencer verbs like *surprise* and *frighten* and interpreting them correctly above chance (Hartshorne et al., 2015) when both the *subject* and *object* are animate. This suggests that there may be an object-experiencer verb class by age 4, as well as an emerging subject-experiencer verb class.

Hartshorne et al. 2015. Hartshorne et al. (2015) conducted experimental studies testing children's comprehension of several subject-experiencer verbs (*admire*, *fear*, *hate*, *like*, *love*, *trust*) and object-experiencer verbs (*amaze*, *bore*, *confuse*, *frighten*, *scare*, *surprise*). They found that four-year-olds correctly interpreted three higher-frequency object-experiencer verbs above chance (*surprise*, *frighten*, *scare*) and no subject-experiencer verbs above chance when both *subject* and *object* were animate. In fact, two low frequency subject-experiencer verbs were interpreted as object-experiencer verbs above chance (*fear*, *trust*). This may suggest that four-year-olds have grouped these five verbs together: *fear*, *frighten*, *scare*, *surprise*, *trust*. When the *subject* was animate while the *object* was inanimate, four-year-olds are above chance at interpreting the three most frequent subject-experiencer verbs correctly: *like*, *love*, *hate*. This suggests that four-year-olds have grouped these verbs together, though they may not always interpret them correctly if the *object* is animate.

A.1.7 Complements: *-ing*, *to*, *that*, *whether/if*.

Bloom et al. 1984, 1989. Bloom, Tackeff and Lahey (1984) conducted an analysis of child-produced speech from four children between the ages of two and three years old. They found suggestive evidence that children have productive use of non-finite *to* in "V-to-V" constructions, such as *I want to see Mommy* (though not in "V-NP-to-V" constructions like *I want Mommy to get balloon*). This suggests that by three years old, children have begun forming a class of verbs that take non-finite *to* as a complement. The specific verbs that involved complement verb contexts in child productions were these: *ask*, *forget*, *get*, *go*, *have*, *know*, *like*, *need*, *show*, *start*, *suppose*, *teach*, *tell*, *try*, *use*, *want*. A subset of these were used specifically with "how to" instructive contexts: *know*, *show*, *teach*. Bloom et al. (1984) note that no *-ing* complements were produced by any of the children they looked at. This suggests acquisition of *-ing* complements occurs after three years of age.

Bloom, Rispoli, Gartner and Hafitz (1989) examined the naturalistic productions from these same children for evidence of productive use of (1) "S-complements" (including both non-finite *-ing* clauses such as *I see Mommy wash(ing) her hands* and finite *-that* clauses such as *I see that Mommy is washing her hands*, and (2) *wh*-complements, such as *I know what the little bear's eating*. They found that *think* and *see* were produced with S-complements while *know* and *see* were produced with *wh*-complements. However, their evidence did not indicate that these children

realized there was a general rule or class of such verbs. Instead, it seemed “children learned this for each matrix verb separately”. This suggests that verb classes involving S-complements and *wh*-complements (i.e., interrogative clauses, which would include *whether/if* clauses) aren’t formed till after three years of age.

Diessel & Tomasello 2001. Diessel and Tomasello (2001) conducted a corpus analysis of seven English-speaking children’s spontaneous speech between the ages of 1;2 and 5;2. They identified seven verbs taking an *if*-complement: *see* (69/98), *tell* (14/98), *wonder*, *ask*, *care*, *know*, *happen* (15/98). This suggests that by five, children have clustered together *see* and *tell*, and may have also clustered together *ask*, *care*, *happen*, *know*, and *wonder*.

Papafragou et al. 2007. Papafragou, Cassidy and Gleitman (2007) investigated the cues children (and adults) use to identify the meaning of a verb, including the syntactic cue of taking a tensed clausal complement introduced by complementizer *that* (e.g., *Matt gorps that his grandmother is under the covers.*). When eliciting guesses about verb meaning from 34 children ages 3;7-5;9, they found that this syntactic frame increased the chances of children guessing belief verbs. In particular, children’s guesses included these verbs: *be surprised*, *dream*, *fall for*, *guess*, *know*, *lie*, *pretend*, *think*, *trick*. This suggests that by four to five, children are forming classes of verbs that allow a tensed sentential complement (specifically here, the belief verb class).

Kidd et al. 2006, 2010. Kidd, Lieven and Tomasello (2006) conducted a sentence recall/lexical priming study on three-, four-, and five-year-olds involving both high and low frequency verbs that take finite complements (e.g., *think*: “*I think she is riding away on the horse.*”)¹. Interestingly, children often made substitutions with different verbs, instead of repeating the verbs previously presented to them. Three-year-olds substituted in these verbs more than once: *think* (179/266), *bet* (34/266), *hope* (24/266), *see* (11/266), *know* (9/266), *say* (4/266), and *hear* (4/266). Four- and five-year-olds substituted in the same verbs, though with higher incidences for some lower frequency verbs (*know*, *say*) than the three-year-olds. This suggests that by age three, children may have clustered together these *that*-complement taking verbs: *bet*, *hear*, *hope*, *know*, *say*, *see*, *think*.

Kidd, Lieven and Tomasello (2010) conducted a similar sentence recall/lexical priming study on four- and six-year-olds involving both high and low frequency verbs that take finite complements (e.g., *say*: “*Mickey says that Minnie is wearing a lovely dress.*”). Again, children often made substitutions with different verbs, instead of repeating the verbs previously presented to them. Four-year-olds substituted in *think* nearly 88% of the time (126/143), and used *get* (1/143), *see* (3/143), *tell* (3/143), and *wish* (6/143) for the remaining 12%. Six-year-olds substituted *think* nearly 75% of the time (102/135), and used *find* (2/135), *laugh* (1/135), *like* (2/135), *persuade* (1/135), *reckon* (13/135), *see* (5/135), *tell* (1/135), and *wish* (1/135) for the remaining 25%. If we assume that any verb substituted in more than once is reliably affiliated with the class of complementizer-*that* verbs, we have the following clusters: at four, children have clustered together *see*, *tell*, *think*, and *wish*; at six, they have additionally clustered in *find*, *like*, and *reckon*.

¹Note that the primes didn’t involve complementizer *that* even though the verbs could all allow it. That is, all the verbs belonged to the class that optionally allows complementizer *that*.

A.2 Verb classes derived from behavioral data

This is a synthesis of the 33 behavioral studies describing the behavior of specific verbs at specific ages. We note that the earliest age of acquisition documented was used for the verb behavior associated with a specific verb.

A.2.1 Passivizable.

By age three, children should cluster together these: *bleed, carry, chase, crash, drop, eat, hit, hold, hug, hurt, kick, kiss, knock, lick, like, marry, punch, pick up, push, scratch, see, shake, trip up, turn (over), wash, watch* (Gordon and Chafetz 1990: short and long passives, O'Brien et al. 2006: pragmatically felicitous long passives, Nguyen et al. 2016: short passives; Hirsch and Wexler 2007, Crain et al. 2009: long passives). Moreover, they should keep them separate from these: *believe, forget, hate, hear, ignore, know, love, remember* (Gordon and Chafetz 1990: short and long passives; Messenger et al. 2009: long passives).

By age four, children should additionally cluster in these: *annoy, bite, bump, find, frighten, jump, kill, pat, pull, ride, scare, shock, shoot, squash, surprise, upset* (Maratsos 1974: long passives, Maratsos et al. 1985: long passives, Messenger et al. 2009: long passives, Crain et al. 2009: long passives).

By age five, children should additionally include these: *love* (Maratsos et al. 1985: long passives).

By age seven, children should additionally include these: *hate, remember* (Hirsch and Wexler 2007: long passives).

A.2.2 Unaccusative.

By two, children have recognized that these verbs can be used unaccusatively and so should be clustered together: *break, come, fall, go, grow, leave* (Déprez and Pierce 1993, Snyder and Stromswold 1997: naturalistic production).

A.2.3 Control object and raising object.

The study by Kirby (2009b) suggests that children should group *want* and *need* together (raising object), and cluster together *ask* and *tell* (control object) separately by age four.

A.2.4 Control subject and raising subject.

Studies by Becker suggest that children should group *want* and *try* (control subject) together, and separate them from *seem* and *appear* (raising subject), by either four years old (Becker, 2007, 2009) or five years old (Becker, 2006).

A.2.5 Subject-experiencer and object-experiencer.

By age four, children have grouped these high-frequency subject-experiencer verbs together: *like*, *love*, *hate* (Hartshorne et al. 2015: truth-value judgment task). They have also grouped together several object-experiencer verbs (*frighten*, *scare*, *surprise*) with lower-frequency subject-experiencer verbs (*fear*, *trust*) (Hartshorne et al. 2015: truth-value judgment task).

A.2.6 Complements: *to*, *that*, *whether*.

***to*-complement.** By age three, children have likely clustered together these verbs that can take a non-finite *to* complement: *ask*, *forget*, *get*, *go*, *have*, *know*, *like*, *need*, *show*, *start*, *suppose*, *teach*, *tell*, *try*, *use*, *want*. A subset of these may be in a separable “how to” instructive context class: *know*, *show*, *teach* (Bloom et al. 1984: corpus analysis of naturalistic productions).

***that*-complement.** By age three, children have likely clustered together these verbs that optionally take a *that*-complement: *bet*, *hear*, *hope*, *know*, *say*, *see*, *think* (Kidd et al. 2006: sentence recall/lexical priming substitution). By age four, children have likely clustered together these verbs as well: *tell*, *wish* (Kidd et al. 2010: sentence recall/lexical priming substitution). By age five, children have likely grouped in these belief verbs together that take a sentential complement introduced by complementizer *that*: *be surprised*, *dream*, *fall for*, *guess*, *lie*, *pretend*, *trick* (Papafragou et al. 2007: elicited verbs). By age six, they have additionally clustered in *find*, *like*, and *reckon* (Kidd et al. 2010: sentence recall/lexical priming substitution).

***whether/if*-complement.** By age five, children have clustered together these verbs that allow *if*-complements: *see* and *tell*. They may have also clustered together *ask*, *care*, *happen*, *know*, and *wonder* (Diessel and Tomasello 2001: spontaneous speech productions).

B Verb classes derived from child behavioral data

Table 1: Attested verb behaviors and verb classes derived from child behavioral data for verbs in the <3yrs dataset appearing 5 or more times.

Verb behavior	Attested verbs
Unaccusative	6: break, come, fall, go, grow, leave
Ditransitive	14: bring, buy, get, give, make, pass, pour, read, say, send, show, tell, throw, write
Non-finite <i>to</i> complement	16: ask, forget, get, go, have, know, like, need, show, start, suppose, teach, tell, try, use, want
Passivizable	27: +: carry, chase, crash, drop, eat, hit, hold, hurt, jump, kick, kiss, knock, lick, like, punch, push, scratch, see, shake, turn, wash, watch –: believe, forget, hear, know, remember
<i>that</i>-complement	9: bet, hear, hope, know, say, see, tell, think, wish
Verb classes	15 classes, 60 verbs
[+unaccusative]	5: break, come, fall, grow, leave
[+ditrans]	10: bring, buy, give, make, pass, pour, read, send, throw, write
[+non-finite <i>to</i>]	9: ask, have, need, start, suppose, teach, try, use, want
[+passive]	20: carry, chase, crash, drop, eat, hit, hold, hurt, jump, kick, kiss, knock, lick, punch, push, scratch, shake, turn, wash, watch
[-passive]	2: believe, remember
[+ <i>that</i> -comp]	4: bet, hope, think, wish
[+unaccusative, +non-finite <i>to</i>]	1: go
[+ditrans, +non-finite <i>to</i>]	2: get, show
[+ditrans, + <i>that</i> -comp]	1: say
[+ditrans, +non-finite <i>to</i>]	1: tell
[+passive, +non-finite <i>to</i>]	1: like
[+passive, + <i>that</i> -comp]	1: see
[-passive, +non-finite <i>to</i>]	1: forget
[-passive, + <i>that</i> -comp]	1: hear
[-passive, + <i>that</i> -comp, +non-finite <i>to</i>]	1: know

Table 2: Attested verb behaviors and verb classes derived from child behavioral data for verbs in the <4yrs dataset appearing 5 or more times.

Verb behavior	Attested verbs
Unaccusative	6: break, come, fall, go, grow, leave
Ditransitive	21: bake, bring, buy, draw, eat, feed, get, give, keep, make, pass, pour, read, say, send serve, show, teach, tell, throw, write
Non-finite <i>to</i> complement	16: ask, forget, get, go, have, know, like, need, show, start, suppose, teach, tell, try, use, want
Passivizable	38: +: bite, bump, carry, chase, crash, drop, eat, find, frighten, hit, hold, hurt, jump, kick, kill, kiss, knock, lick, like, pull, punch, push, ride, scare, scratch, see, shake, shoot, surprise, turn, wash, watch –: believe, forget, hear, know, love, remember
<i>that</i>-complement	9: bet, hear, hope, know, say, see, tell, think, wish
Control object	2: ask, tell
Control subject	2: try, want
Psych: Obj Exp	3: frighten, scare, surprise
Psych: Subj Exp	2: frighten, like, love
Raising object	2: need, want
Raising subject	1: seem
Verb classes	23 classes, 76 verbs
[+unaccusative]	5: break, come, fall, grow, leave
[+ditrans]	15: bake, bring, buy, draw, feed, give, keep, make, pass, pour, read, send, serve, throw, write
[+non-finite <i>to</i>]	4: have, start, suppose, use
[+passive]	26: bite, bump, carry, chase, crash, drop, find, hit, hold, hurt, jump, kick, kill, kiss, knock, lick, pull, punch, push, ride, scratch, shake, shoot, turn, wash, watch
[-passive]	2: believe, remember
[+ <i>that</i> -comp]	4: bet, hope, think, wish
[+raising-subj]	1: seem
[+unaccusative, +non-finite <i>to</i>]	1: go
[+ditrans, +non-finite <i>to</i>]	3: get, show, teach
[+ditrans, +passive]	1: eat
[+ditrans, + <i>that</i> -comp]	1: say
[+ditrans, + <i>that</i> -comp, +non-finite <i>to</i> , +control-obj]	1: tell
[+non-finite <i>to</i> , +control-obj]	1: ask
[+non-finite <i>to</i> , +control-subj]	1: try
[+non-finite <i>to</i> , +raising-obj]	1: need
[+non-finite <i>to</i> , +raising-obj, +control-subj]	1: want
[+passive, +non-finite <i>to</i> , +psych-subj]	1: like
[+passive, + <i>that</i> -comp]	1: see
[+passive, +psych-obj]	2: scare, surprise
[-passive, +non-finite <i>to</i>]	1: forget
[-passive, + <i>that</i> -comp]	1: hear
[-passive, + <i>that</i> -comp, +non-finite <i>to</i>]	1: know
[-passive, +psych-subj]	1: love

Table 3: Attested verb behaviors and verb classes derived from child behavioral data for verbs in the <5yrs dataset appearing 5 or more times.

Verb behavior	Attested verbs
Unaccusative	6: break, come, fall, go, grow, leave
Ditransitive	23: ask, bake, bring, buy, draw, eat, feed, finish, get, give, keep, make, pass, pour, read, say, send, serve, show, teach, tell, throw, write
Non-finite <i>to</i> complement	16: ask, forget, get, go, have, know, like, need, show, start, suppose, teach, tell, try, use, want
Passivizable	38: +: bite, bump, carry, chase, crash, drop, eat, find, frighten, hit, hold, hurt, jump, kick, kill, kiss, knock, lick, like, love, pull, punch, push, ride, scare, scratch, see, shake, shoot, surprise, turn, wash, watch -: believe, forget, hear, know, remember
<i>that</i>-complement	13: bet, dream, guess, hear, hope, know, lie, pretend, say, see, tell, think, wish
Control object	2: ask, tell
Control subject	2: try, want
Psych: Obj Exp	3: frighten, scare, surprise
Psych: Subj Exp	2: frighten, like, love
Raising object	2: need, want
Raising subject	1: seem
<i>whether/if</i>-complement	7: ask, care, happen, know, see, tell, wonder
Verb classes	25 classes, 84 verbs
[+unaccusative]	5: break, come, fall, grow, leave
[+ditrans]	16: bake, bring, buy, draw, feed, finish, give, keep, make, pass, pour, read, send, serve, throw, write
[+non-finite <i>to</i>]	4: have, start, suppose, use
[+passive]	25: bite, bump, carry, chase, crash, drop, find, hit, hold, hurt, jump, kick, kill, kiss, knock, lick, pull, push, ride, scratch, shake, shoot, turn, wash, watch
[-passive]	2: believe, remember
[+ <i>that</i> -comp]	8: bet, dream, guess, hope, lie, pretend, think, wish
[+raising-subj]	1: seem
[+ <i>whether/if</i> -comp]	3: care, happen, wonder
[+unaccusative, +non-finite <i>to</i>]	1: go
[+ditrans, +non-finite <i>to</i>]	3: get, show, teach
[+ditrans, +passive]	1: eat
[+ditrans, + <i>that</i> -comp]	1: say
[+ditrans, + <i>that</i> -comp, +non-finite <i>to</i> , +control-obj, + <i>whether-if</i> -comp]	1: tell
[+ditrans, +non-finite <i>to</i> , +control-obj, + <i>whether-if</i> -comp]	1: ask
[+non-finite <i>to</i> , +control-subj]	1: try
[+non-finite <i>to</i> , +raising-obj]	1: need
[+non-finite <i>to</i> , +raising-obj, +control-subj]	1: want
[+passive, +non-finite <i>to</i> , +psych-subj]	1: like
[+passive, + <i>that</i> -comp, + <i>whether-if</i> -comp]	1: see
[+passive, +psych-obj]	2: scare, surprise
[+passive, +psych-obj]	1: love
[-passive, +non-finite <i>to</i>]	1: forget
[-passive, +non-finite <i>to</i> , + <i>that</i> -comp, + <i>whether-if</i> -comp]	1: know
[-passive, + <i>that</i> -comp]	1: hear
[-passive, +psych-subj]	1: love

C Gibbs sampling in the generative model

The plate diagram for the generative model is presented here again for ease of reference, and Table 4 describes the variables in the plate diagram. Gibbs sampling is done following the process laid out in the plate diagram and described in more detail in the rest of this appendix. Depending on the modeled learner, between 2000 and 4000 iterations of Gibbs sampling were run, with each iteration involving the sampling of all classes, class properties, and hyperparameters, as described below. The number of iterations was determined by doing several sample runs across a range of iteration counts for each intake set, and seeing which one performed best according to the learner’s log probability of the intake data. The iteration counts used for the results reported in the main text are as follows:

(i) <3yrs:

+morphology: UTAH (3000), rUTAH (3000), absolute-no-mapping (2000), relative-no-mapping (2000)

-morphology: UTAH (3000), rUTAH (3000), absolute-no-mapping (3000), relative-no-mapping (4000)

(ii) <4yrs:

+morphology: UTAH (2000), rUTAH (2000), absolute-no-mapping (3000), relative-no-mapping (2000)

-morphology: UTAH (2000), rUTAH (4000), absolute-no-mapping (2000), relative-no-mapping (2000)

(iii) <5yrs:

+morphology: UTAH (3000), rUTAH (2000), absolute-no-mapping (2000), relative-no-mapping (3000)

-morphology: UTAH (3000), rUTAH (2000), absolute-no-mapping (4000), relative-no-mapping (2000)

Figure 1: Plate diagram for the generative model of verb classes.

Variable	Interpretation
V	total number of verbs
F_j	total frames for verb j
F_{ji}	frequency of frame i for verb j
C	number of classes
c_j	class of verb j
θ_c	distribution over class labels
γ_c	hyperparameter (pseudocounts) for class labels
B	number of binary (binomial distribution) properties being tracked ex: +anim-subj, +anim-obj, +anim-iobj, +mvmt = 4
$\pi_{\phi c_j}$	distribution over binary property ϕ for class c_j ex: +anim-subj, +anim-obj, +anim-iobj, +mvmt
$\beta_{\phi_1}, \beta_{\phi_0}$	hyperparameters for Beta distribution prior for property ϕ
M	number of multinomial properties tracked ex: syntactic frames, thematic-subj distr, thematic-obj distr, thematic-iobj distr = 4
$\theta_{\psi c_j}$	distribution over multinomial property ψ for class c_j ex: syntactic frames, thematic-subj distr, thematic-obj distr, thematic-iobj distr
α_{ψ}	hyperparameter for Dirichlet distribution prior for property ψ

Table 4: Variables used in the plate diagram for the generative model and in the details of the Gibbs sampling process.

C.1 How Gibbs sampling works

The general form of the sampler for a situation where outcome x_i takes value k , given previous outcomes $x_{-i} = (x_1, \dots, x_{i-1})$, and hyperparameter/pseudocount β for all K possible outcomes and multinomial distribution θ is:

$$P(k|x_{-i}, \beta) = \int P(k|\theta)P(\theta|x_{-i}, \beta)d\theta = \frac{n_k + \beta}{i - 1 + K\beta} \quad (1)$$

according to the derivation in Goldwater and Griffiths (2007), who refer to the derivation in MacKay and Peto (1995), where n_k is the number of times k occurred in x_{-i} .

This is the basis that we can use to do the sampling for all categorical and binary variables that correspond to a single frame instance (ex: verb classes, +animate-subject, etc). The basic sampling process involves removing the information of the current item being considered, and then calculating the sampling probabilities as directed. Once sampling is complete and the item's information is updated, we add the new information back in. See Resnik and Hardisty (2010) for an excellent tutorial about Gibbs sampling.

C.2 Probability of the category label for a given verb

For all currently existing categories c_j in C and the possibility γ_c of creating a new category, calculate

$$p_{cat_j} = P(c_j | c_{-j}, \gamma_c) = \frac{n_{c_j} + \gamma_c}{n_{all} + C\gamma_c} \quad (2)$$

where n_{c_j} is the number of verbs with category c_j (excluding the verb whose class is currently being sampled (c_{-j})), n_{all} is the total number of verbs excluding the one being sampled, and C is the total number of classes currently. So, the equivalent for the possibility of creating a new category would be

$$P(c_{new} | c_{-j}, \gamma_c) = \frac{\gamma_c}{n_{all} + C\gamma_c} \quad (3)$$

These should then all sum to 1.

Note: When generating a random assignment of verbs to classes, use the above process to generate a class for each verb. That is, for each verb, generate a class (either an existing one or a new one) according to the probability above. In the results reported in the main text for the randomization tests, we use the default value $\gamma_c=1$ for this random generation process, which is the value all modeled learners were initialized with.

C.3 Sampling binary properties

These will include +anim-subj, +anim-obj, and +anim-iobj for all model types. For the model assuming the mapping is already known, +mvmt would indicate whether the observed syntactic positions obey r/UTAH transparently or have moved. All of these apply to the probability of an individual frame f_{ji} appearing with the property within a given verb class c_j for a verb v_j , with $F_{c_{-j}}$ referring to all the frames in class c_j except for the ones from v_j . These properties are represented by π_{ϕ_c} in the plate diagram.

$$p_{\phi_{i,c_j}} = P(f_{ji} | c_j, c_{-j}, F_{c_{-j}}, \pi_{\phi_{c_j}}, \beta_{\phi_1}, \beta_{\phi_0}) = \frac{n_{\phi_{c_j}} + \beta_{\phi_1}}{n_{all_{c_j}} + \beta_{\phi_1} + \beta_{\phi_0}} \quad (4)$$

where $n_{\phi_{c_j}}$ is the number of frames in category c_j that have the property, $n_{all_{c_j}}$ is all the frames in c_j , β_{ϕ_1} is the pseudocount for frames exhibiting the property, and β_{ϕ_0} is the pseudocount for frames not exhibiting the property.

The probability for the entire set of frames F_j is the product of each individual frame token's probability. We can use each individual frame's frequency F_{ji} to calculate this, assuming π_{ϕ} captures the complete distribution (both ϕ_1 and ϕ_0 probabilities) for property ϕ :

$$p_{\phi_{c_j}} = \prod_i p_{\phi_{i,c_j}}^{F_{ji}} \quad (5)$$

for all i frame types in verb v_j . In particular, if the frame f_{ji} has the property and appears F_{ji} times, its contribution is $p_{\phi_{i,c_j}}^{F_{ji}}$; if frame f_{ji} doesn't have the property and appears F_{ji} times, its contribution is $(1 - p_{\phi_{i,c_j}})^{F_{ji}}$.

The joint probability of all B binary properties is the product of p_{ϕ_c} for all binary properties ϕ :

$$p_{binary_{c_j}} = \prod_{\phi=1}^B p_{\phi_{c_j}} \quad (6)$$

C.4 Sampling multinomial properties

This works similarly to the sampling of binary properties – it's just that there are more than two options available. This would apply for the -expect-mapping modeled learner that infers the thematic-syntactic mappings for each verb class. Each underlying intermediate representation's thematic role (e.g., absolute: AGENT-like or thematic: HIGHEST) would map with some probability to a syntactic position (*subject*, *object*, *oblique (indirect) object*). So, there would be three probabilities for semantic arguments: $p_{subj-pos}$, $p_{obj-pos}$, and $p_{obj-pos}$. Each of these has three options of where to appear: syntactic *subject*, syntactic *object*, or syntactic *oblique object*. The probabilities of appearing in those positions are a multinomial distribution.

Syntactic frames are another example that applies to all modeled learners, as a frame can be one of the F frame types available.

This property would be captured by the θ_{ψ_c} in the plate diagram.

$$p_{\psi_{i,c_j}} = P(f_{ji}|c_j, c_{-j}, F_{c_{-j}}, \theta_{\psi_{c_j}}, \alpha_{\psi}) = \frac{n_{\psi_{c_j}} + \alpha_{\psi}}{n_{all_{c_j}} + O * \alpha_{\psi}} \quad (7)$$

where f_{ji} is the i th frame token in the total frames F_j for verb v_j , c_j is the category of v_j , $\theta_{\psi_{c_j}}$ is the distribution over the O options, α_{ψ} is the pseudocount for all options, $n_{\psi_{c_j}}$ is the number of frames in class c_j that have this value, $n_{all_{c_j}}$ is all the frames in class c_j that exhibit any of the values, and O is the number of options of available (e.g., number of syntactic frame types or number of syntactic positions.).

The probability for the entire set of frames F_j is the product of each individual frame token's probability. We can use each individual frame's frequency F_{ji} to calculate this, assuming θ_{ψ} captures the complete distribution for property ψ :

$$p_{\psi_{c_j}} = \prod_i p_{\psi_{i,c_j}}^{F_{ji}} \quad (8)$$

for all i frames in verb v_j .

The joint probability of all M multinomial properties is the product of p_{ψ_c} for all multinomial properties ψ :

$$p_{multinomial_{c_j}} = \prod_{\psi=1}^M p_{\psi_{c_j}} \quad (9)$$

C.5 Complete sampling equation for new verb class for verb

Let λ be the set of hyperparameters needed for this calculation, including the hyperparameters for category selection, binary properties, and multinomial properties. The complete equation for selecting a new verb class is:

$$p_{c_j} = P(c_j | c_{-j}, \gamma_c, F_{-j}, \lambda) = \\ p_{cat_j} * p_{binary_{c_j}} * p_{multinomial_{c_j}}$$

Adjust these probabilities with an annealing temperature if desired (see section C.7 on annealing below), and then roll a C+1 sided die weighted according to the calculated probabilities. Then, select the category label that comes up.

C.6 Hyperparameter sampling

We follow the approach in Goldwater and Griffiths (2007) to sample hyperparameters. In particular, there are priors over each of the hyperparameters (we can assume an improper uniform prior), and use a single Metropolis-Hastings update (Gilks, Richardson and Spiegelhalter, 1996) to resample the value of each hyperparameter after each iteration of the Gibbs sampler through all individual verbs.

To update the value of hyper parameter κ , we can sample a proposed new value κ' from a normal distribution with $\mu = \kappa$ and $\sigma = .1\kappa$. Then, we calculate the probability of the data (all verbs), given κ vs. given κ' .

C.6.1 Verb category hyperparameter γ_c

Let V be the the total number of observed verb types with their collection of observed frames, C be the current verb classes, and $\lambda_{-\gamma}$ be the set of hyperparameters except for γ_c . The current hyperparameter value is γ_c while the proposed one would be γ'_c . However, for purposes of the calculation (which we'll have to do for both), we can represent both of them below as γ .

$$p(C|V, \lambda_{-\gamma}, \gamma) = \frac{p(V|C, \lambda_{-\gamma}, \gamma) * p(C|\gamma)}{P(V, \lambda_{-\gamma}, \gamma)} \\ \propto p(V|C, \lambda_{-\gamma}, \gamma) * p(C|\gamma)$$

We can disregard the denominator since we're just comparing these two values for γ_c and γ'_c , and they'll have the same denominator.

Let's look at each term in turn.

$$p(V|C, \lambda_{-\gamma}, \gamma) = \prod_{j=1}^V p_{binary_{c_j}} * p_{multinomial_{c_j}}$$

Note that none of these terms depend on γ – so these will be the same for both γ calculations. (Effectively, this term is a constant, and all the action happens in $p(C|\gamma)$.)

$$\begin{aligned} p(C|\gamma) &= \prod_{i=1}^C p_{cat_i} \\ &= \prod_{i=1}^C \frac{n_{c_i} + \gamma}{V + C * \gamma} \end{aligned}$$

where n_{c_i} is the number of verbs in class i and V is the total number of verbs.

C.6.2 Binomial property hyperparameters $\beta_{\phi_1}, \beta_{\phi_0}$

Let V be the the total number of observed verb types with their collection of observed frames, C be the current verb classes, and $\lambda_{-\beta}$ be the set of hyperparameters except for the one β value being sampled. The current hyperparameter value is β_{ϕ_x} while the proposed one would be β'_{ϕ_x} . However, for purposes of the calculation (which we'll have to do for both), we can represent both of them below as β .

$$\begin{aligned} p(C|V, \lambda_{-\beta}, \beta) &= \frac{p(V|C, \lambda_{-\beta}, \beta) * p(C|\gamma)}{P(V, \lambda_{-\beta}, \beta)} \\ &\propto p(V|C, \lambda_{-\beta}, \beta) * p(C|\gamma) \end{aligned}$$

(We can disregard the denominator since we're just comparing these two values for β_{ϕ_x} and β'_{ϕ_x} , and they'll have the same denominator.)

Let's look at each term in turn.

$$p(V|C, \lambda_{-\beta}, \beta) = \prod_{j=1}^V p_{binary_{c_j}} * p_{multinomial_{c_j}}$$

Since $p_{multinomial_{c_j}}$ doesn't depend on β , it's a constant for both β calculations. For $p_{binary_{c_j}}$, only the calculation for binary property ϕ will be affected by this β calculation – all the other binary properties will have different β_{ϕ} s that will remain constant for this β calculation. So, the calculation for $p_{\phi_{i,c_j}}$ is the one we pay attention to, calculating that for each verb in V and taking the product:

$$\begin{aligned} p(V|C, \lambda_{-\beta}, \beta) &= \prod_{j=1}^V p_{\phi_{i,c_j}} \\ &= \prod_{j=1}^V \prod_{i=1}^{F_j} p_{\phi_{i,c_j}}^{F_{ji}} \end{aligned}$$

where F_j is the number of frame types in verb v_j , F_{ji} is the frequency of the frame type i displaying a value of the desired property in class c_j , and p_{ϕ_i, c_j} is the distribution over the two options (so that the appropriate probability is used depending on which value the frame displays):

$$p_{\phi_i, c_j} = \frac{n_{\phi_{c_j}} + \beta}{F + \beta + \beta_{other}}$$

where $n_{\phi_{c_j}}$ is the number of frames in class c_j that have the appropriate property value for the β being calculated, F is the total number of frames in class c_j , and β_{other} is the β not being sampled.

$$p(C|\gamma) = \prod_{i=1}^C p_{cat_i}$$

Note that p_{cat_i} doesn't depend on β – so these will be the same for both β calculations. (Effectively, this term is a constant, and all the action happens above in $p(V|C, \lambda_{-\beta}, \beta)$.)

C.6.3 Multinomial property hyperparameters α_ψ

This process is going to be very similar to the binary hyperparameter sampling above.

Let V be the total number of observed verb types with their collection of observed frames, C be the current verb classes, and $\lambda_{-\alpha}$ be the set of hyperparameters except for the α value being sampled. The current hyperparameter value is α_ψ while the proposed one would be α'_ψ . However, for purposes of the calculation (which we'll have to do for both), we can represent both of them below as α .

$$\begin{aligned} p(C|V, \lambda_{-\alpha}, \alpha) &= \frac{p(V|C, \lambda_{-\alpha}, \alpha) * p(C|\gamma)}{P(V, \lambda_{-\alpha}, \alpha)} \\ &\propto p(V|C, \lambda_{-\alpha}, \alpha) * p(C|\gamma) \end{aligned}$$

(We can disregard the denominator since we're just comparing these two values for α_ψ and α'_ψ , and they'll have the same denominator.)

Let's look at each term in turn.

$$p(V|C, \lambda_{-\alpha}, \alpha) = \prod_{j=1}^V p_{binary_{c_j}} * p_{multinomial_{c_j}}$$

Since $p_{binary_{c_j}}$ doesn't depend on α , it's a constant for both α calculations. For $p_{multinomial_{c_j}}$, only the calculation for multinomial property ψ will be affected by this α calculation – all the other multinomial properties will have different α_ψ s that will remain constant for this α calculation. So, the calculation for p_{ψ_i, c_j} is the one we pay attention to, calculating that for each verb in V and taking the product:

$$\begin{aligned}
p(V|C, \lambda_{-\alpha}, \alpha) &= \prod_{j=1}^V p_{\psi_i, c_j} \\
&= \prod_{j=1}^V \prod_{i=1}^{F_j} p_{\psi_i, c_j}^{F_{ji}}
\end{aligned}$$

where F_j is the number of frame types in verb v_j , F_{ji} is the frequency of the frame type i displaying a value of the desired property in class c_j , and p_{ψ_i, c_j} is the distribution over the various options (so that the appropriate probability is used depending on which value the frame displays):

$$p_{\psi_i, c_j} = \frac{n_{\psi_{c_j}} + \alpha}{F + O * \alpha}$$

where $n_{\psi_{c_j}}$ is the number of frames in class c_j that have the appropriate property value for the α being calculated, F is the total number of frames in class c_j , and O is the number of multinomial options there are for this property.

$$p(C|\gamma) = \prod_{i=1}^C p_{cat_i}$$

As with the binary properties, p_{cat_i} doesn't depend on α – so these will be the same for both α calculations. (Effectively, this term is a constant, and all the action happens above in $p(V|C, \lambda_{-\alpha}, \alpha)$.)

C.6.4 Metropolis-Hastings update

We can now do the Metropolis-Hastings update: the probability of accepting the new value depends on the ratio between $p(C | V, \lambda_{-\kappa}, \kappa)$ and $p(C | V, \lambda_{-\kappa}, \kappa')$, with a term correcting for the asymmetric proposal distribution.

1. Calculate a_1 :

$$a_1 = \frac{p(C|V, \lambda_{-\kappa}, \kappa)}{p(C|V, \lambda_{-\kappa}, \kappa')} \quad (10)$$

2. Calculate a_2 :

$$a_2 = \frac{p(\kappa|\kappa')}{p(\kappa'|\kappa)} \quad (11)$$

where $p(\kappa|\kappa')$ is the probability of drawing κ from a normal distribution with $\mu = \kappa'$ and $\sigma = .1\kappa'$, while $p(\kappa'|\kappa)$ is the probability of drawing κ' from a normal distribution with $\mu = \kappa$ and $\sigma = .1\kappa$.

3. Calculate $a = a_1 a_2$.

If $a \geq 1$, accept κ' .

Otherwise, flip a weighted coin (and we can anneal with temperature T if desired). With probability $\frac{a^T}{a^T + (1-a)^T}$, choose κ' . With probability $\frac{(1-a)^T}{a^T + (1-a)^T}$, keep the original κ . If no annealing (or $T=1$ for that iteration), this defaults to probability a and $1 - a$ for the two options.

C.7 Annealing

To help the Gibbs sampler converge faster, a simulated annealing regime is typically used (e.g., in Goldwater & Griffiths 2007) to force more exploration early on by flattening the probabilities and less exploration later on by sharpening the probabilities. The way this is done is by raising the calculated probability to a power (which is the *temperature* T).

$$\text{annealed probability} = \text{probability}^T \quad (12)$$

As the Gibbs sampler does more iterations, the temperature T lowers so the calculated probabilities are sharpened. (Basically, the sampler is more confident about its calculated probabilities later on in learning.) We follow Goldwater and Griffiths (2007) and use a range of $T = 2$ lowered down to 0.8 over the course of all iterations.

D Filtered verb classes

Tables 5-10 show the filtered verb classifications for each strategy implemented by a computational-level Bayesian learner. Each modeled learner ran 10 times for each dataset (<3yrs, <4yrs, <5yrs), and these ten verb clusterings were aggregated into an aggregate verb clustering for each learner. Any verb pair together in more than $\frac{3}{4}$ of the learner runs (>7 out of 10) was put together in the aggregate verb clustering. Similarly, any verb that was in a class of its own (a *singleton*) for more than $\frac{3}{4}$ of the learner runs was put as a singleton in the aggregate verb clustering.

Table 5: <3yrs dataset: Aggregate inferred classes over 10 runs, given 4 strategies that involve the use of surface morphology (+surface-morphology), an intermediate representation (absolute/relative), and an expectation of a mapping between the intermediate representation and observable syntactic positions (+/-expect-mapping).

		+surface-morphology	
+expect-mapping	absolute	+expect-mapping	relative
<i>singletons: begin, confuse, dress, figure, fill, fold, give, happen, knock, lean, mix, name, pick, plug, rain, roll, seem, send, teach, tell, tip, wait, wake, wonder</i>	<i>singletons: begin, confuse, dress, figure, fill, hurry, rain, seem, tip, wait, wonder</i>	<i>singletons: begin, confuse, dress, figure, fill, fold, knock, lean, mix, name, pick, plug, rain, seem, send, teach, tell, tip, wait, wake, wonder</i>	<i>singletons: begin, confuse, dress, figure, fill, knock, plug, rain, seem, tip, wait, wonder</i>
1: answer, beat, bet, bite, blow, bother, break, bring, brush, build, burn, buy, carry, catch, change, chase, check, chew, chop, clean, close, color, count, cover, crack, cut, decide, do, draw, drink, dry, dump, eat, feel, find, finish, fix, forget, get, have, hear, help, hold, hook, hope, hurt, keep, kick, kiss, know, leave, lose, love, make, match, mean, meet, mind, miss, move, open, paint, pinch, pour, pull, push, reach, read, recognize, record, remember, rock, roll, save, say, scare, see, shake, share, shave, shut, sing, snap, spell, spill, spray, squeeze, stick, stir, stop, study, suppose, swing, tape, tease, test, tickle, touch, understand, use, watch, wear, wipe, use, wash, watch, wear, wipe, wish	1: answer, beat, bite, blow, bother, bring, brush, build, bump, buy, catch, change, chase, check, clean, close, color, cool, count, crack, cut, decide, do, draw, drink, drop, dry, eat, feel, find, finish, fix, forget, get, have, hear, help, hold, hurt, keep, kick, know, leave, lose, love, make, mean, mind, miss, move, open, paint, pinch, pour, pull, push, reach, read, recognize, record, remember, rock, roll, save, say, scare, see, shake, share, shave, shut, sing, snap, spell, spill, spray, squeeze, stick, stir, stop, study, suppose, swing, tape, tease, test, tickle, touch, understand, use, watch, wear, wipe	1: answer, beat, bet, bite, blow, bother, break, bring, brush, build, burn, buy, carry, catch, change, chase, chop, clean, close, color, count, cover, crack, cut, decide, do, draw, drink, dry, dump, eat, find, finish, fix, forget, guess, have, hear, help, hit, hold, hook, hope, hurt, keep, kick, kiss, know, leave, lose, love, make, match, mean, meet, mind, miss, move, mow, need, open, paint, pass, pinch, pour, pretend, pull, push, put, reach, read, recognize, record, remember, save, say, scare, scratch, see, shake, share, shave, shoot, shut, sing, smack, snap, spell, spill, spray, squeeze, squish, start, stir, stop, study, swing, take, tape, tear, think, throw, tickle, tie, touch, turn, understand, untie, use, wash, watch, wear, wipe, wish	1: answer, beat, bite, blow, bother, break, bring, brush, build, bump, burn, buy, carry, catch, change, chase, check, chew, chop, clean, close, color, cool, count, cover, crack, cut, do, draw, drink, drop, dry, dump, eat, feel, find, finish, fix, forget, get, have, hear, help, hit, hold, hook, hurt, keep, kick, leave, lose, make, match, meet, mind, miss, move, mow, need, open, paint, pass, pinch, poke, pour, pull, push, put, reach, read, recognize, record, save, say, scare, scratch, see, set, shake, share, shave, shoot, shut, sing, smack, smell, snap, spell, spill, spray, squeeze, squish, start, stick, stir, stop, study, suppose, swing, take, tape, tear, test, throw, tickle, tie, touch, turn, untie, use, wash, watch, wear, wipe 2: decide, know, love, mean, remember, understand
2: get, smell, suppose, test		2: get, suppose, test	
3: rock, taste, tease		3: rock, taste	3: rock, tease
4: belong, bob, bounce, care, cook, crawl, cry, dance, drive, fit, fly, grow, hammer, hang, hide, hop, jump, laugh, lay, listen, live, look, peek, play, ride, ring, row, run, sit, sleep, slip, sound, squeak, stand, stay, step, swim, talk, visit, walk, wind, work, write	2: bang, belong, bob, bounce, care, chirp, climb, come, cook, crawl, cry, dance, drive, fall, fit, fly, go, grow, hammer, hang, hide, hop, jump, laugh, lay, let, lie, listen, live, look, peek, peepee, play, point, pop, ride, ring, row, run, sit, sleep, slip, sound, speak, squeak, stand, stay, step, swim, talk, try, walk, whisper, work, write	4: bang, belong, bob, bounce, care, cook, cry, dance, drive, fit, fly, grow, hammer, hang, hop, jump, laugh, lay, lie, listen, live, look, peek, play, point, ride, ring, row, run, set, sit, sleep, slip, sound, stand, stay, step, swim, talk, tease, visit, walk, wind, work, write	4: bang, belong, bounce, care, cook, crawl, drive, fit, fly, grow, hammer, hang, hide, hop, jump, laugh, listen, live, look, peek, play, ride, ring, run, sit, sleep, slip, sound, squeak, stay, step, swim, talk, walk, work, write
5: fall, hurry		5: come, peepee, pop, speak	5: climb, lay, lie, peepee, point, stand
6: bump, call, drop, serve	3: bet, guess, hope, think, wish 4: break, burn, meet, scratch, squish, untie 5: call, serve 6: carry, chew, chop, cover, dump, hit, hook, match, mow, pass, poke, put, shoot, take, tear, throw, tie, turn, wash	6: bump, call, drop, feel, serve	6: bet, guess, hope, pretend, think, wish
7: dig, juggle	7: dig, juggle 8: drip, smile	7: dig, juggle	7: call, serve
8: entertain, excuse, thank	9: entertain, excuse, thank	8: entertain, excuse, thank	8: dig, juggle
9: freeze, smile	10: freeze, melt	9: freeze, smile	9: entertain, excuse, thank
10: learn, worry	11: learn, worry	10: like, want	10: like, want
11: like, want	12: like, want	11: bless, pet, press	11: pet, press
12: bless, pet, press	13: pet, press		
13: cool, set	14: set, start 15: smell, taste		
14: chirp, climb, come, go, let, lie, peepee, point, pop, speak, try, whisper		12: chirp, climb	12: bob, cry, row 13: chirp, come, dance, go, let, pop, speak, try, whisper
15: feed, show		13: go, let, try, whisper 14: feed, show	14: feed, give, offer, show
16: lick, peel		15: lick, peel	15: lick, peel

Table 6: <3yrs dataset: Aggregate inferred classes over 10 runs, given 4 strategies that don't involve the use of surface morphology (-surface-morphology), an intermediate representation (absolute/relative), and an expectation of a mapping between the intermediate representation and observable syntactic positions (+/-expect-mapping).

		-surface-morphology	
+expect-mapping	absolute	+expect-mapping	relative
<i>singletons: begin, figure, hurry, seem, tip</i> 1: answer, ask, bite, bother, bring, brush, build, bump, burn, buy, call, carry, catch, change, chase, check, chop, close, color, count, cover, crack, cut, dig, do, draw, drink, drop, dry, dump, eat, feed, find, finish, fix, fold, get, give, have, hear, hit, hold, hook, juggle, keep, kick, kiss, knock, leave, lose, make, match, miss, mix, move, mow, name, need, offer, open, pass, peel, pet, pick, pinch, plug, poke, pour, press, pull, push, put, reach, read, recognize, record, rock, roll, save, say, scare, scratch, send, serve, shake, share, shoot, show, shut, sign, sing, smack, spell, spill, spray, stir, stop, study, swing, take, taste, teach, tear, tell, test, throw, tickle, tie, touch, turn, untie, visit, wash, watch, wear, wind, wipe	<i>singletons: begin, figure, seem, tip</i> 1: answer, ask, bite, blow, bother, break, bring, brush, build, bump, burn, buy, call, carry, catch, change, chase, check, chop, clean, close, color, count, cover, crack, cut, dig, do, draw, drink, drop, dry, dump, eat, find, finish, fix, fold, get, have, hear, hit, hold, hook, hurt, juggle, keep, kick, kiss, knock, leave, lose, love, make, match, meet, mind, miss, mix, move, mow, need, open, paint, pass, peel, pet, pick, pinch, plug, poke, pour, press, pull, push, put, reach, read, recognize, record, rock, roll, save, say, scare, scratch, see, send, shake, share, shoot, shut, sign, sing, smack, snap, spell, spill, spray, squeeze, squish, stir, stop, study, swing, take, tape, taste, tear, test, throw, tickle, tie, touch, turn, untie, visit, wash, watch, wear, wind, wipe	<i>singletons: begin, figure, seem, tip</i> 1: answer, bite, bother, build, bump, burn, buy, call, carry, catch, change, chase, close, color, count, crack, cut, dig, do, draw, drink, drop, dry, dump, eat, find, finish, fix, get, have, hear, hit, hold, juggle, keep, kick, kiss, leave, lose, make, miss, move, mow, need, open, peel, pet, pinch, poke, press, push, reach, read, recognize, record, rock, say, scare, scratch, send, shake, share, shut, sign, sing, spell, spill, spray, stir, stop, swing, taste, test, tickle, touch, untie, watch, wear, wipe	<i>singletons: begin, figure, seem, tip</i> 1: answer, bite, bring, build, bump, burn, buy, call, carry, catch, change, chase, close, count, crack, cut, dig, do, draw, drink, drop, dry, dump, eat, find, fix, get, have, hear, hit, juggle, kick, kiss, leave, lose, love, make, miss, move, mow, need, open, peel, pet, pinch, poke, pour, press, put, reach, read, recognize, record, save, say, scare, scratch, send, shake, share, shoot, shut, sign, sing, spell, spill, spray, squeeze, stir, swing, take, taste, test, throw, tickle, touch, untie, wash, watch, wear, wipe, 1: ask, feed, give, name, offer, serve, show, smack, teach, tell
2: beat, lick	2: bang, cook, cool, hammer, listen, play, ride, set, write 3: beat, lick	2: ask, beat, blow, bring, check, chew, chop, clean, cover, fold, hook, knock, lick, match, mix, pass, pick, plug, pour, pull, put, roll, save, shoot, slide, smack, take, tear, throw, tie, turn, wash, wind	2: bother, keep, stop
3: bang, belong, climb, come, cook, crawl, feel, fill, grow, hammer, hang, lay, lean, lie, listen, look, peek, play, point, ride, run, set, sit, slide, smell, sound, stand, step, stick, talk, wake, worry, write	4: belong, climb, crawl, dress, fall, feel, fill, grow, hang, jump, lay, lie, look, peek, peepee, point, pop, run, sit, sleep, slip, smell, sound, speak, stand, stay, step, stick, swim, talk, wake, worry	3: bang, belong, bounce, climb, cook, cool, crawl, dress, drive, fall, feel, fill, fit, fly, grow, hammer, hang, jump, lay, lean, lie, listen, look, peek, peepee, play, point, pop, ride, run, set, sit, sleep, slip, smell, sound, speak, stand, stay, step, stick, swim, talk, wake, worry, write	3: bang, cook
4: bet, confuse, guess, hope, pretend, think, wish 5: bless, entertain, excuse, thank 6: blow, chew, clean	5: bet, confuse, guess, hope, pretend, think, wish 6: bless, entertain, excuse, thank	4: bet, confuse, guess, hope, pretend, think, wish 5: bless, entertain, excuse, thank	4: beat, knock 5: belong, bounce, climb, cool, crawl, dress, fall, feel, fill, fit, fly, grow, hammer, hang, hop, jump, lay, lean, lie, listen, look, peek, peepee, play, point, pop, ride, run, set, sit, sleep, slip, smell, sound, speak, stand, stay, step, stick, swim, talk, wake, worry, write
7: bob, bounce, care, chirp, cool, cry, dance, dress, drip, drive, fall, fit, fly, happen, hide, jump, laugh, live, melt, peepee, pop, ring, sleep, slip, speak, squeak, stay, swim, walk, work 8: break, mind, paint, snap, squeeze, squish	7: bob, bounce, care, chirp, cry, dance, drip, drive, fit, fly, happen, hide, laugh, live, melt, ring, smile, squeak, walk, work	6: bob, care, chirp, cry, dance, drip, happen, laugh, live, melt, ring, squeak, walk, work	6: bet, confuse, guess, hope, pretend, think, wish 7: bless, entertain, excuse, thank 8: blow, check, chew, chop, clean, color, cover, fold, hold, hook, lick, match, mix, pass, pick, plug, pull, push, roll, tear, tie, turn, wind 9: bob, care, chirp, cry, dance, drip, happen, laugh, live, melt, ring, squeak, walk, work
9: decide, know, mean, remember, tease, understand, wonder	8: come, learn 9: decide, know, mean, remember, understand, wonder 10: feed, give, name, offer, serve, show, teach, tell 11: forget, like, suppose, use, want	7: break, brush, hurt, meet, mind, see, snap, squeeze, squish, study, tape 8: decide, know, mean, remember, understand, wonder 9: feed, give, name, offer, serve, show, teach, tell 10: forget, go, learn, let, like, start, suppose, try, use, want	10: break, brush, drive, finish, hide, meet, paint, rock, snap, squish, visit 11: decide, hurt, know, mean, mind, remember, see, study, tape, understand, wonder
10: forget, go, help, let, like, start, suppose, try, use, want	12: go, let, start, try	12: manage, shave 13: row, wait 14: freeze, rain	12: forget, go, help, learn, let, like, start, suppose, try, use, want
11: hurt, meet, see, tape 12: manage, smile 13: row, wait 14: freeze, rain	13: manage, shave 14: row, wait	13: row, wait 14: freeze, rain	13: row, wait 14: freeze, rain

Table 7: <4yrs dataset: Aggregate inferred classes over 10 runs, given 4 strategies that involve the use of surface morphology (+surface-morphology), an intermediate representation (absolute/relative), and an expectation of a mapping between the intermediate representation and observable syntactic positions (+/-expect-mapping).

		+surface-morphology	
+expect-mapping	absolute	+expect-mapping	relative
<i>singletons: begin, confuse, dress, figure, land, rain, seem, wonder</i>	<i>singletons: begin, confuse, dress, figure, land, rain, seem, wonder</i>	<i>singletons: begin, confuse, dress, figure, hurry, land, rain, seem, tip, wait, wonder</i>	<i>singletons: begin, confuse, dress, figure, hurry, land, plug, rain, seem, tip, wait, wonder</i>
1: answer, attach, back, bear, believe, bend, bite, blow, bother, break, bring, build, bump, burn, buy, carry, catch, change, chase, check, chew, chop, clean, close, color, count, cover, crack, cross, cut, decide, do, draw, drink, drop, dry, dump, eat, examine, feel, find, finish, fix, fold, forget, get, hang, have, hear, help, hit, hold, hook, hurt, keep, kick, kiss, know, leave, lose, make, match, mean, meet, mind, miss, move, mow, open, paint, park, pinch, poke, pour, press, pretend, pull, push, put, reach, read, recognize, record, remember, roll, save, say, scare, scratch, screw, see, sell, send, set, shake, share, shoot, shut, sing, smack, spell, spill, squish, stir, study, swing, take, tape, tear, thank, throw, tickle, tie, touch, trade, turn, untie, use, visit, wash, wear, wind, wipe	1: answer, back, beat, bend, bite, blow, bother, break, bring, build, bump, burn, buy, carry, catch, change, chase, check, chew, chop, clean, close, color, count, cover, crack, cross, cut, do, draw, drink, drop, dump, eat, fix, hang, hit, hold, hook, kick, kiss, knock, leave, lose, match, miss, move, mow, open, paint, park, pass, pinch, poke, pour, press, pull, punch, push, put, reach, read, record, roll, scare, scratch, screw, sell, set, shake, share, shave, shoot, shut, sing, smack, spell, spill, squish, stir, study, swing, take, tape, tear, thank, throw, tickle, tie, touch, trade, turn, untie, use, visit, wash, wear, wind, wipe	1: answer, attach, bear, believe, bite, bother, break, bring, build, bump, burn, buy, call, catch, change, chase, check, chop, clean, close, count, crack, cross, decide, do, draw, drink, drop, dry, eat, examine, feel, find, finish, fix, forget, get, have, hear, help, hit, hold, hurt, keep, kill, kiss, know, leave, lose, make, mean, meet, mind, miss, move, name, open, paint, park, peel, pinch, pretend, reach, read, recognize, record, remember, save, say, scare, scratch, see, sell, shake, share, shoot, shut, sing, smell, snap, spell, spill, spray, squish, stick, stir, study, suppose, surprise, tape, test, tickle, touch, trade, understand, untie, use, visit, watch, wear, win	1: answer, ask, attach, back, bear, believe, bend, bite, blow, bother, break, bring, build, bump, burn, buy, carry, catch, change, chase, check, chew, chop, clean, close, color, count, cover, crack, cross, cut, decide, do, draw, drink, drop, dry, dump, eat, examine, feed, feel, find, finish, fix, fold, forget, get, give, hang, have, hear, help, hit, hold, hook, hurt, keep, kick, kill, kiss, knock, know, leave, lick, lose, love, make, match, mean, meet, mind, miss, move, mow, need, offer, open, paint, park, pass, peel, pinch, poke, pour, press, pretend, pull, punch, push, put, reach, read, recognize, record, remember, roll, save, say, scare, scratch, screw, see, sell, send, set, shake, share, shave, shoot, show, shut, sing, smack, smell, snap, spell, spill, spray, squish, stick, stir, study, suppose, surprise, swing, take, tape, tear, test, throw, tickle, tie, touch, trade, turn, understand, untie, use, visit, wash, watch, wear, win, wind, wipe, wish
	2: attach, believe, decide, dry, examine, feel, find, finish, forget, get, have, hear, help, hurt, keep, know, make, mean, meet, mind, pretend, recognize, remember, save, say, see, smell, snap, suppose, surprise, test, understand, watch, win		
2: ask, smack, spray, thank	3: ask, spray	2: back, bend, blow, carry, chew, color, cover, cut, dump, fold, hang, hook, kick, knock, match, mow, pass, poke, pour, press, pull, punch, push, put, roll, screw, send, set, swing, take, tear, throw, tie, turn, wash, wind, wipe	
3: bang, belong, bob, bounce, care, climb, cook, crash, crawl, cry, dance, dream, drip, drive, fall, fight, fit, fly, grow, hammer, hide, hop, jump, laugh, lay, lean, lie, listen, live, look, manage, march, melt, peek, peepee, play, point, pop, ride, ring, row, run, sit, sleep, slip, smile, sound, speak, squeak, stand, stay, step, swim, talk, tease, wake, walk, work, write	4: bang, belong, bob, bounce, care, climb, cook, crash, crawl, cry, dance, dream, drive, fall, fight, fit, fly, grow, hammer, hide, hop, jump, laugh, lay, lie, listen, live, look, march, peek, peepee, play, point, pop, ride, ring, row, run, sit, sleep, slip, smile, sound, speak, squeak, stand, stay, step, swim, talk, taste, wake, walk, work, write	3: ask, smack	
4: beat, knock, pass, punch		4: bang, belong, bob, bounce, care, climb, cook, cool, crash, crawl, cry, dance, dream, drip, drive, fall, fight, fit, fly, grow, hammer, hide, hop, jump, laugh, lay, lean, lie, listen, live, look, march, peek, peepee, play, point, pop, ride, ring, row, run, sit, sleep, slip, smile, sound, speak, squeak, stand, stay, step, swim, talk, taste, tease, wake, walk, work, write	2: bang, belong, bob, bounce, care, climb, cook, cool, crash, crawl, cry, dance, dream, drive, fall, fight, fit, fly, grow, hammer, hide, hop, jump, laugh, lay, lean, lie, listen, live, look, march, peek, play, point, pop, ride, ring, rock, row, run, sit, sleep, slide, slip, smile, sound, speak, squeak, stand, stay, step, swim, talk, taste, tease, wake, walk, work, write
5: bet, guess, hope, think	5: bet, guess, hope, think, wish	5: bet, guess, hope	3: bet, guess, hope, think
6: bless, excuse	6: bless, excuse	6: bless, excuse	4: bless, excuse
7: call, name, serve	7: call, serve		5: call, name, serve
8: chirp, disappear	8: chirp, disappear	7: chirp, come, go, let, melt, shop, try, whisper	6: chirp, come, go, let, peepee, shop, try, whisper
9: come, go, let, shop, try, whisper	9: come, go, let, melt, shop, try, whisper		7: disappear, happen, manage, melt
	10: freeze, ski	8: frighten, measure	8: frighten, measure
10: give, offer, show	11: feed, show	9: feed, give, offer, show, tell	
11: like, want	12: like, want	10: like, want	9: learn, worry
12: love, need	13: love, need	11: love, need	10: like, want
13: peel, pet		12: rock, shave	
	14: rock, tease	12: sign, squeeze	
14: start, stop	15: start, stop	14: start, stop	11: start, stop
15: suppose, wish			

Table 8: <4yrs dataset: Aggregate inferred classes over 10 runs, given 4 strategies that don't involve the use of surface morphology (-surface-morphology), an intermediate representation (absolute/relative), and an expectation of a mapping between the intermediate representation and observable syntactic positions (+/-expect-mapping).

		-surface-morphology	
+expect-mapping	absolute	+expect-mapping	relative
<p><i>singletons: begin, figure, row, seem, wait</i></p> <p>1: answer, bite, bother, build, bump, catch, chase, check, close, dig, drink, dry, eat, frighten, kill, lose, measure, meet, move, mow, open, peel, reach, read, scare, scratch, shake, shut, sing, spell, spray, squeeze, tickle, touch, trade, visit</p> <p>2: ask, bake, break, bring, brush, buy, call, carry, change, cook, crack, do, draw, drop, find, fix, get, have, hear, hit, keep, love, make, mean, mind, name, need, paint, park, recognize, say, see, share, shoot, smack, spill, stir, stop, study, tape, test, use, watch, wear, win</p> <p>3: attach, beat, bend, blow, burn, chop, clean, color, count, cover, cut, dump, fold, hang, hold, hook, kick, knock, leave, lick, match, mix, pass, pick, plug, poke, pour, press, pull, punch, push, put, record, roll, save, screw, slide, spank, swing, take, tear, throw, tie, turn, wash, wind, wipe</p> <p>4: back, hurry</p> <p>5: bang, bounce, climb, cool, crash, crawl, dance, dress, fall, feel, fight, fit, fly, grow, hammer, hop, jump, lay, lean, lie, listen, look, peek, peepee, play, point, pop, ride, run, set, shave, sit, sleep, slip, smell, sound, speak, stand, stay, step, stick, swim, talk, taste, wake, walk, worry, write</p> <p>6: believe, decide, know, remember, surprise, understand, wonder</p> <p>7: bet, guess, hope, think</p> <p>8: bless, entertain, excuse, pay, thank</p> <p>9: bob, chirp, ski</p> <p>10: care, cry, disappear, dream, drip, laugh, march, melt, smile, work</p> <p>11: chew, fill</p> <p>12: come, shop</p> <p>13: cross, examine, kiss, pet, pinch, sell, sign, snap, squish</p> <p>14: feed, give, offer, send, serve, show, teach, tell</p> <p>15: finish, hide, hurt, miss</p> <p>16: forget, help, like</p> <p>17: freeze, rain</p> <p>18: go, land, learn, let, start, suppose, try, want</p> <p>19: happen, squeak</p> <p>20: juggle, tease, untie</p> <p>21: pretend, wish</p>	<p><i>singletons: begin, figure, row, seem, wait</i></p> <p>1: answer, bake, bother, break, brush, build, bump, buy, call, catch, change, chase, check, close, cook, crack, cross, dig, do, draw, drop, dry, eat, examine, find, finish, fix, frighten, get, have, hear, hide, keep, kill, kiss, lose, love, make, mean, measure, meet, miss, move, mow, name, need, open, paint, peel, pet, pinch, reach, read, recognize, say, scare, scratch, sell, shake, share, sign, sing, snap, spell, spill, spray, squeeze, stir, stop, study, test, tickle, touch, trade, untie, use, visit, watch, wear, win</p> <p>2: attach, beat, bend, bring, cover, cut, fill, hold, hook, knock, lick, mix, pass, pick, plug, pour, press, pull, punch, push, put, save, spank, take, throw, turn, wash, wind</p> <p>3: bite, carry, color, count, dump, hit, kick, leave, park, poke, screw, shoot, swing, wipe</p> <p>4: blow, burn, chew, chop, clean, drink, drive, fold, hang, match, record, rock, roll, shut, slide, tear, tie</p> <p>5: back, hurry</p> <p>6: bang, fight, grow, hammer, play, ride, set, shave, taste, write</p> <p>7: bounce, climb, cool, crash, crawl, dance, fall, feel, fit, fly, hop, jump, lay, lean, lie, listen, look, peek, peepee, point, pop, run, sit, sleep, slip, smell, sound, speak, stand, stay, step, stick, swim, talk, wake, walk, worry</p> <p>8: believe, decide, hurt, know, mind, remember, see, surprise, tape, understand, wonder</p> <p>9: bet, guess, hope, think</p> <p>10: bless, entertain, excuse, pay, thank</p> <p>11: bob, chirp, ski</p> <p>12: care, cry, disappear, dream, drip, laugh, manage, march, melt, ring, smile, work</p> <p>13: ask, feed, give, offer, send, serve, show, smack, teach, tell</p> <p>14: forget, like</p> <p>15: freeze, rain</p> <p>16: come, go, land, learn, let, shop, start, suppose, try, want</p> <p>17: happen, squeak</p> <p>18: juggle, squish, tease</p> <p>19: pretend, wish</p>	<p><i>singletons: begin, figure, seem, tip, wait</i></p> <p>1: answer, bake, bite, bother, break, brush, build, bump, burn, buy, call, carry, catch, change, chase, check, close, color, cook, count, crack, cut, dig, do, draw, drink, drop, dry, dump, eat, find, finish, fix, forget, frighten, get, have, hear, help, hit, hold, keep, kick, kill, leave, lose, love, make, mean, measure, meet, move, mow, name, need, open, park, peel, poke, reach, read, recognize, record, say, scare, scratch, screw, sell, shake, share, shoot, shut, sing, spell, spill, spray, stir, stop, study, swing, test, tickle, tie, touch, trade, use, watch, wear, wipe</p> <p>2: attach, beat, bend, hook, knock, lick, mix, pass, pick, pour, press, punch, push, put, save, take, tear, throw, wash, wind</p> <p>3: blow, chew, chop, clean, cover, drive, fold, hang, match, paint, pull, rock, roll, slide, turn</p> <p>4: bear, live</p> <p>5: bang, bounce, climb, cool, crash, crawl, dance, fall, feel, fight, fit, fly, grow, hammer, happen, hop, hurry, jump, laugh, lay, lean, lie, listen, look, peek, play, point, pop, ride, rock, run, set, shave, sit, sleep, slip, smell, sound, speak, squeak, stand, stay, step, stick, swim, talk, taste, wake, walk, worry, write</p> <p>6: believe, decide, hurt, know, mind, miss, remember, see, squeeze, surprise, tape, understand, win, wonder</p> <p>7: bet, confuse, guess, hope, think</p> <p>8: bless, entertain, excuse, thank</p> <p>9: bob, chirp, ski</p> <p>10: care, cry, disappear, dream, drip, manage, march, melt, ring, smile, work</p> <p>11: cross, examine, kiss, pet, pinch, untie</p> <p>12: snap, squish</p> <p>13: ask, bring, feed, give, offer, send, serve, show, smack, spank, teach, tell</p> <p>14: freeze, rain</p> <p>15: come, go, land, learn, let, peepee, shop, start, try</p> <p>16: hide, whisper</p> <p>17: juggle, tease</p> <p>18: pretend, wish</p>	<p><i>singletons: begin, figure, row, seem, tip, wait</i></p> <p>1: answer, bake, bite, bother, break, brush, build, bump, burn, buy, call, carry, catch, change, chase, check, close, color, cook, count, crack, cut, dig, do, draw, drink, drop, dry, dump, eat, find, finish, fix, frighten, get, have, hear, help, hit, hold, keep, kick, kill, leave, lose, love, make, mean, measure, meet, move, mow, open, park, peel, plug, poke, reach, read, recognize, record, say, scare, scratch, screw, sell, shake, share, shoot, shut, sign, sing, spell, spill, spray, squeeze, stir, stop, study, swing, test, tickle, touch, trade, use, watch, wear, wipe</p> <p>2: attach, beat, bend, bring, hook, knock, lick, mix, pass, pick, pour, press, punch, push, put, save, spank, take, throw, wash, wind</p> <p>3: blow, chew, chop, clean, cover, fill, fold, hang, match, pull, roll, slide, tear, tie, turn</p> <p>4: bear, live</p> <p>5: bang, bounce, climb, cool, crash, crawl, dance, fall, feel, fight, fit, fly, grow, hammer, happen, hop, jump, lay, lean, lie, listen, look, peek, play, point, pop, ride, rock, run, set, shave, sit, sleep, slip, smell, sound, speak, squeak, stand, stay, step, stick, swim, talk, taste, visit, wake, walk, worry, write</p> <p>6: believe, decide, hurt, know, mind, miss, remember, see, surprise, tape, understand, wonder</p> <p>7: bet, confuse, guess, hope, think</p> <p>8: bless, entertain, excuse, thank</p> <p>9: bob, chirp, ski</p> <p>10: care, cry, disappear, dream, drip, manage, march, melt, ring, smile, work</p> <p>11: cross, examine, kiss, pet, pinch, untie</p> <p>12: ask, feed, give, name, offer, send, serve, show, smack, teach, tell</p> <p>13: forget, like, need</p> <p>15: come, go, land, learn, let, shop, start, try</p> <p>16: suppose, want</p> <p>17: juggle, tease</p> <p>18: pretend, wish</p>

Table 9: <5yrs dataset: Aggregate inferred classes over 10 runs, given 4 strategies that involve the use of surface morphology (+surface-morphology), an intermediate representation (absolute/relative), and an expectation of a mapping between the intermediate representation and observable syntactic positions (+/-expect-mapping).

+surface-morphology			
absolute	relative		
+expect-mapping	-expect-mapping	+expect-mapping	-expect-mapping
<p>singletons: <i>begin, bob, confuse, dig, dress, figure, hurry, land, rain, rinse, seem, tip, wait, wonder</i></p> <p>1: answer, attach, bear, beat, bend, bite, blow, bother, break, bring, build, burn, buy, carry, catch, change, chase, check, chew, chop, clean, close, color, count, cover, crack, cross, cut, do, draw, drill, drink, drive, dump, eat, find, finish, fix, fold, follow, frighten, grind, hang, hit, hold, hook, hurt, keep, kick, kill, kiss, knock, leave, lick, lose, match, measure, miss, move, mow, open, paint, park, pass, peel, pinch, plug, poke, pour, press, pull, punch, push, put, reach, read, record, rewind, rock, roll, scare, scratch, screw, sell, set, shake, share, shave, shoot, shut, sing, slide, smack, spell, spill, squeeze, squish, stick, stir, straighten, stretch, swallow, sweep, swing, take, tape, tear, throw, tickle, tie, touch, trade, turn, twist, untie, visit, wash, wear, wind, wipe, wrap</p> <p>2: back, belong, bounce, care, climb, come, cook, crash, crawl, cry, dance, dream, end, fall, fight, fit, fly, go, grow, hammer, hide, hop, jump, laugh, lay, lean, let, lie, listen, live, look, march, melt, peek, peepee, play, point, pop, rest, ride, ring, run, shop, sit, sleep, slip, smile, sneeze, sound, speak, squeak, stand, start, stay, step, stop, swim, talk, taste, try, wake, walk, whisper, work, worry, write</p> <p>5: bless, excuse, thank 6: bump, examine, sign, spray</p> <p>7: drip, row 8: dry, feel, watch 9: feed, show 10: freeze, ski 11: get, meet, send, smell, test 12: learn, study, tease 13: like, want</p>	<p>singletons: <i>begin, confuse, dress, figure, hurry, land, rain, rinse, seem, tip, wonder</i></p> <p>1: answer, attach, bear, believe, bite, bother, break, bring, build, bump, burn, buy, catch, change, check, close, cook, count, cover, crack, cross, decide, do, draw, drink, drop, dry, dump, eat, examine, find, finish, fix, follow, forget, get, have, hear, help, hit, hold, hurt, keep, kill, kiss, know, leave, lose, make, match, mean, meet, mind, miss, move, open, paint, peel, pinch, poke, pretend, reach, read, recognize, record, remember, rewind, save, say, scare, scratch, see, sell, send, shake, share, sharpen, shave, shoot, sign, sing, smack, smell, snap, spell, spill, spray, squeeze, squish, stick, stir, straighten, suppose, surprise, swallow, swing, tape, test, tickle, touch, trade, twist, understand, untie, use, visit, watch, wear, win</p> <p>2: beat, chew, knock, pass, plug, sweep</p> <p>3: bend, blow, brush, carry, chase, clean, color, cut, drill, fold, grind, hang, hook, kick, lick, measure, mow, park, pour, press, pull, punch, push, put, roll, screw, set, shut, slide, stretch, take, tear, throw, tie, turn, wash, wind, wipe, wrap</p> <p>4: drive, rock 5: frighten, pet</p> <p>6: back, climb, come, cool, crash, end, fall, go, grow, lay, let, lie, peepee, point, pop, run, shop, stand, try, wake, whisper</p> <p>7: bang, belong, bounce, crawl, fight, fit, fly, hammer, hop, jump, lean, listen, look, peek, play, rest, ride, ring, sit, slip, sound, speak, squeak, stay, step, swim, talk, taste, walk, worry, write</p> <p>8: bob, cry, disappear, laugh, manage, march, sneeze 9: care, dream, live, sleep, trip, work</p> <p>10: dance, hide, start, stop 11: happen, melt</p> <p>12: love, need</p> <p>13: bet, guess, hope, think, wish</p> <p>14: bless, excuse, thank</p> <p>15: call, name, serve</p> <p>16: feed, show</p> <p>17: learn, tease 18: like, want</p>	<p>singletons: <i>begin, confuse, dress, figure, rain, seem, wonder</i></p> <p>1: answer, attach, bear, bend, bite, blow, bother, break, bring, brush, build, bump, burn, buy, carry, catch, change, chase, check, chop, clean, close, color, count, cover, crack, cross, cut, do, draw, drill, drink, drop, dump, eat, examine, find, finish, fix, fold, follow, frighten, get, hang, hear, hit, hold, hook, hurt, keep, kick, kill, kiss, leave, lick, lose, make, match, measure, meet, miss, move, mow, open, paint, park, peel, pet, pinch, poke, pour, press, pull, punch, push, put, reach, read, record, rewind, rock, roll, scare, scratch, screw, sell, send, set, shake, share, shoot, shut, sign, sing, slide, smell, spell, spill, spray, squeeze, squish, stick, stir, straighten, stretch, study, suppose, swallow, swing, take, tape, tear, test, throw, tickle, tie, touch, trade, turn, twist, untie, use, visit, wash, watch, wear, wind, wipe, wrap</p> <p>2: ask, smack, spank 3: beat, chew, fill, grind, knock, mix, pass, pick, plug</p> <p>4: back, bang, belong, bounce, care, chirp, climb, cook, cool, crash, crawl, cry, dance, disappear, dream, end, fall, fight, fit, fly, grow, hammer, happen, hide, hop, jump, laugh, lay, lean, lie, listen, live, look, manage, march, melt, peek, peepee, play, point, pop, rest, ride, ring, run, sit, sleep, slip, smile, sneeze, sound, speak, squeak, stand, stay, step, swim, talk, taste, trip, wake, walk, work, worry, write</p> <p>5: come, go, let, shop, try, whisper</p> <p>6: start, stop 7: believe, decide, forget, have, know, mean, mind, pretend, recognize, remember, say, see, sharpen, snap, surprise, understand, win</p> <p>8: bet, think 9: guess, hope 10: bless, excuse, thank</p> <p>11: call, name, serve 12: drip, row, ski 13: drive, dry, feel, shave 14: feed, give, offer, pay, save, show, tell</p> <p>15: like, love, need, want</p>	<p>singletons: <i>begin, confuse, dress, figure, rain, seem, wonder</i></p> <p>1: answer, attach, bear, believe, bite, blow, bother, break, build, bump, burn, buy, carry, catch, change, chase, check, chop, clean, close, color, count, cover, crack, cross, cut, decide, do, draw, drink, drive, drop, dry, dump, eat, examine, feel, find, finish, fix, follow, forget, frighten, get, have, hear, help, hit, hold, hurt, keep, kill, kiss, know, leave, lose, make, match, mean, meet, mind, miss, move, open, paint, peel, pinch, poke, pretend, pull, reach, read, recognize, record, remember, rewind, roll, say, scare, scratch, screw, see, sell, shake, share, sharpen, shave, shoot, shut, sign, sing, smell, snap, spell, spill, spray, squeeze, squish, stick, stir, straighten, stretch, suppose, surprise, swallow, swing, tape, test, tickle, tie, touch, trade, turn, twist, understand, untie, use, visit, watch, wear, win, wipe</p> <p>2: bake, pet</p> <p>3: beat, bend, bring, chew, drill, fold, grind, hang, hook, kick, knock, lick, measure, mow, park, pass, plug, pour, press, punch, push, put, send, set, slide, smack, take, tear, throw, wash, wind, wrap</p> <p>4: rock, sweep</p> <p>5: back, chirp, climb, crash, end, fall, grow, lay, lie, melt, point, pop, run, slip, stand, wake</p> <p>6: bang, belong, bounce, care, cook, crawl, cry, dance, dream, drip, fight, fit, fly, hammer, hide, hop, jump, laugh, lean, listen, live, look, march, peek, peepee, play, rest, ride, ring, sit, sleep, smile, sneeze, sound, speak, squeak, stay, step, swim, talk, taste, trip, walk, work, worry, write</p> <p>7: come, go, let, shop, try, whisper</p> <p>8: disappear, happen 9: start, stop</p> <p>10: bet, guess, hope, wish</p> <p>11: bless, excuse, thank</p> <p>12: call, serve</p> <p>13: feed, give, offer, save</p> <p>14: like, want 15: love, need</p>

Table 10: <5yrs dataset: Aggregate inferred classes over 10 runs, given 4 strategies that don't involve the use of surface morphology (-surface-morphology), an intermediate representation (absolute/relative), and an expectation of a mapping between the intermediate representation and observable syntactic positions (+/-expect-mapping).

	absolute	-surface-morphology	relative
+expect-mapping	-expect-mapping	+expect-mapping	-expect-mapping
<i>singletons: bear, begin, figure, row, seem, tip, wait</i>	<i>singletons: begin, figure, row, seem</i>	<i>singletons: figure</i>	<i>singletons: figure</i>
1: answer, bite, brush, build, bump, burn, catch, change, chase, check, close, count, cover, dig, draw, drink, drive, eat, fix, frighten, kill, match, move, mow, open, peel, pull, reach, read, record, rewind, scratch, screw, set, shake, shoot, shut, sign, spray, stir, swallow, swing, tie, touch, trade, visit	1: answer, bake, bother, break, build, bump, buy, carry, catch, change, chase, check, close, cook, count, crack, dig, do, draw, drink, drive, drop, dry, eat, find, finish, fix, follow, forget, frighten, get, have, hear, help, hide, hit, keep, kick, kill, learn, like, lose, love, make, mean, measure, meet, move, mow, need, open, paint, peel, read, recognize, rewind, say, scare, scratch, sell, share, shoot, sing, spell, spill, stir, swallow, swing, tape, test, tickle, touch, trade, untie, use, watch, wear	1: answer, bake, bite, bother, bring, build, bump, burn, buy, carry, catch, change, chase, check, close, color, count, crack, do, draw, drink, drive, drop, eat, find, fix, follow, frighten, get, have, hear, hold, keep, kick, kill, leave, lose, love, make, measure, move, mow, need, open, peel, read, recognize, record, scare, scratch, screw, sell, share, shoot, shut, sign, spank, spell, spill, squeeze, stir, swallow, swing, tape, test, tie, touch, trade, untie, use, visit, watch, wear	1: answer, bake, bite, bother, build, bump, burn, buy, call, carry, catch, change, chase, check, close, color, count, cover, crack, cut, dig, do, draw, drink, drive, drop, eat, find, fix, follow, frighten, get, have, hear, hit, hold, keep, kick, kill, leave, lose, love, make, measure, move, mow, need, open, peel, reach, read, recognize, record, scratch, screw, sell, set, share, shoot, shut, sign, spell, spill, spray, stir, swallow, swing, test, tie, touch, trade, use, visit, watch, wear
2: ask, feed, give, offer, pay, send, serve, show, smack, teach, tell	2: ask, call, feed, give, offer, pay, send, serve, show, smack, teach, tell	2: forget, like	2: cook, paint, untie
3: attach, beat, bend, bring, chew, chop, clean, color, cut, drill, dump, fill, fold, hang, hold, hook, kick, knock, leave, lick, lift, mix, park, pass, pick, plug, poke, pour, press, punch, push, put, rinse, roll, save, slide, spank, take, tear, throw, turn, wash, wind, wipe, wrap	3: attach, bend, bite, bring, burn, chop, clean, color, cover, cut, drill, dump, fold, hold, hook, knock, leave, lick, mix, park, pick, plug, poke, pour, press, pull, punch, push, put, reach, record, rinse, roll, save, screw, set, shake, shut, sign, slide, spank, spray, squeeze, take, tear, throw, tie, turn, visit, wash, wind, wipe, wrap	3: meet, miss	3: forget, like
4: back, bang, bounce, climb, cool, crash, crawl, dance, end, fall, feel, fight, fit, fly, grow, hammer, hop, jump, lay, lie, listen, look, peek, play, point, pop, rest, ride, run, shave, sit, slip, smell, stand, stay, step, stick, swim, talk, taste, wake, walk, worry, write,	4: chew, hang	4: ask, call, feed, give, hit, name, offer, pay, send, serve, show, smack, teach, tell	4: ask, feed, give, offer, pay, send, serve, show, smack, teach, tell
5: bake, bother, buy, call, carry, crack, do, drop, find, follow, get, have, hear, help, hit, keep, lose, love, make, measure, name, need, recognize, sell, share, spell, spill, tape, test, use, watch, wear	5: back, fall, fit, grow, hammer, hop, hurry, lay, lie, listen, peek, play, point, pop, rest, ride, run, shave, sit, slip, smell, stand, stay, step, stick, talk, taste, wake, write	5: attach, beat, bend, brush, chew, chop, clean, cover, cut, drill, dump, fill, fold, hang, hook, knock, lick, lift, mix, park, pass, pick, plug, poke, pour, press, pull, punch, push, put, rinse, roll, save, set, slide, take, tear, throw, turn, wash, wind, wipe, wrap	5: attach, beat, bend, bring, brush, chop, clean, drill, dump, fold, hook, knock, lick, mix, park, pass, pick, plug, poke, pour, press, pull, punch, push, put, rinse, roll, save, set, slide, take, tear, throw, turn, wash, wind, wipe
6: believe, decide, finish, hurt, know, mean, mind, miss, pretend, remember, say, see, study, surprise, understand, wish, wonder	6: bang, fight, fly, worry	6: back, bounce, climb, come, cool, crash, crawl, dance, dress, end, fall, feel, fit, fly, grow, hop, hurry, jump, lay, lean, lie, listen, look, peek, peepee, play, point, pop, rest, ride, run, shave, shop, sit, slip, smell, sound, speak, stand, stay, step, stick, swim, talk, taste, wake, walk, worry, write	6: chew, fill, hang, slide, wrap
7: belong, trip	7: bounce, climb, cool, crash, crawl, dance, end, jump, speak, squeak, swim, walk	7: bang, fight, hammer	7: back, bang, blow, bounce, climb, cool, crash, crawl, dance, end, fall, feel, fight, fit, fly, grow, hammer, hop, hurry, jump, lay, lie, listen, look, match, peek, play, point, pop, rest, ride, rock, run, shave, sit, slip, smell, sound, speak, stand, stay, step, stick, sweep, swim, talk, taste, wake, walk, worry, write
8: bet, guess, hope, think	8: believe, decide, hurt, know, mind, miss, pretend, remember, see, study, surprise, understand, wish, wonder	8: believe, decide, hurt, know, mean, mind, pretend, remember, say, see, study, surprise, understand, wish, wonder	8: believe, break, decide, dry, finish, hurt, know, mean, meet, mind, miss, remember, rewind, say, scare, see, sing, squeeze, stop, study, surprise, tape, tickle, understand, win, wonder
9: bless, entertain, excuse, thank	9: belong, trip	9: belong, trip	9: pretend, wish
10: blow, rock, sweep	10: bet, confuse, guess, hope, think	10: bet, guess, hope, think	10: belong, trip
11: bob, chirp, ski, sneeze	11: bless, entertain, excuse, thank	11: bless, entertain, excuse, thank	11: bet, guess, hope, think
12: break, cook, fry, hide, meet, paint, scare, sing, squeeze, tickle, untie	12: blow, match, rock, sweep	12: blow, match, rock, sweep	12: bless, entertain, excuse, thank
13: care, cry, dream, drip, happen, laugh, live, march, melt, ring, sleep, smile, work	13: bob, chirp, ski, sneeze	13: bob, chirp, freeze, rain, ski, sneeze	13: bob, chirp, ski, sneeze
14: come, dress, go, land, lean, learn, let, peepee, shop, start, stop, try	14: care, cry, dream, drip, happen, laugh, live, march, melt, ring, sleep, smile, work	14: break, cook, finish, paint, reach, rewind, shake, sing, spray, stop, win	14: freeze, rain
15: cross, examine, kiss, pet, pinch, sharpen, snap, squish, stretch, twist	15: come, go, land, lean, let, peepee, start, try, whisper	15: care, cry, disappear, dream, drip, happen, laugh, live, march, melt, ring, sleep, smile, squeak, work	15: care, cry, dream, drip, happen, laugh, live, march, melt, ring, sleep, smile, squeak, work
16: cross, examine, kiss, pinch, snap, squish, stretch, twist	16: cross, examine, kiss, pinch, snap, squish, stretch, twist	16: go, land, learn, let, try, whisper	16: come, dress, land, lean, peepee, shop
17: grind, straighten	17: dress, feel, look, shop, sound	17: cross, examine, kiss, pet, pinch, sharpen, stretch, twist	17: cross, examine, pet, pinch, sharpen
18: juggle, tease	18: grind, straighten	18: grind, straighten	18: grind, straighten
19: suppose, want	19: juggle, tease	19: juggle, snap, squish, tease	19: juggle, kiss, snap, squish, stretch, tease, twist
	20: pet, sharpen	20: suppose, want	20: go, learn, let, start, suppose, try, want
	21: suppose, want		

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