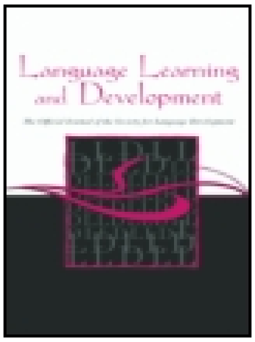

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Seeing and Believing: The Relationship between Perception and Mental Verbs in Acquisition

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ABSTRACT

Perception verbs and mental verbs have significant overlap in their syntax and semantics; both reference mental representations when taking embedded clauses, as in *I see that Maria was here* and *I think that Maria was here*. Some have suggested that perception is more accessible for young children than mental states, raising the question of whether perception verbs could serve as a semantic model for the acquisition of mental verbs via their shared syntax. Since embedded clauses are key to referencing mental states for both verb classes, we examine the developmental trajectory of perception vs. mental verbs in these constructions and others. Using a sample of 5,884 child-produced utterances and 8,313 parent-produced utterances from the Brown and Gleason corpora of CHILDES, we analyze children's production of perception and mental verbs in their syntactic frames, as well as that of their parents. We find that children begin to produce embedded frames for both perception and mental verbs around the same time, but produce embedded frames with mental verbs more often, especially as they get older, despite greater use of perception verbs overall. These patterns do not reflect parental input: parents produce both verb types with similar frequency and use embedded frames more often than their children. These findings suggest that perception verbs are unlikely to serve as a model for mental verbs, and instead that mental verbs and their regular occurrence with embedded frames may provide a model for perception verbs when the latter reference mental states. We propose a semantic updating account for children's acquisition of perception verbs, arguing that children's early knowledge of perception verbs may not include mental state representations as a component of their meaning, and that this may only develop later as children learn the propositional syntax that is shared by and regularly occurs with mental verbs.

"*Seeing is believing.*" The widespread use of this aphorism suggests an intimate link between our perceptual and mental states. Although perception is not the sole origin of all mental representations, there is evidence that even infants and toddlers identify perceptual information as a source of one's own beliefs and those of others, including both true and false beliefs, and use this information to reason about differences in mental states (Gopnik et al., 1994; Song & Baillargeon, 2008; *inter alia*). As early as 2 years of age, children begin to produce both perception and mental verbs in simple sentences including statements about their own perception (e.g., *I see truck*), queries about others' perception (*See it?*), statements about their own state of knowledge (*I thought he was sleeping*), and queries about what others know (*How do you know?*) (Bloom et al., 1989; Bretherton & Beeghly, 1982; Brown, 1973; Frank et al., 2017). This is quite remarkable, given that the meanings of perception verbs (e.g., *see, hear*) and mental state verbs (e.g., *think, know, believe, remember, forget)* refer to invisible, abstract

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processes and representations in one's own mind and in the minds of others.[1] Without an easily observable component to their meaning, these verbs cannot be learned simply by observation alone; indeed, both classes of verbs have served as key examples of the need for syntactic information as a structural source of meaning that children can use to make inferences about the meanings of verbs (Landau & Gleitman, 1985; Papafragou et al., 2007).

Despite the firm evidence for children's use of syntactic frames for learning these two classes of verbs, we know remarkably little about their early semantic or syntactic representations, especially for perception verbs. Yet understanding the earliest facts about their acquisition could generate significant insights about several issues. First, children's earliest understanding of mental states appears to be deeply entwined with their understanding of perception; if so, their knowledge of perception and mental verbs may also be intertwined. Second, perception and mental verbs show significant and interesting overlap in the syntactic contexts in which they occur, which in turn reflect their shared semantics. Key in this overlap is the sharing of a syntactic frame that expresses propositional content: one can say "I think that … " or "I see that … ", and in both cases, the complement following *that* expresses a proposition referring to a mental representation. This overlap in syntactic contexts may be a crucial force in the development of children's understanding that perception and mental verbs are conceptually related. Moreover, there is evidence that the acquisition of complementation is involved in the development of mental state understanding; some researchers have even proposed that mastery of embedded tensed complements supports, and may be a prerequisite for, abilities like false-belief reasoning (de Villiers, 2007; de Villiers & Pyers, 2002; Durrleman et al., 2016; Schick et al., 2007; but see also Baillargeon et al., 2010; Grosse Wiesmann et al., 2016).

Here, we explore the relationship between the two classes of verbs in early acquisition by examining the developmental contours of children's production of these verbs, with a focus on the syntactic frames in which they occur. Our key questions are whether the trajectories of perception and mental verbs in their shared frames overlap to a great extent, or whether the acquisition of one class is markedly different from the other in terms of timeline or frequency of production. If perception verbs together with a rich set of syntactic frames (most notably sentential complements) appear earlier in acquisition or occur more frequently, this might suggest that they serve as a model for mental state verbs (as has been suggested for non-linguistic understanding of perceptual vs. mental states; see below). Alternatively, if mental verbs lead in the expression of propositions via their rich syntactic frames, then the encoding of propositions as complements of perception verbs (e.g., *I see that …*) may depend on the acquisition of mental verbs and their syntactic contexts.

To explore these questions, we analyzed the use of perception and mental verbs in the Brown and Gleason corpora of CHILDES to examine whether production of perception verbs in specific frames precedes, follows, or co-occurs developmentally with production of mental verbs in the same frames, as well as how the use of these verbs and their frames changes over time. While previous research has documented children's early production of perception and mental verbs (Bretherton & Beeghly, 1982; Frank et al., 2017), there is no research, to our knowledge, that has specifically examined perception and mental verbs in parallel, nor in the context of their shared syntax. Our analysis, therefore, includes looking closely at developmental timetables for the production of perception and mental verbs along with the syntactic frames in which these verbs appear. We give special attention to the proposition-embedding frames shared by both perception and mental verbs.

Before turning to our study, however, we review two bodies of evidence that render plausible the idea that children's understanding of perception might serve as a model for their understanding of mental states, and that the parallel syntactic structures for the two verb classes might allow one to bootstrap the other.

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[1]Perception verbs – especially verbs of vision – might seem like they map primarily to physical actions (e.g., *look* = point one's eyes toward), but in fact, the semantics of verbs like *see* and *hear* typically require that the perceiver achieves a mental representation as a result of a perceptual experience (Landau & Gleitman, 1985; Viberg, 1983). This is perhaps best exemplified by the acceptability of statements like *She looked right at it but didn't see it*.

Understanding of perception and mental states in early childhood

Several decades of developmental research provide support for the idea that children's knowledge about perception and mental states are tightly linked – specifically, that what we perceive informs our knowledge and beliefs, and that perceptual experience, like knowledge and beliefs, can vary between individuals. For example, research suggests that even infants assume that seeing leads to knowing. Studies using violation-of-expectation tasks with 14-month-olds have shown that they are surprised (i.e. look longer) when they see an agent search for a toy in a new location despite the fact that the agent did not actually witness the toy being moved there from its previous location (Onishi & Baillargeon, 2005; but see Apperly & Butterfill, 2009; Grosse Wiesmann et al., 2016 for alternative interpretations). Infants also appear capable of understanding that individuals can arrive at false beliefs as a result of perceptual mis-information. Song and Baillargeon (2008) found that 14.5-month-olds expected an agent to use a misleading visual cue – what appeared to be a doll's hair protruding from a closed box – to locate the doll, even if the infants themselves knew that the doll was elsewhere.

By around age three, children come to understand that what one person sees may be different from what another person sees, and that these differences lead to potentially conflicting mental representations. For example, three-year-olds know that their own view of a vertically held card differs from that of a person sitting across from them, viewing the other side of the card (Flavell, 2004). Around the age of 4–5 years, young children also come to understand that perceptual appearances may be misleading – for example, that even though an object may look like a rock, it could actually be a sponge with the same superficial visual characteristics as a rock (Flavell et al., 1983, 1986; Gopnik & Astington, 1988). These findings show that infants and young children recognize that perception can vary from person to person, and that perceptual experience can give rise to true or false beliefs on the part of the perceiver.

Based on this and other evidence, Gopnik et al. (1994) proposed that an understanding of perception might emerge first in development and serve as a conceptual model for belief. Their view is that representations based on perceptual experience may be more accessible and thus easier to reason about than representations of mental states, which do not have to be directly grounded in perceptual experience and therefore may be more abstract (see also Gopnik & Astington, 1988). This proposal is supported by their finding that three-year-old children performed fairly well on a perception task with many similarities to typical appearance-reality and false-belief tasks, despite the fact that preschool children often fail on the latter two (Wellman et al., 2001, and references therein). In Gopnik et al.'s study, children participated in a perception task in which misleading perceptual information (a green cat with a red filter placed in front of it, making the cat appear black) led the child or another individual to initially have a false belief about an object's properties, and were also tested in a typical "deceptive contents" false-belief task. Children performed better on perception questions (e.g., "How did it look to you/her?") and belief questions (e.g., "What color did you/she think it was?") for the perception tasks than they did on comparable questions (e.g., "What did you/she think was in the box?") for the false-belief tasks. Three-year-olds' greater success on the perception task questions suggests that understanding perception could be an earlier developmental achievement than understanding belief. Slaughter and Gopnik (1996) also found that children who initially failed false-belief tasks improved on these tasks as much from training on a perception task as from training on belief tasks.[2]

If understanding perceptual representations emerges before understanding mental representations, then this ordering might extend to the acquisition of perception and mental verbs. The greater accessibility of perception could make learning the meanings of perception verbs like *see* easier than learning the meanings of mental state verbs like *think* and *know*. In the next section, we review the

[2]In the perception training condition, children were trained using the same perception task from Gopnik et al. (1994); children in the belief training condition were asked to report their own or another person's false belief in two separate deceptive appearance tasks (e.g., a golf ball that turned out to be soap).

semantics and syntax of perception and mental verbs, in particular the shared aspects of their meaning and the syntactic structures that would highlight these similarities.

The semantics and syntax of perception and mental verbs

Given the close connection between perceptual and mental states, it is perhaps unsurprising that the verbs in these two domains share semantic features and syntactic contexts. Of particular interest is the overlap between mental verbs and "experience" (Viberg, 1983) or "*see*-type" (Levin, 1993) perception verbs, such as *see* and *hear*, which take as their subject the individual who has a perceptual experience of some object or event.[3] Experience perception verbs encode reference to both the *perceptual stimulus* (i.e. the thing that is perceived) and the *perceiver's corresponding mental representation* of that stimulus. So, in an utterance like (1),

(1) Mary saw that it was snowing.

the complement of *see*, "that it was snowing," refers to two things: the event that was the source of Mary's visual experience, and the representation in Mary's mind of what she perceived visually. Because they typically refer to mental representations, many uses of perception verbs are *epistemically non-neutral* – i.e., the truth of the perceptual reports depends on the subject believing the content of the complement (Moulton, 2009).[4] For (1) to be true, Mary must *believe* it was snowing, in addition to having actually witnessed snow. This kind of use of perception verbs – where the complement requires consideration of the perceiver's mental state – is what we are most interested in here.

Experience perception verbs can also be used to refer only to the perceptual stimulus, without any commitment to the perceiver's belief. These are *epistemically neutral* perceptual reports, in which the truth of the report does not depend on what the perceiver believes (Barwise, 1981; Higginbotham, 1983; Moulton, 2009).

(2) John saw a vulture.

[3]Viberg (1983) (as well as Rogers (1971), using different labels) describes two other classes of perception verbs in his typology, distinct from experience verbs. These other classes of perception verbs are less syntactically productive than experience verbs, and do not overlap much, if at all, with mental verbs in the complements they license. In particular, they do not take sentential complements. For that reason, the focus in this paper is on experience perception verbs. *Activity* perception verbs, such as *look (at)* and *listen*, take as their subject an agent that consciously controls some action or process related to perception.

(i) John looked at the house.
(ii) Roberta listened to the conversation.

Copulative perception verbs, such as *look* and *sound*, take as their subject the entity that is the source of some perceptual property.

(iii) The table looked red.
(iv) The music sounded lovely.

[4]The discussion here focuses primarily on *de dicto* attitude reports, rather than *de re* attitude reports, which can contain descriptions of individuals or events that are (extensionally) correct but that the attitude holder would not assent to. For example, consider a scenario in which Sally watches someone dressed in a bear costume maliciously knock a child's ice cream cone out of their hand. Sally thinks the person in the bear costume is a jerk, but unbeknownst to her, that individual is her brother, who she believes is a kind person.

(v) Sally thinks that the person in abear costume is ajerk. (*de dicto*)
(vi) Sally thinks that her brother is a jerk. (*de re*)

Since the descriptions *the person in the bear costume* and *her brother* pick out the same individual, (vi) is true on a *de re* reading, even though Sally would not agree with it. There are many discussions and analyses of the *de re* and *de dicto* distinction in the semantics literature (e.g., Burge, 1977; Keshet & Schwarz, 2019; Lewis, 1979; Quine, 1956; *inter alia*). However, both *de dicto* and *de re* attitude reports are epistemically non-neutral, and the data presented here do not require any unique treatment of the *de re/de dicto* distinction.

It is possible for (2) to be true even if the description of the thing John perceived (*a vulture*) does not match John's belief about what he perceived – for example, if John did not know what kind of bird it was, or if John thought it was a hawk. However, epistemically neutral interpretations are available only with certain non-embedded complement structures, and often require explicit qualification (e.g., *John saw a vulture, but he thought it was a hawk*) or contextual cues to indicate that report does not reflect the perceiver's beliefs.

Mental verbs like *think, know*, and *believe* are always epistemically non-neutral, since the truth of a report of the contents of an individual's mental state necessarily depends on that individual's beliefs. Utterances like (3–4) are only true if John believes the proposition that it is raining.

(3) John thinks that it is raining.
(4) John knows that it is raining.

The truth of mental verb complements must be evaluated relative to the mind of some individual, which is also frequently the case for perception verb complements, as in (1).

In addition to sharing the semantic feature of epistemic non-neutrality, perception and mental verbs also share syntactic structures. Both perception and mental verbs can take non-embedded complements (such as noun phrase (NP) complements) and embedded complements (such as sentential complements), and there are only a few syntactic frames that are licensed by one verb class but not the other.[5] The fact that both verb types take embedded complements[6] intersects critically with the "belief" aspect of their semantics. Although perception verbs used with non-embedded complements can yield either epistemically neutral or non-neutral interpretations, when perceptions verbs take embedded complements they can *only* receive epistemically non-neutral interpretations. That is, perception verbs with sentential complements behave like mental verbs. This is illustrated by the following examples:

(5) Joanna saw an egret land in her yard.*(neutral or non-neutral)*
(6) Joanna saw that an egret had landed in her yard.*(non-neutral only)*
(7) Joanna knew that an egret had landed in her yard.*(non-neutral only)*

Because (5) contains a non-embedded complement, it is potentially ambiguous with regard to Joanna's beliefs; (5) could be true even if Joanna does not believe the event she witnessed was that of an egret landing in her yard (e.g., if she mistakenly thinks that the bird was a heron, or that the bird did something else). In contrast, (6), like (7), is true only if Joanna believes the proposition that an egret landed in her yard.[7] The use of an embedded complement is so powerful in driving belief interpretations of perception verbs that it can lead to a mental state reading even when there is no direct perception, but rather only indirect perceptual evidence or even non-perceptual inference. For example, the following two sentences are felicitous without direct perception being involved; *see* is then interpreted with a belief-like meaning.

(8) Peter saw that a book had fallen off the shelf.
(9) Francine saw that the argument was flawed.

[5]For example, perception verbs take small clause complements, but mental verbs do not.

(vii) David saw Nancy leave.

*David thought Nancy leave.

[6]Embedded complements represent propositions whose truth-values must be evaluated relative to some possible world (Hintikka, 1962; Lewis, 1986; Montague, 1974); the world of evaluation is specified by the matrix clause under which the complement is embedded.

[7]The truth of (6) and (7) also depends on the complement being true, since both *see* and *know* are factive verbs that presuppose the truth of their clausal complements.

(8) can be true even if Peter did not directly witness a book falling off the shelf, but rather simply walked into the room and saw a book on the floor next to the bookshelf. Similarly, (9) can be true even if Francine had no visual evidence upon which to base her belief that the argument was flawed, but inferred it from other kinds of information. Thus, embedded clause complements push the semantics of experience perception verbs like *see* toward mental state interpretations that closely overlap with the semantics of mental verbs.

Because perception and mental verbs are most semantically similar when they take embedded clause complements, we consider them to be the critical frames for highlighting the semantic connections between the two verb classes. Specifically, using embedded complements with perception or mental verbs would suggest that the speaker has some knowledge that these complements refer to a proposition that holds in an individual's mind, i.e. a belief. If and when children use embedded complements with perception verbs, we can infer that their semantic representations for these verbs likely include mental state reference. The same inference cannot necessarily be made when children use perception verbs with non-embedded complements, which can be ambiguous between epistemically neutral and non-neutral interpretations.

Previous studies on the acquisition of mental and perception verbs

Children's acquisition of mental verbs has received a fair amount of attention in developmental research. Prior work has shown that children begin using some mental verbs around the age of two to three, but that children's ability to make adult-like distinctions between the meanings of different mental verbs may not emerge until four or later. For example, four-year-olds, but not three-year-olds, recognize the difference between mental terms like *be sure* vs. *think*, and *know* versus *think* and *guess* (e.g., Johnson & Maratsos, 1977; Moore et al., 1989, 1989), suggesting that younger children do not have a firm grasp of how these verbs' semantics differ on dimensions like certainty and factivity. Other research indicates that until as late as six or 7-year old, children have trouble distinguishing knowing from correctly guessing (Miscione et al., 1978); that they do not always correctly use verbs like *remember* and *forget*, for example, using *forget* to refer to an individual's lack of knowledge regardless of whether he had previous knowledge (Wellman & Johnson, 1979); and that they cannot appropriately differentiate *remember, know*, and *guess* by using contextual information about knowledge states (Johnson & Wellman, 1980). It thus appears that while children learn the general meaning of mental verbs somewhat early, and distinguish them as a class from other types of verbs, they need more time to fine tune the nuanced semantic representations of individual verbs to include features like factivity (Dudley et al., 2015), prior knowledge, and certainty.

While the acquisition of perception verbs has received less attention than the acquisition of mental verbs in the developmental literature, the research that has been done points to two particular trends: first, that perception verbs are generally acquired earlier than mental verbs; and second, that children's early understanding of perception verbs may be rather limited. Bretherton and Beeghly (1982) examined maternal reports of children's production of internal-state terms, including perception verbs and mental ("cognition") verbs. They found that by the age of 28 months, the majority of the children in their study were producing the perception verbs *see, look, watch, hear, listen, taste, smell*, and *feel*, and that a much greater proportion of children produced these verbs than the mental verbs *know, think, remember, forget, understand, pretend, guess*, and *mean*. Similarly, parental report data from Wordbank shows that by 30 months, roughly 80–90% of children produce the perception verbs *see, hear, look*, and *watch*, while only around 50% are reported to produce the mental verbs *think* and *pretend* (Frank et al., 2017). These parental report studies document which verbs are produced and when, but do not investigate the details of how children use these verbs, such as their occurrence in different syntactic frames or the meanings children assign to them.

Other research has probed some aspects of children's developing semantic representations for perception verbs. Landau and Gleitman (1985) found that three-year-old sighted children interpreted visual verbs like *look* and *see* only as involving perception via visual experience; even when blindfolded, sighted children turned their head and eyes toward something when instructed to "look." Research by Elli et al. (2020) also suggests that sighted children interpret visual verbs as encoding solely direct visual perception. In their study, participants were asked what body part a blind individual would use to see something; four- and six-year-old children, but not nine-year-olds or adults, would typically answer this question with "her eyes." These findings indicate that younger children assign narrower meanings to perception verbs than older children or adults (who reason that the blind person can "see with their hands"), believing that a verb like *see* can only refer to an event involving perceiving directly with one's eyes.

It appears, then, that both mental and perception verbs may have a somewhat extended acquisition process, in which children's semantic representations are incomplete (or at least non-adult-like) when they first begin to use these verbs, and then become refined over time. However, the precise trajectory of their acquisition – especially that of perception verbs – remains unclear.

The current study

If even infants recognize that perception leads to mental representations, then this could provide a foundation for links between the perception and mental verbs in acquisition. But this leaves unanswered how the child identifies the similarity in the semantics of verbs like *see* and *think*. Evidence on the use of syntax to infer the meaning of perception verbs like *see* (Landau & Gleitman, 1985) and mental verbs like *think* (Papafragou et al., 2007; *inter alia*) suggests that the syntactic structures shared by the two verb classes should play a critical role for the learner. Our question is whether such syntactic information is evident in young children's production, and if so, what the developmental trajectories are for the two different verb classes. We propose two possibilities.

One possibility follows from Gopnik et al.'s (1994) proposal that understanding perception fosters understanding belief, and extends this idea to verb learning: if perception does serve as a conceptual model for belief, then perception verbs might similarly serve as a model for mental verbs. While Gopnik et al. do not specify the mechanism through which children could extend conceptual knowledge about perception to belief, we propose that in verb learning, a prime candidate would be the syntax shared by both verb classes that is crucial in children's acquisition of any mental predicates – embedded complements. Specifically, children who have mastered clausal complements with perception verbs would, upon hearing a mental verb in the same structure, be able to infer that this verb likely also refers to mental representations and is epistemically non-neutral. This would entail that children have mapped the "vision leads to belief" concept to a verb like *see* before they begin to learn verbs like *know* and *believe*. This hypothesis thus predicts that the use of perception verbs in syntactic structures shared by mental verbs – especially sentential complements – should appear earlier or more prominently in children's speech. Such an account fits naturally with Gopnik et al.'s hypothesis, as well as with existing evidence that young children produce perception verbs earlier and more frequently than mental verbs, both in general (Bretherton & Beeghly, 1982) and with some complement clauses (Bloom et al., 1989).

The second possibility is simply the reverse: mental verbs could lead the way in acquisition by serving as the clear and consistent linguistic model required for learning that perception verbs can also have epistemically non-neutral (mental state) readings. Children might need to learn the relationship between complementation and the expression of mental representations in the context of mental verbs, which are unambiguously non-neutral, in order to recognize that the same relationship holds when perception verbs occur in the same structures. The stronger syntactic evidence provided by mental verbs may be necessary to trigger a revision of children's existing semantic representations of perception verbs, assuming that belief is not initially included as a component of their meaning, which seems plausible given what is known about children's early understanding of perception verbs. If so, then this alternative hypothesis predicts that the use of sentential complements would occur earlier or more frequently with mental verbs than perception verbs.

In the following, we examine the developmental trajectory for children's production of perception verbs compared to mental verbs and their syntactic contexts, concentrating on embedded structures like sentential complements, which are key to the use of these verbs to reference the representational content of mental states. We also examine parental input, to determine whether there are biases in input for the two classes that could influence the acquisition trajectory. Much of our analysis focuses specifically on experience perception verbs (e.g., *see* and *hear*), compared to mental verbs, as they are the only perception verbs that take embedded complements, the structure most critical to our hypotheses.[8]

Participants, materials, and coding

Participants were 17 children from the Brown and Gleason corpora of CHILDES (Brown, 1973; Masur & Gleason, 1980), along with their parents. The three children from the Brown corpus were recorded in their homes during interactions with their parents. Adam was recorded for 55 sessions from age 2;3 to 4;10; Eve was recorded for 20 sessions from age 1;6 to 2;3; and Sarah was recorded for 139 sessions from age 2;3 to 5;1. Preliminary analyses of the Brown data showed that there were comparatively very few tokens from recordings done under the age of 2;0 and over the age of 4;11 (1 recording for Adam; 13 recordings for Eve; and 6 recordings for Sarah), so these were excluded from our sample. The children from the Gleason corpus were recorded for three sessions each: one session with the mother in the laboratory; one session with the father in the laboratory; and one session during dinner at home with both parents. The laboratory sessions included play with a toy car, reading a picture book, and playing store. We selected 14 children out of the 24 participants in the Gleason corpus based on age (between 2;0 and 4;11) and gender, so that in combination with the participants from the Brown corpus there were similar numbers of children in each of the age ranges used in our analysis (see Results below) and nearly equal numbers of girls and boys (9 females, 8 males). For four children from the Gleason corpus, only two recorded sessions were included in our sample because either the file for one of the sessions was not available or the date of the session, and thus the exact age of the child, was unknown. The number and names of children in each age range from both corpora are listed in Table 1.

We searched our sample for nine perception verbs and 10 mental verbs (Table 2). All but one of the perception verbs are in Viberg's (1983) typology of perception verbs; the additional verb, *watch*, was also included because it is quite common in young children's speech and has been examined in previous work on children's production of perception verbs (e.g., Bretherton & Beeghly, 1982; Frank et al., 2017). For the mental verbs, we searched for 10 verbs that have been the focus of previous studies on children's acquisition of mental verbs (e.g., Bretherton & Beeghly, 1982; Johnson & Wellman, 1980; Lyon & Flavell, 1994; Miscione et al., 1978; Shatz et al., 1983; Wellman & Estes, 1987; Wellman & Johnson, 1979; *inter alia*). This search yielded 5,884 target verb tokens produced by the children and 8,313 produced by their parents, after excluding ambiguous uses (see next paragraph). Children overall produced 3,978 tokens of perception verbs and 1,906 tokens of mental verbs, and parents produced 4,113 tokens of perception verbs and 4,200 tokens of mental verbs. For both children and parents, the most frequently occurring target verbs were *see,*

Table 1. The children included in our sample from the Brown and Gleason corpora.

Age Range	N	Child Name (# of Sessions; Total # of Utterances in Age Range)
2;0–2;5	6	Patricia (2; 190), Victor (2; 218), William (3; 272), Adam (6; 1789), Eve (7; 2081), Sarah (12; 389)
2;6–2;11	6	Charlie (1; 96), Laurel (1; 53), Patricia (1; 87), Richard (2; 164), Adam (13; 4708), Sarah (24; 1788)
3;0–3;5	6	Charlie (2; 177), Guy (3; 270), Laurel (2; 199), Olivia (3; 216), Adam (13; 6539), Sarah (24; 2518)
3;6–3;11	5	Isadora (3; 373), Ursula (2; 545), Wanda (1; 116), Adam (9; 4131), Sarah (23; 2206)
4;0–4;5	6	Andy (3; 276), Eddie (3; 337), Helen (1; 76), Wanda (1; 56), Adam (7; 3864), Sarah (25; 3247)
4;6–4;11	3	Helen (2; 311), Adam (6; 3236), Sarah (22; 2703)

[8]We found no instances of activity or copulative perception verbs used with embedded complements in our data set.

Table 2. Target verbs extracted from the Brown and Gleason corpora.

Perception	Mental
see	*know*
hear	*think*
feel	*believe*
taste	*understand*
smell	*remember*
look	*forget*
listen	*guess*
watch	*pretend*
sound	*dream*
	mean

know, look, and *think*; these four verbs made up 84.4% of the child-produced tokens and 83.7% of the parent-produced tokens in our sample. Table 3 shows each of the verbs that made up 1% or more of our sample. We also estimated the total number of verbs in the two corpora by using the CLAN program (MacWhinney, 2000) to count all items tagged as verbs. This yielded an estimate of 43,231 child-produced verbs and 46,760 parent-produced verbs in the recordings included in our sample. Based on this estimate, our 19 target verbs made up 13.6% of children's total verb uses and 17.8% of parents' total verb uses.

Utterances containing the target verbs were manually coded for the specific verb, verb type (mental or perception[9]), and syntactic frame each specific verb occurred in. We coded all syntactic frames that appeared in the data; these are shown in Table 4 along with examples from Adam, which are representative of utterances from all of the children. We relied on the surface structure of utterances for coding of syntactic frames.[10] We excluded any instances that were ambiguous, e.g., when the transcription was incomplete, the transcribed sentence/utterance boundaries were unclear,[11] or the token might have been a noun or other part of speech.[12] Given our assumption that the use of embedded complements with perception and mental verbs would most directly reflect children's understanding of the mental state readings of these verbs, the complements were further classified as non-embedded or embedded, following the semantic analyses of Higginbotham (1983), Moulton (2009), and Davis (2016).[13] Our focus was the developmental trajectories of the target verbs in these frames, as an indicator for whether perception verbs lead mental verbs, or vice versa, in the encoding of this element of the verbs' meaning.

The majority of utterances in our sample were coded using a two-step iterative process. Primary coders were trained by the first author and then proceeded with coding the sample. A secondary coder (the first author) then blind coded 20% of the utterances, selected randomly. If an agreement between primary and secondary coders was found to be less than 90%, coding was reviewed to identify any systematic errors. If any systematic errors were found, primary coders were retrained and then they recoded categories in which errors had been identified. The secondary coder then blind coded another 20% of the utterances, again selected randomly. There was one exception to this general procedure: for

[9]Perception verbs were also coded as experience, activity, or copulative, following Viberg's (1983) typology. For polysemous perception verbs like *look, feel, taste*, and *smell* this classification was determined by context and/or frame. This coding was not used in our analysis, however, beyond separating out experience perception verbs, as discussed in the Results section.

[10]Verbs (especially mental verbs) that occurred without a complement (e.g., *I don't know*) could be considered to have elided complements. However, attempting to recover a possible complement structure from discourse context would be quite difficult since it would not always be clear what the elided complement might have been. Moreover, it is still the case that the verb was produced without a complement in such instances. It can also be difficult to distinguish between potentially elided complements (e.g., *I don't know [how to tie my shoes]*) and formulaic uses that may not carry true mental content or be intended to express full propositions (see Diessel & Tomasello, 2001).

[11]For example, an utterance transcribed as "look (.) Mommy", where (.) indicates a possible sentence/utterance boundary.

[12]For example, an utterance such as "watch going" when Adam and his parents were discussing wristwatches.

[13]In the analyses of Higginbotham (1983), Moulton (2009), and Davis (2016), small clause complements are treated as non-embedded complements. From a strictly syntactic point of view, small clauses are a type of embedded clause; however, it can be argued that semantically they function quite differently from sentential complements since they do not carry propositional content (Higginbotham, 1983; *inter alia*). For this reason, they can be treated as similar to noun phrase complements (Parsons, 1990). See Davis (2016; and references therein) for further discussion.

Table 3. The verbs that made up 1% or more of the coded utterances in our sample for children and parents. Verbs that made up less than 1% of coded utterances in our sample are not listed individually.

Children				Parents			
Verb	Verb Type	N	%	Verb	Verb Type	N	%
see	perception	2175	36.96	*see*	perception	2089	25.13
know	mental	1216	20.67	*know*	mental	1826	21.97
look	perception	1190	20.22	*think*	mental	1580	19.01
think	mental	386	6.56	*look*	perception	1465	17.62
watch	perception	297	5.05	*remember*	mental	257	3.09
hear	perception	170	2.89	*hear*	perception	203	2.44
forget	mental	84	1.43	*watch*	perception	167	2.01
guess	mental	70	1.19	*mean*	mental	133	1.60
other		296	5.03	*forget*	mental	132	1.59
Total		**5884**	**100.00**	*guess*	mental	121	1.46
				pretend	mental	89	1.07
				other		251	3.02
				Total		**8313**	**100.00**

Table 4. Frames used in coding child and parent utterances with target verbs. Examples are utterances produced by Adam.

Frame	Perception verb examples	Mental verb examples
Non-embedded complements		
V	See?	I don't know.
V NP	I heard a motor boat.	I remember him.
V PP	Look in your bags.	I dreamed about Ursula too.
V Adj	He looks funny.	*Not attested*
V NP VP	Watch me come back.	*Not attested*
Embedded clause complements		
V CP	I see you carried the book with you.	He thinks the chair moves by itself.
V Q	See what I got in my hand?	I know what is missing.
V VP	*Not attested*	I forgot to make a sailboat.

half of the parent utterances from the Gleason corpus the first author was the primary coder, and the secondary coder was another trained coder. After this process, overall agreement between primary and secondary coders was between 90% and 96%, with an average of 93%.

Results

We analyzed the production of perception vs. mental verbs and non-embedded vs. embedded frames by children and parents overall and by child age. Statistical analyses used children's precise chronological ages, but for visualizations presented here, children's ages are binned into half-year units (e.g., 2;0–2;5, 2;6–2;11, etc.). We also analyzed the production of verbs and frames by children's mean length of utterance (MLU) stage, a proxy for linguistic development. However, we found that MLU stage was redundant with age in these data, and so that analysis will not be reported.[14]

Overall use of perception vs. mental verbs (independent of frames)

Based on our estimate of the total number of verbs produced in the sessions included in our sample, on average perception verbs made up a greater proportion of children's overall verb production (M = 0.078) than mental verbs (M = 0.057), as shown in Figure 1. This accords with past findings on young children's use of these verbs (e.g., Bretherton & Beeghly, 1982). Parents also produced more

[14]We conducted separate analyses on children's verb type and frame production using age and MLU as predictors in our models. MLU showed the same trends and significance levels as age as a predictor of verb type and frame production.

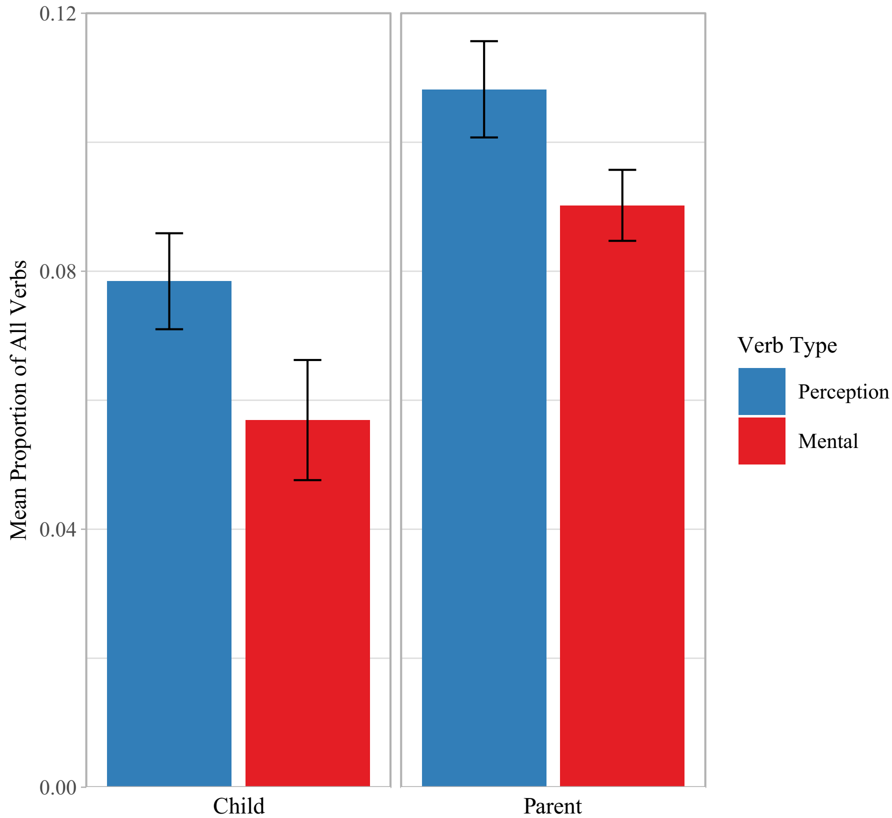

Figure 1. The mean proportions of perception verbs and mental verbs out of all verbs produced by children (left) and parents (right) in our sample from the Brown and Gleason corpora. Mean proportions account for the variability in the size of the samples from the two corpora.

perception verbs (M = 0.11) than mental verbs (M = 0.09). Analysis of the proportions of each verb type produced per child and their parents using a linear regression model showed that perception verbs were produced significantly more often than mental verbs ($\beta = -0.02$, $SE = 0.01$, $t = -2.02$, $p <$ .05) and that parents produced significantly more target verbs than children did ($\beta = 0.03$, $SE = 0.01$, $t = 2.79$, $p < .05$), but there was no interaction between subject group (child vs. parent) and verb type ($\beta = 0.003$, $SE = 0.02$, $t = 0.23$, $p > .05$).

To determine the developmental timeline of children's use of perception and mental verbs, we looked at the proportions of perception and mental verbs by child age (Figure 2a). We evaluated this with a multinomial logistic regression model using the *nnet* package in R (Venables & Ripley, 2002), in which age was the predictor for the frequency of each verb type. Verbs were categorized as perception, mental, or "other," with "other" serving as the baseline against which perception and mental verbs were compared. The counts of "other" verbs were calculated by subtracting the combined count of perception and mental verbs from the estimated counts of all verbs produced during the sessions included in our sample. Children's production of both verb types increased significantly with age, but the change was much greater for mental verbs ($\beta = 0.72$, $SE = 0.03$, $p< .05$) than perception verbs ($\beta = 0.05$; $SE = 0.02$, $p<$ .05). A Wald test showed that the estimated effect of age for mental verbs was significantly greater than the estimated effect of age for perception verbs ($\chi^2(1) = 295.98$, $p < .001$), indicating that children's use of mental verbs increased more sharply between 2 to 5 years than their use of perception verbs did. This points to different developmental trajectories for perception and mental verbs. We also evaluated the

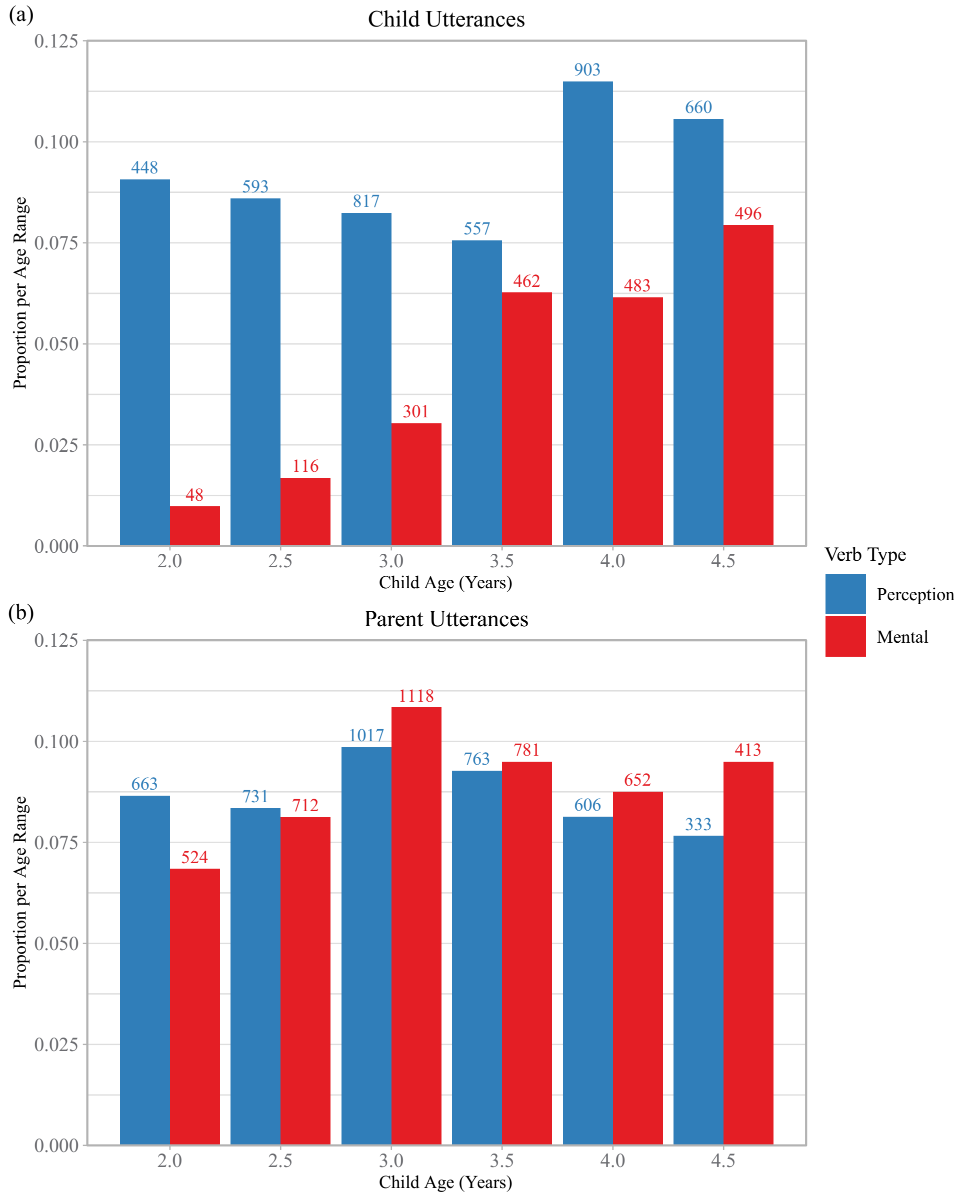

Figure 2. (a) shows the proportions of perception and mental verbs out of all verbs produced by children from ages 2–4.5, in half-year age bins; (b) shows the same for parents' production. Absolute numbers of tokens are shown above each bar.

proportions of perception and mental verbs out of all verbs used by parents over time (Figure 2b). Parents produced slightly fewer perception verbs ($\beta = -0.16$, $SE = 0.02$, $p < .05$) and roughly the same number of mental verbs ($\beta = -0.02$, $SE = 0.02$, $p > .05$) as their children got older.

Use of syntactic frames with perception and mental verbs

In our analysis of the use of perception verbs and mental verbs with different types of syntactic frames, we excluded activity and copulative perception verbs and included only experience perception verbs (*see, hear, feel, taste*, and *smell*[15]), since they are the only perception verbs that take sentential complements; these made up 60% of perception verbs produced by children (n = 2383) and 56% of perception verbs produced by parents (n = 2322) in our sample. Amongst experience perception verbs and mental verbs, the verbs *see, know*, and *think* were by far the most frequently used, making up 88% of the child-produced tokens and 84% of the parent-produced tokens overall, and 90% and 89%, respectively, of verbs produced with embedded complements.[16]

We then examined whether there were differences between children and parents in their production of syntactic frames, as well as whether there were effects of child age and verb type. Specifically, we looked at use of non-embedded vs. embedded frames overall by children vs. parents; use with perception verbs by children vs. parents; use with mental verbs by children vs. parents; use by age and verb type for children only; and use by (child) age and verb type for parents only. We analyzed the data with logistic mixed effect models using the *lme4* package in R (Bates et al., 2014). All models included child (i.e. subject) as a random intercept. A summary of the models is given in Table 5.[17]

Our analysis showed that children produced fewer embedded frames than their parents did both overall and with each verb type. Embedded frames occurred in only 24% of children's uses of experience perception and mental verbs, compared to 49% of parents' uses of those verbs ($\beta = -1.16$, $SE = 0.21$, $p < .05$). Children also produced embedded frames less often than non-embedded frames with each verb type: only 8% of perception verbs and 44% of mental verbs occurred with embedded complements in children's speech. Parents used perception verbs with embedded frames 18% of the time, significantly more than children ($\beta = -0.75$, $SE = 0.33$, $p < .05$), and produced mental verbs with embedded frames 66% of the time, also significantly more than children ($\beta = -1.27$, $SE =$

Table 5. Summary of model estimates, standard errors, and z-values for logistic mixed effect model analyses of production of embedded frames with perception and mental verbs. For *Child or Parent*, child was numerically coded as 0.5 and parent as −0.5; for *Verb Type*, perception verbs were coded as −0.5 and mental verbs as 0.5.

Use of Embedded Frames	*Estimate*	*Std. Error*	*z-value*	
Overall				
(Intercept)	−0.47	0.11	−4.447	
Child or Parent	−1.16	0.21	−5.451	*
With Perception Verbs				
(Intercept)	−1.47	0.17	−8.814	
Child or Parent	−0.75	0.33	−2.255	*
With Mental Verbs				
(Intercept)	0.18	0.10	1.757	
Child or Parent	−1.27	0.21	−6.028	*
By Children				
(Intercept)	−5.38	0.44	−12.32	
Child Age	1.16	0.08	13.82	*
Verb Type	2.51	0.60	4.20	*
Child Age*Verb Type	−0.07	0.15	−0.47	
By Parents				
(Intercept)	−0.78	0.20	−3.901	
Child Age	0.19	0.05	3.539	*
Verb Type	2.13	0.30	7.158	*
Child Age*Verb Type	0.02	0.09	0.241	

* $p < .05$

[15]Since *feel, taste*, and *smell* are polysemous, this subset included only uses that were coded as experience perception verbs. (See footnote 9.)

[16]We carried out the same analyses reported in the previous section to ensure that the general characteristics of the full data set held for just experience perception verbs and mental verbs. We found the same overall trends for this subset as for the full sample containing all perception verbs: a linear regression model showed no interaction between subject group (child vs. parent) and verb type (experience perception vs. mental) for overall verb production ($\beta = 0.019$, $SE = 0.013$, $t = 1.51$, $p > 0.05$), and a multinomial logistic regression showed that the estimated effect of age for experience perception verbs ($\beta = 0.11$) compared to mental verbs ($\beta = 0.74$) was similar to the effect of age for all perception verbs compared to mental verbs.

[17]Verb type was included as a fixed, rather than random, effect in our models as we are not attempting to generalize beyond the specific verbs or verb classes examined here (see Clark, 1973).

0.21, $p < .05$). Children's non-adult-like production of embedded complements with perception and mental verbs suggests that their use of verbs and frames does not simply duplicate relative input frequencies from their parents.

In terms of developmental change in the use of perception and mental verbs with their frames, we proposed that if perception verbs serve as model for mental verbs during acquisition, then children should produce embedded clauses with perception verbs earlier or more often than with mental verbs. Our analysis did not find evidence to support this prediction. Even at age two, the proportion of mental verbs produced in embedded frames (21%) was higher than the proportion of perception verbs produced in embedded frames (2%). By age four, children were using mental verbs with embedded frames more than with non-embedded frames (59% vs. 41%, respectively). In fact, although the difference before age three is quite small, the number of children's uses of mental verbs in embedded frames – not just the proportion – was actually higher than the number of uses of perception verbs in embedded frames across all ages (Table 6), despite the fact that children were producing more perception verbs than mental verbs overall.

We found effects of both age and verb type for children's use of non-embedded vs. embedded frames with perception and mental verbs between 2 and 5 years of age. Children's production of embedded frames did increase significantly over time for both verb types ($\beta = 1.16$, $SE = 0.08$, $p < .05$; Figure 3a), fitting with existing evidence of children's growing use of complementation after age two (Bloom et al., 1989; Brown, 1973). However, children were significantly more likely to use embedded frames with mental verbs than with perception verbs ($\beta = 2.51$, $SE = 0.60$, $p < .05$). While the increase in embedded frames with age appeared greater for mental verbs than for perception verbs (Figure 4), the interaction between age and verb type was not reliable ($\beta = -0.07$, $SE = 0.15$, $p > .05$), suggesting that the gap between use of embedded frames for mental vs. perception verbs was relatively consistent over time.

Parents, like their children, were significantly more likely to use embedded frames with mental verbs than with perception verbs ($\beta = 2.13$, $SE = 0.30$, $p < .05$; Figure 3b). Parents' use of embedded frames also increased with child age ($\beta = 0.19$, $SE = 0.05$, $p < .05$); there was no interaction between child age and verb type in parents' production of embedded frames ($\beta = 0.02$, $SE = 0.09$, $p < .05$; Figure 4).

One might wonder whether the collective trends amongst children could be attributed to just a few children who use embedded frames very frequently or show large differences in their use of embedded complements with perception vs. mental verbs, or if such production patterns are exhibited by multiple children individually. We found that the overall pattern of using embedded frames more with mental than perception verbs was also true for individual children in our sample. Twelve of the 17 children used embedded frames more with mental verbs than with perception verbs overall; a sign test showed that this was significant ($S(14) = 2$, $p = .01$). Only one child (Richard, age 2;9) produced no embedded frames with either verb. There was some variation in children's production of embedded frames with perception and mental verbs at the youngest ages: only four of the six children between ages 2;0–2;5 and three of the six children between ages 2;6–2;11 produced the target verbs in

Table 6. Number of uses (raw count) and percentage of experience perception verbs and mental verbs used with embedded frames by age in children's speech.

	Uses (%) with Embedded Frames	
Age	Perception Verbs	Mental Verbs
2;0–2;5	7 (2%)	10 (21%)
2;6–2;11	1 (0.2%)	9 (8%)
3;0–3;5	25 (6%)	92 (31%)
3;6–3;11	36 (10%)	181 (39%)
4;0–4;5	55 (10%)	286 (59%)
4;6–4;11	57 (15%)	265 (53%)

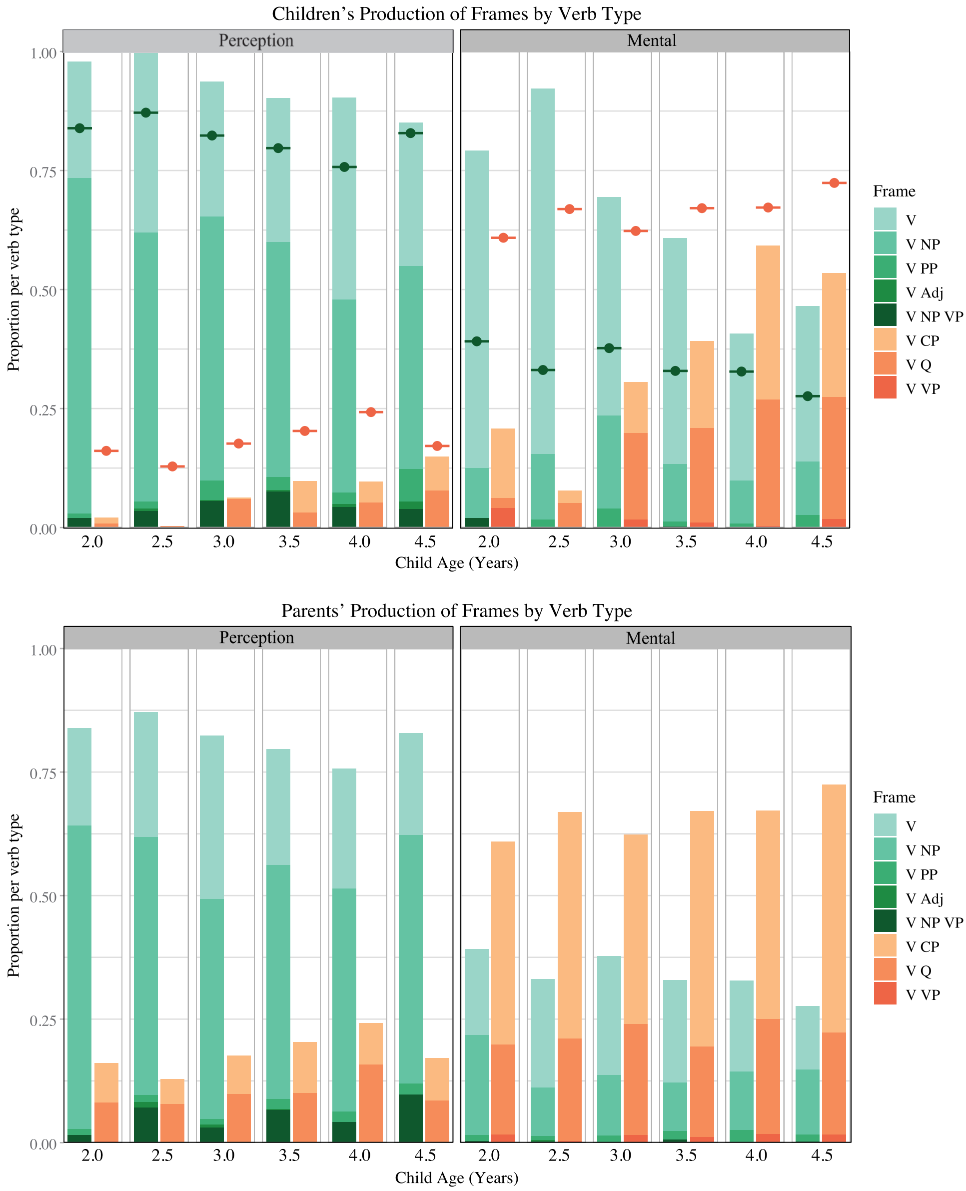

Figure 3. (a) The proportion of perception verbs (left) and mental verbs (right) produced in different syntactic frames by age in children's speech. Non-embedded frames are shown in shades of green, and embedded frames in shades of orange. Points indicate parents' total proportion of non-embedded (green) and embedded (orange) frames, showing that children used more non-embedded frames and fewer embedded frames than parents did. (b) The proportion of perception verbs (left) and mental verbs (right) produced in different syntactic frames in parents' speech by child age.

embedded frames. However, 100% of the children age 3;0 and older in our sample produced embedded frames with one or both verb types (Table 7).

Our analysis of children's production of perception and mental verbs shows that between the ages of two and five, children consistently use embedded frames with mental verbs more than with perception verbs. Given that perception verbs are not used as regularly with embedded frames as mental verbs, it seems unlikely that they would be a model for mental verbs in this way, and that mental verbs are more likely to be a model for perception verbs instead.

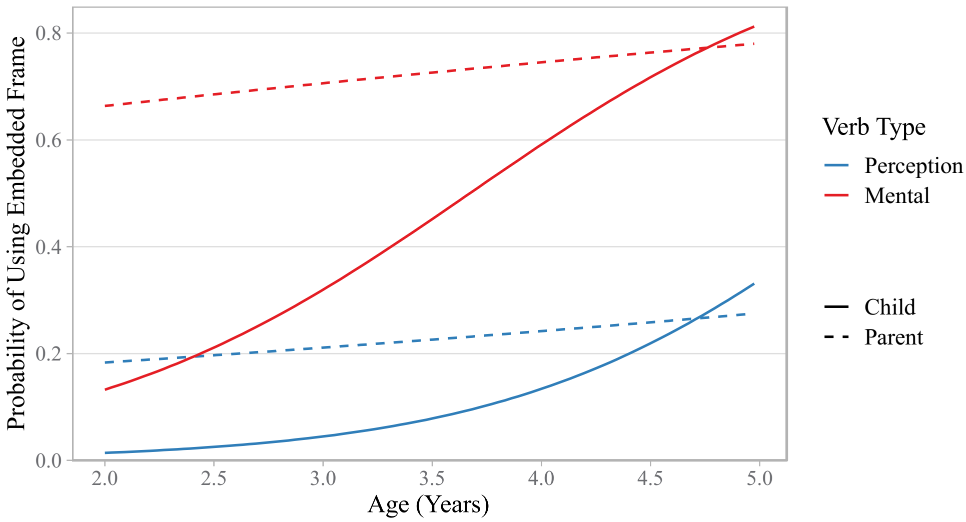

Figure 4. The probability of using embedded frames with perception vs. mental verbs over child age for children and parents.

Table 7. Number of uses (raw count) of experience perception verbs and mental verbs used with embedded frames per child by age. A + in the rightmost column indicates when this number was greater for mental verbs than perception verbs.

			Embedded Frame Uses		
Age Range	Child (Sessions)	Corpus	Perception	Mental	
2;0–2;5	Adam (6)	Brown	0	0	
	Eve (7)	Brown	4	6	+
	Sarah (12)	Brown	0	0	
	Patricia (2)	Gleason	0	2	+
	Victor (2)	Gleason	1	1	
	William (3)	Gleason	2	1	
2;6–2;11	Adam (13)	Brown	0	5	+
	Sarah (24)	Brown	0	0	
	Charlie (1)	Gleason	0	2	+
	Laurel (1)	Gleason	1	2	+
	Patricia (1)	Gleason	0	0	
	Richard (2)	Gleason	0	0	
3;0–3;5	Adam (13)	Brown	11	49	+
	Sarah (24)	Brown	2	27	+
	Charlie (2)	Gleason	0	4	+
	Guy (3)	Gleason	10	6	
	Laurel (2)	Gleason	0	3	+
	Olivia (3)	Gleason	2	3	+
3;6–3;11	Adam (9)	Brown	14	105	+
	Sarah (23)	Brown	4	31	+
	Isadora (3)	Gleason	2	12	+
	Ursula (2)	Gleason	16	30	+
	Wanda (1)	Gleason	0	3	+
4;0–4;5	Adam (7)	Brown	33	158	+
	Sarah (25)	Brown	15	100	+
	Andy (3)	Gleason	2	10	+
	Eddie (3)	Gleason	3	14	+
	Helen (1)	Gleason	1	0	
	Wanda (1)	Gleason	1	4	+
4;6–4;11	Adam (6)	Brown	35	141	+
	Sarah (22)	Brown	20	121	+
	Helen (2)	Gleason	2	3	+

Discussion

The aim of the present study was to investigate two competing hypotheses about the relationship between perception and mental verbs in development, in particular how children learn that both types of verbs refer to mental representations. These hypotheses focus on the idea that one verb class could serve as a semantic model for the other via shared syntax – specifically, embedded complements that convey the propositional content of perceptual and mental states. One hypothesis is that perception verbs are a model for mental verbs, and so children should produce embedded frames with perception verbs earlier or more frequently. A second hypothesis is that mental verbs are a model for perception verbs, and therefore embedded frames should be produced with mental verbs earlier or more frequently.

We analyzed child and parent production of perception and mental verbs in the Brown and Gleason corpora and found that children did not produce perception verbs in embedded frames earlier or more frequently than they produced mental verbs in these frames, despite greater production of perception verbs overall in early childhood. In fact, once embedded frames began to occur in children's speech more regularly around age three, children used them with mental verbs far more often than with perception verbs, and the frequency with which embedded frames were used with perception verbs remained low over time. Although we cannot identify the reason for this difference through production data alone, our results argue against the hypothesis that perception verbs might serve as a semantic model for mental verbs via shared syntax.

Our finding that mental verbs were used with embedded complements with greater frequency than perception verbs before the age of five provides some tentative support for the hypothesis that mental verbs might serve as a model for the mental state component of perception verbs' meaning. Additionally, our finding that the use of embedded frames appears around the same time for both perception and mental verbs – albeit skewing (frequency-wise) toward mental verbs – suggests that the acquisition of complex propositional syntax, and the understanding that such syntax can reference mental contents, may emerge at the same time for the two verb types (and presumably others as well). However, if acquiring propositional syntax is a single developmental achievement, then it appears to happen after perception verbs are already well established in children's production, since young children use perception verbs (but not mental verbs) quite frequently prior to their consistent use of clausal complements.

Overall, the asymmetry found in the production of embedded complements with perception vs. mental verbs suggests a developmental story for how mentalistic semantics for perception verbs emerges over time. The core idea is that children may have to master mental verbs with embedded frames before they can transfer knowledge about the syntax and semantics of mental representation to the domain of perception verbs. If so, then this could explain why perception verbs without embedded complement structures occur earlier and more often in children's production than mental verbs. It is because – as other research suggests – perception verbs are initially acquired with simpler semantic representations that are primarily epistemically neutral and do not obligatorily encode reference to mental states. Instead, children's early meanings for verbs like *see* and *hear* may be focused more on the participants and physical acts in perceptual events, and less on the perceiver's resulting representation of the world. By contrast, children may find mental verbs to be a clearer example of reference to mental states than perception verbs, since all uses of mental verbs are epistemically non-neutral, unlike perception verbs, which can be epistemically ambiguous with non-embedded complements. On this account, once children have acquired both mental verbs and propositional syntax, the embedded frames shared by both verb types open the door to learning that perception verbs are like mental verbs and can also express propositional content. This new development would invite children to revise or update their semantic representation for perception verbs to include encoding mental representations. The fact that, until at least age five, children produce perception verbs with embedded frames much less frequently relative to mental verbs and compared to adults could be an indication that this revision of perception verbs' semantics is a relatively protracted process.

Our proposal that perception verbs undergo semantic updating is consistent with past work on children's trajectory for learning the meanings of mental verbs. As discussed earlier, this research has shown that children do not appear to have the same fine-grained semantic representations of mental verbs as adults when they begin to produce these verbs, and have difficulty with semantic features like factivity (Dudley et al., 2015) and prior knowledge (Lyon & Flavell, 1994; Moore et al., 1989). Four- to six-year-old children also appear to interpret perception verbs much more narrowly than adults do, tending to interpret a verb like *see* as only being about perceiving something directly with one's eyes (Elli et al., 2020; Landau & Gleitman, 1985). Both of these lines of research support the idea that children may first acquire perception verbs with a stricter, direct perception-focused meaning, and then later expand this to include reference to perceptually based mental states. That syntax could be responsible for this shift is bolstered by other work on children's word learning that has shown that syntactic information allows children to overcome conceptual biases in assigning meanings to novel words; for example, it has been found that syntax corresponding to count or mass nouns modulates children's shape/object bias for nouns (Subrahmanyam & Landau, 1995), and that the order of arguments used with transitive verbs can override an agency bias for verbs (Fisher et al., 1994).

The semantic updating account also makes sense if one considers the role of (un)observability in the acquisition of perception and mental verbs. It has been postulated that one reason mental verbs are particularly hard for children to learn is that they are used to talk about internal states – thoughts, beliefs, etc. – that are invisible to others, and so these verbs do not easily afford learning via "word-to-world" pairings (Gleitman, 1990; Papafragou et al., 2007). As a result, children are much more reliant on syntactic structural information to infer the meanings of mental verbs. In this respect, perception verbs should be easier to learn, as perceptual events are somewhat more observable than mental ones – for example, it is possible to observe another's gaze and the object or event toward which that gaze is oriented. However, this would likely only support children's ability to learn perception verbs with non-embedded complements describing objects and events, which report relatively simpler, more observable relations between a perceiver and a perceptual stimulus, rather than perception verbs with embedded complements describing propositions, which report more complex, unobservable relations between an individual and their mental representations (see Gillette et al. (1999) for further discussion of observability/imageability and word learning). These facts would predict the exact pattern that appears to emerge from our data: that children acquire perception verbs with non-embedded complements more easily, and thus use them in these frames more frequently at an early point in development, and only later come to learn the uses of perception verbs that refer to mental representations and that take unobservable entities – propositions – as their complements.

We have suggested that the acquisition of complementation may trigger children's understanding that perception verbs can explicitly refer to the propositional content of mental states. We view complementation as key for several reasons. First, it is only when perception verbs take embedded complements that they *must* make reference to the perceiver's mental representations (at least in the mature interpretation of these constructions). Second, embedded complements are the frames used most frequently with verbs referring to mental representations, namely mental verbs, and so should be the most likely to elicit structural and semantic comparisons, in line with the framework of syntactic bootstrapping (Gleitman, 1990; Landau & Gleitman, 1985). Third, complementation is the linguistic encoding of the relation between an individual and their mental world – their beliefs, knowledge, thoughts, etc. Complementation, therefore, serves as an essential tool for representing and describing this relation and the contents of these mental states. The crucial role of complementation has been suggested before: de Villiers and colleagues have argued that the ability to wield this syntactic tool – specifically to linguistically represent false propositions – is a necessary prerequisite for succeeding on (traditional) false-belief tasks (de Villiers, 2007; de Villiers & Pyers, 2002; Schick et al., 2007). Although the demonstration of false-belief understanding in infants and pre-school children (Baillargeon et al., 2010; He et al., 2012; Onishi & Baillargeon, 2005; Rubio-Fernández & Geurts, 2013; Scott & Baillargeon, 2009; Setoh et al., 2016; Song & Baillargeon, 2008) raises questions about the necessity of linguistic complementation for solving more traditional false-belief tasks, complementation is an important means for children to talk about mental states and to understand conversations about the same. What we attempt to shed light on here is how children map their existing conceptual knowledge about perception and mental states – which increasingly appears to be fairly sophisticated even in infants – to the particular lexical items and syntactic structures that are used to express them, and why there might be gaps between what children know and what children say or comprehend.

Our study cannot offer definitive evidence to support the idea that acquiring complementation leads to a revision of perception verb semantics toward the expression of perception as a mental state. There are limitations to using production data for assessing children's linguistic knowledge. First, corpus samples may not be fully representative of children's language use (Ambridge & Rowland, 2013). Second, relying solely on production data could mask production-comprehension asymmetries in either direction: children may comprehend certain structures or lexical items well before they produce them (Goldin-Meadow et al., 1976), with production serving as a marker of the endpoint of acquisition; alternatively, children may demonstrate seemingly adult-like production well before adult-like comprehension (as in the case, for example, of evidential morphology; Ünal & Papafragou, 2018). However, longitudinal production data, like that in the Brown and Gleason corpora, may provide a more detailed picture of a child's developing linguistic competence than structured interaction in a single laboratory visit. Analysis of production data should serve as a complement to other approaches. Ongoing work in our lab is examining children's interpretations of perception verbs when a mental state reading is possible – for example, the extent to which children will accept using a verb like *see* to report a mental representation (inference) of an event based on visual evidence vs. to report direct visual perception of that event. The goal is to determine when young children have gained an adult-like understanding that perception verbs encode mental representations, especially when used with sentential complements.

Our study has moved beyond previous studies, which have simply examined *when* children produced perception verbs; instead, we investigated *how* children use perception verbs by looking at the syntactic frames in which the verbs occurred. We compared the use of perception verbs to mental verbs, which share syntax and semantics, with the idea that the developmental trajectory of verb and frame production for these two verb classes could shed light on how these two domains interact in acquisition. While our study suggests that perception verbs are unlikely to function as a model for mental verbs, there is still reason to believe that syntactic and semantic connections to mental verbs may contribute to how children develop a mature understanding of perception verbs. We have proposed that children may initially acquire perception verbs without a full understanding of how they can refer to mental representations resulting from perceptual experiences, and that later, complementation structures used with mental verbs could support the development of adult-like semantics for perception verbs. We suggest that this hypothesis can provide the theoretical grounding for future studies of the relationship between perception verbs, mental verbs, and sentential complements, using both further corpus analyses and experimental probes.

Disclosure statement

No potential conflict of interest was reported by the authors.

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