Children's developing conversational and reading inference skills: a call for a collaborative approach

Elspeth Wilson
University of Cambridge, UK

Kate Cain
Lancaster University, UK

Catherine Davies
University of Leeds, UK

Jenny Gibson
University of Cambridge, UK

Holly Joseph
University of Reading, UK

Ludovica Serratrice
University of Reading, UK
UiT The Arctic University of Norway, Norway

Margreet Vogelzang
University of Cambridge, UK

Abstract: In this perspectives article, we call for a collaborative approach to research on children's development of conversational inferences and of reading inferences. Despite the clear commonalities in their focus, the two rich research traditions have remained almost entirely separate, primarily within the fields of Developmental Psychology and Experimental Pragmatics, on the one hand, and Cognitive, Developmental and Educational Psychology on the other. We briefly survey research on conversational and reading inferences, and show how both similarities and differences in theoretical approach, methodologies and findings raise significant questions, including: What effect does both context (conversation or reading) and modality (oral, visual, written) have on the need for children to make inferences, and for the opportunities for them to learn to do so? And how do linguistic and background knowledge, socio-cognitive and environmental factors support different inferences across contexts and modalities? We propose that a collaborative agenda is timely and crucial for interdisciplinary work. Researchers need to develop theoretical models of how different types of inference cluster together and are supported or affected by the context, modality, and other linguistic, socio-cognitive and environmental factors. They must also develop methodologies which enable reliable and valid measures of inferencing ability that can capture quantitative and qualitative changes across development. Ultimately this will contribute to better understanding children's pragmatic development, as well as teaching and intervention practices in communication and reading comprehension.

Keywords: pragmatic development; pragmatic inference; reading comprehension; reading inference.

Corresponding author(s): Elspeth Wilson, Faculty of Education, University of Cambridge, CB2 8PQ, UK. Email: elspeth@elspethwilson.uk.

ORCID IDs:
Elspeth Wilson: 0000-0001-6114-1294
Kate Cain: 0000-0003-2780-188X
Catherine Davies: 0000-0001-9347-7905
Jenny Gibson: 0000-0002-6172-6265
Holly Joseph: 0000-0003-4325-4628
Ludovica Serratrice: 0000-0001-5141-6186
Margreet Vogelzang: 0000-0003-2811-5419

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Introduction

Accumulating evidence highlights the importance of pragmatic inferences for conversation and reading comprehension skills (Bohn & Frank, 2019; Matthews, 2014; Oakhill, 2020; O'Brien et al., 2015). For instance, children have to learn what a speaker means when they say, 'My sister's a hedgehog', or how two sentences relate in a text such as: 'There was a loud crash in the kitchen; "Where is the dustpan and brush?", asked Ben'. Pragmatic language skills, broadly defined, are crucial not only for successful communication and comprehension (Cain & Oakhill, 1999; Nation, 2005; Norbury & Bishop, 2002), but also for building peer relationships and socio-emotional and behavioural development across childhood and adolescence (Conti-Ramsden et al., 2019; Coplan & Weeks, 2009; Helland et al., 2014; Mok et al., 2014; St Clair et al., 2011). In addition, reading comprehension in particular enables access to learning materials and contributes to educational and employment outcomes (OECD, 2019; World Literacy Foundation, 2018).

Developmental research on conversational inferences and reading inferences has remained almost entirely separate, despite their common focus. Pragmatic inferences in conversation have largely been studied within the fields of Developmental Psychology and Experimental Pragmatics (a branch of Linguistics), while reading inferences have primarily been investigated within the domains of Educational, Developmental and Cognitive Psychology. Our working assumption, though, is that just as a child might encounter a new word in conversation, and then extend their understanding from a book, or vice versa, so too when they learn to understand ironic utterances, resolve anaphoric reference or derive any kind of inference in one context (conversing or reading), they will likely be able to call on and develop these skills in the other context, notwithstanding some interesting differences which we will discuss. Modality – whether the language is oral (or visual in the case of sign languages) or written – is a dimension that actually cuts across these contexts: while conversational inferences broadly align with oral language, and reading inferences with written language, there is no neat mapping, in research programmes or in the real-world. For instance, studies on reading inferences might involve *listening* to texts, just as children listen to books in the context of shared book reading; studies on conversational inferences may present short utterances without discourse context, possibly in written modality.

In this perspectives article, we therefore aim to highlight commonalities and differences in research findings about children's development of inference skills across contexts in conversation and reading; to show how these commonalities and differences raise some fundamental questions about the development of inferencing; and to set out a collaborative agenda for future research. As authors we have taken the first step in this collaboration, combining our expertise as theoretical and experimental linguists, developmental and cognitive psychologists, speech and language therapists and educators, who have researched either conversational or reading

inferences, or both. We intentionally take a broad view in our survey of the state of the art, bringing in research on a range of inferences across a range of ages, based on a range of theoretical frameworks. And we intentionally raise more questions than answers – to show how integrating current research on inferencing reveals directions to address outstanding issues in future research.

Deepening our empirical understanding and honing our theoretical models of inferencing development will ultimately contribute to more effective teaching and intervention practices. In England, "making inferences on the basis of what is being said and done" is set out in the National Curriculum as a requirement for teaching reading comprehension from age 5 (Key Stage 1), as is, more generally, "listen[ing] and respond[ing] appropriately to adults and their peers" (Department for Education, 2013). Similarly, for instance, making inferences from texts is also part of the US Common Core, while formulating ideas about the author's intention is an aim for readers in primary school in Saxony, Germany (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010; Staatsministerium für Kultus Freistaat Sachsen, 2019). Collaboration and alignment between academic researchers in the fields mentioned above, and crucially, with educational and clinical practitioners, is essential for optimal support of children's language and literacy development (Davies et al., 2022, 2023). In addition, inferencing may be the target of intervention with particular clinical populations, such as children with Developmental Language Disorder or autistic children (Adams et al., 2009; Bishop et al., 2016; Dawes et al., 2019; Matthews et al., 2018).

First, we summarise the state of the art in the study of conversational and reading inferences and their development. Then, we reflect on the similarities and differences between findings on inference development across research traditions – similarities in some conceptions of pragmatic inference and an increased focus on factors associated with developing inference ability, and differences in motivations for research, inference types, methods, and theory. This review highlights some fundamental questions which still need to be addressed to develop both theory and practice: how modality affects the learning of inferences; which inferences children learn over development; and how cognitive, psychological and environmental factors influence their development. Finally, we identify some promising ways forward by laying out a collaborative research agenda.

Conversational inferences

Research on children's development of pragmatic inferences has investigated a range of inference types, including quantity implicatures (for reviews see Papafragou & Skordos, 2016; E. Wilson & Katsos, 2020), relevance implicatures (E. Wilson & Katsos, 2022), metaphor (Pouscoulous & Tomasello, 2020), metonymy (Köder & Falkum, 2020), irony (Filippova, 2014; Köder & Falkum, 2021; Zajączkowska et al., 2020),

genericity (Lazaridou-Chatzigoga et al., 2019), reference and anaphora resolution (Davies & Kreysa, 2018; Rabagliati & Robertson, 2017; Serratrice & Allen, 2015), and indirect speech acts (Schulze et al., 2013) – see Table 1 for examples of these kinds of inference. As well as receiving attention within Developmental Psychology, much of this research has been situated within the field of Experimental Pragmatics, which aims to test and develop pragmatic theory. It is particularly inspired by the work of Grice (1975), but also neo-Gricean and post-Gricean approaches, including Relevance Theory (Sperber & D. Wilson, 1995; D. Wilson & Sperber, 2012) and, more recently, probabilistic pragmatic approaches (e.g. Goodman & Frank, 2016). Grice's key insight was that conversation is a co-operative act, with speakers and listeners sharing expectations that a speaker will be informative, relevant and true, and will observe conventions of language use; this enables listeners to infer speakers' *intended* meaning in a particular context. Take an example of a simple quantity implicature: 'What did you pack in your bag?' 'I packed a book'. Here, the questioner can reason that the addressee means a book *and nothing else*, assuming that the addressee is being informative (giving the most possible information that is relevant) and is knowledgeable about the situation. Then imagine, instead, the following scenario: 'Anyone who packed a book can take a bookmark' 'I packed a book'. In this case, the inference that the speaker packed a book and nothing else is unlikely to be derived, as that is no longer relevant to the discourse. Again, if the speaker instead says, 'I'm not sure, but I think he packed a book', then an exhaustive inference, a book and nothing else, is less likely to be made. These examples show that, crucially, the inferential process is dependent on the context – including the discourse context – and the listener's knowledge of the speaker – including the speaker's knowledge or certainty about the situation being described.

Developmental research has investigated when and how children become able to derive a range of different inferences; a complementary line of research has examined children's production of implicated meaning, either in naturalistic contexts, such as corpus data, or in experimental ones (e.g. Davies & Katsos, 2010; Eiteljoerge et al., 2018; Serratrice & Allen, 2015). Thanks to increasingly child-appropriate methodologies (Veenstra & Katsos, 2018), one consistent finding has been that, for most inference types, children actually begin to be able to derive the speaker's intended meaning at a much younger age than initially thought: at 3 or 4 years, for example, for some quantity or relevance implicatures (Horowitz et al., 2018; Stiller et al., 2015; E. Wilson & Katsos, 2022) and simple perceptual metaphors (Pouscoulous & Tomasello, 2020). Irony, however, is consistently later in developing, from 6 years and throughout childhood (Filippova, 2014; Köder & Falkum, 2021; Zajączkowska et al., 2020), which could be due to the way irony inferences draw on more complex social-cognitive skills (Mazzarella & Pouscoulous, 2021). The aim of this line of research is to understand children's communication in conversation, and so the measures which are used predominantly present stimuli in an oral modality (while written is frequently used with adults). However, the experimental context is often far from a naturalistic

conversation, which has important consequences for the interpretation of data and our understanding of the development of inferencing – we return to this important point below. There is also an extensive and valuable literature on pragmatic development in clinical contexts, such as children with Developmental Language Disorder or autistic children. Such studies may use bespoke experimental measures or a variety of standardised global measures of pragmatic ability, such as the Test of Pragmatic Language (Phelps-Terasaki & Phelps-Gunn, 1992), the relevant Comprehensive Assessment of Spoken Language subscales (Carrow-Woolfolk, 1999), the Language Use Inventory (O'Neill, 1996) and the Children's Communicative Checklist (Bishop, 2003). However, these typically include a battery with a broad range of different inferences, as well as skills which are considered pragmatic only in a very broad sense, such as turn-taking (for a review see Matthews et al., 2018). Understanding pragmatic development in a variety of languages and learning experiences is highly important, although in this article we focus predominantly, for the sake of space, on research with typically developing children. Likewise, for brevity, and because this is where the bulk of current research lies, we focus on inference comprehension, but a similar contribution on the production of inferences in conversation and in writing would be welcome.

Recent studies have also begun to investigate factors which support inference development: that is, the skills and knowledge children need to make an inference. This includes structural language (lexical and syntactic knowledge and processing), sociocognitive skills (such as mentalising or Theory of Mind), and Executive Function (EF), including inhibition and working memory. These skills may themselves have complex direct and mediating associations. For instance, children only begin to reliably derive scalar quantity implicatures with 'some' around the age of 5 (see Table 1 for an example), though there is cross-linguistic variability (Katsos et al., 2016). Studies can then examine whether this is because younger children lack the necessary semantic knowledge (Horowitz et al., 2018), have not yet formed a lexical scale such as <some, all> (Barner et al., 2011), or have difficulty tracking what the relevant alternatives are in the discourse context (Skordos & Papafragou, 2016). More generally, developing implicature inferencing is associated with vocabulary and grammatical knowledge, and it could be that better vocabulary aids inferencing, that inferencing skills aid vocabulary acquisition, or, most likely, both (Foppolo et al., 2020; E. Wilson & Katsos, 2022).

To take another example, Gricean theory is often taken to imply a key role for Theory of Mind in pragmatic inferences, as the listener has to reason about the speaker's mental states in assuming that the speaker is knowledgeable and truthful. Studies have examined whether Theory of Mind correlates with children's pragmatic abilities, such as irony (Zajączkowska et al., 2020) and pronoun resolution (Kuijper et al., 2021), and whether children are able to take into account another's perspective, which may be different from their own, in implicature derivation (Kampa & Papafragou,

2020; E. Wilson et al., 2022). So far the evidence is mixed – findings both support and do not support the role of mentalising in quantity implicatures, depending, for instance, on the precise inference required and the measure used (Barner et al., 2018; Hochstein et al., 2016; Kampa & Papafragou, 2020; E. Wilson et al., 2022). More generally in Experimental Pragmatics, the evidence on children's development is also scattered, with research having focused on some inference types, and having used some methodological paradigms more than others, providing a fragmented and incomplete picture of competence in conversational inference to date. Critical calls have challenged the field to expand the phenomena studied and consider more carefully the effects of context on pragmatic strategies and children's inferencing abilities (Andrés-Roqueta & Katsos, 2017; Falkum, 2022). Likewise, there is an increasing awareness of the need to include a diversity of languages and learning experiences in this research, including bi-multilingual children, as linguistic experience could be an important factor itself in pragmatic development (Antoniou et al., 2020; Antoniou & Katsos, 2017; Fortier et al., under review; Katsos et al., 2016; Zhao et al., 2021).

Table 1. ***Examples of inferences typically studied as conversational inferences***

Inference	Example
Implicature (ad hoc quantity)	'Did you meet his parents?' 'I met his mum.' +> not his dad.
Implicature (scalar quantity)	I packed some of the books. +> I pack some but not all of the books.
Implicature (relevance)	'How was the theatre trip?' 'There was a train strike.' +> I couldn't go.
Irony	'I am sorry to announce that the 09:10 train to Cambridge has been cancelled.' 'Superb!' +> Disastrous!
Metaphor	The tree was wearing a white hat. +> The tree was covered in snow.
Metonymy	The nursery emailed some information. +> A member of staff at the nursery emailed some information.
Presupposition	I went to Paris again. +> I'd been to Paris before.
Indirect speech act	Can you give me your shoes? +> Give me your shoes.

Reading inferences

Making inferences is acknowledged as a crucial part of learning to read, both in research (Castles et al., 2018; Kendeou et al., 2016) and in teaching practice (e.g. Such, 2021). Indeed, inferencing ability is found to be a key predictor of reading comprehension (Bowyer-Crane & Snowling, 2005; Oakhill & Cain, 2012). For example, take the text: 'Finally the family arrived. They flung open the car doors, heard the gulls, and felt the salt spray on their faces'. To explain where the action took place, a good comprehender might make the global coherence inference that the family had arrived at the seaside, although that is not explicitly stated in the text. In contrast, a poor comprehender might struggle to draw on information across the text and fill in information from background knowledge to make this inference. To take another example, reading 'Jake gave the book to Tom. He thought he'd like it', the reader can infer that the two instances of the pronoun 'he' refer to Jake and Tom respectively, and that the two sentences are related *causally* (*because* Jake thought Tom would like the book) – examples of local cohesion inferences. Again, a poor comprehender could struggle to make these inferences and therefore to access the full meaning of the text.

Table 2. ***Examples of inferences typically studied as reading inferences***

Inference	Example
Global coherence	The delicate glass vase fell to the floor. Sue went to fetch a brush. +> The vase broke and Sue intended to clear up the mess.
Local cohesion – anaphor resolution	Jake gave the book to Tom because he thought he'd like it. +> Jake gave the book to Tom because he (Jake) thought he (Tom) would like it.
Local cohesion – causative	Jake gave the book to Tom. He thought he'd like it. +> Jake gave the book to Tom *because* he (Jake) thought he (Tom) would like it.

Research on reading inferences shares with research on conversational inferences some of its origins in early psycholinguistics (Graesser et al., 1994). The motivation is to understand how children comprehend *texts,* and as such it is concerned not just with children's reading but also *listening* to texts, which is particularly important for younger children who are still learning to decode (Language and Reading Research Consortium & Muijselaar, 2018). Methodologically, this means texts may be presented within studies in written or oral modality, testing reading or listening comprehension – again, a point we return to below. One important driver in this line of research is the need to identify components of reading comprehension which, separately or

together, may present challenges to children, resulting in poor comprehension (Oakhill, 2020), and this ultimately contributes to the development of interventions to boost reading skills (Elbro & Buch-Iversen, 2013; Elleman, 2017; Kispal, 2008; Whatmuff, n.d.).

A widely-adopted theoretical framework for reading comprehension is The Simple View of Reading (Hoover & Gough, 1990), which defines reading comprehension as the product of decoding (reading individual words) and listening comprehension (for reviews of other frameworks, see Cain & Barnes, 2017; McNamara & Magliano, 2009). That is not to say that reading comprehension is simple; rather, the framework simply encapsulates its two main components, with listening comprehension being the result of complex linguistic and cognitive processes that contribute to building a mental model of a text. The complementary Rope Model (Scarborough, 2009) breaks down listening comprehension into multiple strands: knowledge of and access to vocabulary, background knowledge, understanding of sentence structure, inferencing, and knowledge of texts and their structures; to this have been added other factors like comprehension monitoring (Oakhill et al., 2015). The outcome of successful reading (and listening) comprehension is a situation model: a mental representation of the state of affairs described by a text, which goes beyond the literal meaning, and includes meanings integrated across sentences and inferences constructed from the text and background knowledge (Kintsch, 1998).

Inferences for text comprehension are classified or modelled in a variety of ways. First, a distinction is sometimes made between necessary and elaborative inferences. Necessary inferences, as in the examples above, are required to build a coherent mental model, whereas elaborative inferences enrich the mental model but are usually not regarded as essential for comprehension (Barnes et al., 1996; Cain et al., 2001). For example, a reader might infer that the family in the example above had arrived at a sandy beach with blue sea, or were happy to be there after a long journey – but these inferences are not necessary for a coherent mental model. Concentrating on necessary inference, we have already illustrated the distinction between global coherence and local cohesion – see Table 2 for examples of these types of inference. Studies on the development of reading inferences may use just one type of inference, local or global (Oakhill, 1982; Oakhill & Yuill, 1986; Yuill et al., 1989), or both (e.g. Barnes et al., 1996; Cain, Oakhill, & Bryant, 2004; Cain & Oakhill, 1999; Davies et al., 2019; Joseph et al., 2021), but they typically use a range of inferences for each type (e.g., anaphor resolution and causal relations for local cohesion). In addition, they may present texts aurally (listening comprehension (Currie & Cain, 2015)) or visually (reading comprehension (Barnes et al., 1996)). Alternative taxonomies focus on different functional distinctions of inferences as well as their sources of information, such as connecting inferences or backward elaborations (van den Broek et al., 1993). According to still other approaches, categorising different inference types is less important than characterising a general inference skill, which "depends on the core, fundamental

processes of activation and integration of information and generalises across contexts" (Kendeou, 2015, p. 160).

One key finding from large-scale, longitudinal studies is that inferencing skills in reading (or listening to texts) improve across childhood, from 4 to 15 years (e.g. Barnes et al., 1996; Language and Reading Research Consortium & Muijselaar, 2018). In general, very young children can make inferences about causal, spatial and temporal relations, in real-world situations and then in linguistic communication. However, in linguistic communication and especially reading, there are a number of complex interacting factors which constrain the number and the type of inferences a child can actually make during comprehension (Cain & Barnes, 2017; Kendeou, 2015). Availability and accessibility of background knowledge, working memory, inhibition and cognitive load (e.g. from conflicting sequencing of information or from decoding) all change over development, meaning that on the whole children make more inferences with age (Barnes et al., 1996; Currie & Cain, 2015). Further, there is a clear relationship between inferencing and vocabulary within age groups, and a reciprocal relationship over development. This is particularly the case for vocabulary depth – how much a reader knows about words – rather than just vocabulary breadth – how many words they know. Vocabulary depth predicts later inferencing, and inferencing predicts later vocabulary depth (Cain & Oakhill, 2014; Language and Reading Research Consortium et al., 2019). These studies often require participants to answer comprehension questions about the text, to assess which inferences children have made, i.e. their explicit knowledge of inferred meaning is assessed. In older children, online eye-tracking while reading can be used to address questions about the time course of inferencing. For instance, 8- to 13-year-olds prioritise efficiency when reading: they initially only make the most necessary inferences, and then go back if they meet inconsistent information and need to revise their interpretation (Joseph et al., 2021).

A significant body of work has examined factors associated with reading comprehension in general (which typically includes inferencing). One focus has been on EF, and especially working memory, based on the assumption that this is required for keeping information in mind and integrating it across sentences to contribute to a mental model of the text (Follmer, 2018; Language and Reading Research Consortium et al., 2019; Nouwens et al., 2021). Theory of Mind, although given less attention so far in reading studies, has also been argued to be important (Dore et al., 2018). It has been found to be related to listening comprehension more generally (Kim, 2020; Kim & Phillips, 2014), and to predict reading comprehension longitudinally (Atkinson et al., 2017). Finally background or world knowledge is crucial for inferencing, as particular coherence inferences result from integrating information provided explicitly by the text with background knowledge (Smith et al., 2021).

Taking stock: similarities and differences between conversational and reading inferences

Our review highlights striking similarities in the findings to date across research on children's conversational and reading inferences. However, there are also differences in approach, methods, and findings which lead us to some fundamental questions about children's development of inferences – and which invite a collaborative research agenda to address them.

In both conversation and reading, learning to make inferences is crucial for understanding meaning, as well as for learning about language and about the world (Bohn et al., 2021; Horowitz & Frank, 2016). In both contexts, arguably, inferences are made for coherence and relevance, either to arrive at the intended meaning of the speaker or the writer. Further, a variety of factors have been identified which are at the very least correlated with inferencing skills, and which may well be contributors to their development. For both conversational and reading inferences, studies have shown associations with vocabulary; background or world knowledge; Theory of Mind; and EF, including working memory and inhibition. We take up this point of convergence below, but also note that the availability and strength of evidence varies across contexts, inference types and age groups, and so there are still gaps in our empirical understanding and theoretical models of the development of inferencing.

There are also differences between the dominant research traditions on children's conversational and reading inferences, which we summarise in Table 3. First, research on conversational inferences has typically sought to identify qualitative changes in development: when children become able to derive certain inferences, and which theoretically-motivated prerequisite factors might prevent or allow inferences. On the other hand, research on reading inferences has often focussed on quantitative change, observing a gradual improvement of children's inferential skills over time, perhaps in the number of inferences made or the number of cues required for an inference (Currie & Cain, 2023; Van den Broek et al., 2015). The difference in age group studied is important here: studies on conversational inferences typically sample 3- to 7-year-olds, depending on the type of inference studied, whereas studies of reading, by their very nature, typically begin around 5 years at the start of reading instruction, right through to the teenage years, although tasks which involve listening to written texts may be used with younger children.

Second, different phenomena have been the focus of research across studies on conversational and reading inferences. In general, for conversational inferences the focus has been on implicatures, alongside metaphor, metonymy, irony, anaphora and more; whilst for reading the focus has been on global coherence and local cohesion inferences, alongside some other figurative language use such as idioms. Thus, the study of conversational inferences has focused on classic pragmatic phenomena,

which are clearly communicative (linked to speaker intention) and linguistic (based on speaker utterances); approaches to reading inferences have examined either pragmatic–syntactic or pragmatic–lexical phenomena (e.g., lexical disambiguation and anaphora resolution), or potentially general inferences, like causality or character intent, most analogous to relevance implicatures.

Third, these two areas of research – on conversational inferences and reading inferences – are set in different theoretical frameworks: in a Gricean approach to pragmatics, the listener's goal is to arrive at the speaker's intended meaning; in typical models of reading comprehension, the reader's goal is to construct a coherent mental model, which does involve the author's intended meaning (Kintsch, 1998). Gricean approaches tend to model inferencing at the computational level of explanation (answering 'what' and 'why' questions) in terms of logical or rational steps in reasoning; where the nature of reading inferences is specified, it tends towards a psycholinguistic notion of spreading activation – inferencing skill depends on activation of information from the text or background knowledge and integration of this with new information (Kendeou, 2015). These approaches are though by no means mutually exclusive, of course.

Fourth, the different research traditions have both employed a whole range of experimental designs and paradigms. There is, though, a tendency for research on developing conversational inferences to involve small-scale, tightly controlled bespoke tests on a single conversational inference type, using implicit measures like picture-selection. Research on the development of reading inferences, meanwhile, has additionally involved large-scale studies, and has included both standardised and experimenter-designed tests, requiring expressive responses from participants, such as answering questions explicitly (alongside eye-tracking for fluent readers).

Below we examine how these differences raise a number of important questions about the type of inferences children are learning to derive, and the factors playing a role in children's development of inferencing. First, though, we address the issue of modality and what effects it might have on that development.

Table 3. ***Summary of key differences between research programmes on conversational and reading inferences***

Feature of research	In research on conversational inferences	In research on reading inferences
Typical types of research question	Are the predictions of pragmatic theory fulfilled in pragmatic development? When do children acquire the ability to derive a particular type of pragmatic inference? What are the socio-cognitive and linguistic factors which facilitate or hinder children's inferencing ability?	How does inferencing relate to reading comprehension? How does general inferencing ability develop with age? What are the socio-cognitive and linguistic factors associated with inferencing ability?
Prominent theoretical frameworks	Gricean and neo-Gricean pragmatic theory (e.g., Degen & Tanenhaus, 2014; Grice, 1975; Levinson, 2000) Relevance Theory (Sperber & D. Wilson, 1995; D. Wilson & Sperber, 2012) Probabilistic Pragmatics, including Rational Speech Act theory (Frank & Goodman, 2012; Franke & Jäger, 2016) Speech Act theories (Austin, 1962; Searle, 1969)	The Simple View of Reading, and the Rope Model (Hoover & Gough, 1990; Scarborough, 2009) Construction-Integration model of text comprehension (Kintsch, 1998) Connectionist models of text comprehension (Graesser et al., 1994) For other accounts see McNamara & Magliano (2009)
Age group typically studied	3–7 years, and older for later developing inferences like irony	From 5 years, with some listening comprehension studies at younger ages
Typical methodologies	Truth Value Judgement or Felicity Judgement Sentence-to-picture matching (with reaction time) Visual world paradigm eye-tracking Action-based tasks	Question-and-answer comprehension tasks (explicit responses) Eye-tracking while reading (for older children)
Typical research designs	Cross-sectional, with participants grouped by age or age taken as a continuous variable Focussed on a single inference type with experimental manipulation Uses a bespoke measure Often small-scale, conducted in psychology and linguistic labs	Cross-sectional or longitudinal May include a range of inferences in an inference or reading comprehension task May use a bespoke or validated or standardised measure Can be large-scale, conducted in schools

What is the effect of modality on inferencing?

Children start learning how to derive communicative inferences in conversation as they develop oral language skills; from a young age, they also make inferences from wordless picture books, and when they are read to during shared book reading (e.g. Paris & Paris, 2003; Silva & Cain, 2015); and they then bring these skills to the task of learning to read. How might modality affect how children develop their inferencing abilities? Of the many differences between text and spoken language, there are some which seem important both for inferencing itself and for the opportunity to learn inferencing.

In a conversation the interlocutor is typically co-present, whereas when reading a text, the author is not. Spoken utterances therefore include cues such as prosody and gesture, and are supported by facial expressions and immediate context. As mentioned previously, in Gricean models of conversational inference, the listener's reasoning about the speaker's epistemic state plays a fundamental role, but it has also been suggested that the co-presence of the speaker can be an important cue for this mentalising (Katsos & Andrés-Roqueta, 2021). A text, on the other hand, gives its own kind of context, including descriptions of characters or the writer's epistemic state, together with genre and background knowledge, and there may well be pictures in children's books. Theory of Mind has also been suggested as an important factor in reading, but primarily to follow characters' mental perspectives and emotions in narrative texts (Dore et al., 2018).

Furthermore, the opportunities to learn inferential processes and cues to meaning may differ across modalities. In conversation, there is the opportunity to repair miscommunication through questioning – something we know to be important for referential production, at least (Matthews et al., 2012); and miscommunication itself may be revealed by speaker feedback. When reading, there is the possibility of going back over a text, for example if it becomes clear that something earlier was misunderstood, or a necessary inference was not made (Joseph et al., 2021). For children, this revision may be prompted by questioning, which may be particularly effective when it immediately follows the inference-triggering text, rather than comes at the end of the text (Butterfuss et al., 2022; Freed & Cain, 2017).

If we consider existing research, we can see that the distinction between oral and written language does not map onto studies targeting conversational and reading inferences, respectively. First, as part of the suite of rigorous methods used in Experimental Pragmatics, carefully controlled stimuli often involve utterances being presented to the listener somewhat 'out-of-the-blue', with little information about the speaker, and, in the case of adults or older children, often as text. Indeed, such studies typically pay little attention to whether an utterance is read or heard. That is: much of the body of research on conversational inferences to date does not include much

conversation, and does not focus on the affordances of the oral modality. The aim of this approach is to break down the 'building blocks' of communication, and be able to focus on a particular type of inference, reducing the effects of confounding factors, but this may involve removing supporting cues like prosody, gesture and facial expression, as well as discourse context (Noveck, 2018). Second, studies on reading inferences include children's inferences when listening to texts read aloud and when viewing wordless picture books. This reflects the ways children encounter texts not just when they themselves are reading, but, more often in early childhood, when they are being read to, in a shared book context. It is also motivated by the need to mitigate for the influence of developing word reading skills: in the early stages of reading acquisition, a focus on decoding written words on the page takes cognitive effort which can obscure children's comprehension skills, including inferencing. We summarise these relationships between modalities and typical research paradigms in Table 4.

Table 4. ***Summary of the ways in which the features of modality intersect with current studies on conversational and reading inferences***

	Studies on conversational inferences	Studies on reading inferences
Modality	May be presented in oral or written modality	May be presented in oral or written modality (listening or reading comprehension)
Discourse context	Sentences may be presented out of the blue, or in simple question-and-answer pairs, with little or no discourse context	Texts may consist of a few short paragraphs
Social context	Interlocutor may or may not be co-present; stimuli may be presented on a computer screen and/or as spoken by an avatar or fictional character; participant may be an observer rather than interlocutor.	Texts may or may not be presented in a shared book reading context.
Nature of experimental stimuli	Sentences are often highly controlled in vocabulary and grammatical structure; there may or may not be naturalistic prosody.	Sentences may be controlled and may not reflect lexical and syntactic patterns typically found in children's books.

When we then think of the implications of bringing together findings on reading and conversational inferences, we first need to be careful to take them in their experimental context. Second, we can see that in those controlled experimental contexts there may actually be fewer differences between stimuli targeting 'conversational inferences' and those targeting reading inferences, than we would see between naturalistic conversation or reading. Naturalistic conversation and reading may differ substantially, for example, in lexical or syntactic complexity (Dawson et al., 2021). Furthermore, the affordances of oral and written modalities give rise to some interesting questions: how do children learn how to look out for and give appropriate weight to different cues that need to be taken into consideration when deriving inferences, across different modalities? And how do spoken and written language provide differing opportunities to do this? To give an example: deriving a late-developing inference like irony, associated with mentalising skills, is likely to be aided by the cues of a co-present speaker, which in itself provides a strong signal of the need for mentalising, along with features like prosody. On the other hand, another inference type like anaphora resolution may be less affected by modality, although the temporal affordances of reading – being able to go back over text – might be beneficial. In general, the role of modality needs to be addressed with a collaborative approach to the study of inferencing development.

Which inferences are children learning?

We observed that research on conversational and reading inferences has tended to have different foci in terms of types of inferences. Why might this be? A first possible explanation is that different theoretical frameworks or simply historical precedent could have played a role: there is no reason a priori to think quantity implicatures, for example, could not be studied in a text, or coherence inferences studied in conversation, as indeed has been the case under some approaches, such as in Literary Pragmatics (e.g. Chapman & Clark, 2019). Second, given the tendency for studies on conversational inferences to start with young children, aged 3 years and upwards, and for those on reading inferences to examine older children, from 5 years, another explanation is that these studies focus on those inference types particularly developing in those periods. However, we have already seen that this is not (solely) the case: some typical conversational inferences such as irony are relatively late developing, from around 6 years (Filippova, 2014); typical reading inferences such as coherence inferences are surely required in conversation too, before learning to read, and indeed phenomena like anaphor and reference resolution have been studied across modalities and contexts (e.g. Arnold et al., 2007; Pyykkönen et al., 2010; Serratrice, 2007; Song & Fisher, 2007). That said, there could be a third explanation, based on either qualitative or quantitative differences in the kinds of inferences which children develop in conversation and in reading, due to the different nature of the input. Just as there are differences in vocabulary, syntax or structure between language typically used in conversation and in reading and writing (Castles et al., 2018), there could be

differences in the inferences required to understand the speaker's or the author's intended meaning: certain inference types could only be encountered in one context or, more likely, encountered more frequently in one context than another. This is an important empirical question that requires further investigation – and is indeed crucial to understanding the pragmatic challenges in learning to communicate and learning to read. In order to achieve an accurate and complete understanding of children's pragmatic development, we need to look at all kinds of inference in all contexts – conversation, reading and listening to texts.

This leads us to the next set of questions: what is the interaction between pragmatic skills and reading development? In other words, which inferencing skills do children bring to learning to read, and which do they develop *for* reading? And then what is the effect of learning to read on pragmatic development more generally? In other realms of linguistic development, reading, and being read to, are key contributors: for example, a reciprocal relationship between vocabulary and reading comprehension has been observed (e.g. Oakhill & Cain, 2012), and that relationship is, in part, mediated by inferential skills (Cain, Oakhill, & Lemmon, 2004; Elleman, 2017; Language and Reading Research Consortium et al., 2019). We expect transfer of linguistic skills across modalities and across contexts, and it would be surprising if this was not also the case in the realm of pragmatics, notwithstanding the possible effects of modality on learning to make inferences which we have already discussed. To date, however, developmental studies within Experimental Pragmatics have paid very little attention to whether children are readers or not (though Katsos et al, 2016, did find an effect of being in school on quantifier understanding). One study, however, which actually compared typical cases of conversational and reading inferences directly in 7–13-year-olds, found a surprisingly low correlation between a textual local inference task and an implicature task, about the same as with vocabulary and grammar skills, with analysis suggesting that task-specific skills play an important role (A. C. Wilson & Bishop, 2022). These questions clearly need further research, by adopting developmental approaches to this kind of comparative data, taking into account modality, context, and inference type. The answers to these questions are particularly important for the first years of formal education: inferencing skills are known to be developing significantly in both conversation and reading; children are exposed to texts both as readers and as listeners; and they are given a new linguistic experience in the classroom.

What are the explanatory factors in children's inferencing development?

Research on the development of conversational and reading inferences has identified a variety of knowledge, skills, processes and experiences which are involved in deriving inferences: conceptual and structural knowledge (background and world knowledge, vocabulary and grammar); social cognition; environmental factors (linguistic and multilingual experience, and socioeconomic status); and EF. These can be

related to inferencing abilities directly or in a mediated way, but to date the amount of research and strength of evidence across different factors and inference types is very variable. For example, vocabulary knowledge is required to understand the semantic content of an utterance or piece of text, which is needed for deriving any one inference, but vocabulary knowledge also provides more opportunities in general to access at least some meaning in a discourse or text, and thereby practise pragmatic skills (LARRC et al., 2019; Oakhill & Cain, 2012; E. Wilson & Katsos, 2021). To take another example, social cognition (particularly Theory of Mind) has been widely implicated in the development of conversational inferences, but there is growing evidence that its role may depend on the inference and discourse context at hand (Katsos & Andrés-Roqueta, 2021). For reading inferences, social cognition has been particularly linked to inferences about characters' perspectives and emotions (Dore et al., 2018). The effect of socioeconomic factors on pragmatic skills has received relatively little attention; a whole number of factors associated with socioeconomic experience could impact inferencing, including access to books, libraries, and material resources more broadly, diversity of linguistic input, structural language skills, and cognitive skills including mentalising (e.g. Cutting & Dunn, 1999; Hughes et al., 1999). Cross-linguistic work has also started to reveal the effect of language for conversational inferences, as languages grammaticalize or lexicalise different information (e.g. Katsos et al., 2016 for quantifiers), while studies with multilingual children have so far yielded mixed evidence on the effects of learning more than one language on inferencing development (Antoniou et al., 2020; Antoniou & Katsos, 2017; Dupuy et al., 2019). A systematic review of empirical research of these factors across conversational and reading inferences is needed to identify consistencies, inconsistencies, and gaps in knowledge to inform the development of testable theoretical models of inference development.

To illustrate in a little more detail the task of building a model with factors which contribute to the development of inference-making, take the example of Executive Function. EF is itself a complex construct, most commonly conceived as including working memory, inhibition and cognitive flexibility. Crucially, it is developing over the preschool and early school years – both in its components and their integration (De Cat, 2015; Diamond, 2006). Within Experimental Pragmatics, children's challenges with inferences have sometimes been attributed to 'processing difficulties', sometimes EF in particular (e.g. Huang & Snedeker, 2009; Pouscoulous et al., 2007; Siegal et al., 2010). Recently, there has been an increased understanding of which particular cognitive skills may be required, in theory, for particular types of inference. For example, quantity implicatures require generating and accessing alternatives: when a speaker says, 'I ate some of the biscuits', the listener has to generate the alternative, 'all', as both a lexically plausible and contextually relevant alternative, and then negate it, to arrive at the meaning, *I ate some but not all of the biscuits.* This has led to the hypothesis that inhibition might play an important role in negating the literal meaning of the utterance. Developmental studies, however, have so far offered

mixed findings: they have not observed an association between inhibition and inferencing skills, when testing whether performance on an implicature task is predicted by performance in an inhibition task. For example, Antoniou, Veenstra, Kissine and Katsos (2020) found no evidence for an effect of inhibition, but did find that performance on a battery of pragmatic inferences was predicted by a combined working memory measure in 10–12-year-olds (see too Horowitz et al., 2018; Nordmeyer et al., 2016; see also Zajączkowska & Abbot-Smith, 2020 for cognitive flexibility and irony).

When it comes to reading inferences, the focus has largely been on working memory, given the need for the reader to hold in mind information from across sentences and then integrate that with the mental model of the text and with newly activated background knowledge (Oakhill et al., 2015). For example, in LARRC, Currie and Mujselaar's (2019) large-scale longitudinal study with children aged 4 to 9 years, children heard short texts, including sentences such as: 'Even though Tim's thumb was bruised and sore, he was smiling. He put the hammer that had caused the pain away in his toolbox'. They then had to answer questions like, 'Why did Tim have a sore thumb?', which require integration of information from the two sentences, prior text and background knowledge. After variance associated with vocabulary was taken into account, they found little influence of working memory on inferencing at each grade; this reflects a trend in results across studies that suggests working memory alone is not a unique predictor of inferencing (see too for a meta-analytic review Peng et al., 2018). This sits against a backdrop, though, of a large body of work which has found evidence for the role of all Executive Functions, including working memory, in reading comprehension in general (see Follmer, 2018 for a meta-analytic review).

Research on explanatory factors in children's inferencing development, including contradictory findings and incomplete evidence, opens up a number of important questions. First, are the key predictors the same for conversational and reading inferences? Or are there differences in the required cognitive, linguistic and social resources which are due to either the context (conversation or text) or the modality itself? Socio-cognitive capacities, linguistic experience and knowledge, and learning strategies and processes are also developing significantly in early childhood, so we would expect cascading development across these domains to affect inferencing skills (Bohn & Frank, 2019; Oakes & Rakison, 2019). We might expect the relative contribution of related skills to change over time too. Second, how do different inference types vary in the knowledge and skills they require? For instance, inferences might call on more or less challenging vocabulary and grammatical knowledge, depending on the features of the utterance or text; or require higher or lower levels of inhibition and working memory, depending on the strength of relevant information to be inhibited, or length of discourse or text implicated in an inference; or engage more or less with social cognition, depending on whether the speaker or writer's perspective has to be actively taken into account to resolve the intended meaning. An informative approach to understand apparently contradictory findings could be to consider the different

inference types at stake in different experimental contexts, and the differences in cognitive load and processes potentially involved. This needs to be done at quite a fine-grained level: for example, reading inference studies testing 'local cohesion inferences' can often include both anaphora resolution and bridging inferences, which draw on different levels of lexical and grammatical knowledge, and potentially other areas of knowledge and cognitive functions to differing extents too.

Third, how can these complex interactions be modelled and motivated theoretically? When considering associations between two complex constructs, like inferencing skills and EF, there are multiple mutually-inclusive possible linking hypotheses (Matthews et al., 2018): even for a factor like vocabulary knowledge, there are potentially different roles of vocabulary breadth and depth, and immediate or long-term ways that these contribute to inferencing. Finally, to what extent do the experimental measures used contribute both to hypothesised predictors and to their observed effects? Longer texts used to test reading inferences, often with multiple questions at the end of a text, are likely to reveal more individual differences in working memory, for instance, than the single-sentence stimuli which are designed to trigger inferences within Experimental Pragmatics studies. Furthermore, it can be hard to disentangle confounds in the measures used: for instance, verbal working memory tasks may rely on verbal skills, but vocabulary and verbal intelligence are themselves predictive of reading inferencing ability (Cain, Oakhill, & Bryant, 2004; Kidd et al., 2018). In sum, there are many complex interactions still to map out, a challenge which lends itself to a collaborative approach.

A collaborative approach to children's inferences

We have suggested that bringing together research, and researchers, on conversational and reading inferences brings to light a number of core questions for children's development of inferencing, which we have collated in Table 5. These include: What effect does both context (conversation or reading) and modality (oral, visual, written) have on the need for children to make inferences, and for the opportunities for them to learn to do so? And how do linguistic and background knowledge, socio-cognitive skills and environmental factors support different inferences across contexts and modalities? We suggest that a collaborative approach is the best way of addressing these outstanding questions.

First, a collaborative approach to the study of children's development of communicative inferences means that linguists, cognitive psychologists, developmental psychologists and educational psychologists across a number of research approaches have to work together, possibly in adversarial collaborations where differing theoretical frameworks are tested empirically. This paper itself was born out of a workshop hosted at the University of Cambridge which brought together researchers from different research areas with a common interest in children's inferencing. Working

together throws light on differing assumptions – for instance, about what a communicative inference *is*, or how to test children's inferencing skills – as well as common or contradictory findings, which give rise to the kinds of questions we have outlined. For example, several papers discussing reading comprehension argue and provide evidence for the idea that inferencing in reading has earlier precursors in oral language or general inferencing skills (Cain & Barnes, 2017; Kendeou, 2015; Van den Broek et al., 2015), while linguists approaching developmental pragmatics questions would assume this was the case – but they in turn often do not pay attention to whether children are readers, and which modality an utterance is presented in.

Table 5. ***Summary of questions raised for future collaborative research on conversational and reading inference development***

What is the effect of modality on inferencing?	How do children learn how to look out for and give appropriate weight to different cues that need to be taken into consideration when deriving inferences, across different modalities? How do spoken and written language provide differing opportunities to do this?
Which inferences are children learning?	What is the interaction between pragmatic skills and reading development? Which inferencing skills do children bring to learning to read, and which do they develop for reading? What is the effect of learning to read on pragmatic development more generally?
What are the explanatory factors in children's inferencing development?	Are the key predictors the same for conversational and reading inferences? Or are there differences in the required cognitive, linguistic and social resources which are due to either the context (conversation or text) or the modality itself? How do different inference types vary in the knowledge and skills they require? How can these complex interactions be modelled and motivated theoretically? To what extent do the experimental measures used contribute both to hypothesised predictors and to their observed effects?

Second, it means considering in more detail how existing theories which were developed to account for developing conversational and reading inference skills overlap and interact. We echo the call of Matthews, Biney and Abbot Smith (2018), writing in light of their review of individual differences in pragmatic skills, "to integrate the

results of modelling individual differences data and complementary experimental work … into psycholinguistic models of language processing" (2018:202). We need to be clear about the levels of analysis that current models are operating at (Franke & Jäger, 2016; Geurts & Rubio-Fernández, 2015), and aim ultimately for a mechanistic model which can connect inferencing to related areas of cognition. The aim would be to establish how different types of inference cluster together, both in terms of their developmental trajectory in children's comprehension, and also in how they are supported or affected by the context (conversation or reading), modality, and other linguistic, socio-cognitive and environmental factors. This may show that inferences, which were previously separately categorised or differently labelled, may pattern together, or that grouped inferences actually behave differently. Such a model, on the one hand, is informed by and informs theories of meaning which motivate inference making; and on the other hand, can then be related via linking hypotheses to underlying processes, including EF. The key is that the ongoing, interactive development of oral language skills and literacy are taken into consideration.

Third, it means combining methods: by comparing children's performance on tightly controlled experimental methods and more naturalistic measures to explore and begin to explain task factors from different experimental contexts; by combining insights from these different designs to improve both experimental and naturalistic measures; and by implementing them longitudinally, as has been a particular tradition in studies on reading inferences. A particular challenge is the availability of standardised measures which are psychometrically valid and reliable, but which also measure particular pragmatic inferences rather than a mix of pragmatic and communication skills (see Matthews, Biney and Abbot Smith, 2018, for a review). Likewise, task reliabilities for cognitive measures can also be surprisingly poor, both in terms of test–retest reliability and order of presentation in an experimental session (Schuch et al., 2022). A further problem for the studies of individual differences is the widespread correlation, or positive manifold, across different cognitive measures – sometimes attributed to a g factor or to interacting developmental processes (Van Der Maas et al., 2006). One study in pragmatics that has moved in a promising direction, A. C. Wilson and Bishop (2022), found evidence for a family of pragmatic skills, with only modest correlation between them, and differing levels of association with vocabulary and grammatical skills with a test battery for older children aged 7–13 years; a particular strength of this study was its testing of the reliability of the measures in an adequately powered sample. Similarly, Bohn et al. (2023) tested six tasks for pragmatic inferencing in 3-5-year-olds (including quantity implicature and informativeness inferences) for retest reliability, formalised the shared features of these inferences theoretically, and then tested their association with other cognitive skills including EF in an individual differences study; they found evidence for a systematic relationship between the pragmatic and EF tasks. The next steps are to extend these kinds of approaches to more inference types and across age groups, particularly from preliteracy through the primary school years as children learn to read.

This is a substantial challenge, but it is one that has important consequences. Poor inferencing skills have been identified as one of the causes of poor communication and poor reading comprehension outcomes (e.g. Botting & Adams, 2005; Cain & Oakhill, 1999; Oakhill & Cain, 2012). Ultimately, we need to identify exactly which of the family of pragmatic skills and processes are most at risk across contexts, and then develop and test interventions which can boost those inferential skills. It is even an open question as to whether targeted inferencing interventions are most effective given limited educational time and resources (Davies et al., 2019; Elleman, 2017; Kendeou et al., 2020; Whatmuff, n.d.), or whether a focus on vocabulary, grammar, background knowledge or high level communication skills have enough positive influence on pragmatics (West et al., 2021). Butterfuss, Kendeou, McMaster, Orcutt & Bukut (2022) developed and tested a reading inferencing intervention with audiovisual and non-reading contexts in preliterate pre-schoolers, and while they did find a boosting effect of questioning, scaffolding and feedback, this was greater for children who already had higher language skills and EF – a Matthew effect, where children who already have more advanced skills develop even more than those who do not. In either case, understanding the similarities and differences in inferencing in both conversation and reading contexts, and across modalities, is likely to be crucial. A collaborative approach to researching children's development of inferences across oral language and reading has the potential to provide a more accurate and fuller picture of children's developing pragmatic skills, and a deeper understanding of how they can be improved.

In sum, in this perspectives article we have called attention to the two distinct bodies of research on inferencing development – targeting conversation and reading. In general, they share some basic assumptions about what inferencing is for, and an increasing focus on the factors which are associated with developing inference skills. However, there are also some interesting and potentially critical differences, in the phenomena studied, in methodologies, and in motivation, which may account for apparently contradictory findings and provide insight into future avenues of research that will provide more comprehensive accounts of linguistic and cognitive development. Not least this includes how learning to make inferences in conversation relates to learning to make inferences when listening to or reading texts, and vice versa. We have argued that combining theoretical and empirical expertise on inferencing in conversation and reading is crucial for gaining a full understanding of children's pragmatic development.

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All authors conceived the project, and wrote and revised the manuscript. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Authors excepting EW appear in alphabetical order.

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