

Figuring out root and epistemic uses of modals: The role of the input

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Abstract

This paper investigates how children figure out that modals like *must* can be used to express both epistemic and “root” (i.e. non epistemic) flavors. The existing acquisition literature shows that children produce modals with epistemic meanings up to a year later than with root meanings. We conducted a corpus study to examine how modality is expressed in speech to and by young children, to investigate the ways in which the linguistic input children hear may help or hinder them in uncovering the flavor flexibility of modals. Our results show that the way parents use modals may obscure the fact that they can express epistemic flavors: modals are very rarely used epistemically. Yet, children eventually figure it out; our results suggest that some do so even before age 3. To investigate how children pick up on epistemic flavors, we explore distributional cues that distinguish roots and epistemics. The semantic literature argues they differ in “temporal orientation” (Condoravdi 2002): while epistemics can have present or past orientation, root modals tend to be constrained to future orientation (Werner 2006, Klecha 2016, Rullmann & Matthewson 2018). We show that in child-directed speech, this constraint is well-reflected in the distribution of aspectual features of roots and epistemics, but that the signal might be weak given the strong usage bias towards roots. We discuss (a) what these results imply for how children might acquire adult-like modal representations, and (b) possible learning paths towards adult-like modal representations.

1. Introduction

Almost half of the world’s languages have modal forms that can be used to express different “flavors” of modality (van der Auwera & Ammann 2005). For instance, in English, a *must* sentence like (1) can express an epistemic necessity (*Alex is probably a tofu eater*), or various kinds of “root” necessities (i.e. non epistemic; Hoffmann 1966): deontic (*Alex is required to eat tofu*), bouletic (*Alex wants to eat tofu*), or teleological (*Alex needs to eat tofu*). This flavor flexibility seems to be particular to “functional modals”, i.e., words from a grammatical category seemingly dedicated to modality (in English, modal auxiliaries like *must* and semi-modals like *have to*), in contrast to “lexical modals”, i.e., verbs (e.g. *require*), adjectives (e.g. *likely*) or adverbs (e.g. *maybe*), which also express possibilities and necessities, but typically in a single flavor.

(1) Alex must eat tofu.

This paper investigates when and how children solve the difficult mapping problem of linking functional modals like *must* to both root and epistemic flavors on the basis of their input representation, by looking at how modals are used in naturalistic speech to and by young children. By laying bare the mapping problem for modals, and articulating and quantifying what cues are available to resolve it, this work paves the way for asking what capacities—linguistic, conceptual or pragmatic—must be in place, and what expectations learners must have about how modality is expressed in natural language.¹

The previous acquisition literature shows an asymmetry in children’s functional modal productions: children start with root meanings around age 2, but fail to produce epistemic meanings until at least age 3 (Kuczaj & Maratsos 1975, Wells 1979, Stephany 1979, Astington 1993, Cournane 2015a,b,2021 a.o.). This “epistemic gap” (Cournane 2015a,b) is often taken to reflect a conceptual lag (Sweetser 1982, Shatz & Wilcox 1991, Astington 1993, Papafragou 1998), or grammatical development (Heizmann 2006; Cournane 2015a,b; Veselinović & Cournane 2020). This literature tacitly assumes that once the concepts or grammar are in place, mapping modal words to the meanings they express is trivial. In this paper, we show that the mapping problem for functional modals is in fact far from trivial, and yet, we also show, that children resolve it even sooner than originally thought. We investigate how they might do so.

To appreciate the depth of the mapping problem for modals, let’s first consider the case of their close relatives, attitude verbs, such as *think* and *want*. Because these verbs express abstract concepts, learners can’t rely on visual cues to learn their meanings, and their acquisition thus need to rely heavily on linguistic cues. As such, they have been hailed as parade cases for “syntactic bootstrapping” (Landau & Gleitman 1985, Gleitman 1990), the hypothesis according to which children learn a word’s meaning by exploiting principled links between its meaning, which is closed to observation, and its syntactic distribution, which is more easily observable. In the case of *want* and *think*, children would observe that *think* takes finite complements, *want* nonfinite complements, expect finiteness to track a belief vs. desire split amongst attitude verbs, and from there infer that *want* expresses desire and *think* expresses belief (Hacquard & Lidz 2018). Indeed, children do seem to exploit finiteness to figure out attitude verb meanings (Harrigan *et al.* 2019). For modals, the situation is even more complicated, since the *same* word can express both desire (root) and belief (epistemic) meanings. Can children also rely on syntactic cues to figure out modal meanings? Given that modals take nonfinite complements, the bootstrapping strategy for attitudes might lead them to infer root (desire) meanings. This mapping to root meanings might be reinforced by two factors. First, the concepts underlying root meanings may be more easily accessible than those underlying epistemic ones (Bartsch & Wellman 1995, Perner *et al.* 2003, de Villiers 2005, Steglich-Petersen & Michael 2015), even if both types of concepts may be in place in infancy (Onishi & Baillargeon 2005, Southgate *et al.* 2007). Second, root meanings may be particularly salient in discourse: root modals can routinely be used to perform requests, a discourse function which young children seem particularly attuned to (Shatz 1978, Spekman & Roth 1985). Thus, various factors from syntax to pragmatic or conceptual salience may conspire for children to initially map modals to root meanings. And, once children have mapped a modal word to a root meaning, why not stop there? Why assume that modals can *also* be used to express epistemic flavors? Note that root and epistemic meanings are not mutually exclusive: if it’s *likely* that Alex eats tofu, then she might well *need* to eat it. Thus, we can’t expect epistemicity to be self-evident

¹We’re interested in how children figure out that words like *must* can be used to express different flavors at the type, rather than token level. That is, how children learn that these words have the *potential* to express various flavors, rather than what flavor a particular modal use has in a given context.

because root meanings would be false whenever epistemic meanings are intended. How, then, do children pick up on epistemic flavors?

The answer to this question depends in part on whether children expect their language to have flavor flexible modals. After all, not all languages do. Children might get a head start and expect flavor flexibility for functional modals, if, as Hacquard & Cournane (2016) argue, there is a principled link between the functional status of modals (e.g., the fact that they are auxiliaries) and their ability to express both root and epistemic flavors. If true, realizing that a modal like *must* is functional from its auxiliary status (marked morpho-syntactically) would make available the possibility that it is flavor flexible. A learner equipped with this expectation would get flavor flexible semantics for free based on syntactic category, but would still need to ascertain whether both types of flavors actually occur for any given modal (some modals only express one type, e.g., *can* is not epistemic unless negated). Alternatively, children may not have any particular assumptions about functional modals with respect to flavor flexibility. They would then only postulate flavor flexibility on the basis of positive evidence. For example, they might first hypothesize that *must* is deontic, and would then have to revise this hypothesis when they discover that it can also have epistemic uses. Under either assumption, children need to realize which of their modals express epistemic flavors, in the absence of clear physical cues. Are there any linguistic cues that would give away epistemic flavors? We address this question by looking for environments in which root flavors are ruled out, or at least unlikely.

We first probe the depth of this mapping problem, using a larger and more densely sampled corpus than prior studies, by examining (i) children’s input: do children hear modals with both root and epistemic uses? Which modals, in what proportions, and in what linguistic environments? And (ii) children’s productions: do children produce both root and epistemic modals before age 3? Which modals, in what proportions, and in what linguistic environments? Our input results show that the mapping problem is made worse by the fact that parents overwhelmingly use modals with root flavors in speech to children, even more so than reported for adult speech (Ruppenhofer & Rehbein 2012, Rubinstein *et al.* 2013, Marasović *et al.* 2016). And yet, our child productions results show that already at age 2, English-learning children show evidence of having learned that at least some functional modals can express epistemic flavors.

We investigate possible morphosyntactic cues that differentiate root and epistemic modals in principled ways, which children could exploit to infer epistemic meanings. After reviewing several candidates from the literature, we argue that the most promising is a constraint on the “temporal orientation” of modals (Condoravdi 2002), according to which root modals tend to be future-oriented, while epistemics can be past or present-oriented (Werner 2006, Klecha 2016, Rullmann & Matthewson 2018). What makes this constraint particularly compelling from a bootstrapping perspective, is that first, it is supposed to be principled (it is motivated by informativity considerations: whether the modal makes a non trivial meaning contribution), and second, it has clear morphosyntactic correlates, as temporal orientation is largely determined by aspect (Condoravdi 2002). When the modal’s “prejacent” (the proposition that the modal combines with) consists of a bare eventive (i.e., with no overt aspect), as in (2), a modal can have both future and present orientation (the running follows or overlaps the time of possibility), and both root and epistemic interpretations are possible (*Alex is allowed to run*; *Alex is a potential runner*). However, with a stative prejacent, as in (3), or with a progressive, as in (4), the orientation is present; with a perfect, as in (5), the orientation is past: in such cases, only epistemic interpretations seem possible.

(2)	Alex may run.	Future/Present TO	root, epistemic
(3)	Alex may love running.	Present TO	??root, epistemic
(4)	Alex may be running.	Present TO	??root, epistemic
(5)	Alex may have run.	Past TO	??root, epistemic

This constraint suggests a possible avenue for discovering epistemic flavors: by observing modals with present or past orientation, that is, modals with perfect, progressive, or stative prejacent, a learner privy to the temporal orientation constraint could infer that the modal must be interpreted epistemically. We explore the viability of this proposal by examining the aspectual distribution of roots and epistemics. We find that while the constraint is well-reflected in child-directed modal usage, the signal is weakened by the strong bias towards root uses. We discuss ways in which children could still exploit these aspectual cues, through additional cues from different kinds of subjects with roots and epistemics, and contextual cues. We explore possible learning paths towards adult-like representations.

The rest of this paper is organized as follows. In section 2, we provide further background about how root and epistemic flavors differ in meaning and distribution, notably in their interactions with subjects and aspect. Section 3 presents an overview of the modals used by two-year-olds and their mothers in the Manchester Corpus (Theakston *et al.* 2001) on the CHILDES database (MacWhinney 2000), and shows that adults and children produce both roots and epistemics with an overall bias towards root meanings, which is even more pronounced for children. Section 4 examines the aspectual profiles of roots and epistemics in the input, and shows that they differ significantly. However, because of the large frequency skew towards root uses, learners may only be able to use this distributional difference if they use it in conjunction with contextual cues. In section 5, we discuss the distribution of subjects and show that roots and epistemics differ in the kinds of subjects they take, though, again, the large frequency skew towards root uses makes it difficult to use reliably. In section 6, we discuss how children might be able to exploit aspectual and subject cues, and sketch possible learning paths towards adult-like modal representations. Section 7 concludes.

2. Background

2.1. Modal flavors: meaning differences

In a language like English, the same modal words can be used to express both root and epistemic flavors: (1) can express an obligation or a likelihood. In the adult grammar, this is a case of ambiguity rather than generality, as can be shown using Zwicky & Sadock (1975)'s Identity of the Senses tests. A sentence like *Alex and Billy must eat tofu* can either mean that both Alex and Billy are required to eat tofu, or that both are likely tofu eaters, but mixed readings are disallowed. In this way, modals pattern with ambiguous terms like *bank*, rather than general terms like *teacher*. The source of this ambiguity is however a matter of debate: is it lexical ambiguity (several *musts*), polysemy (several senses of *must*), or is there just one *must*, whose restriction is provided by context, and leads to different flavors, as in the classic Kratzerian account?

Kratzer (1981) analyzes possibility and necessity modals as existential and universal quantifiers over possible worlds. In this framework, a modal's domain of quantification is determined by two conversational backgrounds, a *modal base* (MB), and an *ordering source* (OS): the modal quantifies over the best worlds of MB, i.e., those that most closely approach the ideal set by OS.

- (6) a. $[[\text{can}]]^{w, \text{MB}, \text{OS}} = \lambda q_{\langle s, t \rangle}. \exists w' \in \text{Best}_{\text{OS}(w)} (w' \in \text{MB}(w): q(w'))$
 b. $[[\text{must}]]^{w, \text{MB}, \text{OS}} = \lambda q_{\langle s, t \rangle}. \forall w' \in \text{Best}_{\text{OS}(w)} (w' \in \text{MB}(w): q(w'))$
 where $\text{Best}_{\text{OS}(w)}(X)$ selects the most ideal worlds from X , given the ordering given by $\text{OS}(w)$ ²

In this system, roots and epistemics differ in MB: epistemics take an epistemic MB, which picks out worlds compatible with the available evidence. Roots, which include ability, circumstantial, deontic, bouletic, and teleological modals, take a circumstantial MB, which picks out worlds compatible with relevant circumstances. Root modals are further differentiated via an OS, which provide different orderings: deontic, teleological, bouletic.³ Some authors (e.g. Condoravdi 2002) add a third “metaphysical” (or “historical”) MB, which picks out worlds that share a common history but diverge in their future. Others reanalyze purported metaphysical modality as involving a circumstantial MB, like roots (Abusch 2007, 2012, Thomas 2014).

What flavor a modal expresses then depends on what MB and OS the context makes available. Yet, epistemic and root modals seem to differ systematically in their interactions with elements like tense and aspect, in ways that seem to go beyond contextual differences. This has led some to give up on the unified Kratzerian account, and postulate distinct epistemic and root lexical entries for functional modals like *must*.⁴ Here we can remain agnostic as to whether there happens to be one or several *musts* in the adult grammar: under either view, the learning puzzle remains for how children figure out that the same string can be used to express distinct flavors, and not just general possibility or necessity. And under either view, the distributional differences between roots and epistemics provide potential avenues for children to pick up on epistemic flavors: if a modal appears in an environment where root meanings are illicit, it could cue them in that the modal expresses an epistemic flavor. We turn to these possible constraints next.

2.2. Constraints on modal flavors

There are two kinds of interactions for which roots and epistemics have been argued to systematically differ. These could potentially be exploited for a syntactic bootstrap of epistemic flavors: the first involves subjects, the other tense and aspect.⁵ Turning to subjects first, root and epistemic modals were initially thought to differ in argument structure, with roots treated as control predicates, and epistemics as raising predicates (Ross 1969, Jackendoff 1972, Lightfoot 1979, Zubizarreta 1982, Roberts 1985, Brennan 1993), based on an apparent thematic relation between root modals and their subjects. Were learners to expect a thematic relation between a root modal and its subject, the appearance of an expletive subject would be a strong indication that the modal

² The ‘Best’ operator is from Portner (2009).

³ In this system, the types of flavors are even more fine grained than the labels ‘deontic’, or ‘bouletic’ might suggest, as the OS can denote various rules or preferences (one’s doctor’s or parent’s orders, county or country laws, etc.).

⁴ The Zwicky & Sadock tests argue for at least two distinct readings for a sentence like *Alex and Bill must eat tofu*, one epistemic, the other some kind of root flavor. It’s less clear, however, that they distinguish different root flavors, as mixed root readings seem possible: the sentence can express that Alex has a moral obligation, while Billy’s necessity is desire-based. There is thus robust evidence for a distinction between epistemics and roots both from their interactions with tense and from ambiguity tests, but the case for an ambiguity amongst root uses is less clear.

⁵ Roots and epistemics are also argued to differ in their interactions with negation and with each other, but neither seems promising for acquiring English modals: (i) the scope of negation is not transparent and is subject to lexical idiosyncrasies (e.g., negation appears below modal auxiliaries, but can be interpreted above some: epistemic *may* scopes over negation, deontic *may* scopes under, *must* scopes over negation under both interpretations); (ii) double modals don’t occur in the variety of English we examine. These interactions could potentially be more useful for other languages.

is epistemic. However, it was later shown that root modals can occur with expletive subjects, and generally behave like raising predicates (Hackl 1998, Bhatt 1999, Wurmbrand 1999). The special relation that roots seem to have with their subject need not be syntactic, but could stem from a root modal's need to be semantically anchored to one of the preadjacent event's participants, not necessarily its subject (Hacquard 2006, Kratzer 2012). This is illustrated in (7). Weather *it* can appear with epistemic *might* (7a), but seems degraded with *can*, which can only receive root interpretations in positive contexts (7b). However, the sentence improves when a location is explicitly mentioned (7c). Thus, while there may not be a difference in terms of a syntactic requirement, we might still expect roots and epistemics to differ in the kinds of subjects they tend to combine with. We examine their distribution in section 5, and assess whether differences could potentially be suggestive to the learner.

- (7) a. It might rain.
 b. ??It can rain.
 c. It can rain hard in this part of the world. Hacquard (2006)

Epistemic and root modals have also been argued to differ in temporal properties, both in terms of *Temporal Perspective* (the time at which the modality is evaluated) and *Temporal Orientation* (the time at which the preadjacent is evaluated relative to the modal's time of evaluation). In terms of *Temporal Perspective* (TP), many argue that while root modals' TP is set by tense, epistemics always have a present TP (Groenendijk & Stockhof 1975, Stowell 2004, Abusch 1997, Hacquard 2006, a.o.). This is often taken to follow from a difference in scope: epistemics scoping above tense, and roots below, in accordance with Cinque's hierarchy (Cinque 1999). This can be illustrated with semi-modal *had to*, which, when interpreted deontically, must refer to a *past* obligation, but which seems to refer to a *current* necessity when epistemic: (8), for instance, expresses that "it's necessary given what we know now that there were a hundred people there".

- (8) There had to be a hundred people there. Stowell (2004)

Not everyone agrees that epistemics must have a present TP (see von Stechow & Gillies 2010 and Rullmann & Matthewson 2018 for arguments they don't). But even assuming they must, it's unclear that this could help learners discover epistemic flavors. To make use of TP, learners would first have to notice that, despite surface appearances, the modal's time of evaluation in (8) is present. They would further need to realize that the *current* necessity is not a mere past necessity that still happens to hold at utterance time. This seems rather implausible, especially since epistemic *had to* is virtually absent in the input.⁶ Thus, TP seems like an unlikely avenue for discovering epistemic flavors.

The difference in *Temporal Orientation* (TO) in roots and epistemics seems more promising, given its pervasiveness and robust morpho-syntactic correlates. As discussed in the introduction, root modals have been argued to be restricted to future TO, unlike epistemics, which can have present and past TO (Werner 2006, Klecha 2016, Rullmann & Matthewson 2018).⁷ Thus, while *Alex may run* can express a deontic possibility about a future run, *Alex may have run* and

⁶ We only found 1 epistemic *had to* in 339,795 utterances (2,400 *have to*) in the Manchester corpus.

⁷ Whether epistemics *allow* future TO is a matter of debate: for some authors, they do (Condoravdi 2002), for others, epistemics disallow future TO because of an incompatibility between the uncertainty of the future and the certainty of epistemic modality (Thomason 1970, Abusch 1997, Klecha 2016, Werner 2006).

Alex may be running, which trigger a past and a present TO respectively, seem to only be epistemic. If past and present TO are constrained to epistemic modality, learners could in principle discover epistemic readings by noticing modal uses with present or past TO.

The exact underpinnings of the *temporal orientation constraint (TOC)* are debated in the literature, but it is generally taken to follow from informativity considerations preventing vacuous uses of modals, where a modal statement would be indistinguishable from its unmodalized counterpart. The first such principle, called the *Diversity Condition (DC)*, was proposed by Condoravdi (2002) to explain why metaphysical modals, in contrast to epistemic modals, seem restricted to future TO. The DC requires that a modal's prejacent *p* not be "settled" amongst the worlds of the modal base (MB): the MB has to contain both *p* and *non p* worlds. Because the past and the present are settled, the same facts hold throughout worlds that share a history (Condoravdi's "metaphysical alternatives"). This means that, with present or past TO, the worlds of a metaphysical MB cannot differ with respect to *p*, violating the DC. The future, on the other hand, is not settled, hence the worlds of the MB can differ as to whether *p* holds in the future. The DC, on the other hand, doesn't constrain epistemic MBs, which pick out worlds compatible with what is known. What we know about the past or the present may leave some uncertainty about *p*, hence, even with past or present TO, an epistemic MB can have both *p* and *non p* worlds. Condoravdi's proposal was later extended to all root modals (Werner 2006, Klecha 2016, Rullmann & Matthewson 2018): roots take a *circumstantial* MB, which picks out worlds compatible with a set of circumstances. Circumstances are supposed to be settled up to the present, thus circumstantially accessible worlds are indistinguishable until then, and therefore can't differ with respect to *p* in the past and in the present, in violation of the DC.

While some take the TOC to be a semantic requirement that applies to all root modals (Werner 2006, Klecha 2016, Rullmann & Matthewson 2018), others point to possible counterexamples, and assume that the TOC is more of a pragmatic tendency (Matthewson 2012, Thomas 2014, Harr 2019). One type of counterexample involves deontic modals, as in (9).⁸

(9) Sam **ought to** be at church. (Thomas 2014)

Another type of counterexample involves "actuality entailments" (Bhatt 1999), which arise when a root modal combines with perfective aspect, and triggers an implicative inference that the prejacent occurred in the actual world. Actuality entailments were first shown in languages like Hindi or French which distinguish perfective and imperfective aspect overtly in the past, as shown in the French example in (10): (10) entails that Jane took the train. Given that circumstances are settled, Jane should take the train in all of the MB worlds, in violation of the DC (Matthewson 2012). The TO is present, in violation of the TOC, as the time of the possibility and that of the prejacent event overlap exactly (Mari & Martin 2007).

(10) Jane **a pu** prendre le train, #mais elle ne l'a pas pris. (Hacquard 2009)
Jane could-pst-pfv take the train, #but she didn't take it.

Importantly for our purposes, actuality entailments also seem to occur in English in the present, when an ability modal takes a prejacent with a perception verb (Dieuleveut, in progress), as illustrated in (11): (11) has an implicative reading according to which the speaker sees Venus. We

⁸An anonymous reviewer points out cases like *John can swim*, which seem to involve a present TO. Such cases may involve a generic interpretation (Thomas 2017), and are still taken to fall under Thomas' (2017) *Modal Economy*.

will see that such actuality entailments are relatively frequent in speech to children, and present the biggest challenge to the exploitation of the TOC for the discovery of epistemic modality.

(11) I **can** see Venus from where I'm standing. (Dieuleveut, in progress)

While examples like (9)-(11) violate the original DC, some argue that they still obey some informativity principle that preserves its spirit, which essentially prohibits uses of modals that would be equivalent to their non-modal alternatives (e.g. Thomas' 2017 *Modal Economy*). For instance, despite their actuality entailments, (10) and (11) convey an additional meaning compared to their unmodalized counterpart, for instance, an inference that the ability described is not trivial (Bhatt 1999).

Thus, while the exact nature and basis of the TOC are still a matter of active debate, there is general consensus that epistemic and root modality tend to differ in temporal orientation, and that this tendency is principled: root modality tends to be restricted to future orientation, because of informativity considerations ruling out trivial uses of modals. If learners expect speakers to avoid trivial meaning contributions, in particular of modals, they could use the TOC to infer epistemic meanings: observing a possibly trivial use of a modal, because of its present or past TO, could alert them to the possibility that the modal has a different flavor than the one they initially ascribed to it. But for the TOC to be used in such a way, a modal's TO would have to be observable from the way modals are used in children's input. In section 4, we examine the morphosyntactic footprints of the TOC in English, to assess whether its exploitation could be a viable strategy to uncover epistemic flavors of functional modals.

3. Modal input and child productions

To get a sense of the kind of modal talk children hear and produce, we ask how frequently parents and children express epistemic vs. root modality, how frequently modality is expressed using lexical vs. functional modals, and among functional modals, how often are they used with root vs. epistemic meanings.

3.1. Methods

The Manchester Corpus consists of 12 child-mother dyads, recorded for one hour in play sessions, twice every three-week period, spanning an age range from 1;09 to 3;00.⁹ We used the data from ages 2;00 to 3;00¹⁰ to get the results from the epistemic gap period specifically, with age 2 as the reported onset of functional modal usage. We chose this corpus for its relative density and uniformity of sampling sessions during the epistemic gap period. The density allows us to get a more accurate picture of rare early child uses of epistemics than any previous study, and the uniformity across 12 dyads allows us to generalize observed patterns above and beyond individual differences, particularly since the speakers are all from the same speech community and time period.

All utterances containing modal words were extracted (81,854 of 564,625 total utterances). Modals were coded for syntactic category, as in (2) (*functional*: auxiliaries, quasi-auxiliaries; *lexical*: adverbs, adjectives, verbs), and for flavor (root, epistemic, future), by hand, by reading all contexts. With respect to epistemic flavor coding, there is controversy about what modality *might*

⁹Non-child directed speech was not transcribed in this corpus. We leave for future research how modal utterances from overheard speech might differ from child-directed speech.

¹⁰See Shatz & Wilcox (1991), Cournane (2015a,b, 2021) for production data from children above 3.

expresses: does it only express epistemic possibility (as was assumed in Kratzer 1981, 1991), or can it also express *metaphysical* possibility (Condoravdi 2002)? We coded *might* as epistemic, but we also provide numbers for potentially metaphysical uses, and return to this issue in section 4. Functional modals *shall*, *will*, and *going to* express future meanings; we have included them here for completeness but we will exclude them from further analyses in section 3 as our focus here is on those modals that express root and epistemic modality. The complete list of modals occurring in our sample is provided in appendix 1.

(12) Modal lemmas by syntactic category:

- Functional* Aux = can, could, may, must, should, might, shall, will, would
 Quasi-Auxiliaries (QA) = have to, got to, ought to, supposed to, going to
- Lexical* V = *epis*: know, think, seem...; *root*: want, order, let's...
 Adv = *epis*: maybe, perhaps, probably...
 Adj = *epis*: sure, certain... *root*: able, capable... *epis/root*: possible...

We do not differentiate amongst various root flavors (e.g. ability, teleological, deontic), and leave the question of how children figure out that modals can be used to express a variety of different non-epistemic flavors for future work, though see section 4 for a brief discussion. Repetitions (repeating oneself or what someone else said) from both children and adults were excluded except in the aggregate (Table 1 and 3). All data is available at osf.io/v9ure/.

3.2. Results

In the following subsections, we provide the results of our corpus study on lexical and functional modals, first for the adult data, followed by the child data.

3.2.1. Input: Mothers' modal production

The results by syntactic and semantic category are summarized in Table 1. We find that for lexical modals, both epistemic and root modality are well attested in the input (4.6% of all mother utterances contain a lexical epistemic vs. 3.7% for lexical root modals). Functional modals are well-represented in the input: 13% of all adult utterances contain a functional modal. Examples of input utterances for each category are given in (13).

Table 1: Modal input by syntactic and semantic category (12 adults, % of total utterances)

Lexical modality			Functional modality	
epistemic	root	epis/root	epis/root	future
15,750 (4.6%)	12,433 (3.7%)	2,434 (0.7%)	20,528 (6%)	22,661 (6.7%)
30,617 (9%)			43,189 (12.7%)	

(13) Examples of modal utterances from the input¹¹

- a. Lexical epistemic: **Maybe** there are no trousers. Mother (Ruth 2;00)
 b. Lexical root: why did you **want** to become a mouse? Mother (Aran, 2;06)

¹¹There are other ways to convey modal meanings, e.g., imperatives, which we did not include here. The counts only include modality that can be tied to particular lexical items.

- c. Lexical root/epistemic:¹² If that's **possible** which I don't think it is? Mother (Warren, 2;05)
- d. Functional epistemic: **must**_{epi} have just fallen out, Nicole. Mother (Nicole, 2;09)
- e. Functional root: I'm sure polar bears **can**_{root} ride in cars. Mother (Warren, 2;03)
- f. Functional future: I'll take it away Mother (Liz 2;00)

To investigate how often functional modals are used for root and epistemic flavors in the input, we focused in on modals that can theoretically express root or epistemic flavors (*can*, *could*, *may*, *must*, *should*, *have to*, *got to*, *supposed to*, *ought to* and *might*).¹³ Table 2 shows the distribution of root vs. epistemic flavors for each modal. We find that, overall, functional modals are used much more frequently to express root (90.7%) over epistemic (9.3%) modality. This effect is driven by the fact that the most frequent modals (*can*, *have to*) are nearly always used to express root modality. Our results further show that modals that can express both root and epistemic flavors in principle are mostly used for one or the other: *can*, *could*, *have to*, *got to*, *should*, *supposed to* and *ought to* express root modality more than 90% of the time. *Must*, *might* and *may* are more often used with epistemic flavor (the latter is infrequent in this corpus). For *might*, we report in parentheses the number of potentially metaphysical readings.

Table 2: Functional modals by flavor, ordered by descending frequency (12 adults)

Modal	Total	Root	Epistemic	% root
<i>can</i>	11,488	11,448	40 ¹⁴	99.7%
<i>have to</i>	2,401	2,395	6	99.8%
<i>could</i>	1,452	1,322	130	91%
<i>might</i>	1,218	0	1,218 (including 434 potentially metaphysical ¹⁵)	0% (35,6%)
<i>got to</i>	940	933	7	99.3%
<i>should</i>	793	734	59	92.6%
<i>must</i>	452	159	293	35.2%
<i>supposed to</i>	335	326	9	97.3%
<i>ought to</i>	84	84	0	100%
<i>may</i>	39	22	17	56.4%
Total	19,202	17,423	1,779	90.7%

3.2.2. Interim discussion on the input

To sum up, looking at both lexical and functional modal input, children hear a fair amount of epistemic modal vocabulary, and of utterances with functional modals. Whatever is responsible

¹²Verbs, nouns and adjectives like *feel*, *possibility*, *possible*, which can potentially express root or epistemic meanings (e.g., *it is possible that John is here* (epistemic) vs. *it is possible to apply for a visa* (deontic)).

¹³An interrater reliability analysis using the Kappa statistic was performed to determine consistency among raters in modal flavor. 500 modal sentences were double-coded, and the interrater reliability for the raters was found to be $\kappa=0.95$ (Landis & Koch 1977). All double codes are available at osf.io/v9ure/.

¹⁴*Can* only has root meanings in the adult grammar, except under negation or, arguably, in interrogatives. 19 (48%) of adults' epistemic *cans* were under negation. The others were in questions, such as *Where can it be?*. Such uses could well be circumstantial (*possibility given the circumstances*), but they could be viewed as epistemic (*possibility given the evidence*). In cases where it was difficult to tease apart epistemic from root modality, we erred on the side of epistemic modality.

¹⁵We coded as metaphysical all instances where the modal's preadjacent could be future-oriented.

for the purported epistemic gap, it is not a lack of exposure to epistemic vocabulary.¹⁶ However, for functional modals we see that epistemic and root flavors are not equally well-represented in the input. The higher frequency of root uses might make it challenging for learners to see that functional modals can also express epistemic modality.

The proportion of epistemics is substantially lower than in the corpus studies on adult speech mentioned in the introduction (Ruppenhofer & Rehbein 2012, Rubinstein *et al.* 2013, Marasović *et al.* 2016, see also Coates 1983, Klages & Römer 2002, Hacquard & Wellwood 2012, Baker *et al.* 2012). For some of these studies, the difference might be due to the fact that they involve written language (Coates 1983 and De Haan 2011 show that modal use differs substantially in written vs. spoken language). But even studies on spoken adult language show a higher proportion of epistemics: in the MASC corpus of American English, Marasović *et al.* (2016) find 26% epistemics in almost 2,000 functional modals (n=508, their Table 5, p.17). The difference between these studies and ours could be a difference between American vs. British English. Or it could be a difference between child- and adult-directed speech: this study is the first to investigate child-directed speech. The Manchester corpus only includes speech to children (see fn. 8), thus, it's possible that children hear more epistemics from overheard speech. Note, however, that in a similar study probing modal use in Dutch input (van Dooren *et al.* 2019), which did include overheard speech, the proportion of epistemics was still extremely low (1.7% epistemics out of 10,903 modal sentences).

We turn next to children's productions. What modals do children produce and with what flavors? How well do children's productions mirror that of their parents?

3.2.3. Child modal production

Children produce a fair number of utterances with lexical and functional modals (4.6% and 3.4% of total utterances, respectively), though proportionally less so than their mothers. These results are summarized in Table 3, and examples are given in (13). Children also produce proportionally fewer lexical epistemics than their mothers (0.8% of total utterances vs. 4.6%), and less than they produce lexical root modals (the reverse pattern of adults). Thus, while young children may be less disposed to express epistemic modality, they do produce some lexical epistemics before age three, in line with O'Neill & Atance's (2000) and Cournane's (2015a,b, 2021) results.

Table 3: Child modal production, by category (12 children, % of total utterances)

Lexical modality			Functional modality	
epistemic	root	epis/root	epis/root	future
1,911(0.8%)	7,475 (3.3%)	1,003 (0.4%)	5,389 (2.4%)	2,305 (1%)
10,389 (4.6%)			7,694 (3.4%)	

(14) a. Lexical epistemic: **Maybe** want to go on this. (John, 2;09)

¹⁶The most frequent lexical epistemics were *think* and *know*, which are rarely used to discuss doxastic or epistemic states, but mostly to perform indirect assertions or indirect questions, respectively (Dudley *et al.* 2017). Thus, while epistemic words are frequent, epistemic states are not often topics of conversation, which may further contribute to children's difficulty picking up epistemic meanings. In North American English, the adverb *maybe* is also present at somewhat higher rates than in our British corpus, and NA English children use it by age 2 (Cournane 2021).

- b. Lexical root: I **want** mine tower. (Dominic, 2;05)
- c. Functional epistemic: It **must**_{epi} 've blown away. (Joel, 2;08)
- d. Functional root: **Must**_{root} wash it. (John, 2;08)
- e. Functional future: I'll do this bit. (Anne 2;07)
- f. Lexical root/epistemic: **Need** to clean all the car. (Carl, 2;05)

Children's functional modals overwhelmingly express root meanings (98%, Table 4).¹⁷ However, children do produce some epistemics (total of 116 for all 12 children) within the age range of the purported epistemic gap.¹⁸ The epistemic modals children produce are those that are most often used epistemically by adults: *might*, *must*, and *may*. Examples of epistemic child uses with context are given in (14). Some children (n=8) produce the same modal with both root and epistemic uses within our sample, examples provided in (15)-(16).

Table 4: Functional modals by flavor, ordered by descending frequency (12 children)

Modal	Total number of occurrences	Root	Epistemic	% root
<i>can</i>	3,709	3,708	1	99.9%
<i>have to</i>	357	356	1	99.7%
<i>could</i>	88	80	8	90.9%
<i>might</i>	80	0	80 (incl. 34 possible metaphysical)	0% (42.5%)
<i>got to</i>	291	291	0	100%
<i>should</i>	22	19	3	86.4%
<i>must</i>	117	99	18	84.6%
<i>supposed to</i>	10	10	0	100%
<i>ought to</i>	1	1	0	100%
<i>may</i>	9	4	5	44.4%
Total	4,684	4,568	116	98.3%

- (15) a. Child: where my sticker?
 Mother: where's your sticker?
 Mother: I think it's probably come off, hasn't it?

¹⁷An interrater reliability analysis using the Kappa statistic was performed to determine consistency among raters in modal flavor. 500 modal sentences were double-coded, and the interrater reliability for the raters was found to be $\kappa = 0.81$ (Landis & Koch 1977).

¹⁸Though see Cournane (2021) for evidence that the milestones defining this gap show individual differences of up to a year even in more sparsely sampled corpora, when looking at many children (n=17, from the North American English corpora on CHILDES). However, lexical epistemics appear to uniformly precede functional, and root functional modals uniformly precede epistemic.

- Child: where **could** it be? (Anne, 2;06)
- b. Child: he's [/] he's lost his hat.
Child: it **must**'ve blown away. (Joel, 2;08)
- c. Mother: it's lost.
Child: Mummy find it.
Mother: no.
Mother: I don't know where to look for it.
Child: **might** be upstairs. (Warren, 2;02)
- (16) a. Child: I got crane out my box.
Investigator: oh you've got your box as well yeah.
Child: I **must**_{root} get crane. (Aran, 2;02)
- b. Mother: oh we've got a bit of hair stuck, haven't we?
Child: look.
Child: it **must**_{epis} be some of dolly's hair. (Aran, 2;09)
- (17) a. Child: it's got mud over it.
Mother: I see.
Mother: right.
Child: **must**_{root} wash it. (John, 2;08)
- b. Child: my yellow one.
Child: can't see it.
Child: **must**_{epis} be gone. (John, 2;09)

3.2.4. Interim discussion on child production

To sum up, our results show that children overwhelmingly produce roots over epistemics, even more so than their mothers. However, they do produce some epistemics (both lexical and functional) at age 2, suggesting that the epistemic gap reported in the literature (Kuczaj & Maratsos 1975, Wells 1979, Stephany 1979, Astington 1993, Cournane 2015a,b, 2021 a.o.) may be an effect of the lower sampling density of previous corpus studies.

The lower overall rate of epistemics confirms Cournane's (2015a,b) finding that when children start to produce epistemic functional modals, they are at lower rates than their mothers. This suggests that children in this age range have a root bias. Specific support for this bias comes from the results on *must*. While mothers in our sample use *must* mostly with epistemic flavor (64.8%), children mainly use it with root flavor (84.6%). Yet, two-thirds of the children in our sample already use some functional modals with both root and epistemic flavors before age 3, suggesting they have already solved the complex mapping problem for these modals. This finding further bear on our understanding of children's conceptual maturity. The absence of epistemic modals in children's speech was originally attributed to a lack of the underlying concept (e.g., Papafragou 1998 ties it to immature theory of mind). To the extent that mastery of the word reflects mastery of the underlying concept, our results suggest that the concepts underlying epistemic modality are in place before age 3.

3.3. Discussion of Input and Child Production

Our corpus results show that the way adults talk about possibilities and necessities may make it

challenging to see that functional modals can express both root and epistemic flavors, as they are mostly used to express the former. As we saw earlier, other factors already tip the scale towards root flavors: modals take nonfinite complements like verbs that express root meanings (e.g., *want*), the concepts underlying root meanings may be more accessible, and root meanings may be particularly salient to children attuned to (indirect) requests. Once children assign root meanings to modals, how do they discover that they can also express epistemic meanings?

Our child production results suggest that some children pick up on functional modals' epistemic flavors already at age 2, i.e., a year earlier than has been previously reported in the literature (see also Cournane 2021). How do they manage to do this, given the low frequency of adult epistemic uses of functional modals? We next explore whether there are reliable morpho-syntactic cues that children could exploit that reflect the constraints on root modality discussed in section 2. We turn to aspectual features in section 4, and to subjects in section 5.

4. Distributional differences between roots and epistemics: TOC and aspectual cues

As we saw in section 2, the most promising restriction on the availability of root flavors is the *Temporal Orientation Constraint (TOC)*, according to which roots can only be future-oriented, while epistemics can be past- or present-oriented. The TOC could alert learners to a possible epistemic flavor, if they notice a non-future oriented use of a modal where a root interpretation shouldn't be possible. But how can learners pick up on temporal orientation if they don't yet know the meaning of the modals? How 'observable' is temporal orientation? Fortunately, temporal orientation may largely be determined by aspectual features of the modal's preajacent. Given their morpho-syntactic nature, aspectual features should be easier to observe than temporal orientation itself, and could help learners pick up on temporal orientation first, assuming they understand the temporal contributions of these aspectual features, and on modals' epistemic meanings second, assuming they expect modal uses to be governed by something like the *Diversity Condition* and the *TOC*.

English modals take nonfinite complements, where temporal orientation (TO) is largely determined by both grammatical aspect (perfect, progressive), and lexical aspect (stative or eventive) (Condoravdi 2002). As we saw in (2)-(5), repeated below as (18)-(21), root modals are generally incompatible with stative (19), progressive (20), or perfect (21) preajacents, as these tend to trigger present or past TO. Only bare eventive preajacents (18) freely allow future TO.

(18)	Alex may run.	Future/Present TO	root, epistemic
(19)	Alex may love running.	Present TO	??root, epistemic
(20)	Alex may be running.	Present TO	??root, epistemic
(21)	Alex may have run.	Past TO	??root, epistemic

We hypothesize that due to their morpho-syntactic nature, aspectual cues will be easier to observe than TO itself. Thus, as an operational assumption, we recast the TOC as a *Stativity Constraint (SC)*. Note that both the perfect and the progressive can be viewed as stativizers. We can thus subsume the aspectual restrictions as follows:

- (22) *Stativity Constraint (SC)*: root modals are incompatible with stative preajacents (bare stative preajacents or preajacents with progressive or perfect aspect)

We thus want to see whether the SC is illustrated in children's input in a clear enough way to help them discover epistemic meanings. For the SC to be useful, two requirements must be met.

First, epistemic modals should occur frequently with stative prejacent. Were epistemic modals to mostly take bare eventives, learners couldn't rely on the SC to discover epistemic uses, as these might be hard to distinguish from root ones. Second, the SC needs to be robust and track the TOC closely: there should be very few counterexamples to it (i.e., root modals with stative prejacent), and whatever counterexamples there are should somehow be differentiable from epistemic uses through other cues.

Importantly, the TOC and the SC are not equivalent. Indeed, it is possible for the prejacent of a root modal to be stative, but still future-oriented. This is illustrated in (23), whose use seems to grant a permission for a future state of having an apple.

(23) You can have an apple (later).

A further type of counterexample to the SC but not to the TOC, are counterfactual uses, illustrated in (24). With counterfactual uses, the modality is not epistemic, but either metaphysical or circumstantial, depending on one's theory.¹⁹ Such uses are counterexamples to the SC because of the presence of the perfect, which, at least on the surface, seems to be part of the prejacent. However, counterfactual uses are not counterexamples to the TOC, because the resulting interpretation is one where the modal is interpreted with a *past* temporal perspective, but a *future* orientation. The perfect, which on the surface appears under the modal, seems to be interpreted above it, backshifting the modal's time of evaluation (Condoravdi 2002): (24) expresses a *past* possibility for a (counterfactual) win in the *future* of that past.

(24) Alex **could** have won, but she didn't. future TO root/metaphysical

Hence, various cases could threaten the usefulness of the SC, the operational counterpart of the TOC. First are counterexamples to the TOC itself, discussed in section 2: actuality entailments (e.g., *I can see Venus from here*), which are present-oriented, as well as other cases where root modals are present or past-oriented (e.g., *Sam ought to be at church*). Second are counterexamples to the SC, but not the TOC: future-oriented statives and counterfactuals, as we just saw. In the next section, we plumb the input to test the usefulness of both the TOC and the SC as a means to discover epistemic meanings, by looking at (i) whether counterexamples to the TOC and the SC occur, and with what frequency; and (ii) whether epistemic modals reliably take stative prejacent. We document counterexamples to the TOC and to the SC separately, because it can help us sort out what children need to exploit either: if the SC is not robust, but the TOC is, then learners shouldn't be able to rely solely on aspectual cues. Furthermore, as the first corpus study examining the robustness of the TOC,²⁰ naturally-occurring counterexamples may be useful independently of learnability considerations to understand their cause, be it the *Diversity Condition*, or one of its descendants.

4.1. Methods

To assess the distribution of aspectual cues with respect to modal flavor, all input sentences with a functional modal were coded for grammatical and lexical aspect. For grammatical aspect, we

¹⁹ In what follows we treat such uses as root (as opposed to epistemic).

²⁰The studies that come closest are De Haan (2011), which looks at temporal and aspectual properties of *must*, and Marasović *et al.* (2016), which uses the modal lemma and temporal-aspectual properties in combination with other variables such as subject and negation to tag modal flavor automatically.

coded for presence of a perfect or a progressive in the prejacents. For all prejacents that lacked an overt grammatical aspect marker, we coded for lexical aspect: whether the prejacent was stative or eventive. The tests used were the classic tests from Dowty (1979). The full list of predicates is in Appendix 2.

We treated perception verbs (*see, hear, feel, smell*), including cognitive ones (*understand, remember, tell*) as a separate category, because they show hallmarks of both eventivity (25a) and stativity (25b). Both Vendler (1957) and Dowty (1979) classify them as either stative or inchoative (an achievement (25c), which is a punctual, telic event).

- (25) a. I stopped *seeing* the car. available in complement of *stop*, eventive
 b. I *see* the car. simple present as non-habitual, stative
 c. Suddenly, I *saw* the car. inchoative, eventive

Sentences with elided prejacents like (25) were excluded (total=56 roots, 30 epistemics) as it could not be unequivocally determined from the sentence whether *be* or *have* was the main verb or the auxiliary, both options being possible in the Manchester dialect.

- (26) a. I thought it **must** *be*. (Mother, Liz, 2;03)
 b. I **might** *have* yes. (Investigator, Aran, 2;08)

4.2. Results

Turning first to grammatical aspect, we expect that only epistemics should embed perfect or progressive aspect. Our results, reported in Table 5, show that this expectation is borne out: functional modals combine with embedded aspect ~10% of the time when epistemic, but 1% of the time when root.²¹ To test for the distribution of grammatical aspect per flavor, we employed the *glmer* function in the statistical package *lme4* in R (R Core Team, 2013). The data was fitted into a generalized linear mixed (logit) model²² using the maximum likelihood method (Laplace Approximation) (Baayen, 2008; Dixon, 2008; Matuschek *et al.* 2017). Fixed effects included flavor (epistemic vs. root) and aspect (grammatical aspect vs. bare), as well as the interaction between flavor and aspect. The 12 child/adult pairs were entered as a random effect (flavor ~ grammatical aspect + (1| child)). The model shows a significant difference of the distribution of grammatical aspect depending on flavor, $\beta=2.47$, $Z=21.5$, $p<0.001^{***}$.

Table 5: Grammatical aspect by modal flavor, input (n = 12 adults)

	Epistemic (n = 1,749) (% of total epis)	Root (n = 17,367) (% of total root)
Progressive	29 (1.7%)	68 (0.4%)
Perfect	142 (8.1%)	99 (0.6%)

²¹An interrater reliability analysis using the Kappa statistic was performed to determine consistency among raters in grammatical aspect and lexical aspect. 500 modal sentences were double-coded, and the interrater reliability for the raters for grammatical aspect was found to be $\kappa=0.91$ and for lexical aspect $\kappa=0.97$ (Landis & Koch 1977).

²²We also ran a chi-square test of goodness-of-fit with Yates continuity: grammatical aspect occurrence (with, without) differs significantly by flavor (root, epistemic), $X^2(1)=705.87$, $p<.0001^{***}$. Chi-square tests are standard in child corpus research, so we provide this for comparison. However, these may be problematic because of lack of full independence of observations: each observation from the same speaker may be affected by being from that speaker (likewise from the same sub-corpora dyad).

Total	171 (9.8%)	167 (1.0%)
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Turning to lexical aspect, we expect root modals to mostly combine with bare eventives, and epistemics to combine with both eventives and statives. Our results are reported in Table 6. We find that epistemics combine with statives ~68% of the time, and roots ~13% of the time, putting aside perception verbs. To test for the distribution of lexical aspect per flavor, we employed the *glmer* function in the statistical package *lme4* in R (R Core Team, 2013). The data was fitted into a generalized linear mixed (logit) model²³ using the maximum likelihood method (Laplace Approximation) (Baayen, 2008; Dixon, 2008; Matuschek *et al.* 2017). Fixed effects included flavor (epistemic vs. root) and lexical aspect (stative vs. eventive), as well as the interaction between flavor and aspect. The 12 child/adult pairs were entered as a random effect (flavor ~ lexical aspect + (1|child)). The model shows a significant difference of the distribution of lexical aspect depending on flavor, $\beta=2.48$, $Z=395$, $p<0.001$ ***.

Table 6: Lexical aspect by modal flavor, input (n = 12 adults)

	Epistemic (n=1,406) (% of total epis)	Root (n=15,307) (% of total root)
+ stative	951 (67.6%)	2,042 (13.3%)
+ eventive	445 (31.7%)	10,740 (70.2%)
+ perception	10 (0.74%)	2,525 (16.5%)

Finally, to see how frequently each flavor occurs with a stative/stativized preajcent, we combine the information from grammatical and lexical aspect. The results are reported in Table 7. The pattern we see is similar to what we see above: epistemics and roots show in fact the opposite distribution from each other (~70% statives for epistemics and ~70% eventives for roots). To test for the distribution of flavor (epistemic vs. root) by stativity, we employed the *glmer* function in the statistical package *lme4* in R (R Core Team, 2013). The data was fitted into a generalized linear mixed (logit) model using the maximum likelihood method (Laplace Approximation) (Baayen, 2008; Dixon, 2008; Matuschek *et al.* 2017).²⁴ In this and later models, we treat flavor of usage as the dependent variable, and observable features of the utterances as independent variables, essentially asking if the observable condition leads to a significantly greater likelihood of one flavor over the other; for the child, does what they can observe predict flavor of use? We treated aspect (stative vs. eventive) as a fixed effect and the 12 child/adult pairs as a random effect (Flavor ~ stative + (1|child)). The model shows a significant difference of the distribution of flavor depending on aspect, $\beta=2.58$, $Z=41.5$, $p<0.001$ ***.

Table 7: Aspect of the preajcent by modal flavor, input (n = 12 adults)

	Epistemic (n=1,577) (% of total epis)	Root (n = 15,474) (% of total root)
+ stative	1,119 (71%) (grammatical: 168; lexical: 951)	2,208 (14.3%) (grammatical: 166; lexical: 2,042)
+ eventive	445 (28.2%) (incl. 434 meta <i>might</i>)	10,740 (69.4%)
+ perception	13 (0.8%)	2,526 (16.3%)

²³ Chi-square test of goodness-of-fit with Yates continuity: Lexical aspect type (eventive, stative) differs significantly by flavor (root, epistemic), $X^2(1)=1052$, $p<.0001$ ***.

²⁴ Chi-square test of goodness-of-fit with Yates continuity: Stativity type (stative, non-stative) differs significantly by flavor (root, epistemic), $X^2(1)=2342.1$, $p<.0001$ ***.

Our results show a clear difference in the aspectual properties of the prejacent of epistemic and root modals: epistemics mostly combine with statives, roots mostly with eventives. However, a substantial number of roots still occur with stative prejacent, especially if we treat perception verbs as statives. In the rest of this section, we take a closer look at these statives, to assess whether they are counterexamples to the TOC, or just to the SC. We then discuss ways in which learners might distinguish counterexamples to the TOC/SC from genuine epistemic uses.

We first provide a breakdown of preajcent types by epistemic modal in Table 8. We find that uses of *might* account for the vast majority of epistemics with bare eventives (437/448). As mentioned earlier, the status of *might* is controversial: some treat it as unambiguously epistemic, others argue that it can be metaphysical. So far, we have treated all *might* as epistemic. If we exclude cases where *might* is arguably metaphysical, the correlation between epistemicity and stativity is extremely strong: practically all epistemic prejacent (98%) are stative (see Table 11).

Table 8: Aspectual properties of the preajcent for epistemic uses by modal, input (n = 12 adults)

Modal	stative			bare eventive	perception	total
	progressive	perfect	bare			
<i>might</i>	17	38	575	434	13	1,077
<i>must</i>	7	87	162	3	0	259
<i>could</i>	2	6	106	1	0	115
<i>should</i>	1	0	49	4	0	54
<i>can</i>	0	6	28	1	0	35
<i>may</i>	0	2	13	0	0	15
<i>supposed to</i>	1	0	7	1	0	9
<i>have to</i>	0	0	5	1	0	6
<i>got to</i>	1	0	6	0	0	7
Total	29	139	951	445	13	1,577

We now turn to root modals with stative prejacent. Table 9 shows the distribution of aspectual properties by modal.

Table 9: Aspectual properties of the preajcent for root uses by modal, input (n = 12 adults)

Modal	stative			bare eventive	perception	total
	progressive	perfect	bare			
<i>can</i>	2	1	1,138	6,493	2,418	10,052
<i>have to</i>	1	0	232	2,071	33	2,337
<i>could</i>	0	25	167	795	47	1,034
<i>got to</i>	3	0	125	776	9	913
<i>should</i>	31	69	223	263	2	588
<i>supposed to</i>	28	3	114	164	3	312
<i>must</i>	1	0	17	103	14	135
<i>ought to</i>	2	0	16	64	0	82
<i>may</i>	0	0	10	11	0	21
Total	68	98	2,042	10,740	2,526	15,474

To assess whether these counterexamples to the SC are also counterexamples to the TOC,

we examined each root modal use individually, to assess its temporal orientation. A summary is provided in Table 10. In a nutshell, we find that most root uses are future-oriented, except for a class of counterexamples involving perception verbs (whose stativity status is controversial).

Table 10: Temporal orientation of root modals with stative prejacent, input (n = 12 adults).

	Root modals with stative prejacent (n = 4,618 ²⁵)
Future TO	1,985
Command/permission	1,381
Explicit future reference	46
Imaginary play	220
Counterfactuals	338
Non future TO	2,633
Non perception verbs	107
Perception verbs	2,526

Putting aside perception verbs, we find that the majority of stative prejacent are future-oriented (1,985 out of 2,092). Most of these (1,381 instances) are performative uses of root modals to issue commands, or give or request permissions, as illustrated in (27). Commands and requests can only be felicitous if the state requested or allowed doesn't already hold, and hence are typically future-oriented.

- (27) a. **May** I *have* a spoon to eat it with? (Mother, Nicole 2;02)
 b. You **have to** *have* more than three. (Mother, Aran 2;08)

Another type of future oriented uses involves 'imaginary play' (Garvey & Kramer 1989) (220 instances), where a speaker decrees that a new state is about to hold. This is illustrated in (28), where the area that the mother is pointing to is to become the carpark.

- (28) Mother: where's the carpark, Anne? [...] (Mother, Anne 2;02)
 Mother: I think this **could** be the carpark, couldn't it in here?

We also found 338 instances of counterfactuals, illustrated in (29). These include most instances of root modals with perfect prejacent, and most uses of modals *should* and *supposed to*. Finally, 46 cases contain an explicit future reference, illustrated in (28).

- (29) a. You **could** *have said* hello. (Mother, Carl 2;04)
 b. You **should** *have eaten* it at dinnertime. (Mother, Anne 2;03)
 c. You're not **supposed to** *be eating* the stethoscope. (Mother, Ruth 2;02)
- (30) We'll **have to** have the Hoover out after this. (Mother, Ruth 2;00)

²⁵This number includes statives and perception verbs. Note that there is a slight discrepancy between the number of statives here and in Table 7 (n= 117). This is because in reviewing each case individually, we noticed a few coding errors (some modals coded as root were in fact epistemic (n=38), some were not modal (n=3), some involved individual miscodes for stativity (n=33)). These errors are consistent with our strong, but imperfect, Kappa interrater reliability scores for the first round of coding. We did not update the numbers in Table 7, since we did not also review epistemic cases individually, which presumably might include the same percentage of coding errors).

This leaves a total of 107 counterexamples to the TOC out of the 2,092 instances of root modals with stative prejacentes (other than perception verbs). Out of these 107 counterexamples, 20 arguably do not involve root modals *per se*, but rather quantificational modals (Heim 1982, Brennan 1993, Portner 2009), where the modal’s contribution is to provide quantification either over individuals as in (31a), or over situations, as in (31b): (31a) seems to express that *some* men are teachers, (31b) that the subject is *sometimes* excitable. Of the remaining 97 cases, 23 involve idiomatic expressions like *I can’t believe...*, or *I can’t stand...* Two are cases of actuality entailments. The remaining 61 cases seem to mostly involve necessity modals (25 instances), as in (31a), or negated possibility modals (20 instances), as in (32b). The full list can be found in Appendix 3. To sum up, putting aside perception verbs, counterexamples to the TOC are extremely rare (about 0.7% of all root modals).

- (31) a. Men can be teachers. (Mother, Nicole 2;10)
 b. She can be a bit excitable. (Father, Liz 2;08)
- (32) a. You have to have those tops on things. (Father, Nicole 2;06)
 b. You can’t have everything. (Mother, Joel 2;07)

Turning now to the rather frequent perception verb prejacentes, we find that the vast majority occur with *can* (2,418/2,526; see Table 9). When *can* combines with a perception verb, it triggers an actuality entailment (Dieuleveut, in progress), illustrated in (33): (33) seems to imply that the mother actually sees lots of footprints. Such actuality entailments are not only counterexamples to the SC (if we consider perception verbs as statives), but also to the TOC: the TO is present, since the time of the state has to coincide with the time of the ability.

- (33) *Context: mother and child are reading the book the Night before Christmas*
 Mother: And I **can** see lots of footprints, look. The dog’s made some footprints and the children have made some footprints. (Mother, Anne 2;04)

Table 11 summarizes our findings in terms of TO. We find a strong correlation between flavor and aspect: most roots are future-oriented (virtually all, if we exclude perception verbs), most epistemics are not (virtually all if we group metaphysical *might* with root modals).

Table 11: TO by flavor, grouping metaphysical *might* with root modals; input (n = 12 adults)

	Epistemic (n=1,143) (% of total epis)	Root (n = 15,908) (% of total roots)
Future TO	11 (1%)	13,275 (83.4%)
Non future TO (excl. perception verbs)	1,119 (97.9%)	107 (0.7%)
Non future TO (perception verbs)	13 (1.1%)	2,526 (15.9%)

Recall the two requirements of a syntactic bootstrapping strategy²⁶ relying on the SC, rather than the TOC: first, epistemics have to reliably combine with stative prejacentes to be

²⁶ Strictly speaking, our proposal is not one of “syntactic bootstrapping”, since a learner relying on the SC would need to know which predicates are statives vs. eventives (a semantic distinction). However, it seems plausible that children have figured out the stativity distinction by the time they solve the modal flexibility problem (Wagner 2001). We can refer to this type of bootstrapping as “selectional bootstrapping” (J. Lidz, p.c.).

discoverable. Second, there need to be very few counterexamples, i.e., root modals with stative prejacent. We see that the first requirement is clearly met: epistemics mostly take stative prejacent. However, the second requirement is not: while most root modals combine with eventive prejacent (~70%), 30% combine with stative prejacent, half of which are future-oriented, half of which involve perception verbs. Given the big skew towards root meanings, the number of stative prejacent of root modals is in fact twice as much as stative prejacent of epistemic modals. Hence, if learners were to rely strictly on aspectual cues, they could be misled into treating root modals with stative prejacent as epistemic, or treat epistemic uses as mere noise.

However, the strategy might still be exploitable if learners can supplement aspectual cues with contextual cues. As we saw, counterexamples to the SC fall into two categories: (i) actuality entailments with perception verbs, which violate both the SC and the TOC; and (ii) future-oriented statives, which only violate the SC. In the next section, we argue that both types may involve particularly salient contextual cues, which differentiate them from genuine epistemic uses. In a nutshell, one characteristic of epistemic modality is that its use requires contextual uncertainty—or at least a lack of direct evidence—about the truth of the prejacent. Crucially, the counterexamples to the SC that we find in our corpus differ clearly from epistemics in this respect: in the case of actuality entailments with perception verbs, the *truth* of the prejacent should be rather salient, since it involves direct perceptual evidence; in the case of future-oriented statives, which mostly consist of commands, imaginary play, and counterfactuals, the *falsity* of the prejacent should also be fairly obvious.

4.3. Can contextual cues distinguish epistemics from roots when aspectual cues fail?

Turning first to future-oriented statives, the context should be particularly clear about their future orientation, despite the potentially misleading aspectual cues: this is because in the types of cases found in the corpus, the state expressed by the prejacent can clearly be inferred not to hold. First, requests and permissions are felicitous only if the state requested doesn't already hold. In (27a), for instance, the speaker must clearly not have a spoon for her request to make sense. Similarly, 'imaginary play' involves proposals about the future. In (28), the mother is suggesting that from speech time onward, the child and her pretend that a certain object serves as something other than its usual function. As for counterfactuals, if children understand that counterfactuality is about future (unrealized) possibilities from a point in the past, they should be able to use the falsity of the prejacent at speech time to infer its future-orientation. A cursory examination of the context suggests that the falsity of the prejacent is particularly salient in these cases. For instance, in (29a), the child should be aware that he did not say 'hello'. Finally, cases with explicit reference to a future time like (30), wear their futurity on their sleeve.

Turning next to actuality entailments which occur when *can* combines with perception verbs, the context should be particularly clear that the state expressed by the prejacent holds, especially since these cases involve perception, making it likely that there are visual or other sensory cues in the situational context (Landau & Gleitman 1985). In (33), for instance, both the mother and the child should be able to see actual footprints (the mother uttering *look*, further suggests that she is drawing the child's attention to the footprints).

Thus, for the vast majority of counterexamples to the SC, the situational context seems to make either the truth or the falsity of the prejacent particularly salient. In comparison, for *epistemics* with stative prejacent, illustrated in (34), the context should make neither the truth nor the falsity of the prejacent salient, given that epistemics typically require contextual uncertainty about the prejacent, and are infelicitous when there is direct evidence for it (von Stechow & Gillies

2010; Mandelkern 2017, a.o.): asserting that it must or might be raining when standing in pouring rain is infelicitous (von Fintel & Gillies 2010).

- (34) a. I think it **may** be an apple. (Mother, John 2;07)
b. **must** have just fallen out, Nicole. (Mother, Nicole, 2;09)

4.4. Discussion

In this section, we focused on whether TO could help learners discern epistemic uses. If root modals are restricted to future-oriented prejacent, a past or present TO could alert learners that the modal expresses an epistemic meaning. For this strategy to work, the input has to provide clear cues that distinguish epistemic and root uses in terms of TO. Given that TO might be hard to identify in context, especially when the intended flavor is not known, learners may be able to exploit aspectual cues that correlate with TO and are easier to observe: for learners to exploit the TOC, there need to be clear cases of stative prejacent with epistemics, and none with roots.

Our results show that aspect does distinguish roots and epistemics: roots mostly combine with eventives, epistemics mostly combine with statives. However, we do find a significant number of roots with statives. While the numbers are proportionally low relative to all root uses, and proportionally significantly lower than stative prejacent of epistemics, they are rather frequent in terms of raw counts. In fact, because of the skewed distribution of roots and epistemics, the raw counts of roots with a stative prejacent ($n=2,208$) is actually higher than the raw count of epistemics with a stative prejacent ($n=1,119$), a number made much worse if we include perception verbs (1,132 epistemics vs. 4,734 roots). What this means is that children would roughly have only a 1 in 3 (or 1 in 5) chance of getting an epistemic when they hear a modal with a stative prejacent. Given the sheer number of roots, the counterexamples to the SC thus call into question its usefulness.

However, when we take a closer look at counterexamples to the SC, we find that many are not counterexamples to the TOC: they involve future-oriented statives, in the context of offers, requests, imaginary play, or counterfactuals. Whereas picking up on TO in general might be difficult, we believe that these instances are cases where the context should be particularly clear that the prejacent doesn't yet hold, making its future orientation salient. We do find a well-attested class of counterexamples to the TOC, and not just the SC, namely present-oriented cases of actuality entailments triggered by ability modals with perception verb prejacent. But here as well, there should be particularly clear contextual cues: given the perceptual nature of these examples, the truth of the prejacent should be particularly salient. In this way, both types of counterexamples differ from epistemic uses, for which the truth of the prejacent should be contextually uncertain. Thus, our results argue that aspectual cues could provide a promising avenue to help learners bootstrap epistemic meanings for their modals, but only if they consider them in conjunction with correlated situational cues. If children can pick up on these situational cues, they may be able to exploit the SC to discover epistemic flavors in the following way. If, for the purposes of identifying modal meanings, children *ignore* uses of modals where the prejacent is either clearly true or clearly false, then aspectual cues are highly predictive of flavor: root modals are virtually always future-oriented, but epistemic modals are not. That children would initially ignore modal uses where the prejacent is either clearly true or clearly false when inferring modal meanings seems plausible: after all such uses are cases where neither possibility nor necessity seems at issue, and where the modal's contribution might thus be particularly obscure. Once children are more secure in their modal meanings, they may be in a better position to figure out the stranger cases, like

counterfactual uses. Acknowledging there are also grammatical factors at play (e.g., the complexity of *if...then* conditional constructions), children produce (Tulling & Cournane, 2019) and understand (see McCormack et al. 2018; Nyhout and Ganea 2019, i.a.) counterfactual possibilities relatively late compared to more basic modal possibilities.

5. Subject distribution of roots and epistemics

Recall that another possible distributional difference between roots and epistemics involves subjects: root modals seem to have a special relationship with their subjects, but not epistemics. This was originally thought to derive from roots being control predicates, but was later shown to be illusory, and perhaps due to root modality needing to be anchored to one of the preadjacent's event participants. Because of this apparent connection with subjects, we might expect root modals to only rarely combine with expletive subjects. Hence, the presence of an expletive subject could potentially alert learners to the possibility (if not necessity) that the modal expresses an epistemic flavor.²⁷

Aside from an asymmetry in availability of expletive subjects, we might further expect differences in subjects across root and epistemics both in terms of person and animacy. First, root modals can be used to direct other people's actions, which might result in a tendency to have animate subjects, as these are typically the kind of entities that can act upon the wish, goal, or obligation expressed by the modal. Second, child-directed speech generally mainly contains verbs in 1st and 2nd person (Laakso & Smith 2007:732). In conversations with others, root modals are expected to fall in line with this tendency as they encode wishes, goals, or obligations, typically those of one of the interlocutors. In contrast, epistemic claims about the speaker or the addressee may be marked, as speakers typically have direct access to the states or events they participate in (*??I must be eating*). Given these considerations, we might expect roots to mostly combine with animate subjects, mostly 1st and 2nd person, while epistemics could more freely combine with 3rd person subjects, inanimates, and even expletive subjects.

5.1. Methods

Subjects were coded for person (1st, 2nd, 3rd) for the 12 mothers in the input, and for animacy for a subset of 6 mothers. Animacy was coded as animate (35a) vs. inanimate (35b). Toys representing an animate being (dolls, animals) were coded as animate, as pretend play treats them as animate. For pronouns, we treated 1st and 2nd person pronouns as uniformly animate, and for 3rd person pronouns, we coded for whether it referred to animate or inanimate agents (36a vs. 36b) if it was recoverable from the context. Finally, we coded for whether inanimate pronouns were expletive pronouns (37a) or pronouns referring to an event (37b).

- | | | |
|------|---|---|
| (35) | a. well can <i>Mummy</i> have a go on your seesaw?
b. no <i>the xylophone</i> must be somewhere else. | (Mother, Aran 2;00)
(Mother, John 2;02) |
| (36) | a. <i>it</i> [figure made from clay] might be a dolphin.
b. <i>it</i> [a beaker] can't be hers. | (Mother, John 2;07)
(Mother, Anne 2;09) |
| (37) | a. <i>it</i> might rain or go dark before morning. (expletive <i>it</i>)
b. <i>that</i> [readjusting the toys] might be better. (eventive <i>that</i>) | (Mother, Aran 2;00)
(Mother, Becky 2;07) |

²⁷See Becker (2007, 2009) for the usefulness of this cue in the acquisition of raising vs. control predicates.

5.2. Results

Turning to person first, we find that 77% of roots occur with a 1st or 2nd person subject while only 26% of epistemics do (Table 12).²⁸ To test for the distribution of flavor by person, we employed a similar model as above.²⁹ We treated person (1/2 vs. 3) as a fixed effect and the 12 child/adult pairs as a random effect (flavor ~ person + (1|child)). The model shows a significant difference of the distribution of flavor depending on person, $\beta=2.33$, $Z=39.44$, $p<0.001$ ***.

Table 12: Subject person by modal flavor, input (n = 12 adults)

Person	Epistemic (n=1,778) (% of total epis)	Root (n = 17,409) (% of total root)
1 st person	195 (11.0%)	5,072 (29.1%)
2 nd person	266 (15.0%)	8,383 (48.2%)
3 rd person	1,153 (64.8%)	3,270 (18.8%)
No subject	164 (9.2%)	684 (3.9%)

Turning next to animacy, the overall results are presented in Table 13.³⁰ A breakdown per modal, can be found in Appendix 4. As expected, we find that while 37% of epistemics combine with a non-animate (inanimate, expletive, eventive) subject (n=331), less than 5% of roots combine with these subject types (n=377). To test for the distribution of flavor by person, we employed a similar model as above.³¹ Fixed effects included flavor (epistemic vs. root) and animacy (animate vs. non-animate), as well as the interaction between flavor and animacy. The 12 child/adult pairs were entered as a random effect (flavor ~ stative + (1| child)). We treated animacy (animate vs. non-animate) as a fixed effect and the 12 child/adult pairs as a random effect (flavor ~ animacy + (1|child)). The model shows a significant difference of the distribution of flavor depending on animacy, $\beta=-2.51$, $Z=28.04$, $p<0.001$ ***. The difference is not solely due to the majority of 1st and 2nd person subjects in roots (which are uniformly animate): if we focus in on 3rd person subjects, we still find the contrast, as 54% of 3rd person subjects with epistemics are non-animate, while 25% of 3rd person subjects with roots are non-animate.

Table 13: Subject animacy by person and flavor, input (n = 6 adults)

Person	Animacy	Epistemics (n = 886) (% of total epis)	Roots (n = 7,672) (% of total root)	
1 st /2 nd person	animate	212 (23.9%)	5,979 (77.9%)	
3 rd person	animate	278 (31.4%)	1,128 (14.7%)	
	non-animate	inanimate	257 (29.0%)	365 (4.8%)
		expletive pronoun	41 (4.6%)	3 (0.0%)

²⁸An interrater reliability analysis using the Kappa statistic was performed to determine consistency among raters in subject and animacy. 500 modal sentences were double-coded, and the interrater reliability for the raters for subject was found to be $\kappa=0.96$ and for animacy $\kappa=0.87$ (Landis & Koch 1977).

²⁹Chi-square test of goodness-of-fit with Yates continuity: person type (1/2 vs. 3) differs significantly by flavor (root, epistemic), $X^2(1)=2162.4$, $p<.0001$ ***.

³⁰We only coded 6/12 adults for subject animacy as looking up the referents for pronouns is highly time-consuming. We think this is warranted, since the results for the 6 adults show consistently low proportions of roots with inanimate subjects, ranging from 3.0% to 7.3% (epistemics with inanimate subjects show more variation, but are much higher for each adult: the proportions range from 21.9% to 53.8%).

³¹ Chi-square test of goodness-of-fit with Yates continuity: Animacy type (1/2 vs. 3) differs significantly by modal flavor (root, epistemic), $X^2(1) = 1176.3$, $p < .0001$ ***.

		eventive pronoun	33 (3.7%)	9 (0.1%)
		not recoverable from context	1 (0.1%)	1 (0.0%)
No subject	NA		64 (7.2%)	187 (2.4%)

5.3. Discussion

Our results show that epistemics and roots differ in the types of subjects they combine with for both person and animacy. Roots occur mostly with 1st and 2nd person subjects, which are also the most frequent subjects overall in this sample and in child-directed speech generally. Epistemics, on the other hand, mainly occur with 3rd person subjects. For animacy, we see a similar pattern, which is unsurprising, as 1st and 2nd person subjects are animate. Roots combine overwhelmingly with animate subjects, epistemics combine most frequently with non-animate subjects. Looking more closely at 3rd person subjects for animacy where the results are not confounded with person, we find that while most root 3rd person subjects are animate, epistemics show more expletive and eventive subjects, and inanimate referents. Thus, we see an overall preference for animate subjects for roots, and a greater proportion of non-animate subjects with epistemics.

As with temporal orientation, we find a significant distributional difference between root and epistemic uses of functional modals. Can the learner make use of these distributional facts? A problem might be that given the overall usage bias towards root meanings, the raw number of root modals with a non-animate subject (n=377) is actually higher than that for epistemics (n=331). This asymmetry means that the likelihood of an epistemic interpretation when hearing a modal with a non-animate subject is about the same as that of a root interpretation. Hence, hearing a non-animate subject does not unambiguously direct the learner to an epistemic meaning. What is more, none of the combinations of subject, animacy, and flavor are actually ruled out. As discussed earlier, roots are acceptable with non-animate 3rd person subjects. While rare (see Table 13), we did find instances of roots with inanimate (38), eventive (39), and expletive (40) subjects. While some could arguably count as animates (*the tractor* in (37b) might be personified by the speaker), (39) and (40) clearly show that roots can combine with non-animate subjects in child-directed speech).

- (38) a. What color **should** *the tree* be? (Mother, John 2;09)
b. Oh now *the tractor* **can** get back to work, can't it? (Mother, Aran 2;03)
- (39) a. Because *it* **can** be dangerous if you've got a tractor without a cab like that you know. (Mother, Aran 2;07)
b. *That*'ll **have to** do. (Mother, Aran 2;08)
- (40) a. *There* **should** be four eggs altogether. (Mother, John 2;06)
b. Er well *there* **should** be forks around. (Mother, Ruth 2;07)

In sum, while the distribution of subject animacy over roots and epistemics clearly differ, the overall skew towards root meanings make animacy cues difficult to exploit on their own.

6. Discussion: exploiting aspectual and person cues and possible learning paths

Children need to figure out that modals can express both root and epistemic flavors, despite the fact that they mostly hear them with root uses, that the root concepts they express may be more accessible, and that modals' complements resemble that of verbs that express root meanings. How

do children figure this out? Because modals express abstract concepts with few physical correlates, they're exactly the type of expressions that motivate syntactic bootstrapping, the hypothesis according to which learners exploit principled links between a word's syntactic distribution and its meaning. But modals present a challenging twist: the same word is used to express these different meanings.

In sections 4 and 5, we looked for syntactic features that could differentiate roots from epistemics, and found that they differ both in terms of the aspectual properties of their prejacent and their subjects: roots mostly combine with eventives, epistemics mostly combine with statives; roots mostly combine with 1st and 2nd person subjects, and epistemics with 3rd person subjects, often non-animate. However, in both cases, the usage skew towards root interpretations calls into question the usefulness of these cues: even if roots mostly combine with eventives, the number of stative prejacent with roots is larger than the number of stative prejacent with epistemics. Similarly, roots mostly take animate subjects, but the number of non-animate subjects with roots is comparable to the number of non-animate subjects with epistemics. Can these cues nonetheless be exploitable, and if so, what would children need to exploit them?

It's not entirely clear what learners might be able to infer from subject cues alone, given that the link between subject type and epistemic modality is rather indirect. It's possible that inanimate, or even 3rd person, subjects would stand out, given their overall rarity in the input, and draw children's attention to the utterances in which they appear, even if it might not point them directly to an epistemic interpretation.

The aspectual cues might be more promising. While the number of counterexamples to the stativity constraint (SC) is significant, they largely fall into two categories: (i) statives that are nonetheless future-oriented, and thus in line with the temporal orientation constraint (TOC), which mostly occur in the context of requests, imaginary play, or counterfactuals; (ii) actuality entailments with perception verbs, which violate both the SC and the TOC. In both cases, however, we argued that there might be particularly salient contextual cues that distinguish them from epistemic uses, as either their truth (for actuality entailments) or falsity (for future statives) should be fairly obvious. In contrast, the prejacent should neither be obviously true nor obviously false with epistemics, as their use requires a lack of direct evidence. If children initially ignore modal uses when the prejacent is clearly true or clearly false, that is, where the modal's contribution is rather unclear, they should be able to exploit aspectual cues to infer modal flavor.

Can we really expect children to pay attention to temporal orientation, if the TOC is a violable pragmatic constraint, rather than a semantic requirement? If non future-oriented root modals are not semantically impossible, would learners *necessarily* postulate epistemic readings? We believe that even if the TOC is merely pragmatic (Matthewson 2012, Thomas 2014, Harr 2019), it could still be useful in alerting learners to *possible* violations of the Diversity Condition (DC), especially in the *absence* of clear contextual cues that the prejacent is either true or false. And, given the lack of more reliable syntactic correlates, the TOC may well be the best pathway for discovering epistemic flavors of functional modals.

Could there be other, non-syntactic, routes to epistemicity? Again, because modals express abstract concepts, cues from the physical context are bound to be limited. However, children might be able to exploit pragmatic cues, which have been argued to play an important role in the acquisition of attitude verbs (Lewis *et al.* 2017, Dudley *et al.* 2017). From a very young age, children are sensitive to speakers' goals and their illocutionary intents. They notably seem to understand requests as such, whether direct or indirect (Shatz 1978, Spekman & Roth 1985). If children are attuned to illocutionary goals, they may be able to make inferences about a modal's

underlying meaning. In particular, the ease with which deontic modals can be used to perform orders (Ninan 2008, Portner 2009) might alert learners that they express obligations. But, while this kind of pragmatic bootstrapping might be particularly useful for root meanings, it's not clear how much it would help pick out epistemic flavors. Indeed, the kind of indirect speech acts typically performed with epistemics are of an assertoric nature. But from a discourse function perspective, such acts may not stand out from direct assertions describing root possibilities or necessities: Noticing that a modal statement is used to assert might not readily give away its epistemicity. Thus, the morpho-syntactic route, and in particular, the one that exploits aspectual cues, might be the most promising to solve the mapping problem of modals.

What would it take for children to exploit aspectual cues, and is there evidence that the relevant linguistic, pragmatic and conceptual capacities are in place by age 2? First, learners should expect modals to be governed by something like the DC. Recall that the DC is often taken to fall from more general informativity considerations,³² so children would not necessarily need a modal-specific principle, but perhaps simply expect speakers to avoid trivial uses of (modal) expressions, and let such considerations guide their hypotheses about modal meanings. Second, by the time children are learning epistemic meanings for functional modals, they would need to be able to make certain aspectual distinctions, both at the grammatical and lexical level. The acquisition literature suggests that they likely have these abilities in place very early in syntactic-semantic development (Wagner 2001, van Hout 2016). Third, they should be able to exploit situational and pragmatic cues in conjunction with aspectual cues: being attuned to the truth or falsity of the prejacent when contextually salient, for instance, could help them pick up on counterfactuality or actuality entailments. Being sensitive to the request made with sentences like *Can I have a cookie?* could help them figure out the future orientation of the prejacent despite its stativity. Here again, there is experimental evidence that children understand indirect requests (Shatz 1978, Spekman & Roth 1985). Fourth, children would need to have access to the concepts underlying modal flavors, particularly the more-contested epistemic concepts. And here as well, there is growing evidence that they do (Onishi & Baillargeon 2005, Southgate *et al.* 2007). Finally, for children to be able to exploit situational and pragmatic cues in conjunction with aspectual cues, they should be able to reliably track correlated statistical information in their input. None of the trackable properties of the input that we examined is categorically true, so children will need to learn possible meanings of modals from statistical tendencies. While the bulk of statistical learning work with children has focused on transitional probability and simple frequency of occurrence tracking (e.g., Saffran *et al.* 1996, Thompson & Newport 2007, Smith & Yu 2008; Vouloumanos 2008), the results show that infants and toddlers are remarkably good at tracking statistical information (in language and elsewhere). Note that statistical learning alone would not garner the learning results that we see with children, as the assumptions we discuss for the TOC, and the grammatical combinations for root vs. epistemic interpretations, are necessary priors for the statistical learning to be fruitful.

How children make use of these cues depends on what assumptions they can make about modals. There are two possible starting points. First, children may not initially expect that modals can express multiple flavors. If so, they might first postulate root meanings for modals, and then discover, via aspectual cues that they must also express epistemic flavors, and update their lexicon accordingly. Alternatively, children may have a bit of a head start: they may expect functional modals to be able to express multiple flavors, if there is a principled link between a modal's functional status and flavor flexibility that children are privy to (Hacquard & Cournane 2016). In that case, learners would have to discover which of their modals allow epistemic flavors. Even if

³² See Kamp & Partee (1995) for similar considerations in another domain.

there is a principled link between functional status and flavor flexibility, it may not always be obvious, as in the case of a semi-modal like *have to*, which syntactically resembles a regular verb. Thus, children may have differing expectations about different modals, and the acquisition of these modals may follow different paths.

When we look at individual functional modals, we see that some are more likely to be used epistemically, namely *might* and *must*: not only do these modals express epistemic modality more often, they further show a stronger signal for both aspectual and animacy properties. Previous corpus and production studies³³ (Papafragou 1998; Cournane 2014, 2015a,b, 2021; Hirzel *et al.* in progress) show that *might*, and for some *must*, are the first functional epistemic modals children use. In our study, epistemic *might* and *must* comprise 98 of the 118 child functional epistemic productions. Once children pick up on the epistemicity of these modals, they may be able to use them to analogize epistemic meanings for other modals (Cournane 2015a:94). Finally, realizing that a modal can express different subflavors of root modality, could make it easier to extend this one-to-many mapping to non-root flavors (but see Philips & Knobe 2018 and references therein for claims that children have trouble distinguishing modal concepts).³⁴

Finally, whether learners actually make use of aspectual cues remains an open question. A number of comprehension studies test children's sensitivity to aspectual properties of the preajacent when interpreting modals. The overall results show that while preschoolers access epistemic interpretations of necessity modals in Spanish, German, English, and Bosnian-Croatian-Serbian (BCS), the exact role of aspect in triggering epistemic readings is unclear because these studies: (a) only look at one preajacent type (Fond 2003), (b) involve a small sample (Heizmann 2006), (c) children had a weak deontic bias at age 3 and a strong epistemic bias by age 5 (Cournane 2015a, Cournane & Pérez-Leroux 2020). The best evidence for children using morphosyntactic cues³⁵ for modal flavor comes from BCS, where 3-year-olds show adult-like preferences for root versus epistemic uses of *morati* (*must*) (Veselinović, 2019; Cournane & Veselinović, *submitted*), although older children show a non-adult epistemic bias.

7. Conclusion

In this paper, we investigated how children figure out that functional modals can express epistemic flavors in addition to root flavors. The previous acquisition literature suggests that while children produce root meanings early on, they are delayed in producing epistemic meanings (Kuczaj & Maratsos 1975, Cournane 2015a,b). Through this corpus study, we have explored child productions at a larger scale than previously done, to ask whether children really fail to produce epistemics before age 3. Our results show that the epistemic gap is in large part an input effect: the way speakers use functional modals makes it difficult to see that these modals can express epistemic meanings, as they mostly express root modality. Yet, children eventually pick up on epistemic meanings. Our results show that some seem to do so before age 3, a year earlier than was originally thought (see also Cournane 2021).

We have argued that figuring out modal meanings—particularly for functional modals that can express different flavors—is no trivial task, especially given the way modals are used in the

³³One caveat: most of these studies were done on children learning North American English, while this corpus contains British English data.

³⁴This might also be informative in the other direction: figuring out epistemic flavors might help children realize that there are different subflavors of root modality.

³⁵BCS modals differ by flavor not just in aspect: epistemics show default agreement (roots show subject phi-agreement) and occur in biclausal structures (*vs.* monoclausal for roots).

input. We have highlighted ways in which the linguistic context, and in particular, the way modals interact with aspects, could be helpful in providing cues that correlate with modal flavor. We however also showed that the large skew towards root uses make it impossible to exploit these aspectual cues on their own: children need to use them in conjunction with various pragmatic and situational cues. Thus, the acquisition of modal meanings seems to require a combination of sophisticated linguistic, pragmatic, conceptual, and statistical capacities. The fact that children eventually pick up on modal meanings, and might do so even before age 3, suggests that such capacities are in place very early in development.

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Appendix 1: Classification of modals

Category	Items
Lexical epistemics	ADJ <i>aware certain correct likely obvious sure unlikely</i> ADV <i>absolutely apparently certainly definitely maybe necessarily obviously perhaps possibly presumably probably surely</i> N <i>knowledge prediction suspicion</i> V <i>appear assume believe bet convinced detect discover doubt expect explain foresee gather guess hear imagine know me_thinks presume realize reckon seem sense suggest suspect think understand</i>
Lexical roots	ADJ <i>able capable eager forbidden necessary sufficient</i> ADV <i>unnecessarily</i> N <i>capacity potential rule</i> V <i>allow decide encourage force insist intend let let's manage order prefer promise recommend request require want wish wishing</i>
Lexical root/epistemic	ADJ <i>determined important impossible possible</i> N <i>impossibility</i> V <i>feel need persuade</i>
Functional epi/root	<i>can could got_to has_to may might must ought should suppose</i>
Functional future	<i>going_to shall will would</i>

Appendix 2: Classification of lexical aspect

Eventive

afford	break	climb	decorate	eat up	flatten
agree	breathe	collect	deliver	empty	fly
answer	bring	color	destroy	escape	follow
arrange	brush	comb	dig	expect	fool
arrive	build	come	disappear	explain	force
ask	build up	complain	discuss	extend	forget
assume	bump	cook	divide	face	get
attach	bury	cope	do	fall	give
bake	buy	count	drag	fasten	glue
balance	call	cover	draw	father	go
bang	carry	cram	dress up	feed	go to sleep
bark	catch	crash	drill	feel	grab
bear	change	crawl	drink	fetch	guess
behave	chase	creep	drive	fight	hammer
bend	chat	cry	drop	fight back	handle
bend over	check	cuddle	drop	figure out	heat up
bite	chew	curl	drown	fill	help
blow	choose	cut	dry	find	hide
blow up	chop	damage	dump	finish	hit
borrow	chuck	dance	earn	fix	hold
bounce	clean	decide	eat	fit + NP	hook up

hop	make	pin down	scribble	stamp	try
hug	manage	play	scrub	stand -NP	turn
hurt	match	plural	secure	start	twist
ignore	measure	point	see	stay	undo
imagine	meet up	post	sell	steal	unload
include	melt	pour	send	stick	unlock
insist	mend	practice	send for	stitch	unscrew
interest	mention	press	set going	stop	unstick
join	mess	pretend	share	straighten	use
joke	miss	prick	shoot	stretch	waft
jump	model	pull	shout	stroke	wait
keep	mop	push	show	suck	wake up
kick	move	put	shut	swim	walk
kiss	muddle	queue	sign	swing	warm up
knock	nail	race	sing	switch off	wash
land	needed	rain	sit	take	watch
lasso	nurse	reach	skate	talk	water
last	offer	read	sleep	tape	wear
laugh	open	remind	slide	tell +NP	wee
lay	pack	repair	slow down	think of	wee-wee
lean	paint	replace	smack	throw	weigh
learn	park	rescue	smell	throw out	wiggle
leave	pass	return	snuggle	tickle	win
let	pat	ride	sort out	tidy up	wind
lick	pause	ring	speak	tie	wipe
lie down	pay	rinse	spell	tighten	work
lift	peck	rock to	spend	till	worry
lip read	pedal	sleep	spill	tip	wrap
listen	peel	roll	spin	toss	write
live	pet	row	spoil	touch	zap
load	phone	run	squash	tow	zoom
lock	pick	save	squeak	trade	
look	pick up	say	squeeze	transport	
lose	pile	screw	stack	treat	

Stative

believe	fit - NP	know	love	think
belong	have	like	need	want
fancy	hope	live	stand +NP	

Perception verbs

feel
hear
see
smell

Cognitive perception verb

tell - comp
understand
remember
look like

Appendix 3: Stative prejacent of root modals with non-future orientation (excl. perception verbs)

Quantificational modals

1. Because it can be dangerous if you've got a tractor without a cab like that you know.
2. Because she can be a bit of a pest, can't she?
3. It's just she can be a bit excitable, can't she?
4. Well she can be but she can also be a pest.
5. Well she can be but she can also be a pest.
6. Half an hour's about as long as you can be good, isn't it?
7. I think you could be good sometimes.
8. You can be so cheeky.
9. He can be very naughty tiger, can't he?
10. Meat can be very expensive.
11. Now the meat can be very expensive, can't it?
12. They can be.
13. Grapes can be sticky.
14. They can be nice when they're hot too.
15. You can be really mardy when you want to be.
16. You can be very noisy sometimes.
17. You can be very awkward when you want.
18. Could ladys be policemen?
19. Men can be teachers too you know.
20. Well you can have doctors that are ladys, Warren.

Idioms

1. Along came a crocodile sleepy as can be.
2. Along came a crocodile as sneaky as can be.
3. I can't believe this is the same little boy.
4. I can't believe that.
5. I should think so.
6. Others can't stand getting wet.
7. You know I can't stand this book, don't you?
8. Can you believe that?
9. I should hope so too.
10. Can't believe he's taking them out one at a time.
11. The one thing I can't stand is when you willn't do as you're told.
12. Like to take them off again because I can't believe you just did that.
13. I can't stand you when you're like this.
14. Should hope not.
15. What did you say when I was going I can't believe you've not gone to sleep.
16. Should hope not.
17. You can't stand it.
18. Just can't stand it, can you?
19. You can't stand it when they've got clothes on.
20. I can't believe you can see anything out of those.
21. I can't stand squealing children.
22. The ginger cat cannot believe that mice can move so fast.
23. I can't stand it.

Actuality entailments

1. We went to the woods and we had to be careful, didn't we where we walked.
2. We had to have a strong bird feeder <at home, didn't> [//] at our last house, didn't we?

Necessity modals

1. Must be just the right shape.
2. It has _to be different.
3. They've got _to be the same, haven't they?
4. It's got _to be the same as this one to say snap.
5. Had to be tied in.
6. You have _to be careful when you get in boats.
7. One has _to be smaller than the other.
8. Has _to be Madeira cake though.
9. You have _to be at home sometime.
10. You have _to be a proper train driver, don't you to drive a train.
11. Engines have _to be quite sensible going round tracks.
12. So you should be xxx.
13. You put the funnel where it ought _to be.
14. Because he's got _to have lots for all the children hasn't he?
15. He's got _to have enough toys for all the children.
16. Got _to have holes in [/] in t-shirts,, haven't you?
17. You mustn't have this on now.
18. Why do all babas have _to have their clothes off?
19. A train should have a driver and that's what that is.
20. You did have _to have lots _of a pile.
21. You have _to have those tops on things, Nicole.
22. You have _to have it flat, don't you on the bottom?
23. Henry has _to have special coal, doesn't he?
24. So Mummy has _to have it when Daddy's out.
25. Why've you always got _to be climbing up me?

Negated possibility modals

1. I can never be sure which one you're saying when you say it.
2. Bricks can't be fed up.
3. I don't think that can be right, can it his ears?
4. Those ears can't be right, can they?
5. Can't be too tight.
6. Except when I can't be bothered to take you upstairs.
7. Can't have a picnic without your dinner ,, can you?
8. You can't have a Daddy hen.
9. You can't have a dodie@c while you're having your tea.
10. You can't have cheese on its own for tea.
11. You can't have a cow with a horse for a baby.
12. Can't have a train that's got no driver, can we?
13. We can't have music on when Caroline's here.
14. We can't have any music on.
15. No you can't have the tape on while we've got people here.
16. We can't have the music on, can we?
17. I know it's not got ears but you can't have everything.
18. We can't seem to find any milk today.
19. You can't like everything, can you?
20. You can't have broke it again.

Possibility modals

1. So how can he be twenty if [/] if he's going to school?
2. How can Thomas be in there?

3. How can it be stuck?
4. How can it be broken?
5. Can women be in the police?
6. Where can she be?
7. Can we xxx out because I can't stand that noise.
8. I can live without chips.
9. You can want as much as you like but you're not having it.
10. Though how you can want lunch after several cakes I don't know.
11. Or you could put animals in it I should think.
12. That one can fit.
13. His bottom can fit in though.
14. They can fit.
15. The horse can just about fit.
16. Percy can fit in there too.
17. Oh they can fit under the gates.

Appendix 4: Animacy of subjects by modal by flavor, input (n = 6 adults)

Roots (n = 7,672)	no subject	animate	inanimate	expletive	eventive	can't tell
<i>can</i> (n = 4,994)	80	4747	163	0	4	0
<i>have to</i> (n = 1,006)	62	900	42	0	2	0
<i>could</i> (n = 703)	17	629	57	0	0	0
<i>got to</i> (n = 506)	21	463	21	1	0	0
<i>should</i> (n = 314)	3	265	42	2	2	0
<i>supposed</i> (n = 97)	1	58	36	0	1	1
<i>must</i> (n = 37)	3	32	2	0	0	0
<i>ought to</i> (n = 12)	0	10	2	0	0	0
<i>may</i> (n = 3)	0	3	0	0	0	0
total (n = 7,672)	187	7,107	365	3	9	1

Epistemics (n = 886)	no subject	animate	inanimate	expletive	eventive	can't tell
<i>might</i> (n = 585)	33	352	148	24	27	1
<i>must</i> (n = 158)	16	79	49	13	1	0
<i>could</i> (n = 69)	11	19	37	0	2	0
<i>can</i> (n = 31)	3	17	9	1	1	0
<i>should</i> (n = 20)	1	8	6	3	2	0
<i>may</i> (n = 8)	0	6	2	0	0	0
<i>supposed</i> (n = 8)	0	5	3	0	0	0
<i>have to</i> (n = 4)	0	2	2	0	0	0
<i>got to</i> (n = 3)	0	2	1	0	0	0
total (n = 886)	64	490	257	41	33	1

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