"If you catch my drift...": ability to infer implied meaning is distinct from vocabulary and grammar skills [version 1; peer review: 1 approved with reservations]

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Abstract
Background: Some individuals with autism find it challenging to use and understand language in conversation, despite having good abilities in core aspects of language such as grammar and vocabulary. This suggests that pragmatic skills (such as understanding implied meanings in conversation) are separable from core language skills. However, it has been surprisingly difficult to demonstrate this dissociation in the general population. We propose that this may be because prior studies have used tasks in which different aspects of language are confounded.

Methods: The present study used novel language tasks and factor analysis to test whether pragmatic language skills are separable from core language skills. 120 adult participants were recruited online to complete a 7-task battery, including a test assessing comprehension of conversational implicature.

Results: In confirmatory analysis of a preregistered model, we compared whether the data showed better fit to a two-factor structure (including a pragmatic conversation comprehension and core language factor) or a simpler one-factor structure (comprising a general language factor). The two-factor model showed significantly better fit.

Conclusions: This study supports the view that interpreting context-dependent conversational meaning is partially distinct from core language skill. This has implications for understanding the pragmatic language impairments reported in autism.

Keywords
Autism, pragmatic language, social communication, implicature, conversation, psychometric, online research
Introduction: Theoretical underpinnings

Observations of people with autism and social communication difficulties suggest that it is possible to have problems with conversational language in the relative absence of impairments in aspects of “core language”, such as vocabulary knowledge and grammatical competence (e.g. Baird & Norbury, 2016; Lam & Yeung, 2012). However, attempts to demonstrate this dissociation using objective tests have mostly failed. Two separate reviews have concluded that conversational skills are closely related to core language abilities (Andrés-Roqueta & Katsos, 2017; Matthews et al., 2018). However, these findings are based on language tests that may not act as pure indicators of particular language skills. Our goal was to devise novel language tests to give a more convincing answer to the question of whether core language abilities and sensitivity to social aspects of language are separable sets of skills in the general adult population.

While standardised tests of core language skills are in abundance, only a limited range of tests focus on social aspects of language (Norbury, 2014). Social communication is, of course, a broad construct. It has been defined as the combination of “social interaction, social cognition, pragmatics (verbal and nonverbal) and receptive and expressive language processing” that supports conversation (Adams, 2005, p. 128). The broad nature of this construct makes it difficult to study with precision. By contrast, pragmatics is a specific facet of language processing that can potentially be more easily operationalised for assessment - although, from the offset, we should note that the term has frequently been overextended in the field of communication disorders to essentially mean all social aspects of communication (Cummings, 2007). In linguistics, pragmatics is defined as “a process of reasoning based on features of context” that mediates between dictionary meaning and a speaker’s communicative meaning (Cummings, 2007, pp. 425–426). It involves using context to “read between the lines”. As an example of pragmatics in action, consider the utterance “it’s cold here”. Descriptively, the speaker tells us about the temperature of a place. Through pragmatic processing of the utterance in its particular context, we might also infer that the speaker is implying they want to close a window, for instance, or to go inside.

Existing tests of communication skills are not sufficiently focused to measure pragmatic processing. Communication is often measured globally, through observation of semi-naturalistic conversation (e.g. using the Pragmatic Protocol, Prutting & Kirchner, 1987) or through behavioural checklists completed by informants (e.g. the Children’s Communication Checklist, Bishop, 2003). These assessments are likely to conflate pragmatics, social interaction and core language skills. A further drawback is that they focus on social communication “behaviours” rather then the cognitive functions that underpin them. Pragmatic processing may or may not be responsible for these behaviours. Let’s consider an example: how might we interpret a failure to produce contingent turns in conversation? This was a problem for autistic children assessed using the Yale in vivo Pragmatic Protocol, a semi-naturalistic conversational assessment including “specific pragmatic probes” for eliciting target behaviours (Schoen Simmons et al., 2014). A lack of contingent turns may arise from difficulty inferring what is relevant in the communicative context - i.e. a pragmatic problem. Alternatively, the problem may be a lack of social interest, reduced joint attention, performance anxiety, reduced ideational fluency, problems in finding words, perseveration on one’s own topic of interest, or other issues besides. These are not pragmatic problems.

To quantify pragmatic skills, psychometric assessment is necessary. However, traditional standardised language measures do not pick up pragmatic difficulties (Conti-Ramsden et al., 1997), and tests designed for this purpose have been quite uninformative. The Test of Pragmatic Language-2 (TOPL-2) is perhaps the most well-known pragmatic test. It requires the individual to produce situationally-appropriate speech acts, and can detect pragmatic impairment in groups with autism (Young et al., 2005). However, it is not consistently sensitive (Reichow et al., 2008; Volden & Phillips, 2010). The same problem exists with the pragmatic judgement subtest of the Comprehensive Assessment of Spoken Language, which is a similar, commonly used test (Klusek et al., 2014). These tests correlate highly with core language skills (e.g. Akbar et al., 2013), and they do not attempt to minimise demands on vocabulary/grammar or expressive language ability, so we should question their specificity as tests of pragmatics. In addition, both these tests focus on politeness and knowledge of social rules, which is different from the linguistic definition of pragmatics, as inference of meaning from context. Another “pragmatic” test, the new Pragma test (Loukusa et al., 2018), discriminates well between autistic and neurotypical individuals, but is not a pure test of pragmatics, as it contains subscales tapping rather different skills, such as theory of mind and emotion recognition. While this kind of test may be useful clinically for picking up communicative problems, it is not well-suited for our purposes, i.e., pinpointing the underlying nature of those problems.

We need to be clear what we should measure in a pragmatic test. In reviewing definitions of pragmatics, Ariel (2010) stresses the need to contrast semantics and pragmatics. While semantics involves decoding conventional “dictionary” meaning, pragmatics is all about inference: we use context to infer further non-codified meaning. Relevance Theory is an influential model of communication that assumes that inference is critical in all language processing (Sperber & Wilson, 1986). On the one hand, we need to infer the full “explicit” meaning of particular words and phrases; this is explicature. Partly this is a semantic process, as we need to access the dictionary meaning for the word/phrase; however context is important in determining the appropriate meaning, so this is also a pragmatic process. In addition to explicature, we may also infer further “implicit” meaning, or implicature, from a global understanding of the utterance in context. This involves “reading between the lines” and understanding what has not been directly stated. This is a purer pragmatic process, as it depends wholly on inference. For illustration, consider the following dialogue:

SPEAKER ONE. Can you pick Sally up from the station?

SPEAKER TWO. I’m working all day.
In terms of explicature, “I’m working all day” might be taken to mean “Today I will be doing work tasks at my workplace during my working hours”. Here we make local-level inferences about what the speaker’s individual words mean in context. In addition, we might derive implicature through a global understanding of the utterance in its communicative context. For instance, “I’m working all day” implicitly turns down SPEAKER TWO’s request to pick Sally up. In other contexts, these words would not communicate anything about picking a person up from the station: the implicated, indirect meaning is only expressed here because we assume that an utterance in this context must relevantly address SPEAKER ONE’s question, and so we actively seek an implied meaning.

In designing a theoretically-motivated test of pragmatics, implicature is a good focus, as implicated meaning can only be interpreted through context-dependent inference - i.e. pragmatic processing. Existing research has not explored conversational implicature as discussed above. Generally, empirical research investigating implicature has focused on generalised conversational implicature, especially scalar implicature (where we infer, for instance, that not all the apples are moldy in the sentence “Some of these apples are moldy”). However, with generalised conversational implicature, the implied meaning is invariably present whenever this sort of language is used (e.g. Carston, 1998). Therefore, it is very different from the more particularised conversational implicature discussed above, which is much more dependent on the communicative context.

While research into implicature has generally not been strongly influenced by Relevance Theory, a set of papers by Leinonen, Loukusa and others is an exception (Leinonen et al., 2003; Loukusa et al., 2007a, Loukusa et al., 2007b; Ryder & Leinonen, 2014; Ryder et al., 2008). These researchers report reduced ability in children with language impairments or autism to make inferences on language tests designed based on concepts from Relevance Theory. However, these studies did not focus on implicature in conversational contexts; they focused on making elaborative inferences to fill in semantic gaps in short story material. This focus is likely to miss the more social aspects of implicated meanings, which are important for understanding pragmatic problems affecting everyday communication.

**Introduction: Empirical work**

Our objective was to develop a test of pragmatic language processing that removes as much as possible the effect of grammar/vocabulary skills on scores by (a) using simple language and (b) incorporating control items (see below). We focused on implicature comprehension, as linguists are unanimous in viewing implicature as a complex pragmatic phenomenon (e.g. Ariel, 2010). As well as allowing us to test how far pragmatic skill is separable from other language abilities, the test was designed to be clinically applicable in identifying impairments characteristic of autism and social (pragmatic) communication disorder (SPCD) (e.g. Loukusa & Moilanen, 2009), and to be sensitive to developmental and individual differences. Based on these goals, we were mindful of making our Implicature Comprehension Test (ICT) sufficiently child-friendly, while avoiding ceiling effects in adults.

In a pilot study (see methods), we found that the ICT was internally consistent, and that scores did not correlate significantly with semantic knowledge (measured by tests of vocabulary and recognition of conversational phrases/idioms). This provided some evidence that implicature comprehension dissociates from basic linguistic decoding. In the present study, we set out to collect some more normative data on the ICT in typical adults to replicate that finding, and also to test for a dissociation between implicature comprehension and grammatical ability too. We also aimed to clarify what the ICT measured: a general competence in pragmatics/social communication or a more task-specific, perhaps idiosyncratic skill? As such, we developed a test battery including two tasks that we expected to require sensitivity to conversational contexts as well as a test requiring the individual to attribute mental states in different scenarios. This would allow us to assess whether the ICT tapped a general ability in pragmatic conversational comprehension/social understanding. If it did, the multiple tests with a social communication element would inter-correlate.

We hypothesised that a two-factor model of language skills (core language competence and pragmatic conversation comprehension/social communication) would account for individuals’ performance across our tests. Reviews of existing research indicates that “pragmatic” measures tend to correlate with tests of core language skills (Andrés-Roqueta & Katsos, 2017; Matthews et al., 2018), although we should bear in mind that these “pragmatic” measures suffer from problems of poor specificity as noted above, which may inflate the correlations. However, the possibility that individuals can have relatively specific difficulties with pragmatics (Lam & Yeung, 2012) led us to expect that a two-factor structure would fit the battery better than a single factor structure where all the tests measured general language ability.

**Methods**

This study was preregistered on the Open Science Framework (OSF) with the title “The relationship between comprehension of conversational implicature, core language skills and social cognition” (Wilson & Bishop, 2018): https://osf.io/g4bv3. The study was granted ethical clearance in July 2018 by the Medical Sciences Interdivisional Research Ethics Committee at the University of Oxford: Ref. R57087/RE002. We report below how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

**Participants**

We recruited 120 adults online via the participant recruitment platform, Prolific, who all gave informed consent to participate. Inclusion criteria included: (i) age over 18, (ii) private access to a computer with a good internet connection, (iii) no significant visual or hearing impairment, (iv) native-level fluency in English, and (v) no participation in the pilot study of this project.

Our sample size was based on a power calculation using simulations. We used a p-value of 0.05 to indicate statistical significance: this reflects a single preregistered statistical test for the confirmatory factor analysis (CFA) used in this study. In determining power for the CFA, we simulated data conforming
to a two-factor correlated traits model with a core language factor relating to three tests and a conversation comprehension factor relating to four tests. Factor loadings were set at 0.7 and the factors were correlated at 0.2 (a low correlation was used, as the semantic tests did not correlate with the ICT in the pilot study). In 10,000 simulations of samples of 120 individuals, 9989 datasets showed a significantly better fit to a two-factor compared to a one-factor model, when compared using a chi-square test.

Mean age of the participants was 30 years; 11 months (SD = 11 years; 3 months, range = 18 – 64 years). 65 identified as women, 54 as men, and 1 person did not declare their gender. The majority of the sample was White (103 out of 120); 4 people identified as Mixed Race, 4 as Black, and 8 as Asian. 34 of the participants were students, of whom 28 were completing undergraduate studies and 6 were postgraduates. Of the 86 individuals who were not students, highest level of education was high school/secondary school for 18 individuals, vocational training/colleges courses for 13, bachelor’s degree for 53, and a higher degree for 9.

Procedure
This was an online study supported by Gorilla and all data were collected via Prolific on 2nd August 2018. Participants completed the study at a time and place of their convenience. The study took around 30–45 minutes to complete and individuals were remunerated £5 for their time.

Measures
Seven short language tasks were presented in the order described below.

Implicature Comprehension was measured using the Implicature Comprehension Test (ICT). The task involves watching a series of 57 short cartoon videos (each is approximately 8 s in length). Each video consists of a conversational adjacency pair between two characters: typically this is a closed question from Character 1 (eliciting a “yes” or “no” response) followed by a response from Character 2. Each utterance is between 6 and 8 words in length, and age of acquisition of the words does not exceed middle primary school level. Following the adjacency pair, the participant hears a comprehension question; typically, this echoes the question posed by Character 1 during the video. The participant then hears a beep, and is asked to give a “yes”-“no”-“don’t know” response to the question, recorded by keyboard presses. There is a 5-second limit for responding. Note that there were few instances of time-outs in this study. Among the 117 participants whose data were included for this task, responses were missing for only 0.5% of trials. The most trials missed by any one participant was 4, and 94% of participants missed one or fewer trials (83% did not miss any). An example item (one of the practice trials) is available as Extended data (Wilson & Bishop, 2019).

In 27 or the 57 trials, Character 2’s response provides an answer to Character 1’s question that must be inferred via implicature. Half of these represent a “yes” response; half a “no” response.

Example: Character 1: “Could you hear what the police said?” Character 2: “There were lots of trains going past.” Comprehension Question: “Do you think she heard what the police said?” Correct Answer: “No.”

In a further 10 trials, Character 2’s response provides a more explicit response to Character 1’s question. The structure of these items and the overall language level was similar to the implicature items, and therefore they represent positive control items, designed to check that basic language comprehension and task structure did not cause any problems. In this study, mean accuracy on these items was 95.4% (SD= 9.95%), indicating that these items functioned well.

Example: Character 1: “Did you see the policemen earlier on?” Character 2: “I saw them standing on the platform.” Comprehension Question: “Do you think he saw the policemen?” Correct Answer: “Yes.”

In a further 10 trials, Character 2 provides a “don’t know” response to the question, and for these trials, the correct response to the follow-up comprehension question is “don’t know”. These trials are designed to legitimize “don’t know” responding so that participants don’t feel that providing a “don’t know” response always represents an incorrect answer. The aim of this is that participants who are less sensitive to implicature are likely to provide “don’t know” responses to implicature items too. These trials functioned well in getting participants to use the “don’t know” response; mean accuracy on these items was 87.5% (SD= 20.1%).

Example: Character 1: “Did the police speak to anyone else?” Character 2: “I wasn’t watching them much.” Comprehension Question: “Do you think the police spoke to anyone else?” Correct Answer: “Don’t know.”

Finally, the task involves a further 10 “open context” implicature items. In these items, Character 1 produces a statement rather than a question. Character 2’s response implicitly addresses Character 1’s statement. The follow-up comprehension question assesses whether participants have appreciated the implicature; half of the comprehension questions are correctly answered by “yes”, half by “no”.

Example: Character 1: “Normally the station doesn’t get busy.” Character 2: “Lots of people were coming on holiday today.” Comprehension Question: “Do you think the station was busy?” Correct Answer: “Yes.”

Utterance length and psycholinguistic variables (word frequency, word age-of-acquisition and word concreteness) are controlled for the different item types. Mental state words are also avoided, to remove the theory of mind demand of these. There were two measured variables: the sum of implicature items correctly answered (out of 37) and the sum of control items correctly answered (out of 10).

Receptive vocabulary was measured by a Synonyms Test devised for this study. This includes 25 items. In each trial, participants
choose which of four words is a synonym for the target word. This is a timed task (up to 12 s per item). There was one measured variable: the sum of items correctly answered (out of 25).

**Receptive grammar** was measured by a Grammaticality Decision Test devised for this study. In this task, participants listen to sentences and decide if they are well-formed and grammatical. There are 50 items and half are grammatical. Grammatical violations represent mistakes that native speakers would not tend to make, such as using an incorrect auxiliary verbs (e.g. “If I will see Ann today, I’ll ask her opinion) or atypical placing of adverbs (e.g.”If you can’t find it, I can send again the letter”). Participants have up to 6 seconds to listen to each sentence and indicate by a button press whether or not it is grammatical. There was one measured variable: the sum of items currently answered (out of 50).

**Sensitivty to social awkwardness** was measured using the Awkward Dialogues. This task is based loosely on the Faux Pas Recognition Test (Baron-Cohen et al., 1999). Individuals needed to detect discomfort or offence implicitly conveyed in short dialogues. The test was designed not so much to measure a single skill but rather to tap general conversational competence, including pragmatics, mental state attribution, and understanding of paralinguistic cues such as intonation, as well as core language skills.

In the Awkward Dialogues, participants listen to eight short dialogues of around 80–90 words in which two characters each take five conversational turns. In five of the dialogues, one of the characters says something that is socially awkward. Three of the dialogues are control stimuli, in which nothing awkward is said. Participants need to indicate whether something awkward was said, and if they indicate that it was, they are asked to produce a written response to explain what was awkward, why the interlocutors spoke as they did and how they might have felt.

Participant responses on the five awkward dialogues were marked out of two by the first author. Two marks were given if the response expressed the main point that made the dialogue awkward, one if the response gave a glimmer of a correct answer, and zero if the participant missed the awkwardness in the dialogue. Responses from 50 participants were checked by a second independent marker; Cohen’s Kappa was 0.78 indicating good inter-rater reliability. Scores for the five awkward dialogues were entered into an item response model, so that factor scores could be extracted as our measure of participant ability on this test. We chose to use factor scores rather than sum totals, since it was not clear that the intervals in the mark-scheme (i.e. between 0, 1 and 2) ought to be seen as equal. Using a polytomous item response model allowed a solution to this issue, as such models treat data as ordinal and model participant ability as a function of the pattern of responses across items.

In addition to being asked whether dialogues are socially awkward, participants are asked a factual recall question to check basic comprehension of each dialogue (1 mark for each of 5 questions). Participants were excluded if they incorrectly answered more than one factual recall question, as these individuals were outliers (according to the outlier definition below). Where participants incorrectly answered one factual recall question and did not score two marks for that dialogue, their mark for that item was deleted and re-imputed by the item response model based on their scores for the other four awkward dialogues.

**Comprehension of fillers/backchannel continuers** was measured using a Test of Fillers and Backchannels devised for this study. We expected this test to require sensitivity to the role of conversational fillers in turn-taking. Fillers are thought to have functions in conversation; they are not merely “rubbish” produced by inefficient language production systems. For instance, “um” and “uh” are used to claim or hold the floor (Clark & Fox Tree, 2002). Meanwhile, backchannel continuers, such as “mhmm” and “uhuh”, cede the floor to the interlocutor (Jurafsky et al., 1998). As these examples indicate, many fillers are non-lexical speech sounds which do not have substantive meaning but which nonetheless have a communicative function in negotiating who speaks in an interchange. We expected comprehension of fillers/backchannels to allow quite a “pure” test of sensitivity to the turn-taking mechanics of conversation, as this should make minimal demand on core language skills (i.e. vocabulary and grammar), especially given the non-lexical nature of many fillers/continuers.

Participants watch short videos in which Character 1 makes an utterance of between 5 and 9 words. Next, Character 2 produces a word or non-lexical speech sound. The video then cuts off before anything else can be heard. Participants need to indicate who they think would speak immediately after what is observed in the video. They provide their answer by clicking a button showing the face of the character. A third button shows a question mark that participants may click if it is “very difficult to say”. The task includes 40 items. Character 1 says 20 different utterances in the course of the task, with each one produced twice. Character 2 follows up the utterance with a backchannel continuer (or the repair initiator “huh?”) one time and a filler claiming the floor the other time. Where a backchannel continuer or “huh?” is used, participants need to select Character 1 as the person likely to speak, and Character 2 where a filler claiming the floor is used. There are 4 backchannel continuers (mm-hmm, uh-huh, really, right) and 5 fillers claiming the floor (um, uh, yeah, oh, well). The backchannel continuers are much more often used in this role than to signal an incipient speaker (e.g. in corpus analysis by Jurafsky et al., 1998). With the five fillers, “um” and “uh” are taken to mark a slight pause in which Character 2 formulates what they want to say, and “yeah”, “oh” and “well” are fillers claiming the floor. “Yeah” can be used as a backchannel in conversation, though it is much more commonly used to claim the floor than other backchannels (Drummond & Hopper, 1993) and its function is often signaled by the intensity with which it is spoken (Trouvain & Truong, 2012). We therefore use prosodic information to disambiguate “yeah” (we do the same for “oh”, since this this is likely to function similarly to “yeah”). There was one measured variable: the sum of items correctly answered (out of 40).
Narrative-based inferencing was measured by a Test of Local Textual Inference devised for this study. In this study, we were interested in narrative-based inferencing, as the relationship between this kind of inferencing and other language skills was of theoretical interest. In processing narrative (or spoken/written discourse more generally), it is assumed that we construct a coherent mental representation of a narrative based on its explicit content, while making inferences to fill any gaps using text-based cues and world knowledge (e.g. Garnham & Oakhill, 1992). This type of inferencing depends heavily on core language skills, such as semantics (Adams et al., 2009; Bishop & Adams, 1992; Botting & Adams, 2005; Lucas & Norbury, 2014). We expected narrative-based inferencing to be quite a different process to interpreting an implicated meaning in a two-way conversational context. For the latter, a key feature is that we need to understand what is expected of a speaker such that their turn is relevant at the particular point in the conversation. As such, we expected to find a dissociation between narrative-based inferencing and comprehension of conversational implicature. Since Relevance Theory stipulates that all language is underdetermined and requires inferences to be made at the local level to enrich and disambiguate the utterance, we expected this type of inferencing to reflect core language competence.

In this task, participants read two 100-word sections of a short story and after each section they respond to ten questions with a word or short phrase. Participants have as long as they like to read the text, and then up to 25 seconds to type their response to each individually-presented question. The text remains on the screen when the questions are asked. The questions assess whether participants can make coherence inferences to build up a comprehensive representation of a text. Participants are informed that they may respond that they don’t know the response to a question (if there’s no relevant information, for example). Four questions are correctly answered by “don’t know”. Two marks were awarded for a correct response and one mark for a partially correct response, making a maximum total of 40 points.

Mental state attribution was measured using the Frith-Happé Animations (Abell et al., 2000). Each animation shows two moving triangles that sometimes interact. In this study, individuals were presented with a shorter version of the task, which included all the animations showing a “theory of mind” scenario or goal-directed behaviour; we did not use those animations depicting random movement. The “theory of mind” animations show the triangles interacting as if they are trying to influence the thoughts and feelings of each other. The “goal-directed” animations show the triangles physically interacting (e.g. fighting). In this version of the task, participants watched animations around 20 s in length (original clips were shortened), before providing a typed answer describing what happened in each animation. As in the original instructions, participants were told that the triangles would interact, and sometimes they would interact as if they were aware of each other’s thoughts and feelings. There were five “theory of mind” trials (the four in the original task, plus one of the items originally designated as practice) and four goal-directed trials. We gave the original goal-directed practice item as our single practice item. Each of the participant’s written descriptions were scored on their appropriateness (i.e. how accurately they inferred the scenario the cartoon represents) out of 3 by the first author according to the mark scheme used by Castelli et al. (2000). A second independent marker also scored the responses given by 50 participants; Cohen’s Kappa was 0.79 indicating good inter-rater reliability. Scores for the “theory of mind” animations were entered into an item response model, for the same reason as the scores for the Awkward Dialogues, and factor scores were used as our measured variable for this task.

Pilot study
Prior to our main study, we wanted to establish the reliability of our Implicature Comprehension Test and the distribution of scores expected in the general adult population. We also planned to assess how implicature processing relates to other language skills and to the broad autism phenotype.

We conducted an online study supported by Gorilla, using Prolific as a platform for recruiting participants in May 2018. We recruited 120 adults who reported speaking English as a first language and living in the UK. Individuals were excluded if they reported a significant uncorrected hearing or visual impairment. For our preregistered protocol, please see https://osf.io/54htm/. The study was granted ethics clearance by the Medical Science Interdivisional Research Ethics Committee at Oxford University in April 2018 (Ref: R57087/RE001). Participants completed four language tests: the Implicature Comprehension Test (ICT) and Synonyms Test, which were also administered in the main study, and also tests of syntax and idiom recognition (see below). In the pilot study, there was no time limit for responses on the ICT. Participants also completed the Autism-Spectrum Quotient (AQ), a self-report measure of autistic traits (Baron-Cohen et al., 2001).

Receptive syntax processing was measured by the Test of Complex Syntax-Electronic (TESC-E; Frizelle et al, 2017; see https://osf.io/5ntvc/ for full details). Participants watch a series of videos and for each video decide whether an auditorily-presented sentence correctly describes activity in it. The task was originally designed for use with children, and so we incorporated some adaptations to make it more appropriate for adults. In the original version, accuracy was the variable of interest, though we expected a ceiling effect for accuracy, so we instead focused on mean reaction time. In making this change, we needed to present the sentence at the end of the video rather than during it, which was the original format; this meant we could time an individual’s response from the onset of the sentence. Furthermore, we only included the relative clause items, and not the adverbial clause or sentential complement ones. The adverbial clause items make too high a demand on memory when the video and audio are not presented simultaneously, and the sentential complement items (e.g. “She thinks [that] ...”, “He wishes [that] ...”) are likely to demand theory of mind processing that ideally should be removed from this task to ensure that it is a relatively pure measure of structural language skills. In this adapted form of the task, participants watch a series of 20 videos, each around 4 seconds (shorter than in the...
original version to increase the speed of the task for adults). After each video, participants hear a biclausal sentence incorporating a main clause and a relative clause. There are five types of relative clauses: transitive subject relatives, intransitive subject relatives, direct object relatives, indirect object relatives, and oblique relatives. Participants indicate via keyboard presses whether the sentence correctly describes the video.

**Idiom recognition** was measured by an Idiom Decision Test devised for this study. Participants are presented with 40 three-word phrases, each including a transitive verb and its direct object. Half the phrases are idioms (i.e. conventionalised phrases with a meaning that extends beyond the meaning of the component words; e.g. “make your day”) and half are incorrect adaptations of common idioms (e.g. “bite the dirt”, instead of “bite the dust”). Idioms are presented via audio, and participants need to decide as quickly as they can if the phrase is an idiom or not. Responses are given by keyboard presses. Our variable of interest was total accuracy (1 point per correct answer).

See Table 1 for descriptive statistics and the reliability of our measures.

For each variable, we excluded scores according to the criteria of Hoaglin & Inglewicz (1987) for outlier exclusion: 2.2 times the interquartile range below the lower quartile (and above the upper quartile in the case of syntax RT). In analysing the data, we used listwise deletion of any cases with an outlying score. See Table 2 for Spearman’s correlations between the five test variables.

The correlation matrix suggests that the synonym and idiom tests measured closely related semantic skills, and that the syntax test was loosely related to these tests. It is worth noting that the syntax task seemed to have been overly simple for typical adults (as indicated by the strong ceiling effect on accuracy), and so the main demand is unlikely to have been language processing – this perhaps accounts for the low correlations observed between it and the other language tests. Implicature scores on the ICT were not well-correlated with scores on any other tests. We cannot attribute this to noisy tests, as reliability was consistently good across the tests, as indicated by the Cronbach’s alpha values. Similarly, there was no issue with restricted variance on the ICT; while scores were a bit skewed towards the maximum mark, there was nonetheless

| Table 1. Descriptive statistics, excluded values, and reliability coefficients (Cronbach's alpha and standard error of measurement). ICT - Implicature Comprehension Test, RT – response time. |
|---------------------------------|----|-----|------|-------|-----------|--------|-------|------|
| ICT, Accuracy on explicit items | 118 | 9 | 0.63 | 8 | 10 | -1.38 | 0.72 | 6, 1 |
| ICT, Accuracy on implicatures  | 118 | 27.2 | 4.08 | 14 | 35 | -0.79 | 0.37 | 29, 2 |
| Accuracy on synonyms           | 120 | 13.4 | 5.34 | 3 | 25 | 0.12 | -1.03 | 0.85 | 2.07 |
| Accuracy on idioms             | 113 | 35.8 | 3.19 | 26 | 40 | -1.31 | 1.23 | 16, 18, 24, 23, 22, 20, 17 |
| Accuracy on syntax             | 114 | 19.3 | 0.80 | 17 | 20 | -1.01 | 0.46 | 16, 20, 17, 16, 13, 11 |
| Mean RT on syntax (ms)         | 114 | 3320 | 447 | 2188 | 4721 | 0.77 | 0.81 | 2780, 5375, 6131, 4334, 3572, 1231 |
| Total score (out of 50) on AQ  | 118 | 20.7 | 6.92 | 5 | 39 | 0.33 | -0.23 | NA, NA |
|                                |     |     |     |     |     |       |       | 0.79 | 3.17 |

| Table 2. Correlations between language tests and Autism-Spectrum Quotient (AQ). There has been listwise deletion of cases with outlying scores (N = 108). RT – response time. |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                | Accuracy on synonyms | Accuracy on idioms | Mean RT on syntax | Total score on AQ |
| Accuracy on implicatures       | -0.04            | -0.10           | 0.01            | -0.09           |
| Accuracy on synonyms           | 0.49             | 0.25            | 0.04            |                 |
| Accuracy on idioms             | 0.24             | 0.12            |                 |                 |
| Mean RT on syntax              |                 |                 | 0.02            |                 |
substantial variability. Clearly the skills assessed by the ICT were not closely related to other skills measured by the test battery. Likewise, the AQ was not closely related to the other tests, suggesting that the broad autism phenotype was not associated with language skills tested here. This was unexpected, as we thought AQ scores would be negatively related to ICT scores, as autism has been related to difficulties processing implied and indirect meanings. As noted in the main body of the paper, the lack of correlations between the ICT and other tests left us unsure what the test was measuring: very task-specific skills or a more general competence in conversational understanding? This question motivated the follow-up work reported in the main study.

Data analysis
Data were analysed using R version 3.4.0 (R Core Team, 2017); We used the following R packages as part of our data analysis: psych version 1.7.8 (Revelle, 2017), mirt version 1.28 (Chalmers, 2012), MVN version 5.5 (Korkmaz et al., 2014), rcompanion version 1.13.2 (Mangiafico, 2018), and lavaan version 0.6.4.1348 (Rosseel, 2012). Plots were produced using the following packages: ggplot2 version 2.2.1 (Wickham, 2009) and SemiPlot version 1.1 (Epskamp & Stuber, 2017), knitr version 1.21 (Xie, 2017), papaja version 0.1.0.9842 (Aust & Barth, 2018), weights version 0.85 (Pasek, 2016), and htmlTable version 1.11.2 (Gordon et al., 2018) were used to produce the Rmarkdown report for this project. Our data are accessible on OSF (Underlying data (Wilson & Bishop, 2019)).

We assessed item functioning and the reliability of our measures using classical test theory (CTT) and item response theory (IRT; Embretson & Reise, 2000). For each item in each test, we inspected accuracy and the correlation between item-accuracy and total-accuracy on the test with that item excluded (all item-total correlations calculated in this study used test totals with the item excluded). Items were identified as poor if they had low accuracy and a low item-total correlation. We also inspected item characteristic curves (ICCs) produced using IRT analysis, which determines difficulty and discrimination parameters for each item. ICCs are useful in identifying poor items, as they show the probability that an individual of a certain ability score at a particular level on an item; low flat curves indicate items that are ambiguous, with no consensus answer at any point along the ability spectrum. We excluded any items showing this pattern. We then computed the reliability of our measures using CTT coefficients (Cronbach’s alpha and standard error of measurement). We report these below, alongside a summary of the item-total correlations and item-level accuracy for each test; we summarise these as median and upper and lower quartiles. Please note that this CTT reliability analysis was not done for the Awkward Dialogues or Frith-Happé Animations, as we derived factor scores from IRT models for these tests, and therefore used IRT reliability analysis (explained with Figure 1 below).

Any individual with at least one outlying score on any test was excluded from the dataset. Outliers were defined according to Hoaglin & Iglewicz (1987) as 2.2 times the interquartile range below the lower quartile. We also excluded any individuals who had outlying scores on the explicit-response items of the ICT (this threshold was 8/10) or on the factual questions of the Awkward Dialogues Task (4/5), as these were taken to be control variables identifying individuals who did not engage well with the tasks. Then we inspected the data for univariate normality and multivariate outliers. Multivariate outliers were defined as individuals whose adjusted Mahalanobis’ distance was above the 97.5th percentile of the chi-distribution. Where necessary, we transformed variables using the Tukey ladder of power transformations to reduce skew.

We had one preregistered analysis for this study: a confirmatory factor analysis (CFA). We specified a two-factor correlated-trait model with a core language factor and a pragmatic conversation comprehension/social communication factor; see Table 3 for which variables were set to load on which factor. We used maximum likelihood estimation with robust standard errors and a Satorra-Bentler corrected chi-square test to evaluate whether a two-factor model fitted the data significantly better than a one-factor model on which all seven variables were set to load on a single factor. The conventional alpha level of 0.05 was used to indicate statistical significance, as we only preregistered one statistical test. We report confirmatory fit indices (CFIs) and root mean square error of estimation (RMSEA) with 90% confidence intervals.

We carried out one exploratory analysis. As we were particularly interested in whether implicature comprehension was distinct from core language skills, we quantified the proportion of variance shared between implicature comprehension and core language skills (receptive vocabulary and receptive grammar). We also quantified the proportion of variance in implicature scores predicted by our tests tapping pragmatic processing/inferential skills over and above the effect of core language skills. We ran a hierarchical multiple regression, entering receptive vocabulary and receptive grammar as predictors of implicature comprehension in the first stage. In the second stage, the conversation comprehension variables (comprehension of fillers/backchannels and sensitivity to social awkwardness), narrative-based inferencing, and mental state attribution were added to the model. We report F-statistics, p-values, and adjusted R-square values for the stages.
### Results

Table 4 shows descriptive statistics for each language measure. The scores for the Happé-Frith Animations and the Awkward Dialogues are IRT factor scores; for context, the mean raw total for the former (just the “theory of mind” animations) was 10.04 out of 15 (SD= 2.59) and for the Awkward Dialogues was 6.61 out of 10 (SD= 2.51).

#### Reliability analysis

When assessing item functioning, we found a few weak items in the grammaticality test: six showed chance-level accuracy and low item-total correlations, and their ICCs were low and flat. This suggests that the six items were ambiguous, with judgements of grammaticality being essentially random across the ability range, so they were dropped from analysis; maximum score on the final version of the test was therefore 44. In the ICT, there was one similarly poor item, and it was removed from analysis. Maximum score on this test became 36. We did not detect any issues with item functioning in any other test.

The final versions of the tests were reliable, as indicated by the CTT reliability coefficients shown in Table 5. It is notable that

#### Table 3. Study variables for each factor.

<table>
<thead>
<tr>
<th>Test</th>
<th>Study Variable</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversation Comprehension</td>
<td>Implicature Comprehension Test</td>
<td>Implicature Comprehension Total score (36 items, 1 point each)</td>
</tr>
<tr>
<td></td>
<td>Test of Fillers/Backchannels</td>
<td>Comprehension of Fillers/Backchannels Total score (40 items, 1 point each)</td>
</tr>
<tr>
<td></td>
<td>Awkward Dialogues</td>
<td>Sensitivity to Social Awkwardness Factor score derived from IRT model</td>
</tr>
<tr>
<td></td>
<td>Frith Happé Animations</td>
<td>Mental State Attribution Factor score derived from IRT model</td>
</tr>
<tr>
<td>Core Language</td>
<td>Test of Local-level Inferencing</td>
<td>Narrative-based Inferencing Total score (20 items, 2 points each)</td>
</tr>
<tr>
<td></td>
<td>Grammaticality Decision Test</td>
<td>Receptive Grammar Total score (44 items, 1 point each)</td>
</tr>
<tr>
<td></td>
<td>Synonyms Test</td>
<td>Receptive Vocabulary Total score (25 items, 1 point each)</td>
</tr>
</tbody>
</table>

#### Table 4. Descriptive Statistics. We report all excluded values for each study variable. (One excluded value for Sensitivity to Social Awkwardness is NA, as the participant provided no responses to any dialogue.)

<table>
<thead>
<tr>
<th>Study Variable</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Skew</th>
<th>Kurtosis</th>
<th>Exclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implicature</td>
<td>117</td>
<td>28.9</td>
<td>4.50</td>
<td>8</td>
<td>36</td>
<td>-1.20</td>
<td>2.79</td>
<td>13 20 27</td>
</tr>
<tr>
<td>Fillers/Backchannels</td>
<td>120</td>
<td>26.8</td>
<td>5.93</td>
<td>7</td>
<td>37</td>
<td>-0.83</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>Social Awkwardness</td>
<td>118</td>
<td>0.01</td>
<td>0.75</td>
<td>-1.83</td>
<td>0.94</td>
<td>-0.57</td>
<td>-0.57</td>
<td>-1.1 NA</td>
</tr>
<tr>
<td>Mental State Attribution</td>
<td>120</td>
<td>0.00</td>
<td>0.74</td>
<td>-2.23</td>
<td>1.47</td>
<td>-0.38</td>
<td>-0.18</td>
<td></td>
</tr>
<tr>
<td>Inferencing</td>
<td>120</td>
<td>34.4</td>
<td>3.24</td>
<td>24</td>
<td>40</td>
<td>-0.73</td>
<td>0.30</td>
<td>3 12 19 19 20</td>
</tr>
<tr>
<td>Grammar</td>
<td>118</td>
<td>35.2</td>
<td>4.21</td>
<td>25</td>
<td>44</td>
<td>-0.52</td>
<td>-0.37</td>
<td>15 19</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>120</td>
<td>12.1</td>
<td>4.45</td>
<td>3</td>
<td>24</td>
<td>0.31</td>
<td>-0.26</td>
<td></td>
</tr>
</tbody>
</table>

#### Table 5. Reliability Analysis, including Cronbach’s alpha, standard error of measurement (SEm), corrected item-total correlations (totals excluding the item), and item-level accuracy.

<table>
<thead>
<tr>
<th>Study Variable</th>
<th>Alpha</th>
<th>SEm</th>
<th>Lower quartile</th>
<th>Median</th>
<th>Upper quartile</th>
<th>Lower quartile</th>
<th>Median</th>
<th>Upper quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implicature</td>
<td>0.80</td>
<td>2.01</td>
<td>0.23</td>
<td>0.30</td>
<td>0.38</td>
<td>0.68</td>
<td>0.86</td>
<td>0.91</td>
</tr>
<tr>
<td>Fillers/Backchannels</td>
<td>0.80</td>
<td>2.65</td>
<td>0.2</td>
<td>0.27</td>
<td>0.35</td>
<td>0.51</td>
<td>0.67</td>
<td>0.85</td>
</tr>
<tr>
<td>Inferencing</td>
<td>0.75</td>
<td>2.63</td>
<td>0.36</td>
<td>0.27</td>
<td>0.36</td>
<td>1.6</td>
<td>1.76</td>
<td>1.86</td>
</tr>
<tr>
<td>Grammar</td>
<td>0.79</td>
<td>1.93</td>
<td>0.15</td>
<td>0.27</td>
<td>0.36</td>
<td>0.76</td>
<td>0.89</td>
<td>0.93</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>0.76</td>
<td>2.18</td>
<td>0.22</td>
<td>0.31</td>
<td>0.35</td>
<td>0.28</td>
<td>0.49</td>
<td>0.58</td>
</tr>
</tbody>
</table>
item-level accuracy was quite variable on the tests. For some items, there was very high agreement between participants; these items were clearly very easy to interpret or involved highly salient communicative cues. Other items were more difficult. These more difficult items correlated well with total scores excluding that item, indicating that they reliably tapped a particular skill.

See Figure 1 for reliability plots of the tests that we analysed using IRT modeling. IRT models compute standard error of measurement as a function of participant ability, and so we can use this to estimate reliability \[ \text{SEM} = \text{SD} \times \sqrt{1 - \text{reliability}} \]. We present reliability curves for the Awkward Dialogues and Frith-Happé Animations, and also include the IRT curve for the ICT, as we were particularly interested in how this task functioned across the ability spectrum. The low number of items (only five) seems to have limited the reliability of the Awkward Dialogues and Frith-Happé Animations. This IRT analysis is only valid insofar as a unidimensional model fits the data, so we report fit indices for these models: Awkward Dialogues CFI = 1.00, RMSEA = 0.06; Frith-Happé Animations CFI = 0.84, RMSEA = 0.00; ICT CFI = 1.00, RMSEA = 0.01.

Confirmatory factor analyses
As shown in Table 2, a few scores were identified as outliers. We performed listwise deletion of cases including any outliers, meaning that data from 112 individuals were used in the CFAs reported below.

Accuracy on six of the language tests was not normally distributed; the Shapiro-Wilk test was only non-significant for vocabulary. Therefore, the six variables were transformed. Please note that the CFAs reported below were also run using the non-transformed data, and results were very similar. We decided to transform the data because several multivariate outliers were identified in the non-transformed data. Following transformation, there were no multivariate outliers.

Table 6 presents the correlation matrix for the transformed language variables.

We ran two CFAs comparing one and two factor models. A two factor model fitted the data well (CFI = 0.95, RMSEA [90% CIs] = 0.05 [0, 0.11]), whereas a one-factor model did not (CFI = 0.87, RMSEA [90% CIs] = 0.07 [0, 0.13]). The Satorra-Bentler scaled chi-square difference test showed that the two-factor model gave significantly better fit, \( \chi^2 (1) = 5.48, p = 0.02 \).

Inspection of the residuals of the two-factor model indicated that there was some mis-specification in this preregistered model. The four highest residuals were all for correlations between inferencing and the pragmatic/social communication tests, indicating that these relationships were not well accounted for by the model. Therefore, we re-specified the two-factor model with vocabulary and grammar loading on one factor and all the other tests loading on a second factor. This new two-factor model showed good fit (CFI = 1.00, RMSEA [90% CIs] = 0 [0, 0.08]). The Satorra-Bentler scaled chi-square difference test indicated that this two-factor model was significantly better than the one-factor model, \( \chi^2 (1) = 12.47, p < 0.001 \). See Figure 2 for a visualisation of this two-factor model.

Exploratory analysis
In addition to our preregistered analysis, we ran a hierarchical multiple regression to explore predictors of implicature comprehension. In the first stage, the full model was significant, \( F(2, 109) = 6.41, p = 0.002 \). The adjusted R-square value indicated that receptive vocabulary and receptive grammar explained 8.89% of the variance in implicature comprehension. The addition of the rest of the predictors in stage 2 significantly increased the amount of variance explained, \( F(4, 105) = 5.60, p < 0.001 \), and the full model remained significant, \( F(6, 105) = 6.23, p < 0.001 \). However, together the variables only explained 22.04% of the variance in implicature comprehension. See Table 7 for the significance of individual predictors. Note that assumptions of multiple regression were checked: residuals were normally distributed and homoscedastic, and there were no influential observations (maximum Cook’s distance = 0.07).

Discussion
We investigated whether an individual’s ability to process language in its communicative context is distinct from their core language abilities (i.e. their understanding of grammar and vocabulary). This study supports the view that these domains of language processing are distinct, as we found support for a two-factor model underpinning language skills in the typical adult population, with core language skills (grammar and

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**Table 6. Correlations between Study Variables.** Variables have been transformed and there has been listwise deletion of cases to show only the data to be modelled in the Confirmatory Factor Analysis (N = 112).

<table>
<thead>
<tr>
<th></th>
<th>Fillers/Backchannels</th>
<th>Social Awkwardness</th>
<th>Mental State Attribution</th>
<th>Inferencing</th>
<th>Grammar</th>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implicature</td>
<td>0.38</td>
<td>0.26</td>
<td>0.27</td>
<td>0.22</td>
<td>0.32</td>
<td>0.20</td>
</tr>
<tr>
<td>Fillers/Backchannels</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Awkwardness</td>
<td>0.11</td>
<td>0.19</td>
<td>0.16</td>
<td>0.27</td>
<td>0.22</td>
<td>0.13</td>
</tr>
<tr>
<td>Mental State Attribution</td>
<td></td>
<td></td>
<td></td>
<td>0.20</td>
<td>0.09</td>
<td>0.20</td>
</tr>
<tr>
<td>Inferencing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grammar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Vocabulary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.46</td>
</tr>
</tbody>
</table>

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vocabulary) representing one factor and inferential skills and sensitivity to social aspects of language representing a second “pragmatic/communication” factor.

This is in line with our preregistered hypothesis that a two-factor model would fit the data better than a one-factor model, although model fit was improved when one of the three tests set to load on the core language factor (narrative-based inferencing) was modeled as part of the other factor instead. This does raise questions about what this factor represents. The first three tests loading on this factor required individuals to interpret how conversational partners communicate implicitly, how they use fillers to negotiate conversational turns, and how they convey social discomfort/offence to each other. These tests all required sensitivity to a speakers’ communicative intents in conversational contexts. In the fourth test, individuals needed to attribute “mental states” to abstract shapes interacting in short videos. We might expect these four tests to interrelate due to their shared demand on making inferences in social contexts. However, these tests also clustered with a fifth test that involved narrative-based inferencing. In contrast to the other tests, narrative-based inferencing does not necessarily involve a social aspect, but simply requires the individual to integrate information coherently across sentences. This suggests that the tests might interrelate not because of a uniquely social aspect but instead because they tap ability to make inferences in general. We should be careful therefore not to identify this factor with social cognition or “interpersonal communication”; in fact, this factor more closely represents what linguists mean by pragmatics - i.e. inferring meaning through integrating information in context (Ariel, 2010).

While core language skills and pragmatic/inferential skills are related (in our CFA, they were correlated at 0.55), the indication that a two rather than a one factor structure underpins

---

**Table 7. Coefficients for Multiple Regression, with Implicature Comprehension scores as the criterion variable.**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vocabulary</td>
<td>0.03</td>
<td>0.06</td>
<td>0.60</td>
<td>0.553</td>
</tr>
<tr>
<td>Grammar</td>
<td>0.14</td>
<td>0.05</td>
<td>2.86</td>
<td>0.005</td>
</tr>
<tr>
<td>Stage 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vocabulary</td>
<td>0.01</td>
<td>0.06</td>
<td>0.21</td>
<td>0.835</td>
</tr>
<tr>
<td>Grammar</td>
<td>0.09</td>
<td>0.05</td>
<td>1.83</td>
<td>0.070</td>
</tr>
<tr>
<td>Inferencing</td>
<td>0.22</td>
<td>0.26</td>
<td>0.87</td>
<td>0.387</td>
</tr>
<tr>
<td>Social Awkwardness</td>
<td>0.04</td>
<td>0.02</td>
<td>1.64</td>
<td>0.104</td>
</tr>
<tr>
<td>Filler/Backchannels</td>
<td>0.04</td>
<td>0.01</td>
<td>3.03</td>
<td>0.003</td>
</tr>
<tr>
<td>Mental State Attribution</td>
<td>0.06</td>
<td>0.03</td>
<td>1.89</td>
<td>0.061</td>
</tr>
</tbody>
</table>
performance on our language battery suggests that these two sets of skills are partially dissociable in the general population. This would be expected based on the small amount of evidence that core language predicts some of the variance in pragmatic language skills both cross-sectionally (Volden et al. (2009); Whyte & Nelson (2015)) and longitudinally (Bernard & Deleau, 2007; Greenslade et al., 2019; Hale & Tager-Flusberg, 2005; Miniscalco et al., 2014). However, these are separable domains. This agrees with the longstanding clinical intuition that some individuals (such as some of those with autism or pragmatic language impairments) can have difficulties with conversational language in the relative absence of problems with grammar and vocabulary (Baird & Norbury, 2016).

An unexpected finding in this study was the relatively low correlations between the language tests. Reliability of the tests was good, so this cannot be attributed to their being noisy. The only correlation showing a moderate effect size was between grammar and vocabulary, indicating that these tests hung together as measures of core language skills. All other tests were rather weakly correlated. This suggests that performance was influenced by a range of task-specific skills rather than dominated by domain-general abilities. It is particularly interesting that the Awkward Dialogues and Frith-Happé Animations were minimally correlated. Both tests would be assumed to tap advanced theory of mind/mentalizing skills. However, the lack of correlation here indicates that, at least in the general population, individual differences in performance on these tests are not accounted for by a general social cognition factor but rather by much more task-specific skills. This agrees with research in children and adolescents, which has found low correlations between several advanced theory of mind measures (Hayward & Homer, 2017).

One objective of this study was to understand more about what our test of implicature comprehension measured. Core language skills, such as vocabulary and grammar, accounted for only a small proportion of variance in scores on our Implicature Comprehension Test. This means that some individuals might be able to decode the basic “literal” meaning of an utterance, as encoded by the individual words and grammatical structure, without processing an implied meaning. Such individuals would be assumed to include those with autism and related conditions, who are found to have difficulties forming inferences [Loukusa & Moilanen (2009)]; diagnostic criteria often refer to problems with non-literal/implicit meanings (Baird & Norbury, 2016). The dissociation between implicature comprehension and core language skills is also in line with linguistic theories that describe implicature as context-dependent meaning that is not intrinsic to the linguistic code (see Grice’s theories, Relevance Theory, etc. in Arieli, 2010). We also found that an individual’s ability to make inferences, as measured in several of our tests, explained some variability in how effectively people process conversational implicature, even accounting for the role played by grammar and vocabulary skills. This suggests that there is some commonality between processing implicature in conversational interchanges and forming inferences in other contexts - and the contexts in our test battery were wide-ranging, including narratives, abstract cartoons and social dialogues. However, the shared variance was relatively small, leaving a considerable proportion of the variability in implicature scores unexplained. What skills might explain why people varied in their scores on the test? We designed the test under the influence of Relevance Theory, and so an obvious answer might be sensitivity to the principle of relevance (Sperber & Wilson, 1986). In the context of our Implicature Comprehension Test, this is the expectation that an utterance should respond relevantly to the previous contribution in a conversation, and if it doesn’t, then we should be open to the possibility of an implied meaning. It may be that some individuals are more active in seeking relevance and implied meaning, and this tendency may explain individual differences in how people detect implicature.

In summary, this study presents evidence that understanding language in its communicative context is not simply a matter of core language skills. In particular, we found that understanding implicated meanings in conversation is somewhat distinct from vocabulary knowledge and grammatical competence. This raises the question of whether individuals with autism and social communication difficulties may have especial problems with this conversational understanding even if they perform at a typical level on tests of vocabulary and grammar. Our future work will explore this question.

Data availability

Underlying data


This project contains the following underlying data:

- **Data**
  - alldataAnalyse.R (script for collating data, and running confirmatory factor analyses and exploratory regressions)
  - AwkwardConvo.csv (data for the Awkward Dialogues)
  - Backchannel.csv (data for the Test of Fillers and Backchannels)
  - Data_dictionary.xlsx (spreadsheet detailing contents of each data file; one sheet per file)
  - Grammar.csv (data for the Grammaticality Decision Test)
  - Implicature.csv (data for the Implicature Comprehension Test)
  - Implicature_itemcodes.csv (spreadsheet detailing item-type for each item in the Implicature Comprehension Test)
  - Inferencing.csv (data for the Test of Local Textual Inference)
  - TOMAnimations.csv (data for the Frith-Happé Animations)
  - Vocab.csv (data for the Synonyms Test)
Extended data

Materials for tests devised for this study are being developed as an assessment tool that we hope will be sensitive to pragmatic impairments in individuals with social communication difficulties, but we still need to establish validity of the tests in clinical groups before they are made available. We are also concerned that open availability of the materials may reduce their usefulness if participants have already viewed them. Please contact the corresponding author, with an explanation of why access is sought.

Information for researchers wishing to gain access to the Frith-Happé Animations is available here: https://sites.google.com/site/utafrith/animation. Any researchers wishing to use these animations should contact Sarah White (s.white@ucl.ac.uk).


This project contains the following extended data:

- Implicature Comprehension Test
  - Practice_Item_1.mp4 (Example practice trial of the Implicature Comprehension test)

Grant information

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The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

References


I enjoyed reading this paper. Pre-registration and access to the data and R script was a plus. With the exception of the request for more details about the stimuli/items (point 4 – the most important point for me), the following comments are mainly points for discussion (that could be accommodated with clarification in the discussion section or with minor revision to the introduction) not suggestions for substantial revision. I've commented on the paper with a focus on the logic of the arguments put forward.

While I have looked at the R script and the data, I haven't run the script myself. I haven't commented on the stats beyond a couple of questions (about the relation between test development and factor analysis, and about how to interpret the factor analysis).

The goal of this study was “to devise novel language tests to give a more convincing answer to the question of whether core language abilities and sensitivity to social aspects of language are separable sets of skills in the general adult population.” A definition of pragmatics is given and the need to contrast this with semantics discussed. “While semantics involves decoding conventional “dictionary” meaning, pragmatics is all about inference: we use context to infer further non- codified meaning.” While there are theoretical issues here (relating to what ‘conventional dictionary meaning’ is), this is a working definition. Particularised conversational implicatures are settled on as the ideal domain for testing pragmatics given their dependence on communicative context. The goal was to use a p.c. implicature test to find out how far pragmatic skill is separable from other language abilities.

1. It is argued that a focus on p.c. implicatures would be beneficial since conceptually it is the most distinctively pragmatic skill (whereas other skills that are nominally pragmatic have more potential overlap with, e.g., semantics). Does this mean that the results (finding a 2 factor solution) are not necessarily what would be found if we looked at other skills traditionally considered as pragmatic? I wondered to what extent picking the most distinctively pragmatic skill (the one at the far end of the continuum, so to speak) makes it difficult to assess the main question of whether core language abilities are separable from pragmatic abilities (in general).

2. Likewise, does use of CTT and IRT (where during test development items are excluded for poor fit) bias things in favour of finding separable factors? Essentially, the steps here are to devise a test, e.g., with a set of items that theoretically at least all require p.c.implicature. Then any items that do not pattern with most of the others are left out. This is desirable for test development. But I did wonder whether doing this at the same time as factor analysis essentially means that you have chosen items on the basis that they pattern together and then shown in factor analysis that they do. I doubt given the number of items excluded that this is really a problem but it might be worth clarification (whether this is an issue in principle or not, whether it is an issue in practice or not).
3. Given the goal of testing whether formal language skills group separately to pragmatic language skills, to what extent are the four ‘conversation comprehension’ tests cleanly tests of pragmatics? I can see the implicature test is a test of pragmatics (at least as far as it is possible to have a clean test, there is a convincing rationale here). But why are the Frith-Happe’ Animations – a test of mental state attribution intended to be as non-verbal as possible - taken as a measure of conversation comprehension? The discussion recognised this as a somewhat separate test. It seemed odd to go to great lengths to attempt to identify a cleanly pragmatic test (to the exclusion of tests of other nominally pragmatic skills) and then to include a test traditionally seen as tapping ToM and not involving conversation comprehension at all.

Likewise, for the Awkward Dialogues, p.6 reads “The test was designed not so much to measure a single skill but rather to tap general conversational competence, including pragmatics, mental state attribution, and understanding of paralinguistic cues such as intonation, as well as core language skills.” Could you clarify why this would be helpful for addressing the question at hand?

It seems ‘pragmatics’ – already a broad tent - is being stretched further than necessary here. To find out whether that is the case perhaps exploratory factor analysis would help but a broader range of tests would be needed. For this paper, perhaps some further rationale could be given along with a revision to the introduction. (I had followed the introduction – largely focused on the implicature test – and then was surprised when I came to Table 3 at the choice of conversation comprehension measures).

4. Provision of test items. It was great to be able to read this paper, look at the pre-reg document, data and R code. What would have made it really great, and what is perhaps more important for conceptualising the findings, would have been able to see the full list of items from the tests. Without this, I found myself struggling to imagine what was going on exactly. The example p.c. implicatures given seem fairly straightforward such that I guess most of the adults who participated answered correctly. However, there was variance for this measure, so some of the inferences must have been harder to make. I’d have been interested to get a sense of these items, not least because it is a challenge to make a difficult inference test item that has a correct answer. It is reported that some items on this test were more difficult than others and that scores for a given difficult item correlated well with total scores excluding that item, indicating that they reliably tapped a particular skill. I’d like to better understand what the skill is exactly. I guess it could be distracting to give one example that a reader could take issue with for reasons that are beside the point, but given the problems particular to this sub-field, being able to concretely point to what items had in common seems important. What would be really valuable would be to see the full set of stimuli with the difficult items highlighted so that we could try to imagine what those items have in common.

**Suggested revision:** Ideally, the full stimuli sets/list of items would be given so that we can understand the tasks. It is noted in a final section of the paper (‘Extended data’) that stimuli are not provided as test development is underway and future participants might access materials. I would be interested to see the full list but, for publication, would it be possible to give a few example items from the harder end of each test, with information about what % of participants got them ‘right’? This is needed for the implicature, awkwardness, fillers and narrative tests.

More generally – perhaps for discussion - does it always make sense to say there is a correct answer? Or just one that most people alight on? For example, with the filler/give the floor test, there are probabilistic cues to who will speak next. Is the correct answer just the answer that most people would give? Are we looking at norms of behaviour (a participant is correct by virtue of doing what most other people would do) or is there a clear inferential process that should optimally be engaged in?

5. P.9 “Any individual with at least one outlying score on any test was excluded from the dataset”
How many were excluded? Could this be noted in the participants section also?
6. In the results section, it wasn’t entirely clear what question the exploratory analysis was intended to address. Could this be spelt out somewhere?

7. **Conclusions drawn.** I was interested in the discussion on p. 12 about what the second factor (non-grammar factor) represents. I wondered if it might be possible to interpret the CFA a little for people who don’t use it regularly. Does this analysis show there is a second factor that holds together or is it just that a two factor solution is better than having just one factor, one sensible factor is grammar (with vocab) and another dimension is the inferencing test (with other tests also grouping with this but not really strongly related to the second factor). That is, this seems to show that p.c. implicature and grammar are quite distinct. But does it tell us that p.c. implicature and the other tests that are nominally tapping “pragmatic/communication” should be conceptualised as a single factor ‘inferring meaning through integrating information in context’? Looking at the correlation matrix and the loadings, these variables seem quite loosely related. In answer to the main question of “whether core language abilities and sensitivity to social aspects of language are separable sets of skills in the general adult population”, it seems the answer is yes but apparently only in so far as grammar is distinct from p.c. inferencing (which is reflected in the title and final conclusions). What everything else is doing, and what elements of the other nominally conversation measures are pragmatic (or social aspects of language use) seemed less clear to me. Some additional text explaining what this factor analysis allows us to conclude here (and how future studies could further test whether there is a pragmatics factor and if so what it reflects) would be very helpful.

In sum, the title and main conclusion about inferencing and grammar are supported but the question set up in the introduction had a broader scope and the conclusion wrt to that broader question could be clarified.

8. I was interested in the implications of this study for development. Would you predict separation of vocabulary/grammar and pragmatics earlier in development? Given that children start off without a ‘dictionary/code/lexicon’, perhaps some consideration of the co-development of these skills would be helpful for understanding developmental disorders.

9. Typo: well-correlated with >> with

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**Is the work clearly and accurately presented and does it cite the current literature?**
Yes

**Is the study design appropriate and is the work technically sound?**
Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**
No

**If applicable, is the statistical analysis and its interpretation appropriate?**
I cannot comment. A qualified statistician is required.

**Are all the source data underlying the results available to ensure full reproducibility?**
Yes

**Are the conclusions drawn adequately supported by the results?**
Partly

**Competing Interests:** No competing interests were disclosed.
Reviewer Expertise: Pragmatic development.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.