Hope for syntactic bootstrapping

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We explore children's use of syntactic distribution in the acquisition of attitude verbs, such as *think*, *want*, and *hope*. Because attitude verbs refer to concepts that are opaque to observation but have syntactic distributions predictive of semantic properties, we hypothesize that syntax may serve as an important cue to learning their meanings. Using a novel methodology, we replicate previous literature showing an asymmetry between acquisition of *think* and *want*, and we additionally demonstrate that interpretation of a less frequent attitude verb, *hope*, patterns with type of syntactic complement. This supports the view that children treat syntactic frame as informative about an attitude verb's meaning.*

Keywords: language acquisition, syntactic bootstrapping, word learning, attitude verbs, verb learning, semantics, pragmatics

1. Introduction. Propositional attitude verbs, like *think* and *want*, are used to describe the contents of people's minds, such as their beliefs (1) or desires (2) regarding possible states of affairs.

(1) John thinks that Mary is home.
(2) John wants Mary to be home.

Because mental states do not leave reliable correlates in the physical world, acquiring the meaning of attitude verbs may be particularly challenging. Consistent with this, they tend to be acquired later than other verbs. While this delay was initially attributed to conceptual difficulties with mental representations, mounting evidence shows that infants are surprisingly aware of the mental states of others (Onishi & Baillargeon 2005, Southgate et al. 2007, Surian et al. 2007, Buttleman et al. 2009, Kovács et al. 2010, Knudsen & Liszkowski 2012, He & Lidz 2017). From the first months of life, infants give privileged status to human agents and are sensitive to the goals and perspectives of their conversation partners. They attribute goal-directedness to agents from as young as five months (Woodward 1998) and seem to track beliefs from as early as seven months (Kovács et al. 2010). This sensitivity to other minds also helps children in language acquisition. Children can track eye-gaze and use it to learn new words by sixteen months (Baldwin 1991, Bloom 2000). In their second year, infants can use their knowledge of existing words to infer that a novel noun refers to a novel object (Markman & Wachtel 1988, Clark 1990, Mervis & Bertrand 1994, Diesendruck & Markson 2001, Halberda 2003). By age two, children are adult-like in their interpretation of indexical pronouns, which shift reference based on conversational roles (Moyer et al. 2015).

Given the salience of psychological states in infant reasoning and their efficacy in shaping word learning, linking psychological concepts with words may be no more difficult than linking object and event concepts with words. If, due to this richness of the learners' representations of other minds, this linking is indeed straightforward, there

should be no CONCEPTUAL barrier to learning attitude verbs. Yet learners still have to realize that attitude verbs refer to mental states. Because there are no obvious physical cues for *thinkings* or *wantings*, information other than the physical context of use may be required to learn their meanings. The syntactic bootstrapping hypothesis (Landau & Gleitman 1985, Gleitman 1990) holds that the syntactic context provides one relevant source of information that children can use in identifying verb meanings. If attitude verbs depend on the syntactic context to be learned, we can expect syntactic development to function as a bottleneck on their acquisition.

Attitude verbs represent the paradigm case for the bootstrapping hypothesis because (i) the physical contexts in which they are used provide so little evidence about their meanings (Gleitman 1990, Gillette et al. 1999), and (ii) their syntactic distributions are highly restricted (Landau & Gleitman 1985). But while attitudes provide the strongest argument for the plausibility of syntactic bootstrapping, evidence for it is thin on the ground. Most of the evidence for syntactic bootstrapping has focused on simple action verbs (Pinker 1989, Naigles 1990, 1996, Lidz et al. 2003, Scott & Fisher 2009, Yuan & Fisher 2009, Fisher et al. 2010). In this article, we show that children make use of syntactic cues to figure out attitude-verb meanings.

Propositional attitude verbs are so called because they are taken to express the 'attitude' of an individual toward a proposition or state of affairs. The acquisition literature typically focuses on those attitude verbs that express mental states, such as *want* and *think*, because their meanings are arguably the ones with the fewest cues from the situational context. In the present discussion, however, we can understand the term more broadly to extend to all predicates that relate an individual (expressed by their subject) to a proposition (expressed by a sentential complement), including also verbs of communication (*say*, *tell*) and perception (*see*, *hear*).[1]

Syntactic information could be useful for attitude-verb acquisition at both a broad and a narrow level. At a broad level, a verb taking a sentential complement at all, as in 3, might be a good initial cue that the verb describes an attitude, broadly construed, but not an action. And indeed, several experimental findings suggest that the presence of a sentential complement could help learners distinguish attitude verbs as a class from other verbs (Landau & Gleitman 1985, Gleitman 1990, Fisher et al. 1991, Lidz et al. 2003, Gleitman et al. 2005, Papafragou et al. 2007).

    (3) John kertunks that Mary is home.

But syntactic distribution could play a role in alerting the learner not just to the fact that the verb expresses an attitude, but also to the KIND of attitude it expresses. *Wantings* and *thinkings* typically cooccur (e.g. John's desire for Mary to be home spatially and temporally coincides with his believing that she is not with him), and so here again, information other than the physical context may be required to figure out what mental state is being referred to. Again, syntax could provide useful cues. As seen in 1–2 above, the complements of *think* and *want* differ: the complement of *think* is finite, that of *want* nonfinite; compare 4–5.

    (4) *John thinks Mary to be home.
    (5) *John wants that Mary is home.

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[1] We leave aside modals (e.g. *must*, *can*) and verbs that do not allow an overt subject in their complement (e.g. *begin*, *try*, *seem*), though related learnability issues arise. For ways in which syntactic bootstrapping could be relevant in their acquisition, see Becker & Estigarribia 2013 and van Dooren et al. 2017.

Assuming that this kind of syntactic selection tracks a meaningful semantic distinction, children may be able to exploit it when learning attitude-verb meanings.

Promisingly, the syntax and semantics literature argues for a principled link between attitude meaning and attitude syntax. Crosslinguistically, attitude verbs tend to split into two main classes: verbs that express desires—and preferences more generally—like *want* (PREFERENTIAL ATTITUDES), and verbs that express beliefs—and judgments of truth more generally—like *think* (REPRESENTATIONAL ATTITUDES), and this split is tracked by syntactic selection (Bolinger 1968, Searle & Vanderveken 1985, Villalta 2000, 2008, Anand & Hacquard 2013, among others). However, while the same split tends to be found crosslinguistically, its syntactic correlates differ across languages. In French, for instance, the complements of *think*'s and *want*'s counterparts are both finite, but the former is in the indicative mood, as in 6, and the latter in the subjunctive mood, as in 7. How can the learner know what syntactic properties to attend to in their language when figuring out attitude-verb meanings?

(6) Jean pense que Marie est à la maison.
    Jean thinks that Marie is.IND home
      'Jean thinks that Marie is home.'
(7) Jean veut que Marie soit à la maison.
    Jean wants that Marie be.SUBJ home.
      'Jean wants Marie to be home.'

Hacquard and Lidz (2019) propose that while languages differ in the particular syntactic correlates to the preferential/representational split, they converge at an abstract level in that complements of representational attitudes show syntactic hallmarks of declarative main clauses: in Romance languages, for instance, declarative main clauses are in the indicative mood; in English, they are finite. If learners expect a link between declarative syntax and representationality, they could exploit syntactic features such as mood, in French, or finiteness, in English, to infer that the embedding verb expresses a belief vs. a preference (for supporting computational evidence for the feasibility of this bootstrapping hypothesis, see White et al. 2018).

Initial evidence that children are sensitive to the syntax of attitude reports comes from the fact that they systematically distinguish *want* and *think* early on. Children start producing *want* to express desires as young as eighteen months (Bartsch & Wellman 1995). They further seem to understand *want* sentences by around age three (Wellman & Bartsch 1988, Wellman & Wooley 1990, Wellman & Banerjee 1991, Bartsch & Wellman 1995, Repacholi & Gopnik 1997, Harrigan et al. 2018), even when the desired outcome conflicts with reality or with the child's own desires (Moore et al. 1995, Rakoczy et al. 2007, Rakoczy 2010, Harrigan et al. 2015, Harrigan et al. 2018). This requires that the concept of desire be readily available to very young children, that they be proficient at tracking others' minds, and that their sophisticated cognitive capacities allow them to link the word *want* to the desire concept with relative ease. For *think*, however, we see a different trajectory. Many studies find that children have difficulty understanding *think* sentences that report a false belief well into their fourth year (Johnson & Maratsos 1977, Wimmer & Perner 1983, de Villiers & de Villiers 2000, Wellman et al. 2001, de Villiers & Pyers 2002, Perner et al. 2003, de Villiers 2005, 2007). A number of hypotheses address this *think-want* asymmetry in acquisition: some invoke conceptual differences (Perner et al. 2003, Perner et al. 2005, Perner & Ruffman 2005), others, differences in syntactic and semantic complexity between the verbs (de Villiers & de Villiers 2000, 2009, de Villiers 2007), and others still, pragmatic differences in how these verbs are typically used (Lewis et al. 2012, 2017, Hacquard 2014, Hacquard & Lidz

2019). Regardless of the explanation, children differentiate *want* from *think* early. This suggests that some aspect of a child's experience reveals that *think* and *want* belong to different semantic classes, even at a stage when they have not fully mastered their meanings. And given the lack of nonlinguistic cues, this part of children's experience with the words could well be their syntactic distribution.

In this article, we directly test children's sensitivity to syntactic cues when interpreting attitude verbs and provide evidence for the viability of the syntactic bootstrapping hypothesis for attitude verbs. In §2, we review the literature on the syntax and semantics of attitude reports, which argues for a principled link between the two, and spell out a syntactic bootstrapping account. We present in §3 a series of experiments testing children's understanding of an unfamiliar attitude verb, *hope*, comparing it to *think* and *want*. We exploit the fact that *hope* takes both finite and nonfinite complements. The syntactic bootstrapping hypothesis predicts that children will use syntax as evidence about the meaning of unfamiliar attitude verbs, and in particular, that nonfinite complements should lead to desire-like interpretations (like *want*), while finite complements should lead to belief-like interpretations (like *think*). In experiments 1 and 2, we compare children's interpretation of *think* and *want* sentences in an experimental set-up that makes both beliefs and desires salient. We find that four-year-olds are adult-like with *want* and influenced by reality with *think*, reproducing past findings. Experiments 3 and 4 test children's comprehension of *hope*. We find that children are sensitive to syntactic frame, interpreting *hope* sentences differently depending on the complement: children are lured by reality with *hope* with a finite complement, as with *think*, but not with a nonfinite complement, as with *want*.

2. A SYNTACTIC BOOTSTRAPPING HYPOTHESIS FOR ATTITUDE VERBS: BELIEF VS. DESIRE. In this section, we briefly review this *think-want* asymmetry in acquisition, and explanations from the literature. We then establish the link between belief and desire attitudes and their syntactic distributions, and present a syntactic bootstrapping proposal for attitudes.

2.1. *THINK-WANT* ASYMMETRY IN ACQUISITION. Until at least age four, children make consistent errors with *think* sentences used to report false beliefs (Johnson & Maratsos 1977, de Villiers 1995, de Villiers & de Villiers 2000, de Villiers & Pyers 2002, Sowalsky et al. 2009). In a context where John thinks that Mary is home, but she is really away, children typically reject a sentence like 1 (*John thinks that Mary is home*). They do not, however, make the same error with *want* sentences. In a context where John wants Mary to be home, but she is really away, children typically accept a sentence like 2 (*John wants Mary to be home*). In both cases, if Mary happens to be home in reality, John has a mental state about the world that conflicts with reality. Despite conflicts in both cases, three-year-olds are adult-like in assessing the *want* sentence, while being consistently lured by reality with the *think* sentence, seemingly responding to the truth value of the complement, rather than that of the whole sentence (the attitude ascription).

The traditional explanation for this asymmetry from the developmental psychology literature is that it reflects an asymmetry in their grasp of the underlying concepts. Children are said to acquire the DESIRE concept early, while the BELIEF concept awaits the development of full theory of mind, around age four (Perner et al. 2003, Perner et al. 2005, Perner & Ruffman 2005, among others). The relative delay of the belief concept could also be due to less exposure to explicit reference to belief vs. desire, or greater processing demands for beliefs than for desires (see Moore et al. 1995, Rakoczy et al. 2007, Rakoczy 2010). For de Villiers and colleagues (de Villiers & de Villiers 2000,

2009, de Villiers 2007), the development of the belief concept is enabled by the grammatical development of the type of complement that verbs like *think* or *say* select for, namely finite complements, which can be true or false. Mastering this kind of structure, in which a false sentence can be embedded under a true one, gives children the conceptual scaffolding to represent false belief.

That children independently struggle with the belief concept until age four is supported by hundreds of explicit false-belief tasks (for a meta-analysis, see Wellman et al. 2001). However, numerous infant studies in the last fifteen years have cast doubt on the conceptual hypothesis, by showing that infants as young as seven months show surprise when protagonists act in ways that are inconsistent with their beliefs, whether these beliefs are true or false (Onishi & Baillargeon 2005, Southgate et al. 2007, Kovács et al. 2010, among others). While the exact nature of the disconnect between infants' performance on such implicit false-belief tasks and that of older children on explicit tasks is under debate, a growing number of researchers take the former to truly reflect children's conceptual competence and blame factors other than conceptual deficiency—such as additional task demands—to explain older children's consistent failures (Hansen 2010, Rubio-Fernández & Geurts 2013, Helming et al. 2014).

But even putting aside infants' conceptual abilities, we find that three- and four-year-olds' mastery of *think* has been underestimated by the traditional experimental set-up in which they are typically tested. Through a series of experiments, Lewis argues that children's apparent difficulty with *think* is not conceptual or semantic, but pragmatic in nature (Lewis, Hacquard, & Lidz 2012, 2017). Children have access early on to an adult-like representation of *think* and the underlying belief concept, but their competence is masked by difficulty untangling what speakers intend to convey when using *think* sentences.

Adult speakers often use *think* sentences to indirectly assert the complement clause. This happens with so-called parenthetical uses of *think* (Urmson 1952, Hooper 1975), where the main point of the utterance is carried by the complement, and the main clause serves an evidential role (Simons 2007). To see this, consider a context where we are wondering where Mary is.

(8) A: Where is Mary?
    B: John thinks that she's in DC.
    C: No, she's in Baltimore.

In this context, the main point of B's utterance is that Mary is in DC, and, as C's response indicates, C can directly reject this indirect assertion: C is not denying that John holds a particular belief; rather, she is rejecting the claim that Mary is in DC. Lewis et al. argue that children's rejection of false-belief sentences is due to their assuming such indirect assertions, even in cases where adults do not, and they provide experimental evidence in support of this view.

To block indirect-assertion uses, Lewis et al. (2012) manipulated the salience of the reporting belief by contrasting false-belief situations in which one 'seeker' has a belief about a hider's location with cases where two 'seekers' have conflicting beliefs about the hider's location. In the two-seeker condition, performance of four-year-olds significantly improved. To see whether children could access the literal meaning of *think* sentences, Lewis et al. (2017) tested whether three-year-olds are able to reject a *think* sentence whose literal meaning was false. In a typical false-belief scenario, in which Dora thinks that Swiper is behind the toy box but Swiper is really behind the curtain, children reject the sentence *Dora thinks that Swiper is behind the toy box* (because they cannot attribute to Dora a false belief, according to the traditional conceptual hypothe-

sis, and because they assume an indirect assertion that Swiper is behind the toy box, according to the pragmatic hypothesis). Lewis et al. introduce a further condition: in the same scenario, children are asked to evaluate the sentence *Dora thinks that Swiper is behind the curtain*. This sentence is literally false (Dora does not hold this belief), but the complement is true: Swiper is behind the curtain. According to the conceptual hypothesis, children should accept this sentence: if children cannot attribute to Dora a false belief, they have to assume that she thinks that Swiper is behind the curtain, since that is where he is. According to the pragmatic hypothesis, children have access to both the literal and the enriched meanings of *think* sentences. They should thus be able to reject this *think* sentence based on its false literal meaning. This is exactly what was found, suggesting that even three-year-olds have access to the literal meaning of *think*, and thus the underlying concept, and that their errors are mostly pragmatic: they do not have trouble figuring out what *think* sentences mean, but rather what SPEAKERS mean when they use *think* sentences. Note that, building on Lewis et al. 2012, Lewis et al. 2017 exclusively used two-seeker scenarios in order to increase the salience of the reported belief and optimize young children's performance.

2.2. *THINK-WANT* ASYMMETRY IN SYNTAX/SEMANTICS. Attitude verbs have been argued to fall into two main semantic classes: Bolinger's 'representationals',[2] which express judgments of truth, such as *think* or *say*, and 'preferentials', which express preferences such as *want* or *wish* (Bolinger 1968, Searle & Vanderveken 1985, Villalta 2000, 2008, Anand & Hacquard 2013, among others). That representationals—but not preferentials—express judgments of truth, which can be endorsed, can be seen with the following contrast (Pesetsky 1992).

(9) a. John {thinks, said} that Mary is in DC, which is true.
    b. John {wants, ordered} Mary to be in DC, #which is true.

As we saw in the preceding section, speakers can indirectly endorse such judgments of truth, resulting in indirect assertions of the complement. Such indirect-assertion uses are not as routinely available with preferentials like *want*.

(10) A: Where is Mary?
     B_1:   John thinks she's in DC.
     B_2: ??John wants her to be in DC.

The felicity of B_2's answer requires more contextual support: somehow, it has to be that John has authority over Mary's actions (e.g. John is Mary's boss), and thus whatever John wants, Mary does. If John has no say in Mary's whereabouts, B_2's utterance does not seem appropriate. A more routine indirect speech act for desire verbs like *want* is indirect command (Searle 1975).

(11) I want you to go to your room.

Sentence 11 is literally a desire report, but it is routinely used as an indirect command (go to your room!). We thus see that *think* and *want* belong to two different semantic classes of attitude verbs: those that express judgments of truth (representationals), which are routinely used for indirect assertions (whereby the speaker endorses the judgment of truth expressed), and those that express preferences (preferentials), which are routinely used for indirect commands (whereby the speaker endorses the preference expressed).

The formal linguistic literature on selection has argued extensively that this split in representationality is tracked by syntactic selection in different languages. In Romance

[2] The term 'representational' refers to the fact that attitude verbs like *think* present a 'picture of the world'.

languages, for instance, representationals select for complements in the indicative mood, while preferentials select for complements in the subjunctive mood, as shown in 6 and 7 above for French (Bolinger 1968, Hooper 1975, Farkas 1985, Giannakidou 1997, Villalta 2008, Anand & Hacquard 2013, among others). In English, representationality is also tracked syntactically: representationals typically take finite complements, and preferentials nonfinite complements, as we saw in 1–2.[3] In German, the split is tracked by word order. Typically, embedded clauses in German are verb-final. However, representationals, but not preferentials, allow the verb to appear in second position (Truckenbrodt 2006, Scheffler 2008).

    (12) a. Maria denkt, dass Peter heute kommt.
          Maria thinks that Peter today comes
        b. Maria denkt, Peter kommt heute.
          Maria thinks Peter comes today
            'Mary thinks that Peter is coming today.'
    (13) a. Maria will,   dass Peter heute kommt.
          Maria wants that Peter today comes
        b. *Maria will,   Peter kommt heute.
          Maria wants Peter comes today
            'Mary wants Peter to come today.'

    Thus, in English, Romance, and German, syntactic distribution may serve as a cue as to whether a given attitude verb falls into the representational or the preferential class, though the cue differs across languages. This may at first blush seem to be problematic for a bootstrapping learning strategy, as learners cannot anticipate the particular features specific to their language. However, although the specific features associated with both semantic classes differ crosslinguistically, they seem to converge at an abstract level (Hacquard & Lidz 2019): the complements of representationals, but not preferentials, allow syntactic features found in declarative main clauses in that language, the clause type typically used for assertions: indicative mood for Romance, finiteness for English, verb-second for German. Thus, at the right level of abstraction, syntax tracks representationality in ways that might be useful to the learner.

    2.3. A SYNTACTIC BOOTSTRAPPING HYPOTHESIS FOR ATTITUDES. We propose that syntax plays a crucial role in helping the learner map attitude verbs into two main semantic classes: those that express judgments of truth (representationals), and those that express preferences (preferentials). This is because there is a principled link between these two semantic classes and the type of syntactic complement they select for: representationals take complements with syntactic hallmarks of declarative main clauses, and preferentials do not—their complements instead resemble imperative clauses.

    The acquisition trajectory could look as follows: SYNTAX helps the learner map a novel attitude verb into one of two SEMANTIC classes: belief vs. desire. Each SEMANTIC class leads to different routine PRAGMATIC enrichments in the form of indirect speech acts: indirect assertions for the former (endorsement of a judgment of truth) vs. indirect commands for the latter (endorsement of a preference). The former, but not the latter, lead to reality-based errors, when the child rejects an indirect assertion that she knows

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[3] Bolinger (1968) argues that the syntactic feature in English that correlates with mood selection in Romance is complement preposing. Representationals allow preposing (*John is home, I think*); preferentials do not (#*John to be home, I want*). Here we focus on finiteness, which also tracks representationality (see White et al. 2014, White et al. 2018).

to be false. Take the case of *think*. *Think* takes complements with syntactic hallmarks of declarative main clauses. From this, the learner can infer that it must express some judgment of truth. This judgment of truth can be endorsed by the speaker, resulting in the indirect assertion of the complement. When a child hears a *think* sentence, she assumes that the speaker intends to indirectly assert the complement, and she rejects it, if she knows it to be false. As Lewis et al. show, this pragmatic preference can be overridden in the right context. With *want*, children do not assume indirect assertions (they may, however, assume indirect commands, which do not get in the way of truth-value judgment tasks that are typically used to test children's comprehension of attitude verbs). Hence, pragmatics does not get in the way: children accept reports of a desire that conflicts with reality.

Why should children so routinely assume indirect-assertion uses with verbs like *think*? Here we believe that the parallel between the syntax of the complement and the type of speech act for which this syntax is typically used is not accidental. Verbs like *think* take complements with declarative syntax, the syntax typically used for assertions, and *think* sentences are routinely used for INDIRECT assertions. Verbs like *want*, by contrast, do not take such complements.

This syntactic bootstrapping hypothesis makes the following predictions for novel attitude verbs. Upon hearing an unfamiliar attitude verb, children will exploit the syntactic frame in which it appears. We expect that, all else being equal, upon hearing a verb with a finite complement in English, children will assume a representational (belief) meaning for that verb. By default, they will assume an indirect-assertion use, leading to reality-based errors. With a nonfinite complement, they will assume a preferential (desire) meaning. This meaning does not typically lend itself to an indirect-assertion use; hence children will not make reality-based errors. We test these predictions in the next section.

Note that while we focus on finiteness in this article, we do not assume a one-to-one correspondence between finiteness and representationality, or between nonfiniteness and preferentiality. Indeed, nonfinite clauses can appear with various verbs beyond preferentials, including causatives (*make*) and implicatives (*manage*), and also in the complements of some representationals like *believe* and *expect*. Our linking hypothesis is between declarative syntax (rather than finiteness) and representational semantics: the more syntactic hallmarks of declarative clauses there are in a verb's complement, the more likely the verb is to be representational. The reason we focus on finiteness is that it is the most prominent main-clause syntactic feature among the most common attitude verbs in speech to English-learning children: we therefore expect it to be one of the most noticeable frames, and thus use it as our starting point to test the viability of syntactic bootstrapping for attitude verbs (for a more in-depth discussion of the correspondence between syntactic and semantic features in the attitude domain, see White et al. 2014, White et al. 2018, White & Rawlins 2018, and references therein).

3. TESTING THE SYNTACTIC BOOTSTRAPPING HYPOTHESIS FOR ATTITUDE VERBS: *THINK*, *WANT*, *HOPE*. Syntactic bootstrapping provides a plausible explanation for how children first categorize *think* and *want*: their syntactic distribution might alert the learner that they belong to two separate semantic classes, representational vs. preferential. To demonstrate the validity of this hypothesis, we need to show that children are sensitive to syntax when learning a novel attitude verb. Both *think* and *want* are very clear examples—syntactically and semantically—of the representational and preferential subclasses. *Want* expresses only a desire; *think* expresses only a belief. Further-

more, their syntactic distributions are complementary. We focus here on the less straightforward verb *hope*.

Hope shares semantic and syntactic properties with both. Syntactically, we observe distributional facts that are consistent with both classes. *Hope* can take both nonfinite (14) and finite (15) complements.

> (14) John hopes (for Mary) to be home.
> (15) John hopes that Mary is home.

Hope also shares meaning components with both classes. *Hope* has an obvious desire component: it always expresses a preference, regardless of syntactic frame. In the above sentences, the subject desires the content of the embedded clause. *Hope* also seems to have a belief component (Portner 1992, Scheffler 2008, Anand & Hacquard 2013): the complement has to be a doxastic possibility for the subject. In a scenario where Mary is away, and John knows this, John can still *want* her to be home, but it is infelicitous to say that he *hopes* that she is home (16–17). Thus, *think* expresses a commitment to truth, *hope* expresses a commitment to the possibility of truth, and *want* expresses neither.

> (16) John knows Mary is away, but he wants her to be home.
> (17) #John knows that Mary is away, but he hopes she's home.

These facts suggest that syntactic distribution might track semantic features, even in the case of *hope*: *hope* can take both finite and nonfinite complements, and both belief and desire meaning components are present. For our syntactic bootstrapping hypothesis to hold, the learner must be able to use the syntax to get to the semantics. We will now see why *hope* is an ideal case for investigating this.

Think and *want* are quite common in the input. In the CHILDES database (Mac-Whinney 2000), we found that *want* occurs 22,012 and *think* 10,187 times per million utterances. *Hope* is much less frequent, occurring at a rate of 364 times per million utterances. The syntactic distribution of *hope* and its low rate of occurrence in child-directed speech make it a good candidate for a bootstrapping study. Children are less likely to fully know its meaning by the age of four, and may therefore still be flexible in their interpretation. However, because it is a real word, it has the advantage of being somewhat familiar, not causing confusion during the experiment, ultimately allowing for the closest comparisons to our *want* and *think* studies. The fact that it occurs with both kinds of complements also allows us to manipulate syntactic frame without using ungrammatical sentences.

Cases like *hope* may also be informative about the syntactic bootstrapping mechanism. *Want* and *think* occur in complementary distribution; therefore if children are sensitive to the link between syntax and semantics, the subclass of these verbs may be clear from just a few occurrences. Verbs like *hope* present a more complicated learning challenge. The learner must track syntactic information across multiple uses of the verb and link this distributional information to semantic properties. Children have been shown to utilize distributional information across multiple frames to learn verb meanings (Naigles 1996); it is therefore possible that they also use distributional information to hypothesize fine-grained semantic information about attitude verbs. Our first step, however, is to determine whether children are sensitive to syntactic frame AT ALL in hypothesizing attitude-verb meaning. We thus restrict our current work to the finiteness distinction. Future work will continue to explore the extent to which children can glean attitude meanings from a more varied syntactic distribution.

We now present a series of experiments testing children's comprehension of *want*, *think*, and *hope*. Previous research shows that children have difficulty with *think* but not

want, in particular when the complement is false. Thus, in contexts in which the shape under consideration is not a heart, children would typically reject 18, but accept 19.

(18) Froggy thinks that it's a heart.
(19) Froggy wants it to be a heart.

Our experimental set-up makes both beliefs and desires salient, and these are sometimes in line with reality and sometimes counter to it. Our goals with experiments 1 and 2 are to (i) reproduce the *think*/*want* asymmetry within a single experimental paradigm, and (ii) establish patterns of responses to desire (*want*) and belief (*think*) verbs, which we use to compare to the *hope* responses in experiments 3 and 4. In experiments 3 and 4, we test children's comprehension of *hope* and manipulate complement type (finite as in 20, nonfinite as in 21) to see if it influences interpretation.

(20) Froggy hopes that it's a heart.
(21) Froggy hopes to get a heart.

We predict that children's responses to *hope* sentences should be influenced by syntactic frame: with a finite complement (20), children should give *think*-like responses: they should be lured by reality, and reject such sentences when the shape is actually a star. With a nonfinite complement (21), children should give *want*-like responses: they should not be lured by reality, and thus accept such sentences even when the shape is actually a star.

We must also address the shift in nonfinite complements between *want* (19) and *hope* (21). While it would be ideal to keep the nonfinite frame consistent throughout, *hope* does not occur with an embedded subject like *want* can (19). We wanted to use the slightly more complex *want* frame in experiments 1 and 2 to ensure that, if we find adult-like performance on *want* but not *think*, as we predict, we can be sure that success is not solely due to the simpler structure of a subject-less embedded clause in the complement of *want*. Experiments 1 and 2 will show that children CAN get a desire interpretation even with the more complex embedded subject syntax, thus ruling out this complexity as the driving force.

3.1. EXPERIMENT 1. While many studies have made claims about children's understanding of *want* vs. *think*, few directly compare them. In experiment 1, we test *want* and *think* in a single task that makes both beliefs and desires salient.

SUBJECTS. Participants were forty-eight children aged 4;0 to 5;0 (mean = 4;6). Six additional children were excluded, four due to getting too many controls incorrect, one due to parental report of the child's exposure to English as less than 80%, one due to experimenter error. To be included, children needed to complete the experiment and get six of the eight controls correct. Children were recruited from the greater Washington, DC, area and tested in the Project on Children's Language Learning lab at the University of Maryland.

DESIGN AND MATERIALS. To manipulate verb (*want* vs. *think*), we set up a game in which both the beliefs and desires of a character are relevant. The child plays with a puppet, 'Froggy'. The child and one experimenter are behind an occluder, while Froggy is on the other side. In front of the child is a box with forty colored hearts and stars. Color is predictive of shape: fifteen hearts are red and five are yellow, and fifteen stars are yellow and five are red. In the game, the experimenter pulls shapes out of the box to show Froggy. When the shape is a heart, the child gives Froggy a sticker; therefore his desire on every trial is for a heart. On each trial, before Froggy sees what the shape is, he sees a 'clue', which is ambiguous in shape. There is an opening in the occluder

through which Froggy is shown a point—either the point of the heart or one of the points of the star (Figure 1).[4]

FIGURE 1. All four shape and color combinations and the 'point' that is revealed to the puppet during the clue phase.

On every trial, Froggy has both a DESIRE about the shape—because he always wants the shape to be a heart, and a BELIEF—because whenever it is red he thinks it is a heart, and when it is yellow he thinks it is a star. This set-up allows another puppet, 'Booboo', who the child is told is 'silly and wants to learn how to play the game, but often gets things mixed up', to utter test sentences about either what Froggy *thinks* (22) or what he *wants* (23).

(22) Froggy thinks that it's a heart/star.
(23) Froggy wants it to be a heart/star.

The child's job in the task is then to say whether Booboo is correct or incorrect.

In a 2 × 4 × 2 design, we tested Verb as a between-subjects factor (*want* (n = 24), *think* (n = 24)), and Condition (red heart, red star, yellow heart, yellow star) and Mentioned shape (heart vs. star) as within-subjects factors. The child's response of 'yes' or 'no' was the dependent measure. On every trial, Froggy had both a belief and a desire about the next shape. His belief was dictated by the color of the clue. When color correctly predicted shape (red heart and yellow star conditions), his belief was true. When it did not (red star and yellow heart), his belief was false. Similarly, his desire for a heart was sometimes fulfilled (heart conditions), and sometimes unfulfilled (star conditions). Booboo, the silly puppet, uttered test sentences about Froggy's beliefs (22) or desires (23) about getting a heart (Mentioned heart) or star (Mentioned star). This set-up allows for an ideal comparison of interpretation of *think* and *want* sentences—in both cases, the child is asked to reason about a mental state (belief or desire) which may conflict (false belief/unfulfilled desire) or be consistent (true belief/fulfilled desire) with reality. The goal is to see whether children have more difficulty with conflicting beliefs than desires, as in previous literature. In the study, the participant encounters every possible combination of true/false beliefs and fulfilled/unfulfilled desires. The experiment includes four items of each type, for a total of thirty-two test items per child. Table 1 shows all sixteen conditions.

PROCEDURE. Each child was tested in a quiet room with two experimenters. One experimenter sat next to the child and gave the instructions about the game. This experimenter controlled the silly puppet, Booboo, and delivered the test sentences. The second experimenter sat on the other side of the occluder and played Froggy (Figure 2).

The second experimenter also coded the child's responses. Permission was obtained from parents to videorecord each subject in case any responses were missed during the

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[4] Note that this figure and the next are presented in color in the electronic versions of this article, but in black and white in the print version.

VERB (between subjects)	CONDITION (within subjects)	MENTIONED (within subjects)
think	Red heart	Heart
		Star
	Red star	Heart
		Star
	Yellow heart	Heart
		Star
	Yellow star	Heart
		Star
want	Red heart	Heart
		Star
	Red star	Heart
		Star
	Yellow heart	Heart
		Star
	Yellow star	Heart
		Star

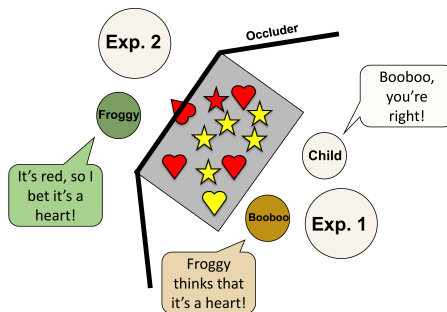TABLE 1. Between- and within-subjects conditions for experiment 1.

FIGURE 2. Experimental set-up.

initial coding. The experiment began by the child being introduced to Froggy: 'Hi, [child's name]. This is Froggy! We're going to play a game with Froggy today!'. The child completed several practice sessions to ensure that they understood all of the necessary elements of the game, including Froggy's desires and beliefs in this context.

PRACTICE SESSIONS. The child participated in a series of practice sessions in order to learn the set-up of the game.

Practice session #1: Distribution. This session directs the child's attention to the distribution of colors and shapes. The shapes are divided up on the table in front of the child.

(24) 'Froggy has a whole bunch of different shapes. Let's look at what shapes he has! Can you tell me about the shapes? Some of them are red! Can you tell me what kinds of red shapes we have?'
…
'That's right! Hearts and stars! Do we have a lot of the red hearts or just a few? And what about red stars?'

The child describes each type of shape—lots of red hearts and yellow stars, few red stars and yellow hearts. This helps them develop the intuition that a red clue is more likely to be a heart and a yellow clue is more likely to be a star, and that Froggy's guesses will reflect this.

Establishing desires. At this point we tell the child that the game will involve pulling shapes out of the box to show Froggy, and we introduce Froggy's preferences. We tell the child that Froggy 'loves getting hearts, but doesn't like getting stars at all' because every time we pull out a heart, Froggy gets a sticker. We then ask the child if they will 'help' us by being in charge of giving Froggy stickers every time we pull out a heart. This compels the child to keep track of what shapes we are pulling out, as well as motivating Froggy's preferences about shape. We check that the child remembers what Froggy 'likes' by practicing pulling out one of each shape and asking the child whether Froggy gets a sticker that time. Froggy reacts positively throughout the game every time he gets a heart (by saying things like 'Yay! I love hearts!' or 'That means it's sticker time!') and negatively when he gets a star (by saying things like 'Oh, no! Not another star!' or 'Yuck, I don't like getting stars!'). Children were very good at remembering when they should give Froggy a sticker, and they enjoyed giving the stickers and watching Froggy's reactions to getting both kinds of shapes.

Practice session #2: Guessing game. During the next practice session, we put all of the shapes in the box, and the experimenter turns the occluder so that the child can no longer see the shapes. She then shows Froggy and the child ambiguous clues—a point sticking through a slot in the occluder. Neither the child nor Froggy can see what the shape is. The child is told that they will guess what the shape is, then Froggy will guess, and then the experimenter will take the shape out so everyone can see. If the shape is a heart, the child gives Froggy a sticker. The shapes pulled out during this session reflect the distribution in the box. This session gives the child experience seeing the ambiguous clues from Froggy's side of the occluder, and gives them the experience of having false beliefs about the shape's identity.

Establishing beliefs. This session also establishes Froggy's beliefs and motivations for those beliefs—that when the clue is red Froggy thinks it is a heart, and when it is yellow he thinks it is a star. In this session, the child sees shapes and clues matched up with the distribution of the box—helping to cement the probabilistic relations between color and shape. They also hear Froggy's 'guesses' each time, based on the clue. On each trial, Froggy looks at the clue and speculates about the shape's identity based on the color, saying 'Hmm, this time it's red, so it's probably a heart!'. This establishes Froggy's beliefs and their motivations. Froggy avoids using any mental-state verbs during all practice sessions. In the next practice session, we confirm that the child has learned this connection.

Practice session #3: Belief check. The next practice session ensures that children understand Froggy's belief (or default guess) for each clue type. The experimenter checks this by asking the following questions:

(25) 'So when Froggy sees a red clue, what kind of shape does he guess?'

    …

    'And when he sees a yellow clue what does he guess?'

Children were overwhelmingly good at remembering Froggy's default guesses based on colors, but were corrected and prompted to try again if they were incorrect.

Practice session #4: Practice with Booboo. In the final practice session, children are introduced to the silly puppet, Booboo, who watches them play the game with Froggy. The child is told the following about Booboo.

(26) 'OK, one more thing! This is Froggy's friend, Booboo! Booboo really wants to learn how to play the game, but he's really silly and he always gets things mixed up! He always forgets what kind of shapes Froggy likes, and what kind of stuff Froggy guesses when he sees clues. But you're good at that, right? So maybe you could help Booboo learn? Booboo is going to watch us play, and sometimes he's going to try to tell us something about Froggy, but he might get it wrong, and your job is to help him out and tell him whether he's right or wrong so he can learn how to play the game.'

After Booboo is introduced, the child is told that we are going to show Booboo some clues and see what he says about Froggy. Then Booboo is shown four clues—one of each type—and says sentences about what Froggy will guess, and whether he likes that shape or not. During the time that the clue is visible only to the child, Booboo says a sentence about what Froggy will guess given the color (27), and after the shape is taken out, Booboo says a sentence about whether Froggy likes that shape (28).

(27) This one is red/yellow … so Froggy is going to guess heart/star!
(28) Oh! Froggy likes/doesn't like that kind!

The child's job is to tell Booboo whether his statement is right or wrong. This gives the child a chance to observe that Booboo is bad at remembering Froggy's mental states and practice telling him when he is right and wrong. This session also serves as a reminder of Froggy's desires and beliefs. If children have any trouble correcting Booboo on this session, they are given help from the experimenter.

Test sentences. After the warm-up sessions are finished, the box of shapes and the occluder are turned so that the child can see which shape is under discussion. They are told that now they are going to be able to 'peek' while we show Froggy some more clues, and Booboo is still going to say something about 'what Froggy likes, or what he might guess'. Then we begin showing Froggy clues and uttering test sentences. For each trial, the experimenter chooses which shape we are going to show Froggy (often letting the child 'help' decide), and then the experimenter slides the shape into the slot so Froggy can see the clue on the other side. On the first two trials, we remind the child, 'Remember, Froggy can't see what the shape is—he can only see the point! So we have to be sneaky!'. Froggy looks at the clue, and confirms that he can see it and that he is thinking about it. He says something like 'Hmm … this time it's red!'. After Froggy confirms that he has seen the clue, Booboo utters the test sentences. After the child responds to Booboo's utterance, we show Froggy the shape, and he responds appropriately. If it is a heart, the child gives him a sticker. Children tend to be interested and engaged throughout the entire process, which takes about twenty-five minutes.

RESULTS. Children's responses were coded by the second experimenter as the child delivered the response. There are three possible response patterns given the experimental set-up. Each pattern is described below, including the predicted responses in each condition consistent with each response pattern. One pattern is to interpret the sentence as describing Froggy's DESIRES. Children behaving this way should assent to sentences that mention 'heart', regardless of the actual shape and color of the shape, because Froggy always wants it to be a heart (Table 2, 'desire' column). The second pattern is responses based on Froggy's BELIEFS. Children should assent to sentences that mention

a heart whenever the clue is red, and to sentences that mention a star whenever the clue is yellow (Table 2, 'belief' column). Finally, we may see responses based on REALITY. Children should assent to sentences in which mentioned shape and actual shape are the same, regardless of color, desire, or belief (Table 2, 'reality' column). The adult-like responses are, of course, to respond based on the puppet's desire when the sentence is about what he *wants* and based on belief when it is about what he *thinks*. Adults should never give reality-based responses. Children should show reality responses in the *think* conditions, and desire responses in the *want* conditions. Table 2 shows the predictions for all three response types; the adult-like responses in each condition are italicized. The rightmost column shows the predictions for children's responses, and the conditions in which we expect children to differ from the adult pattern are bolded.

VERB (between subjs)	CONDITION (within subjs)	MENTIONED SHAPE	DESIRE	BELIEF	REALITY	CHILD PREDICTIONS
	1. Red heart	Heart	Yes	*Yes*	Yes	Yes
		Star	No	*No*	No	No
	2. Red star	Heart	Yes	*Yes*	No	**No**
		Star	No	*No*	Yes	**Yes**
think	3. Yellow heart	Heart	Yes	*No*	Yes	**Yes**
		Star	No	*Yes*	No	**No**
	4. Yellow star	Heart	Yes	*No*	No	No
		Star	No	*Yes*	Yes	Yes
	5. Red heart	Heart	*Yes*	Yes	Yes	Yes
		Star	*No*	No	No	No
	6. Red star	Heart	*Yes*	Yes	No	Yes
		Star	*No*	No	Yes	No
want	7. Yellow heart	Heart	*Yes*	No	Yes	Yes
		Star	*No*	Yes	No	No
	8. Yellow star	Heart	*Yes*	No	No	Yes
		Star	*No*	Yes	Yes	No

TABLE 2. Predictions for all possible response types (desire, belief, reality) in experiment 1. Italicized responses in the 'desire' and 'belief' columns signify the adult-like responses for each verb: adults would give 'desire' responses when they hear sentences with *want* and 'belief' responses when they hear sentences with *think*. Bold responses in 'child predictions' column signify where we expect children to differ from the adult-like pattern, showing a typical 'false belief' error. We predict they will be adult-like when they hear *want* sentences, but non-adult-like when they hear *think* sentences in false-belief contexts.

Children's responses were measured in proportion of *yes* responses. Red heart items were counted as controls: because this is a case of true belief and fulfilled desire, we predict the same pattern of responses, whether based on desire, belief, OR reality. They should say *yes* when a heart is mentioned (29) and *no* when a star is mentioned (30), regardless of verb.

(29) Froggy wants it to be/thinks that it's a heart.
(30) Froggy wants it to be/thinks that it's a star.

We excluded four participants who got fewer than six of the eight red heart items correct.

ANALYSIS. In line with previous work, we find that children are adult-like with *want*, but influenced by reality with *think*. The proportions of *yes* responses for all conditions are shown in Table 3 and Figure 3. Bolded responses show conditions in which children's responses differed from the predicted adult-like responses.

VERB (between subjs)	CONDITION (within subjs)	MENTAL STATE STATUS	MENTIONED SHAPE	ADULT-LIKE RESPONSE	PROPORTION *YES* (*SD*)
think — *Froggy thinks that it's a ___.*	1. Red heart	True belief, Fulfilled desire	Heart	Yes	1.00 (0.00)
			Star	No	0.03 (0.17)
	2. Red star	False belief, Unfulfilled desire	Heart	Yes	**0.14 (0.35)**
			Star	No	**0.85 (0.40)**
	3. Yellow heart	False belief, Fulfilled desire	Heart	No	**0.87 (0.33)**
			Star	Yes	**0.22 (0.41)**
	4. Yellow star	True belief, Unfulfilled desire	Heart	No	0.05 (0.21)
			Star	Yes	0.91 (0.31)
want — *Froggy wants it to be a ___.*	5. Red heart	True belief, Fulfilled desire	Heart	Yes	0.98 (0.14)
			Star	No	0.04 (0.20)
	6. Red star	False belief, Unfulfilled desire	Heart	Yes	0.70 (0.46)
			Star	No	0.17 (0.37)
	7. Yellow heart	False belief, Fulfilled desire	Heart	Yes	1.00 (0.00)
			Star	No	0.06 (0.24)
	8. Yellow star	True belief, Unfulfilled desire	Heart	Yes	0.76 (0.43)
			Star	No	0.16 (0.36)

TABLE 3. Proportion 'yes' responses for all conditions in experiment 1. Bolded responses signify conditions in which children's response patterns differed from the predicted adult-like pattern. The patterns differ only in the *think* conditions in which reality differed from the puppet's belief state, satisfying the predictions in Table 2 and replicating the classic 'false belief' error observed in other studies.
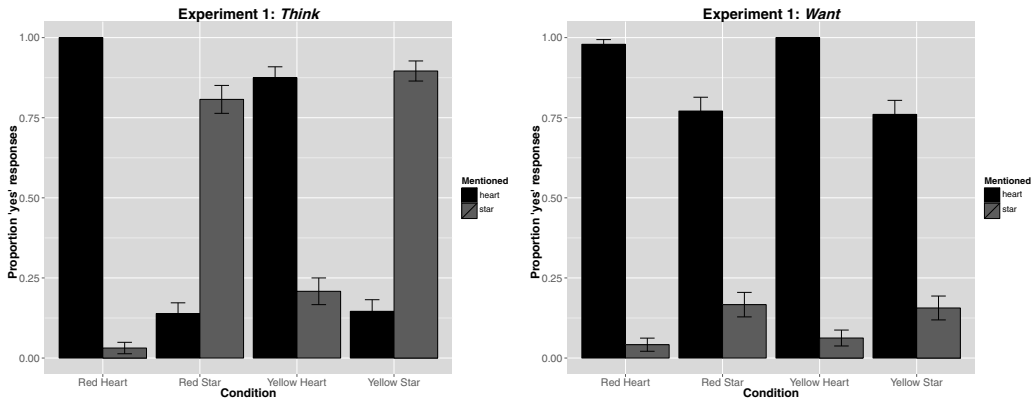

FIGURE 3. Proportion *yes* responses for all conditions in experiment 1. Desire responses are characterized by *yes* responses to mentioned heart sentences (black bars), which is the pattern observed for *want* sentences. Reality responses are characterized by *yes* responses when the mentioned shape matches the actual shape, which is the pattern observed for *think* sentences.

Children are adult-like in their responses to *want*, which match the 'desire' predictions, but not to *think* sentences, which match the 'reality' predictions.

STATISTICAL ANALYSIS OF EXPERIMENT 1. We used generalized linear mixed-effects models to analyze the results. These models are well suited for analyzing categorical data (Baayen 2008, Jaeger 2008). The reported models have random intercepts. These

models predict the probability of a specific response (a correct answer) in the different conditions (see Agresti 2002, Jaeger 2008). We ran a mixed-effect logit model with *yes* responses as the dependent measure, with Verb, Mentioned, and Condition as fixed effects, and Subject as a random effect. We find a three-way interaction of Verb, Mentioned, and Condition ($\chi^2(1) = 28.65$, $p < 0.0001$), showing different patterns of responses across each of the Verb conditions. We then look at each verb separately to best understand interpretation patterns. In the following sections, we describe the models we ran for each Verb condition.

STATISTICAL ANALYSIS OF *THINK* CONDITIONS. For the *think* conditions, we again ran a mixed-effect logit model with *yes* responses as the dependent measure, with Mentioned and Condition fixed effects, and Subject as a random effect. We find a significant two-way interaction between Mentioned and Condition ($\chi^2(1) = 224.28$, $p < 0.0001$), so we analyze each level of Condition separately. We ran four pairwise comparisons over each Condition/Mentioned pair. We find that in the heart conditions, children are significantly more likely to say *yes* to a mentioned heart and *no* to a mentioned star. In the star conditions, children are significantly more likely to say *yes* to star and *no* to heart. Estimated marginal means and *p*-values for each condition are reported in Table 4.

CONDITION	PROBABILITY *YES* RESPONSE (*SE*)		*p*-VALUE
	Mentioned heart	Mentioned star	
Red heart	0.99 (0.01)	0.02 (0.01)	< 0.0001
Red star	0.12 (0.03)	0.83 (0.05)	< 0.0001
Yellow heart	0.89 (0.03)	0.18 (0.05)	< 0.0001
Yellow star	0.12 (0.04)	0.91 (0.03)	< 0.0001

TABLE 4. Pairwise comparisons of probability *yes* responses across *think* conditions. In heart conditions, children are significantly more likely to give *yes* responses to mentioned hearts than mentioned stars. In star conditions, children are more likely to give *yes* responses to mentioned stars than mentioned hearts.

For all conditions, children are more likely to give *yes* responses when the shape mentioned matches the shape in the condition. This replicates previous studies investigating *think*: children are influenced by reality, giving *yes* responses only when the mentioned shape matches the actual shape.

STATISTICAL ANALYSIS OF *WANT* CONDITIONS. For the *want* conditions, we ran a mixed-effect logit model with *yes* responses as the dependent measure, with Mentioned and Condition as fixed effects, and Subject as a random effect. In this model, we find a main effect of Mentioned ($\chi^2(1) = 66.76$, $p < 0.0001$), showing that children respond differently when heart is mentioned than when star is mentioned, consistent with desire interpretations for *want* sentences. We also find a significant two-way interaction between Mentioned and Condition ($\chi^2(1) = 40.37$, $p < 0.0001$), suggesting that we should analyze each level of Condition. We ran four pairwise comparisons over each Condition/Mentioned pair. We find that for all conditions, children are significantly more likely to say *yes* when heart is mentioned and *no* when star is mentioned. Estimated marginal means and *p*-values for each condition are reported in Table 5.

CONDITION	PROBABILITY *YES* RESPONSE (*SE*)		*p*-VALUE
	Mentioned heart	Mentioned star	
Red heart	0.99 (0.01)	0.02 (0.01)	< 0.0001
Red star	0.74 (0.06)	0.14 (0.05)	< 0.0001
Yellow heart	0.99 (0.01)	0.04 (0.02)	< 0.0001
Yellow star	0.80 (0.05)	0.13 (0.04)	< 0.0001

TABLE 5. Pairwise comparisons of probability *yes* responses across *want* conditions. In all conditions, children are significantly more likely to give *yes* responses to mentioned hearts than mentioned stars.

The statistical models support our overall conclusion: children are overwhelmingly responding to *want* sentences based on Froggy's desires—they respond differently based on whether heart or star is mentioned in the test item.

The interaction between Mentioned and Condition demonstrates, however, that children are not completely adult-like in their responses to *want* sentences: they are more likely in some conditions to give *yes* responses to mentioned hearts. To better understand this interaction, we also ran pairwise comparisons within each of the Mentioned levels. In this analysis, we compare the likelihood of *yes* responses across each possible combination of conditions. When heart is mentioned, children are equally likely to give *yes* responses across both heart conditions and equally likely to give *yes* responses across both star conditions; but they are more likely to give *yes* responses to heart conditions than star conditions (*p*-values reported in Table 6)—showing that they are more accurate when Froggy's desire is fulfilled. For the mentioned star conditions, we ran the same pairwise comparisons and find a similar pattern. There is no difference in probability of *yes* responses in the two star conditions or the two heart conditions, but children show a higher pattern of *yes* responses in the star conditions than the heart conditions (*p*-values in Table 6)—again, showing that they are somewhat less accurate when there is a conflicting desire.

CONDITION	Mentioned heart	Mentioned star
	p-VALUE	*p*-VALUE
Red heart / Red star	0.0002	0.0207
Red heart / Yellow heart	0.9396	0.8786
Red heart / Yellow star	0.0012	0.0334
Red star / Yellow heart	0.0010	0.0703
Red star / Yellow star	0.7515	0.9906
Yellow heart / Yellow star	0.0036	0.1133

TABLE 6. Pairwise comparisons of probability *yes* responses across mentioned conditions. For both mentioned heart and mentioned star conditions, we find a significant difference in *yes* responses for every comparison of heart/star conditions: children are always more likely to give *yes* responses to mentioned hearts than mentioned stars. In both mentioned heart and mentioned star conditions, for the two heart conditions *yes* responses were equivalent, and for the two star conditions *yes* responses were equivalent.

This shows that although children's responses are primarily driven by the mentioned shape, there is also an influence of reality on their responses, although to a much lesser extent. The statistical models that we ran for the *want* conditions support our conclusion: children are overwhelmingly adult-like in their ability to assess Froggy's desire, responding primarily based on whether heart or star is mentioned in the test item. They are most accurate in heart conditions, the cases where Froggy's desire is fulfilled, although they are always significantly more likely to give *yes* than *no* responses whenever hearts are mentioned.

EXPERIMENT 1 SUMMARY. When children are tested under the same experimental conditions for both verbs, four-year-olds are more adult-like in their interpretations of *want* than *think*. Children give responses based on reality when interpreting *think* sentences. When interpreting *want* sentences, they primarily respond based on desires, although they are most accurate when the desires are not in conflict with reality, showing a lesser effect of reality in the *want* compared to the *think* conditions.

3.2. EXPERIMENT 2. Experiment 1 provided a novel demonstration that children's success with desire sentences precedes their success with belief sentences, using a single task that makes both beliefs and desires relevant. This effect was revealed between participants. In experiment 2, we manipulate verb within participants, so that we can be

sure that the *think*/*want* asymmetry can be observed within the same children. Shifting to a within-subjects design confirms the robustness of children's representations for the meanings of these verbs and their capacity to perform this task. The within-subjects design is very important for experiment 4, where it is only syntax that changes between blocks, and we needed to first verify that children could, in fact, get multiple different types of interpretations for sentences over the course of this experiment.

SUBJECTS. Participants were forty-eight children aged 4;0 to 5;0 (mean = 4;7). An additional five children were excluded: two got too many controls wrong, and three did not finish the task. To be included, children needed to complete the experiment and get three of the four controls correct. Children were recruited from the greater Washington, DC, area, through a recruitment database or through local preschools, and tested either in the Project on Children's Language Learning lab at the University of Maryland or at local preschools.

DESIGN AND MATERIALS. The design and materials were very similar to those of experiment 1 (see §3.1), except that Verb was a within-subjects factor, meaning that each child heard test sentences with both *want* and *think*, as in 31 and 32.

(31) Froggy wants it to be/thinks that it's a heart.
(32) Froggy wants it to be/thinks that it's a star.

In a 2 × 4 × 2 × 2 design, we tested three within-subjects factors: Verb (*want* vs. *think*), Condition (red heart, red star, yellow heart, yellow star), and Mentioned shape (heart vs. star). Because each subject heard test sentences with both *think* and *want* in a blocked design, we tested Order (1: *think* first ($n = 24$) vs. 2: *want* first ($n = 24$)) as a between-subjects factor. The child's response of *yes* or *no* was the dependent measure. Just as in experiment 1, on every trial Froggy had both a belief and a desire about the next shape, and each participant encountered every possible combination of realized and nonrealized beliefs or desires. However, because we added an additional within-subjects factor, we also needed to adjust the number of items in each condition, as simply doubling the number of items would have resulted in a task that was much too long. Given that children's responses on the star items differ across the *think* and *want* conditions in experiment 1, it was critical to have enough star items to determine whether children were changing their interpretation in the second half of the experiment. For this reason, children got more star items in this experiment—six of each (three heart and three star mentioned items per verb). Because the red heart items are controls, children in experiment 2 got only two of each per verb (one heart and one star mention each). We also reduced the number of yellow heart items to two each per verb (one heart and one star mention per verb): because children's responses in experiment 1 showed the same pattern across both verbs for these conditions, they are less informative about children's ability to differentiate *think* and *want* than the star conditions. This makes a total of thirty-two test items per child (Table 7). All materials were identical to those described in experiment 1.

CONDITION	DESIRE	BELIEF	# PER VERB
Red heart	Fulfilled	True	2
Red star	Unfulfilled	False	6
Yellow heart	Fulfilled	False	2
Yellow star	Unfulfilled	True	6

TABLE 7. Conditions and number of items per condition for experiment 2.

PROCEDURE. The procedure was identical to that described in experiment 1.

RESULTS. Children's responses were coded by the second experimenter as the child delivered the response. As in experiment 1, there are three possible response patterns—desire, belief, and reality (Table 2). Adult-like responses are again to respond based on Froggy's desire when the sentence is about what he *wants*, and based on beliefs when it is about what he *thinks*. In experiment 1, children were adult-like in the *want* conditions, but gave reality-based responses in the *think* conditions. Assuming that their representations of the verbs are robust and not sensitive to priming effects, we expect the same pattern in experiment 2. Children's responses were measured in proportion of *yes* responses. We excluded two participants who got fewer than three of the four red heart items correct.

ANALYSIS. Replicating experiment 1, we find that children are adult-like in interpreting *want*, but influenced by reality with *think*. Proportion *yes* responses for all conditions are shown in Table 8 and Figure 4. Bolded responses indicate conditions in which children's responses differed from adult-like responses. Overall, the conditions in which Froggy's mental state conflicted with reality were closer to chance in experiment 2 compared to experiment 1; hearing both verbs caused children to be somewhat more susceptible to reality. However, the overall pattern of responses still looks very similar to that in experiment 1, with children differing from the adult-like pattern in the false-belief cases (rows 2 and 3, Table 8) more than in the unfulfilled-desire cases (rows 6 and 8, Table 8).

VERB (within subjs)	CONDITION (within subjs)	MENTAL STATE STATUS	MENTIONED SHAPE	ADULT-LIKE RESPONSE	PROPORTION *YES* (*SD*)
think — Froggy thinks that it's a ___.	1. Red heart	True belief, Fulfilled desire	Heart	Yes	0.98 (0.14)
			Star	No	0.04 (0.20)
	2. Red star	False belief, Unfulfilled desire	Heart	Yes	**0.40 (0.49)**
			Star	No	**0.58 (0.50)**
	3. Yellow heart	False belief, Fulfilled desire	Heart	No	**0.77 (0.42)**
			Star	Yes	**0.33 (0.48)**
	4. Yellow star	True belief, Unfulfilled desire	Heart	No	0.15 (0.36)
			Star	Yes	0.80 (0.40)
want — Froggy wants it to be a ___.	5. Red heart	True belief, Fulfilled desire	Heart	Yes	1.00 (0.00)
			Star	No	0.04 (0.20)
	6. Red star	False belief, Unfulfilled desire	Heart	Yes	0.59 (0.49)
			Star	No	0.26 (0.44)
	7. Yellow heart	False belief, Fulfilled desire	Heart	Yes	1.00 (0.00)
			Star	No	0.04 (0.20)
	8. Yellow star	True belief, Unfulfilled desire	Heart	Yes	0.61 (0.49)
			Star	No	0.28 (0.45)

TABLE 8. Proportion *yes* responses for all conditions in experiment 2. Bolded responses signify conditions in which children's response patterns differed from the predicted adult-like pattern. The patterns differ only in the *think* conditions where reality differed from the puppet's belief state, again satisfying the predictions shown in Table 2 as well as replicating experiment 1 and previous tasks with *think* in false-belief situations.

Even in a Verb within-subjects blocked design, children are more adult-like in their responses to *want*, which match the desire pattern, than in their responses to *think*, which match the reality pattern.
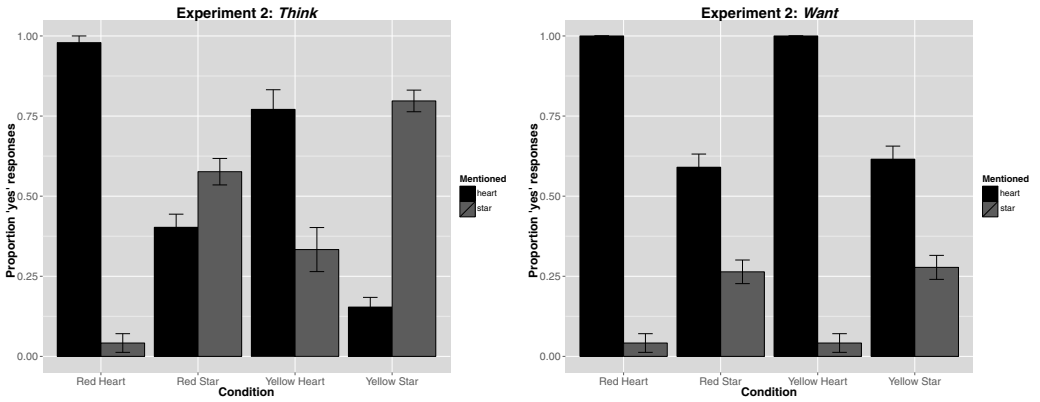
FIGURE 4. Proportion *yes* responses for all conditions in experiment 2. Desire responses are characterized by *yes* responses to mentioned heart sentences, which is the pattern observed for *want* sentences. Reality responses are characterized by *yes* responses when the mentioned shape matches the actual shape, which is the pattern observed for *think* sentences.

STATISTICAL ANALYSIS OF EXPERIMENT 2. We used the same kind of generalized linear mixed-effects models for experiment 2 as for experiment 1. We first combined data from both orders and performed the same analyses as reported for experiment 1. We ran a mixed-effect logit model with *yes* responses as the dependent measure, with Verb, Mentioned, and Condition as fixed effects, and Subject as a random effect. Critically, we find a three-way interaction of Verb, Mentioned, and Condition ($\chi^2(1) = 26.34$, $p < 0.0001$), showing different patterns of responses across each of the verb conditions. As in experiment 1, we therefore split the data by Verb.

STATISTICAL ANALYSIS OF *THINK* CONDITIONS. For the *think* conditions, we conducted the same statistical analyses as described for experiment 1. We ran a mixed-effect logit model with *yes* responses as the dependent measure, with Mentioned and Condition as fixed effects, and Subject as a random effect. In this model the two-way interaction between Mentioned and Condition is significant ($\chi^2(1) = 126.90$, $p < 0.0001$), so again we analyzed each level of Condition. We ran four pairwise comparisons over each Condition/Mentioned pair. As in experiment 1, in the heart conditions, children are significantly more likely to say *yes* to a mentioned heart than to a mentioned star; and in the star conditions, children are significantly more likely to say *yes* to a mentioned star than to a mentioned heart. Estimated marginal means and *p*-values for each condition are reported in Table 9.

CONDITION	PROBABILITY *YES* RESPONSE (*SE*)		*p*-VALUE
	Mentioned heart	Mentioned star	
Red heart	0.98 (0.02)	0.04 (0.03)	< 0.0001
Red star	0.40 (0.04)	0.58 (0.05)	0.0034
Yellow heart	0.78 (0.06)	0.33 (0.07)	< 0.0001
Yellow star	0.15 (0.03)	0.79 (0.03)	< 0.0001

TABLE 9. Pairwise comparisons of probability *yes* responses across *think* conditions. In heart conditions, children are significantly more likely to give *yes* responses to mentioned hearts than mentioned stars. In star conditions, children are more likely to give *yes* responses to mentioned stars than mentioned hearts.

For all conditions, children are more likely to give *yes* responses when the shape mentioned matches the shape in the condition. In the heart conditions, they are more

likely to accept mentioned heart sentences than mentioned star sentences. In the star conditions, they are more likely to accept mentioned star sentences than mentioned heart sentences. This effect is somewhat weaker than in experiment 1 (most notably in the red star condition), suggesting that children are overall somewhat less accurate in experiment 2. This is likely driven by the additional burden of switching between verbs. However, the pattern of responses overall matches experiment 1: children are influenced by reality in their responses to *think* sentences: they accept the sentence when the mentioned matches the actual shape and reject it when there is a mismatch.

STATISTICAL ANALYSIS OF *WANT* CONDITIONS. For the *want* conditions, we again ran a mixed-effect logit model with *yes* responses as the dependent measure, with Mentioned and Condition as fixed effects, and Subject as a random effect. In this model we again find a main effect of Mentioned ($\chi^2(1) = 32.78$, $p < 0.0001$), showing that children respond differently when heart is mentioned than when star is mentioned. We also find a significant two-way interaction between Mentioned and Condition ($\chi^2(1) = 39.75$, $p < 0.0001$). We therefore analyzed further by breaking down each level of Condition. We ran pairwise comparisons over each Condition/Mentioned pair and find that, as in experiment 1, children are significantly more likely to say *yes* when heart is mentioned than when star is mentioned for all conditions. Estimated marginal means and *p*-values for each condition are reported in Table 10.

CONDITION	PROBABILITY *YES* RESPONSE (*SE*)		*p*-VALUE
	Mentioned heart	Mentioned star	
Red heart	0.98 (0.02)	0.03 (0.03)	< 0.0001
Red star	0.59 (0.05)	0.25 (0.04)	< 0.0001
Yellow heart	0.98 (0.02)	0.03 (0.03)	< 0.0001
Yellow star	0.62 (0.05)	0.27 (0.04)	< 0.0001

TABLE 10. Pairwise comparisons of probability *yes* responses across *want* conditions. In all conditions, children are significantly more likely to give *yes* responses to mentioned hearts than mentioned stars.

Our conclusions are again supported—children are overwhelmingly adult-like in their ability to assess Froggy's desires, responding primarily based on whether heart or star is mentioned.

As in experiment 1, the significant interaction between Mentioned and Condition demonstrates that while children are influenced by Froggy's desires when interpreting *want* sentences, they are not completely adult-like. We thus also ran pairwise comparisons within each of the Mentioned levels. As in experiment 1, when heart is mentioned, children are equally likely to give *yes* responses across both heart conditions, and equally likely to give *yes* responses across both star conditions, but they are somewhat more likely to give *yes* responses to heart conditions than star conditions (*p*-values reported in Table 11), showing some influence of reality. For the mentioned star conditions we find a similar pattern. There is no difference in probability of *yes* responses in the two star conditions or the two heart conditions, but children show a higher pattern of *yes* responses in the star conditions than the heart conditions.

As in experiment 1, although children's responses are primarily driven by the mentioned shape, there is also an influence of reality on their responses: they are most accurate when Froggy's desire is fulfilled. Our conclusions are again supported: children are overwhelmingly adult-like in their ability to assess Froggy's desire, responding primarily based on whether heart or star is mentioned in the test item, with some additional influence of reality.

CONDITION	Mentioned heart	Mentioned star
	p-VALUE	p-VALUE
Red heart / Red star	0.0032	0.0213
Red heart / Yellow heart	1.0000	1.0000
Red heart / Yellow star	0.0047	0.0157
Red star / Yellow heart	0.0030	0.0213
Red star / Yellow star	0.9726	0.9931
Yellow heart / Yellow star	0.0044	0.0157

TABLE 11. Pairwise comparisons of probability *yes* responses by Mentioned. We find a significant difference in *yes* responses for every comparison of heart/star conditions: children are always more likely to give *yes* responses to mentioned hearts than mentioned stars. In both mentioned heart and mentioned star conditions, for the two heart conditions, *yes* responses were equivalent, and for the two star conditions *yes* responses were equivalent.

COMPARISON OF ORDERS 1 AND 2. We also ran a model including Order as a fixed effect. Order had no significant interactions with any other factors.

EXPERIMENT 2 SUMMARY. When children hear both *think* and *want* in the same experiment, they are adult-like with *want* and influenced by reality with *think*. This suggests that the *think/want* asymmetry is a strong effect, even within individuals. Additionally, it shows that the task demands are not too high for children to switch between interpretations, even when they get multiple sentence conditions in a blocked design. This will become important in experiment 4.

3.3. EXPERIMENTS 1 AND 2 DISCUSSION. Previous literature suggests that there is an asymmetry in children's mastery of *think* and *want*. However, those verbs were tested with different methods and experimental contexts. In the experiments presented here, we have controlled for possible experimental differences by testing both verbs in a single experimental context that makes both beliefs and desires relevant, and we find different patterns for four-year-olds' interpretation of *think* and *want*. When interpreting *think* sentences, children respond based on reality. When interpreting *want* sentences, they are primarily influenced by desires, although we see some influence of reality as well. These findings suggest that in our task, the actual shape is very salient: children are always, to some extent, lured by the mismatch between mentioned and actual shape. How much they are lured by this, however, differs based on the verb condition. These findings are overall consistent with our predictions, and with the previous literature testing *think* and *want*; children are categorizing them differently by age four and they are influenced by reality when interpreting *think* much more than when interpreting *want*. This pattern holds for both between- and within-subjects comparisons of the verbs.

We can now use the same experimental set-up, which makes salient both beliefs and desires, to test children's interpretation of the unfamiliar attitude verb *hope*. The patterns in experiments 1 and 2 provide a standard against which 'belief'/'desire' verb interpretations can be assessed. We predict that when *hope* appears with a nonfinite complement, children will assign it a desire meaning, and their responses will resemble the *want* conditions. When it appears with a finite complement, however, children will be lured by reality, and their responses will resemble the *think* conditions.

3.4. EXPERIMENT 3. Even in an identical experimental context, children systematically respond differently to sentences about conflicting desires compared to sentences about conflicting beliefs. We hypothesize that children's ability to categorize attitude verbs differently at such a young age stems from their different syntactic distributions. To test whether children use syntactic environment as a cue to attitude-verb meaning, we test their interpretations of sentences with *hope*, manipulating syntactic frame.

SUBJECTS. Participants were forty-eight children aged 4;0 to 5;0 (mean = 4;6). Four additional children were excluded, two due to getting too many controls incorrect, one due to parental report of the child's exposure to English as less than 80%, and one who did not finish the task. To be included, children needed to complete the experiment and get six of the eight controls correct. Children were recruited from the greater Washington, DC, area, through a recruitment database, and tested in the Project on Children's Language Learning lab at the University of Maryland.

DESIGN AND MATERIALS. In a 2 × 4 × 2 design, we manipulated Frame (*hope-to* vs. *hope-that*) between subjects and Condition (red heart, red star, yellow heart, yellow star) and Mentioned shape (heart vs. star) within subjects. Experiment 3 used the same game task as experiments 1 and 2 (see §3.1), where both the beliefs and desires of a character are relevant: the context should not independently bias children toward interpretations based on desire, belief, or reality, which will ultimately provide evidence that any differing interpretations stem from the manipulation of the syntax. Differing response patterns across verb in experiments 1 and 2 demonstrate that the context is neutral, and so any difference in interpretations across conditions in experiment 3 must be driven by the syntactic manipulation. As in the previous experiments, on every trial, Froggy has both a DESIRE about shape—because he always wants it to be a heart, and a BELIEF—because when it is red he thinks it is a heart, and when it is yellow he thinks it is a star. The silly puppet, Booboo, utters test sentences about what Froggy *hopes*, either with a finite complement (33–34) or a nonfinite complement (35–36). The child's job is again is to say whether Booboo is correct or incorrect.

(33) Froggy hopes that it's a heart.
(34) Froggy hopes that it's a star.
(35) Froggy hopes to get a heart.
(36) Froggy hopes to get a star.

All materials were identical to those described in experiment 1.

PROCEDURE. The procedure here was identical to that of experiment 1.

HYPOTHESES AND PREDICTIONS. This experiment tests whether children are sensitive to syntactic frame in interpreting an unfamiliar attitude verb. If they are, we expect different performances in the *hope-to* (nonfinite) and *hope-that* (finite) conditions. Specifically, we expect children to give desire interpretations (like *want*) with a nonfinite complement, and reality responses (like *think*) with a finite complement.

If children are not sensitive to syntactic frame in interpreting *hope*, there are several possible patterns of results we might see. If children already have an adult-like semantic representation for *hope*, or at least know that in this context it references desires, we expect their responses to pattern with *want*, irrespective of complement. If children do not know the meaning of *hope* and guess its meaning through some nonsyntactic strategy, we expect to see chance performance, and no differences between the *hope-to* and *hope-that* conditions.

RESULTS. Children's responses were coded by the second experimenter as the child delivered the response. As in experiments 1 and 2, there are three possible response patterns—desire, belief, or reality responses (Table 2). If children know that *hope* references Froggy's desires, we expect desire-based responses regardless of syntax: children should assent to both 33 and 35. If children do not yet know the meaning of *hope* and are sensitive to syntax, we expect desire responses in the *hope-to* condition and reality responses in the *hope-that* condition: they should assent to 35 regardless of what the

shape actually is, but to 33 only when the shape actually IS a heart. Children's responses were measured in proportion of *yes* responses. Just as in experiment 1, red heart items were controls—because this is a true-belief and fulfilled-desire case, we predict the same responses whether the participant responds based on desire, belief, OR reality. We excluded two participants who got fewer than six of the eight red heart items correct.

ANALYSIS. We find that children are more likely to give desire responses (i.e. look adult-like) in the *hope-to* condition, and to be influenced by reality (i.e. traditional false-belief error) in the *hope-that* condition. Proportion *yes* responses are shown in Table 12 and Figure 5. Highlighted responses show conditions in which children's responses differed from adult-like responses (*yes* to mentioned heart, *no* to mentioned star). Children differ from the adult-like pattern only in *hope-that* conditions, and only in cases in which the mentioned does not match reality.

FRAME (between subjs)	CONDITION (within subjs)	MENTAL STATE STATUS	MENTIONED SHAPE	PREDICTED PATTERN	PROPORTION *YES* EXP. 1	PROPORTION *YES* EXP. 3
hope-that — Froggy hopes that it's a ___	1. Red heart	True belief, Fulfilled desire	Heart	Yes	1.00 (0.00)	0.95 (0.22)
			Star	No	0.03 (0.17)	0.03 (0.17)
	2. Red star	False belief, Unfulfilled desire	Heart	No	**0.14 (0.35)**	**0.32 (0.47)**
			Star	Yes	**0.85 (0.40)**	**0.63 (0.49)**
	3. Yellow heart	False belief, Fulfilled desire	Heart	Yes	**0.87 (0.33)**	0.95 (0.22)
			Star	No	**0.22 (0.41)**	0.03 (0.17)
	4. Yellow star	True belief, Unfulfilled desire	Heart	No	0.05 (0.21)	0.32 (0.47)
			Star	Yes	0.91 (0.31)	0.57 (0.50)
hope-to — Froggy hopes to get a ___	5. Red heart	True belief, Fulfilled desire	Heart	Yes	0.98 (0.14)	1.00 (0.00)
			Star	No	0.04 (0.20)	0.04 (0.20)
	6. Red star	False belief, Unfulfilled desire	Heart	Yes	0.70 (0.46)	0.50 (0.50)
			Star	No	0.17 (0.37)	0.29 (0.46)
	7. Yellow heart	False belief, Fulfilled desire	Heart	Yes	1.00 (0.00)	0.95 (0.22)
			Star	No	0.06 (0.24)	0.04 (0.20)
	8. Yellow star	True belief, Unfulfilled desire	Heart	Yes	0.76 (0.43)	0.48 (0.50)
			Star	No	0.16 (0.36)	0.25 (0.44)

TABLE 12. Proportion *yes* responses for all conditions in experiment 3. The adult-like pattern for both frame conditions is desire responses (see Table 2, 'desire' column), because in adults, the primary meaning for *hope* is preferential. However, we expect that children will interpret the sentences differently based on frame, and therefore predict to see reality responses in the *hope-that* condition, and adult-like desire responses in the *hope-to* condition ('predicted pattern' column). As predicted, children are more likely to give adult-like desire responses in the *hope-to* condition, and reality responses in the *hope-that* condition. For ease of comparison, we have included the results of experiment 1 (*think* sentences rows 1–4, *want* sentences rows 5–8). Responses in the *hope-that* conditions are similar to the *think* conditions in experiment 1, and responses in the *hope-to* conditions are similar to the *want* conditions in experiment 1. Bolded responses signify the classic 'reality lure' error, which occurs in *think* conditions of experiment 1 and *hope-that* conditions of experiment 3. The red star condition is both false belief and unfulfilled reality, and is therefore the condition in which we can see reality-lure errors for both *think* and *hope-that* sentences.

In the *hope-to* condition, children are adult-like, responding based on desires; in the *hope-that* conditions, they respond based on reality.

STATISTICAL ANALYSIS OF EXPERIMENT 3. We used generalized linear mixed-effects models to analyze the results. We first ran a mixed-effect logit model with *yes* responses
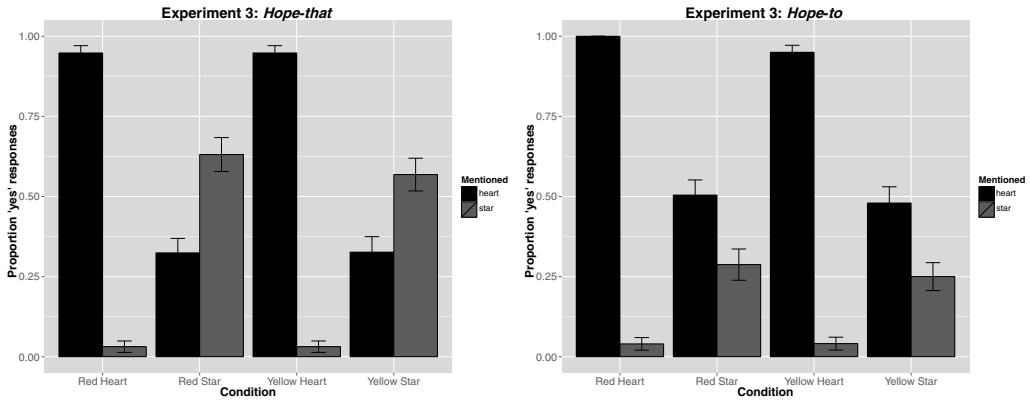
FIGURE 5. Proportion *yes* responses for all conditions in experiment 3. Desire responses are characterized by more *yes* responses to mentioned heart sentences, which is the pattern observed for *hope-to* sentences. Reality responses are characterized by more *yes* responses when the mentioned shape matches the actual shape, which is the pattern observed for *hope-that* sentences.

as the dependent measure, with Frame, Mentioned, and Condition as fixed effects, and Subject as a random effect. In this model, we do not find a three-way interaction between Frame, Mentioned, and Condition ($\chi^2(1) = 5.28$, $p = 0.153$). Since the initial model does not show any significant interactions with Frame, we then attempt to remove Frame from the model entirely, by using backward selection by p-value through ends to find the best-fit model.[5] The best-fit model does show a significant two-way interaction between Frame and Mentioned ($\chi^2(1) = 44.86$, $p < 0.0001$), as well as Mentioned and Condition ($\chi^2(1) = 269.89$, $p < 0.0001$), so we split by frame in order to interpret response patterns across conditions.

STATISTICAL ANALYSIS OF *HOPE-THAT* CONDITIONS. For the *hope-that* conditions, we again ran a mixed-effect logit model with *yes* responses as the dependent measure, with Mentioned and Condition as fixed effects, and Subject as a random effect. In this model, the two-way interaction between Mentioned and Condition is again significant ($\chi^2(1) = 169.69$, $p < 0.0001$), so we ran four pairwise comparisons over each Condition/Mentioned pair. In both of the heart conditions, children are more likely to say *yes* to a mentioned heart than a star. In both of the star conditions, children are more likely to say *yes* to a mentioned star than a heart. Estimated marginal means and p-values for each condition are reported in Table 13.

For all conditions, children are more likely to give *yes* responses when the shape mentioned matches the shape in the condition. Children are influenced by reality in their responses to *hope-that* sentences: they assent when the mentioned matches the actual shape, and reject the sentence when mentioned and actual do not match. This matches the observed pattern for *think* sentences in experiments 1 and 2.

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[5] Backward selection by p-value is a method of variable selection. It is a hierarchical procedure, so it will not remove any main effects if that main effect was involved in an interaction. This procedure first looks to see if the highest-level interaction (in this case three-way) is significant. If it is not, we remove that term from the model, and rerun it at the next level of interactions (two-way). We then repeat this process until no more terms can be removed. This procedure works well here, because it allows us to start with all possible variables in the model, but then appropriately simplify the model to best explain the data. For a further explanation of the process of backward selection by p-value, see Kutner et al. 2004.

CONDITION	PROBABILITY *YES* RESPONSE (*SE*)		*p*-VALUE
	Mentioned heart	Mentioned star	
Red heart	0.95 (0.02)	0.03 (0.02)	< 0.0001
Red star	0.32 (0.05)	0.63 (0.05)	< 0.0001
Yellow heart	0.95 (0.02)	0.03 (0.02)	< 0.0001
Yellow star	0.33 (0.05)	0.57 (0.05)	0.0009

TABLE 13. Pairwise comparisons of probability *yes* responses across *hope-that* conditions. In all conditions, children differ significantly in proportion *yes* responses across mentioned hearts and mentioned stars. In both heart conditions, children are significantly more likely to give *yes* responses to mentioned hearts than mentioned stars. In star conditions, we see the opposite pattern: children are more likely to give *no* responses to mentioned hearts than mentioned stars.

STATISTICAL ANALYSIS OF *HOPE-TO* CONDITIONS. For the *hope-to* conditions, we ran a mixed-effect logit model with *yes* responses as the dependent measure, with Mentioned and Condition as fixed effects, and Subject as a random effect. In this model, we find a significant main effect of Mentioned ($\chi^2(1) = 50.00$, $p < 0.0001$), showing that, like for *want*, children respond differently based on the mentioned shape. We also find a significant two-way interaction between Mentioned and Condition ($\chi^2(1) = 85.55$, $p < 0.0001$), so we analyze each level of Condition. We ran four pairwise comparisons over each Condition/Mentioned pair. We find that for all conditions, children are significantly more likely to say *yes* when heart is mentioned than when star is mentioned. Estimated marginal means and *p*-values for each condition are reported in Table 14.

CONDITION	PROBABILITY *YES* RESPONSE (*SE*)		*p*-VALUE
	Mentioned heart	Mentioned star	
Red heart	0.99 (0.01)	0.04 (0.02)	< 0.0001
Red star	0.50 (0.06)	0.27 (0.05)	0.0013
Yellow heart	0.96 (0.02)	0.04 (0.02)	< 0.0001
Yellow star	0.48 (0.06)	0.23 (0.05)	0.0006

TABLE 14. Pairwise comparisons of probability *yes* responses across *hope-to* conditions. In all conditions, children are significantly more likely to give *yes* responses to mentioned hearts than mentioned stars.

Overall, we see that the pattern here matches most closely the pattern observed for the *want* conditions in experiments 1 and 2; children are responding primarily based on Froggy's desires. Like in the *want* conditions for experiments 1 and 2, children are not completely adult-like in giving desire responses, as indicated by the interaction between Mentioned and Condition. For *hope-to* sentences, we also ran pairwise comparisons within each of the Mentioned levels. When heart is mentioned, children are equally likely to give *yes* responses across both heart conditions, and equally (un)likely to give *yes* responses across both star conditions; but they are more likely to give *yes* responses to heart conditions than star conditions (*p*-values reported in Table 15)—showing that they are more accurate when there is a fulfilled desire. For the mentioned star conditions, we ran the same pairwise comparisons and find a similar pattern. There is no difference in the probability of *yes* responses in the two star conditions or the two heart conditions, but children show a higher pattern of *yes* responses in the star conditions than the heart conditions (*p*-values in Table 15)—again, although they are still more likely to give *yes* responses than *no* responses, demonstrating that while there is some influence of reality on their responses for *hope-to* sentences, they are more likely to respond based on desire than reality.

This shows that although children's responses are primarily driven by mentioned shape, there is also an influence of reality on their responses. Overall, we see that the pattern here matches most closely the pattern observed for the *want* conditions in ex-

CONDITION	Mentioned heart p-VALUE	Mentioned star p-VALUE
Red heart / Red star	< 0.0001	0.0002
Red heart / Yellow heart	0.4379	1.0000
Red heart / Yellow star	< 0.0001	0.0009
Red star / Yellow heart	< 0.0001	0.0003
Red star / Yellow star	0.9800	0.9434
Yellow heart / Yellow star	< 0.0001	0.0011

TABLE 15. Pairwise comparisons of probability *yes* responses for mentioned conditions. Children are always more likely to give *yes* responses to mentioned hearts than mentioned stars. In both mentioned heart and mentioned star conditions, for the two heart conditions, *yes* responses were equivalent, and for the two star conditions, *yes* responses were equivalent.

periments 1 and 2, although they are influenced more strongly by reality with *hope-to* than with *want*.

SUMMARY OF STATISTICAL ANALYSIS FOR EXPERIMENT 3. The main predictor of children's *yes* responses was different across each of the frame conditions. In the *hope-that* conditions, children's *yes* responses are predicted by a match between the mentioned item and actual shape. Children were significantly more likely to give *yes* responses to mentioned hearts in the heart conditions, and to mentioned stars in the star conditions. These results show the same pattern as observed for *think*, suggesting that hearing a novel attitude verb with a finite complement triggers reality responses. In the *hope-to* conditions, children were influenced both by mentioned shape and by a match between mentioned and actual shape, with the strongest predictor being mentioned shape. Although there is a stronger influence of reality here than in experiments 1 and 2, we see the same overall pattern for *want* and *hope-to*. These results indicate that four-year-olds are most likely to get a desire interpretation when hearing a novel attitude verb with a nonfinite complement.

EXPERIMENT 3 SUMMARY. Experiment 3 tests children's sensitivity to syntactic frame when interpreting an unfamiliar attitude verb in a context that makes both beliefs and desires salient. Children show different response patterns for *hope* depending on syntactic frame, suggesting that they use syntax as a cue to attitude-verb meaning. With a nonfinite complement, they are more likely to treat *hope* as a desire verb; with a finite complement, they make the same reality error as with *think*. This suggests that at least one of the factors that triggers the traditional false-belief error is the syntax of finite complement clauses, or perhaps more abstractly, declarative syntax in complement clauses.

Although this experiment shows that children are sensitive to syntactic frame in interpreting an attitude verb, it does not yet provide evidence about the amount of syntactic exposure needed to learn an attitude verb and how flexible early representations are. To further explore the learning process, experiment 4 looks at how syntactic distribution influences interpretation throughout the experiment. We investigate this by manipulating syntactic frame within subjects.

3.5. EXPERIMENT 4. In the previous experiment, we saw that children are influenced by syntactic frame when they interpret an unfamiliar attitude verb. However, we do not yet know how they use the frame for longer-term integration into their semantic representation for the verb. Will the meaning they build for *hope* in the experiment have a lasting influence when the syntactic context changes? Evidence from studies on syntactic bootstrapping and syntactic priming suggest that children can carry word-meaning information gleaned from syntactic context forward to later experiences with words (Naigles 1996, Scott & Fisher 2009, among others). Experiment 4 explores how this

works for attitude-verb learning: are a few experiences with an attitude verb enough for children to influence their future interpretations of the verb? Or is more experience required, and do their representations remain flexible and susceptible to changes in the syntactic frame?

Experiment 4 investigates the question of how children use syntactic frame, and how flexible they are in the meaning they attribute based on frame (cf. Naigles et al. 1993). As in experiment 3, we give children sentences with *hope* in a context that makes both beliefs and desires salient. This time, however, we give children sentences with *hope* with both finite and nonfinite complements. Do children treat each trial as an individual case, or do they integrate information from previous trials into their semantic representation?

SUBJECTS. Participants were forty-seven children aged 4;0 to 5;0 (mean = 4;6). Four additional children were excluded, two due to getting too many controls incorrect and two who did not finish the task. To be included, children needed to complete the experiment and get three of the four controls correct. Children were recruited from the greater Washington, DC, area, through a recruitment database or through local preschools, and tested either in the Project on Children's Language Learning lab at the University of Maryland or at local preschools.

DESIGN AND MATERIALS. Experiment 4 was the same game task used in experiment 2 (see §3.2), except that instead of manipulating Verb (*want*/*think*) within subjects, we manipulated Frame for *hope* in a blocked design. Children heard all of the test sentences (37–40) over the course of the experiment.

(37) Froggy hopes that it's a heart.
(38) Froggy hopes that it's a star.
(39) Froggy hopes to get a heart.
(40) Froggy hopes to get a star.

In a $2 \times 4 \times 2 \times 2$ design, we tested three within-subjects factors: Frame (*hope-that* vs. *hope-to*), Condition (red heart, red star, yellow heart, yellow star), and Mentioned shape (heart vs. star). Because each subject heard both *hope-that* and *hope-to* sentences in a blocked design, we tested Order (1: *hope-that* first ($n = 24$) vs. 2: *hope-to* first ($n = 23$)) as a between-subjects factor. The child's response of *yes* or *no* was the dependent measure. As in experiments 1–3, on every trial Froggy had both a belief and a desire about the next shape, and participants encountered every possible combination of true and false beliefs, and fulfilled and unfulfilled desires. The distribution of items across Condition was identical to that of experiment 2 (Table 7).

All materials were identical to those described in experiment 2.

PROCEDURE. The procedure here was identical to that of experiment 2.

HYPOTHESES AND PREDICTIONS. Experiment 3 showed that children are sensitive to syntactic frame in interpreting an unfamiliar attitude verb. In this experiment, we probe how the semantic representation is built up over multiple exposures. If children immediately integrate information gleaned from syntactic frame, we expect that their performance will change in the second block of this task.

RESULTS. Children's responses were coded by the second experimenter as the child delivered the response. As in all previous experiments reported here, there are three possible response patterns: desire, belief, or reality responses (Table 2). In experiment 3, children were more likely to give desire responses with *hope-to*, and reality responses with *hope-that*. In this experiment, we expect to see the same pattern emerge in the first block. In the second block, however, there are two possible outcomes. One is

that children's interpretations of *hope* are always driven by the current syntax in which it is presented: children should interpret *hope-that* identically regardless of block. The second possibility is that children use their experiences with *hope* in the first half to hypothesize something about its meaning. If so, we expect children's responses in the second half to be influenced by the frame they heard in the first half.

Children's responses were measured in proportion of *yes* responses. We excluded two participants who got fewer than three of the four red heart items correct.

ANALYSIS. Because we are interested in the effect that the first block has on the second block, we present data for each block separately (Table 16, Figures 6 and 7). Looking only at the first blocks—*hope-that* in order 1 and *hope-to* in order 2 (italicized in Table 16), we replicate experiment 3. Children are more likely to give desire responses in the *hope-to* condition and to be influenced by reality in the *hope-that* condition. These reality-lure errors are indicated with bold text in Table 16. In the second blocks (nonitalicized data below), we see a different pattern. When the children in order 1 interpret sentences with *hope-to* after hearing *hope-that* first, the pattern of their responses no longer fits either a desire or a belief response. On the conditions in which desire and reality predict different response patterns (both star conditions), children's responses pattern with neither response type strongly. While they are influenced by the finite frame in the first half, this influence is not enough to completely override the nonfinite frame they hear in the second half. They are influenced by both the frame heard in the first half AND the frame heard in the second half. This pattern is especially evident in the star conditions of the graphs in Fig. 6.

The participants in order 2 hear *hope-to* first and then *hope-that*. In this condition we also see that the first block influences responses in the second block. In this case, however, responses in all conditions look similar to the responses in the first block. This is particularly evident in the star conditions of the graphs in Fig. 7. Children are influenced by the syntactic frames heard in the first half of the experiment. However, the AMOUNT of influence seems to vary with the particular order of frames: when children hear a nonfinite complement first, this experience seems to override the influence of the finite complement at a later point. When they hear a finite complement first they are less influenced.

As shown above, data in the first blocks of each order replicates findings from experiment 3. In the second blocks, children are influenced by syntactic frames that they heard earlier in the study, sometimes even enough to override the syntax of the current sentence.

STATISTICAL ANALYSIS OF EXPERIMENT 4. We split by Order and block to determine how the response patterns across each block match the patterns in experiment 3. For each order, we analyze the first block to ensure replication of experiment 3. Then we analyze the second block to determine whether the response pattern matches conditions of the current frame or the previous frame.

Statistical analysis of order 1, block 1. In the first block of order 1, children heard *hope-that* sentences. As in experiment 3, we ran a mixed-effect logit model with *yes* responses as the dependent measure, with Mentioned and Condition as fixed effects, and Subject as a random effect. In this model, again the two-way interaction between Mentioned and Condition is significant ($\chi^2(1) = 70.72$, $p < 0.0001$), so we ran four pairwise comparisons over each Condition/Mentioned pair. In the heart conditions, children are more likely to say *yes* to a mentioned heart than to a mentioned star. In the star conditions, children more likely to say *yes* to a mentioned star than to a mentioned heart. Estimated marginal means and *p*-values for each condition are reported in Table 17.

ORDER (between subjs)	CONDITION (within subjs)	MENTIONED SHAPE	PREDICTED RESPONSE	ORDER 1 (*hope-that* 1st) PROPORTION *YES* (*SD*)	ORDER 2 (*hope-to* 1st) PROPORTION *YES* (*SD*)
hope-that *Froggy hopes that it's a* .	1. Red heart	Heart	Yes	*1.00 (0.00)*	0.96 (0.20)
		Star	No	*0.00 (0.00)*	0.17 (0.38)
	2. Red star	Heart	No	***0.23 (0.42)***	0.50 (0.50)
		Star	Yes	***0.58 (0.50)***	0.11 (0.32)
	3. Yellow heart	Heart	Yes	***0.92 (0.28)***	1.00 (0.00)
		Star	No	***0.12 (0.33)***	0.08 (0.28)
	4. Yellow star	Heart	No	*0.12 (0.33)*	0.47 (0.50)
		Star	Yes	*0.58 (0.50)*	0.14 (0.35)
hope-to *Froggy hopes to get a* .	5. Red heart	Heart	Yes	0.96 (0.20)	*0.96 (0.20)*
		Star	No	0.08 (0.28)	*0.08 (0.28)*
	6. Red star	Heart	Yes	0.35 (0.48)	*0.52 (0.50)*
		Star	No	0.37 (0.49)	*0.26 (0.45)*
	7. Yellow heart	Heart	Yes	0.92 (0.28)	*0.95 (0.20)*
		Star	No	0.20 (0.41)	*0.13 (0.34)*
	8. Yellow star	Heart	Yes	0.26 (0.45)	*0.50 (0.50)*
		Star	No	0.37 (0.49)	*0.26 (0.44)*

TABLE 16. Proportion *yes* responses for all conditions in experiment 4. Italicized responses indicate first blocks in each order, which replicate findings from experiment 3. When children hear *hope-that*, they give the classic reality responses when asked about a conflicting mental state (indicated with bold text); when they hear *hope-to* they give desire responses. In the second halves, we see differential influence of the frame from the first halves: in order 1, children do not continue to follow the reality pattern, but in order 2, children continue to give desire responses, even after the syntax is no longer suggestive of the desire subclass.
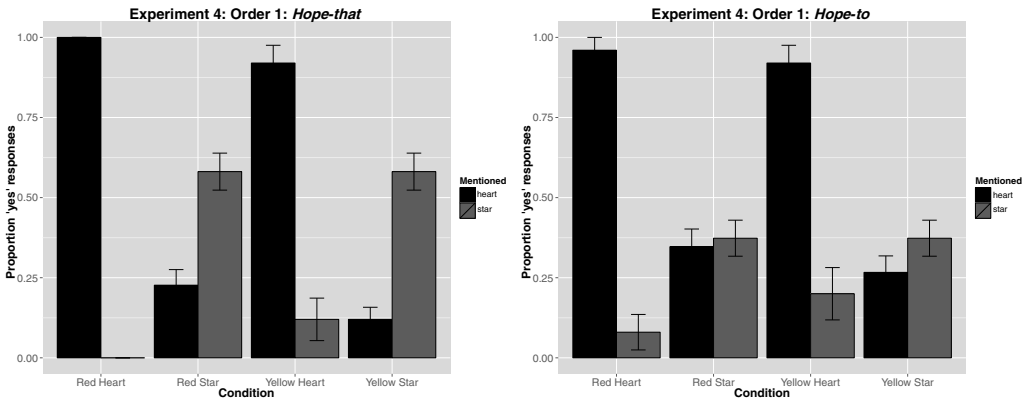

FIGURE 6. Proportion *yes* responses for order 1 of experiment 4. Participants heard *hope-that* sentences first and show the signature reality response: higher proportion *yes* responses when the mentioned shape matches the actual shape. In the second half, when children heard *hope-to*, the pattern disappears, suggesting that they are not maintaining their reality interpretation when the syntax changes in the second half.

Replicating experiment 3, children are influenced by reality. They are more likely to give *yes* responses when the shape mentioned matches the shape in the condition.

Statistical analysis of order 1, block 2. In the second block of order 1, children heard *hope-to* sentences. We ran a mixed-effect logit model with *yes* responses as the dependent measure, with Mentioned and Condition as fixed effects, and Subject as a random effect. In this model, the two-way interaction between Mentioned and Condi-
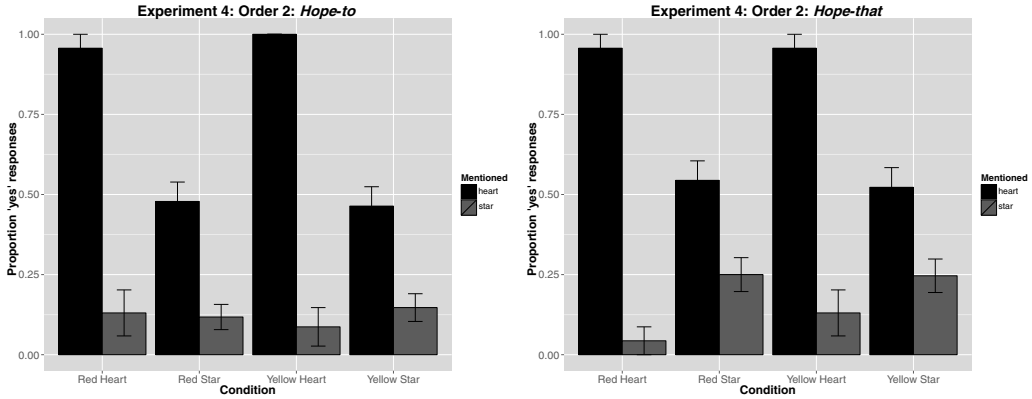
FIGURE 7. Proportion *yes* responses for order 2 of experiment 4. Participants heard *hope-to* sentences first and show the signature desire response: higher proportion *yes* responses for mentioned heart sentences. In the second half, when children heard *hope-that*, they maintain the desire pattern.

CONDITION	PROBABILITY *YES* RESPONSE (*SE*)		*p*-VALUE
	Mentioned heart	Mentioned star	
Red heart	0.97 (0.03)	0.03 (0.03)	< 0.0001
Red star	0.20 (0.05)	0.59 (0.07)	< 0.0001
Yellow heart	0.93 (0.05)	0.10 (0.06)	< 0.0001
Yellow star	0.10 (0.04)	0.59 (0.07)	0.0009

TABLE 17. Pairwise comparisons of probability *yes* responses across *hope-that* conditions. In all conditions, children give significantly different proportions of *yes* responses across mentioned hearts and mentioned stars. In both heart conditions, children are more likely to give *yes* responses to mentioned hearts than stars. In the star conditions, children are more likely to give *yes* responses to mentioned stars than hearts.

tion is significant ($\chi^2(1) = 40.19$, $p < 0.0001$), so we ran four pairwise comparisons over each Condition/Mentioned pair. This reveals a different pattern than we have seen in any of the previous studies—it does not match the desire or the reality patterns. In the heart conditions, children are more likely to say *yes* to mentioned hearts than to mentioned stars, consistent with either a desire or reality interpretation. In the star conditions, however, they are not more likely to say *yes* to either mentioned hearts or mentioned stars. Estimated marginal means and *p*-values for each condition are reported in Table 18.

CONDITION	PROBABILITY *YES* RESPONSE (*SE*)		*p*-VALUE
	Mentioned heart	Mentioned star	
Red heart	0.96 (0.04)	0.08 (0.05)	< 0.0001
Red star	0.34 (0.06)	0.37 (0.06)	0.7300
Yellow heart	0.92 (0.05)	0.19 (0.08)	< 0.0001
Yellow star	0.26 (0.05)	0.37 (0.06)	0.1574

TABLE 18. Pairwise comparisons of probability *yes* responses across *hope-to* conditions. Children are more likely to give *yes* responses to mentioned hearts in heart conditions, but are equally likely to give *yes* responses to either mentioned shape in star conditions.

This supports our conclusion that after hearing sentences with *hope-that*, children's interpretation of sentences with *hope-to* is affected. They are influenced both by the current frame and by the earlier frame.

Statistical analysis of order 2, block 1. In the first block of order 2, children heard *hope-to* sentences. As in experiment 3, we ran a mixed-effect logit model with *yes* re-

sponses as the dependent measure, with Mentioned and Condition as fixed effects, and Subject as a random effect. In this model, the two-way interaction between Mentioned and Condition is significant ($\chi^2(1) = 16.53$, $p < 0.0001$), so we ran four pairwise comparisons over each Condition/Mentioned pair. In all conditions, children are significantly more likely to say *yes* to a mentioned heart than to a mentioned star. Estimated marginal means and *p*-values for each condition are reported in Table 19.

CONDITION	PROBABILITY *YES* RESPONSE (*SE*)		*p*-VALUE
	Mentioned heart	Mentioned star	
Red heart	0.97 (0.03)	0.10 (0.06)	< 0.0001
Red star	0.47 (0.08)	0.09 (0.04)	< 0.0001
Yellow heart	0.97 (0.03)	0.06 (0.05)	< 0.0001
Yellow star	0.45 (0.08)	0.11 (0.04)	< 0.0001

TABLE 19. Pairwise comparisons of probability *yes* responses across *hope-to* conditions. In all conditions, children are more likely to give *yes* responses to mentioned hearts than mentioned stars.

Replicating experiment 3, children are more likely to give *yes* responses to mentioned hearts than to mentioned stars in all conditions.

Statistical analysis of order 2, block 2. In the second block of order 2, children heard *hope-that* sentences. We ran a mixed-effect logit model with *yes* responses as the dependent measure, with Mentioned and Condition as fixed effects, and Subject as a random effect. In this model, the two-way interaction between Mentioned and Condition is significant ($\chi^2(1) = 21.38$, $p < 0.0001$), so we ran four pairwise comparisons over each Condition/Mentioned pair. In all conditions, children are significantly more likely to say *yes* to a mentioned heart than to a mentioned star. Estimated marginal means and *p*-values for each condition are reported in Table 20.

CONDITION	PROBABILITY *YES* RESPONSE (*SE*)		*p*-VALUE
	Mentioned heart	Mentioned star	
Red heart	0.97 (0.04)	0.04 (0.04)	< 0.0001
Red star	0.54 (0.07)	0.23 (0.06)	0.0003
Yellow heart	0.97 (0.04)	0.11 (0.07)	< 0.0001
Yellow star	0.52 (0.07)	0.22 (0.06)	0.0007

TABLE 20. Pairwise comparisons of probability *yes* responses across *hope-that* conditions. In all conditions, children are more likely to give *yes* responses to mentioned hearts than mentioned stars, showing the same pattern as observed in the first block (*hope-to*).

This suggests that children have used the syntactic frame in the first block to hypothesize something about *hope*'s meaning. After hearing *hope-to* first, children continue to interpret *hope-that* sentences consistent with desire interpretations, giving more *yes* responses to mentioned hearts than to mentioned stars across all conditions.

EXPERIMENT 4 SUMMARY AND DISCUSSION. In experiment 4, we explored children's sensitivity to syntactic frame for attitude-verb learning. We find that, as in experiment 3, children use syntactic frame as a cue to meaning. Additionally, we find that children integrate this information across multiple trials. When the frame changed in the second half of the experiment, children did not reliably change their interpretation; rather, they seemed to integrate information from their previous experience with the verb. In the first blocks of each order in experiment 4, we replicate findings from experiment 3, showing that children are more likely to give desire-based responses with a nonfinite complement, and reality-based responses with a finite complement. In the second blocks of both orders, we see evidence of earlier trials influencing later trials, supporting the view that children build a meaning based on exposures in multiple frames. We

know from the results in experiment 2 that children are not always influenced by the first block in this experimental set-up. In experiment 2, children gave reality responses for *think* and primarily desire responses for *want*, regardless of the order of presentation. The fact that we do not see priming effects for *want* and *think* is informative about how to interpret the results here. First, it confirms that children had likely not yet solidified a semantic representation for *hope* before participating in our experiment. It also suggests that the effect is not driven by a lower-level priming within the context of the task (children simply getting into the habit of giving reality or desire responses and continuing this without really listening to the sentence), but may really be about children hypothesizing a meaning for *hope* based on the syntactic frame of the first block.

We also observe that children do not weigh all syntactic information equally. In order 1, children hear *hope-that* first and assign a belief interpretation; in the second block they hear *hope-to* and at least to some extent disregard the belief interpretation in favor of a desire interpretation. When children hear *hope-to* in the first block of order 1, they assign a desire interpretation. When they hear *hope-that* in the second block, they maintain their desire interpretation, despite the change in syntactic frame. This asymmetrical influence suggests that the nonfinite frame may be a more informative learning cue about the meaning of the verb than the finite frame.

POSSIBLE CAUSES OF ASYMMETRICAL INFLUENCE OF SYNTACTIC FRAME. There are multiple possible causes of the asymmetrical results of experiment 4. One is that this effect is driven by an input effect for the verb *hope*. We analyzed instances of *hope* in the Gleason corpus of the CHILDES database (Gleason 1980, MacWhinney 2000). This corpus contains dinnertime conversation transcripts from the families of twenty-four children aged 2;1 to 5;2. The entire corpus contains nineteen uses of *hope* in 36,901 total utterances. All uses of *hope* were from adults. Of these *hope* utterances, two were 'I hope not', one was 'I hope so', and two used *hope* as a noun. Fourteen utterances used *hope* with a sentential complement. Of these, thirteen had a finite complement and only one a nonfinite complement, suggesting that children are more likely to have been exposed to *hope* with a finite complement. So, children's prior experience with *hope*, while limited, may be influencing their performance in our task. Because the finite complement is more common in the input, the nonfinite complement may be more salient to the learner, and therefore have stronger effects in our task.

A second possible explanation for the asymmetry also relies on prior input for *hope*: it could be that prior experience with *hope* is enough for children to have a partial lexical representation of the adult-like desire meaning for *hope*. This partial lexical representation may make children more sensitive to nonfinite complements, because it aligns with their lexical representation and reinforces their hypothesis. Hence, children may weigh nonfinite complements more heavily than finite ones, regardless of order of presentation.

A third possibility is that the observed asymmetry is a methodological artifact. Across all of the experiments, in the *want* and *hope-to* conditions children respond primarily based on the puppet's desires, with more *yes* responses to mentioned hearts and more *no* responses to mentioned stars. In each of the experiments, however, we also see a smaller but consistent effect of reality. It appears that the design of the task makes reality salient enough that children are less accurate even in the *want* conditions when there is a conflict. Hearing *hope-that* first may make the reality conflicts even more salient, enough to cause children hearing *hope-to* in the second block to be lured by reality more often than children hearing *hope-to* alone. It is important to note, however, that the salience of reality is not enough to override a desire interpretation for *want* in the second block of order

1 of experiment 2, suggesting that children are more vulnerable to the influence of reality when interpreting a verb with which they have less experience.

A final possibility is a deeper linguistic connection between non-main-clause syntax and the preferential subclass of attitude verbs. In this case, the nonfinite frame may be a more straightforward cue to the meaning of the embedding verb. Prior crosslinguistic work suggests that at the right level of abstraction, there is a trackable pattern between syntactic distribution and semantic class for attitude verbs (Hacquard 2014, Hacquard & Lidz 2019). Future work may be informative about which aspects of this relation are the most crosslinguistically robust, and therefore possible candidates for innateness. Our results are compatible with each of these possibilities, and we leave adjudicating among them for future research.

3.6. Experiments 3 and 4 discussion. Experiments 3 and 4 addressed children's sensitivity to syntactic frame in interpreting attitude verbs, and how information from syntax carries over future encounters of the same verb in a different frame. We have done this by looking at children's interpretation of *hope* sentences with a nonfinite complement, which is typically associated with desire verbs, and with a finite complement, which is typically associated with belief verbs.

We have shown that children are sensitive to syntactic frame, suggesting that they use syntax as a cue for interpretation: when children hear a verb with a nonfinite complement, they tend to treat it as if it expresses desires; when they hear it with a finite complement, they make the same reality-lure error as with *think*. We have also shown that children integrate syntactic information across multiple trials, and that, at least for *hope*, the finite frame functions as a weaker cue than the nonfinite one.

3.7. Remaining questions and future directions. In this section, we briefly summarize some questions left unanswered and point to some future directions. We are planning a series of follow-up experiments using a similar design, but with a truly novel verb to address some of these issues, and to control for the role of prior experience with *hope* in our results.

One remaining question is whether the syntactic bootstrapping effects we observed in experiments 3 and 4 were driven by surface differences between the two *hope* frames. We argue that children are sensitive to the difference between finite and nonfinite complements, and their early differentiation of *think* and *want* lend some support to this hypothesis. However, the frame used in the *hope-to* condition did not contain an explicit subject in the embedded clause, in contrast to the finite frames throughout all experiments and the nonfinite *want* frame in experiments 1 and 2. This lack of subject could have had an effect on interpretation: perhaps children were interpreting the *hope-to* sentences as referencing Froggy's desires more generally, and not specifically the shape at hand. The novel verb study will allow us to control for this issue, as we will use a nonfinite complement identical to the *want* frames in experiments 1 and 2 (*Froggy gorps it to be a heart*).

The results of experiment 4 show an asymmetry in the influence of finite and nonfinite complements. There are several possibilities for what might be behind these asymmetries, including input effects, partial lexical knowledge for *hope*, or perhaps a deeper, universal relation between desire semantics and nonfinite syntax. Our novel-verb study will also help us better understand this asymmetry. If it is driven by input effects for *hope*, it should disappear with a novel verb. If it is driven by a deeper relation between nondeclarative main-clause syntax and desire meanings, the asymmetry should persist.

Another issue is whether children actually infer something about the lexical semantics of *hope* from the syntactic frame, or merely assume indirect assertions with a finite

frame and respond accordingly.[6] While we cannot rule this option out, a few pieces of evidence suggest that children are truly learning something about the meaning of the verb itself. The first is that in experiment 4, children carried over information about the verb from the first block into the second block, especially when they heard *hope-to* first. If they were just responding to the perceived illocutionary force of the utterance at hand, we would not expect to see such effects. The second piece of evidence comes from findings by Lewis et al. (2017) (discussed in §2). This work suggests that children know something about the meaning of *think* by age three: in the right contexts, children are able to successfully reject literally false sentences, even when the complement is true. This suggests that they have access to the literal, belief-ascription meaning of *think* and that their errors are essentially pragmatic. In our experiment, we failed to replicate this pattern: children tended to respond to the truth of the complement, even when the *think* sentence was false. There are several critical differences between the two sets of studies: in Lewis et al.'s hide-and-seek task, the original question under discussion is that of the hider's location, driving indirect-assertion interpretations. When the second seeker is introduced, however, another question becomes important in the task: that of who will win, and to answer this question, the beliefs of the seekers become very relevant and thus more salient. In our experiments, only Froggy's beliefs are relevant. Although we alert the child to the relevance of his beliefs during the 'belief check', once the game has started, it seems that the most relevant question is whether Froggy will get a sticker on each trial, and thus the shape's identity. The high salience of reality in our task is also evident in the *want* conditions of experiments 1 and 2, where the lure of reality in our task is strong enough to cause some reality errors, although it is well established that children are adult-like in their interpretation of *want* by age 3.

Finally, there are questions about the boundaries of the syntactic bootstrapping mechanism that remain unanswered and will influence our future work. One such open question is that of the full range of syntax-semantics links to which the learner is sensitive. We have started with finiteness, as this is reliable in English for differentiating verbs with which children have a significant amount of early experience, but there is still much to be explored in terms of the syntactic features children can utilize for attitude-verb learning and how far these syntactic features will go toward their learning semantic representations for a full range of attitudes. This work also leaves open questions about the source of children's knowledge of these connections. The crosslinguistic facts discussed in §2 suggest that the link between embedded main-clause syntax and the representational class of attitude verbs may be innate (for evidence that such a link could be exploited in attitude learning even in a morphosyntactically poor language like Mandarin, see Huang et al. 2018).

4. CONCLUSIONS. Attitude verbs express psychological states whose contents are not directly observable. To learn their meanings, children may thus rely on linguistic context, specifically the syntactic frames in which they occur, as evidence about their meanings. Our studies show that children use features of the sentential complement when interpreting an unfamiliar attitude verb. In a series of experiments that make beliefs and desires salient, we have tested children's interpretation of the verbs *think*, *want*, and *hope*. We reproduce the long-noted asymmetry in children's interpretation of *think* vs. *want*: children are adult-like in their responses to *want*, but are lured by reality in their responses to *think*. We further show that children's responses to the unfamiliar verb *hope* are highly influenced by the syntactic frame in which it appears: with a non-

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[6] We thank a referee for helpful discussion on this point.

finite complement, children's responses resemble desire responses; with a finite complement, they resemble their responses to *think*, showing classic reality-based errors.

Although many studies have demonstrated children's ability to use syntactic information for word learning, our experiments explore children's sensitivity to a syntax-semantics connection not previously reported. While the foundational work in syntactic bootstrapping emphasized the utility of syntactic cues in acquiring mental-state verbs (Landau & Gleitman 1985, Gleitman 1990, Gillette et al. 1999), work examining children's use of syntax in verb learning has primarily focused on action verbs (for review, see Fisher et al. 2019). In this body of work, the emphasis has been on the number and position of syntactic arguments, but not their syntactic category. Here, we have shown that children are sensitive to the subtypes of clausal arguments in drawing inferences about the meanings of unfamiliar attitude verbs. This work thus makes good on the promise that syntactic features are an important source of evidence about verbs whose relation to events in the physical world is obscure.

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