Review of Philosophy and Psychology
https://doi.org/10.1007/s13164-023-00704-x

Literalism in Autistic People: a Predictive Processing Proposal

Agustín Vicente[1] · **Christian Michel**[2] · **Valentina Petrolini**[3]

Accepted: 28 August 2023

Abstract

Autistic individuals are commonly said – and also consider themselves – to be excessively literalist, in the sense that they tend to prefer literal interpretations of words and utterances. This literalist bias seems to be fairly specific to autism and still lacks a convincing explanation. In this paper we explore a novel hypothesis that has the potential to account for the literalist bias in autism. We argue that literalism results from an atypical functioning of the predictive system: specifically, an atypical balance between predictions and error signals in language processing may make individuals more uncertain about their own predictions. Such uncertainty is then often resolved by resorting to the safest interpretation, that is, the literal one. We start by reviewing existing explanations of other autistic traits that appeal to predictive processing. We then apply these insights to language, by showing that predictions play a key role in everyday comprehension and that a low level of confidence in one's own predictions is likely to escalate comprehension difficulties. Finally, we take a deeper look at non-literal uses of language by discussing the case of metaphors, to illustrate how a predictive processing account offers a promising explanation of the literalist bias in autism.

✉ Agustín Vicente
agustin.vicente@ehu.eus

Christian Michel
chris.michel08@gmail.com

Valentina Petrolini
valentina.petrolini@ehu.eus

[1] Ikerbasque/University of the Basque Country (UPV/EHU), Vitoria-Gasteiz, Spain

[2] University of Edinburgh, Edinburgh, UK

[3] University of the Basque Country (UPV/EHU), Vitoria-Gasteiz, Spain

Published online: 12 September 2023

1 Introduction: Literalism in Autism

What speakers mean by an utterance typically goes beyond the literal meanings of the words and sentences they use. Inferring what speakers mean in such usual cases involves pragmatic skills that bridge the gap between linguistic meaning and what is communicated.[1] Difficulties in the domain of such pragmatic skills are considered a hallmark of autism spectrum conditions (Tager-Flusberg et al. 2005). In particular, autistic individuals are commonly said to be excessively literalist, in the sense that they tend to prefer literal interpretations of words and utterances, even when speakers intend to be understood non-literally. Such literalism applies in principle to all kinds of implicit meaning, from indirect speech to figurative language, irony, and sarcasm. That said, it seems easier for autistic individuals not to experience such literalist bias as strongly in some areas (e.g., conventional indirect speech acts) compared to others (e.g., irony and sarcasm). While literalism is experienced as an issue for many autistic people (see this Wrong Planet thread for some first-person accounts; and Morra 2016 for a more systematic study), results obtained in laboratory settings fail to offer a clear-cut picture. For instance, a recent set of meta-reviews on figurative language in autism confirms the existence of mixed results (Kalandadze et al. 2018, 2019). While laboratory results suggest that autistic individuals are more likely to encounter difficulties in understanding non-literal language than neurotypicals, some argue that such difficulties appear to be related to general linguistic difficulties, rather than to autistic traits themselves (Gernsbacher and Pripas-Kapit 2012). In particular, since Norbury's seminal work (Norbury 2005), several authors relate difficulties with non-literal uses of language in autism to structural language delays that are also quite common across the spectrum. Andrés-Roqueta and Katsos (2017), for instance, distinguish between linguistic and social pragmatics. According to such a distinction, autistic people may experience two different kinds of difficulties when comprehending non-literal uses of language: difficulties that arise from structural language issues, and difficulties related to theory of mind (ToM) issues, which would mostly impact irony and sarcasm.

Some of us have criticized this view in previous work. The bulk of our criticism hinges on the fact that many studies test whether autistic individuals understand some non-literal uses of language *tout court* (e.g., metaphors), rather than investigating whether they interpret such non-literal uses *literally*. When literalism is directly tested, results are still not uniform, but: (a) the balance tips towards literalism; (b) the specific literalist difficulties in most non-literal uses of language do not appear to be related to more general issues with structural language (see Chahboun et al. 2016, 2017; Vulchanova et al. 2012; Walenski and Love 2017 for "literalist" results on metaphors and idioms; Kasirer and Mashal 2014, 2016, on literalist tendencies remaining after having controlled for language impairment). We discuss these

[1] We ignore here complications – long-debated especially in the philosophy of language – about how exactly to characterize the notion of literal meaning. For present purposes, we take it as uncontroversial what is a literal and a nonliteral meaning (what is literally/linguistically/ conventionally expressed and what is meant) in an utterance such as: "Juliet is the sun".

results in more detail in Section 5.2. For now, our aim is to point out that literalism appears to be a characteristic feature of autism, as it seems to be exhibited by many people on the spectrum, in a fairly specific way, and irrespectively of their grammatical abilities and breadth of vocabulary.

Several explanations have been proposed to account for the literalist bias in autism. We have also criticized such explanations in previous publications (Vicente and Martín-González 2021; Vicente and Falkum 2023). According to our criticism, the two most widespread explanations – i.e., the ones appealing to executive dysfunctions and to ToM difficulties, respectively – only work if one already assumes a prior literalist bias. The executive dysfunction explanation (e.g., Mashal and Kasirer 2011) aims to explain literalism through difficulties in literal meaning inhibition. The ToM explanation (Happé 1993), instead, relates literalism to the arguably diminished mentalizing skills in the autistic population, also assuming that such skills have to be put to use to derive speakers' meanings. Both accounts presuppose literalism because they seem to work only for individuals who have to overcome a particularly strong activation of literal meanings in the first place. For what we know, in typical individuals, interpreting a metaphor or an indirect speech act does not involve inhibiting literal meanings, or reasoning about intentions on the basis of a literal interpretation. By and large, the process of interpreting a piece of non literal language is relatively swift and does not involve figuring out the mental states of speakers (see e.g., Bendtz et al. 2022 for indirect speech; Abbot-Smith et al. 2022, for implicatures; Wilson and Carston 2006 for metaphors and other figurative uses of language).

Besides the executive dysfunction and the ToM accounts, two other theories of literalism have been influential: the local processing view (Happé and Frith 2006) and the structural language account already mentioned above (Norbury 2005). The local processing view explains literalism as an effect of global processing issues, which would make it difficult to integrate the contextual information required to properly understand non literal uses of language. Yet, while local processing undoubtedly affects comprehension of narratives, it is unclear whether it should also be taken to affect the processing of an individual metaphorical sentence, such as: 'that boy is a turtle'. That is, the interpretation of units of the size of a sentence do not seem to require much global processing. The structural language hypothesis, on the other hand, *can* explain why some autistic individuals experience difficulties understanding non literal language, but it fails to explain why they would interpret non literal language literally. Individuals with Developmental Language Disorder (DLD) have also been found to experience difficulties in the domain of the non literal, but they do not exhibit the literalist bias observed in autistic individuals (Bühler et al. 2018). More importantly, while DLD children exhibit the difficulties with non-literal language that are also characteristic of typically developing children of a similar verbal mental age, such correspondence between non-literal language difficulties and verbal mental age seems to be lacking in the case of autism (Chahboun et al. 2017).

In sum, there is reason to believe that the literalist bias typical of autism still lacks a proper explanation. In our previous work we suggested that literalism could be seen as an expression of rigidity or inflexibility, a cluster of patterns of behavior

that are typified as characteristic of autism (APA 2022; Petrolini et al. 2023). In this paper we explore another hypothesis that has the potential to account for the general rigidity trait just mentioned, as well as for literalism in particular. We explain literalism as one effect of an atypical functioning of the predictive system. We hold that an atypical balance between predictions and error signals in language processing may make individuals (more) uncertain about their own predictions, and that such uncertainty may be resolved by selecting the safest interpretation, i.e., the literal one (at least in most cases).

The structure of the paper is as follows. We first offer an overview of existing explanations of autistic traits that appeal to predictive processing (Sections 2 and 3). We then move on to applying these insights to language, by showing that predictions play a key role in everyday comprehension and that a low level of confidence in one's own predictions is bound to escalate comprehension difficulties (Section 4). Finally, we take a deeper look at non literal uses of language by discussing the cases of metaphors and implicatures, to illustrate how a predictive processing account offers a promising explanation of the literalist bias in autism (Sections 5 and 6).

2 The Predictive Processing Account of Autism

Predictive processing holds that the brain, in its effort at building a model of the environment, constantly makes predictions about what the subject is going to experience, updating the model according to the input received. Depending on how reliable the model has proven to be in the past, predictions are assigned prior probabilities. Imagine driving down a familiar road on a foggy day, with prior experiences and expectations effectively shaping what you see. Predictions are then organized in a hierarchical system of layers, such that priors of a specific prediction depend on the priors of related predictions. Representations higher up in the hierarchy are general and abstract: they correspond to a larger spatiotemporal scale, and include beliefs and knowledge about the external world, social norms, cultural background beliefs, or the awareness of certain stable contextual elements in a conversation. Representations in the lowest levels, by contrast, are typically modality-specific and tend to change quite quickly, such as edge patterns in the visual pathway (see, Löhr and Michel 2023, pp. 5–6 for a graphical representation).

The system also contains an *error weighting mechanism*, which estimates the precision of the signals to tune error signals up or down. Such a mechanism can suppress error signals generated by unreliable input. In the foggy road scenario, for instance, we tend to rely less on our visual input and to give greater consideration to prior experiences and expectations. The error weighting mechanism therefore regulates how we should balance expectations and sensory evidence depending on the situation.

Predictive processing (PP henceforth) approaches to autism hold that the basic difference between a neurotypical and an autistic brain is the weight assigned to incoming sensory information or experiences with respect to top-down predictions or priors. The neurotypical brain relies more on its priors, compared to the autistic brain; correspondingly, the autistic brain assigns more weight to sensory data

compared to the neurotypical brain. As a result, the autistic brain modulates sensory data less than the neurotypical brain, with sensory signals being experienced more intensely. Pellicano and Burr (2012), probably the first attempt at accounting for autistic symptoms from a PP approach, used this kind of explanation to account for hypersensitivity, one of the characteristic features of autism. On their view, such hypersensitivity is caused by "hypo-priors" – that is, a diminished confidence in the brain's own predictions as compared to the neurotypical brain. Following this intuition, several accounts have been proposed to further identify PP mechanisms in autism (see Arthur et al. 2022). Van Cruys et al. (2014), for instance, suggest that autistic behavior is driven by inflexible overweighting of prediction errors. Lawson et al. (2017) propose that the observed impairments are a consequence of the overestimation of the environmental volatility. Despite their differences in emphasis and details, all these accounts maintain that autistic individuals experience issues with the stable representation of higher-level priors, which in turn derives from some sort of imbalance in the weighting of top-down and bottom-up information. This has recently been dubbed "the imbalance hypothesis" (Chrysaitis and Seriès 2022). In the next section, we delve deeper into other PP explanations that have been developed to explain a wider range of autistic features.

3 PP Explanations of Other Autistic Features

Since Pellicano and Burr's seminal proposal (2012), PP accounts have offered explanations of most autistic symptoms, from insistence on sameness to social difficulties. Palmer et al. (2017) provide a good summary of existing research. As we mention above, all these strands of research are committed to the view that autistic brains tend to assign greater weight to incoming sensory information at the expense of higher-level priors. This insight is then applied to a wide variety of traits that are regarded as typical in autism. One key case is hypersensitivity to sensory stimulation, a trait that should be expected if prediction errors – i.e., expectation violations – are weighted more highly (see also Van de Cruys et al. 2019). The same applies to local processing and detail-oriented processing styles, which are understood as the result of increased attention towards lower-level prediction error signals (Palmer et al. 2017; Mottron et al. 2006). Cognitive and social autistic traits – such as restricted and repetitive behaviors, theory of mind difficulties, and many others – are also amenable to PP explanations (Palmer et al. 2015; Van de Cruys et al. 2014). In these cases, overestimating the importance of prediction errors arguably prevents autistic individuals from forming higher-level expectations about other people's beliefs and behavior, as well as about the environment. Rigid thinking and behavior, including the reliance on routines and the strict adherence to rules, would emerge as a response that provides some reassurance in the face of a world filled with error and uncertainty (Van de Cruys et al. 2014; Lawson et al. 2017).

PP approaches are thus particularly well-suited to account for the need and preference that autistic people have for a structured, predictable, environment. Such a preference has been widely reported by studies exploring the challenges faced by autistic students and teachers in educational settings (McDougal et al. 2020; Wood

and Happé 2021), as well as by first-person accounts and lived experiences of autistic individuals (see for instance Mol 2020). Such a preference towards structure and stability can also be related to a diminished confidence in priors. If some version of the imbalance hypothesis is correct, the world would easily get too chaotic for autistic individuals. Repetition and routines would thus serve the function of simplifying things considerably, either by arranging things so that predictions are successful (i.e., you know more confidently what is coming next), or by having an external agent or tool – e.g., a planner – boosting confidence in your predictions, thereby lowering uncertainty. While in some cases the environment gets to be structured by individuals themselves – e.g., through self-imposed routines – in other cases external agents are driving the process – e.g., in educational or intervention settings.

In this respect, the construct of Intolerance of uncertainty (IU) appears to be particularly interesting to develop a PP account of autism. Intolerance of uncertainty has been introduced in the context of autism research fairly recently (Boulter et al. 2014; South and Rodgers 2017; Hodgson et al. 2017; Vasa et al. 2018), while it has been previously investigated as a psychological construct in anxiety, depression, and obsessive-compulsive disorder (Carleton et al. 2012; Dugas et al. 2001). Studies investigating IU in non-autistic populations characterize it in terms of "decreased thresholds for the perception of ambiguity and enhanced discomfort with ambiguity" (Dugas et al. 2001), "negative beliefs about uncertainty and its implications" (Carleton et al. 2012), or as an "increased tendency to become overwhelmed by the unexpected and the unknown" (Jenkinson et al. 2020). Although the association between IU and anxiety has proven robust in non-autistic populations, it is still unclear whether these results have been successfully replicated in autistic samples. This is mostly due to the fact that existing studies are overwhelmingly cross-sectional in nature, and that questionnaire measures of IU – such as Dugas et al. (2004) – have not yet been validated with autistic individuals (see Jenkinson et al. 2020 for a review). Moreover, although some PP accounts have employed IU with autistic populations (Neil et al. 2016), other proponents have recently cast doubt on its applicability (Bervoets et al. 2021). For our purposes, it is interesting to briefly discuss this construct because it has been related to implicit meaning comprehension in autism (Wilson and Bishop 2021), and also because it has the potential to explain several challenges that autistic people experience with respect to non-explicit communication in general.

From a PP perspective, we propose that autistic people should display *higher uncertainty* instead of being *more intolerant of uncertainty than neurotypicals* (see Bervoets et al. 2021 for a similar suggestion). We may distinguish between higher uncertainty and intolerance of uncertainty as follows. Intolerance of uncertainty would imply that two individuals A and B hold the same probability assignments, but display different psychological or emotional reactions. In other words, A tolerates the same degree of uncertainty to a lesser degree than B. For example, neither A nor B know whether they will be able to catch the next flight, but they both know that it's highly likely. Yet, A gets more anxious than B. Higher uncertainty, by contrast, would imply different probability assignments that generate different psychological or emotional reactions. On this reading, A and B's degrees of uncertainty are different to begin with: for instance, A might assign lower probability to (or be less

confident about) each of the relevant predictions that compose the belief: "We are catching the next flight". If confronted with each of these relevant predictions piece by piece, A would thus be more likely to say "I don't know" more often than B.[2]

In what follows we set out to apply predictive processing frameworks to issues related to language in autism, by focusing on non-literal uses of language. First, we draw on some recent proposals that emphasize the role played by prediction in typical language comprehension (Section 4). Then, we flesh out in more detail what we take this to imply for autistic communication (Section 5).

4 Prediction in Language

Until recently, classic models of language comprehension have been incremental: hearers would build a representation of the speaker's utterance on the basis of the pieces they were hearing, as they were hearing them. Yet, according to some relatively novel accounts, predictions play a key role in linguistic comprehension. In a series of publications, Pickering and collaborators (Pickering and Garrod 2013, 2021; Gambi et al. 2015; Pickering and Gambi 2018) have proposed a model of language understanding where hearers are constantly issuing predictions about prosody, syntax, content, and intentions of the speaker. Predictions at these different levels are constantly and dynamically updated depending on what the speaker is actually producing. For instance, the hearer may predict a noun coming next, but the speaker produces a verb, which forces the hearer to revise the syntax she had initially predicted. Generally speaking, there is robust evidence that hearers anticipate what is coming next at various levels, even if predictions may sometimes be just about the word class or about semantic features of the upcoming word.

Although Pickering and Garrod's account is not explicitly couched within a PP framework,[3] it emphasizes the central role of predictions as well as the idea that comprehension and production should not be regarded as different systems. Rather, comprehension occurs through the production system: linguistic predictions are

[2] To better understand this point, it is helpful to consider the results of a recent visual search experiment conducted by Allenmark et al. (2021). Two groups of individuals – autistic and neurotypical – were instructed to look for a target object appearing on a screen at different locations, while a distractor was appearing with higher or lower probability in different parts of the display. Specifically, the distractor appeared with 90% probability in one half of the display, and with 10% probability in the other half. Eye-tracking data show that, upon habituation, both autistic and neurotypical individuals were able to avoid being distracted by the object appearing in the "frequent region". Yet, autistic individuals were slower to identify the target object when this would appear after the distractor was in the "rare region". In these situations, autistic individuals were more likely to look at the target, then move on to search elsewhere to finally return to the target and identify it correctly. This suggests that they initially misidentified the target as a distractor, and then went on to double-check and make sure before answering, thereby displaying greater uncertainty. By contrast, neurotypical individuals were more likely to gloss over the rare distractor event and directly go for the target, thereby employing a rough-and-ready heuristics that turned out to be correct in most circumstances. These results suggest that autistic individuals might overreact to prediction errors, and take them seriously whenever they occur.

[3] Generally speaking, PP accounts adhere to a broader set of commitments beyond the merely predictive nature of language, such as hierarchical generative models, precision weighting, and so on.

based on covert imitation of the speaker's production, so that hearers predict what the speaker is going to say and mean by engaging their own productive system.[4] As it happens in other areas, predictions are deemed to be challenged by errors. Errors force (or at least encourage) hearers to update their predictions, although many errors are simply ignored. For example, people understand 'The mother gave the candle the daughter' as meaning the daughter receiving the candle because it is the content they have predicted (Cai et al. 2022). A substantial body of work on "good enough" linguistic processing (e.g., Ferreira et al. 2002; Ferreira and Lowder 2016; Karimi and Ferreira 2016) rejects the picture of careful bottom-up and compositional sentence processing. Rather, as many examples of *semantic* and *grammatical illusions* show, processing tends to be biased towards jumping to overall situational conclusions. This is the case for so-called "Moses sentences" ("How many animals took Moses on the arch?") as well as for semantic illusions ("This book fills a much-needed gap").

As these examples show, good-enough processing sits quite comfortably with a PP apparatus. A successful predictive system for conversation requires a delicate balance of weight assignments between predictions and incoming signals. Moreover, predicting what an interlocutor is going to say engages all kinds of levels in the hierarchy, as such predictions involve the cultural, social and institutional environment, as well as more specific knowledge about the interlocutor and the situation at hand. When conversations are not one-on-one, but in a group, difficulties escalate even further. This suggests that autistic people may encounter general difficulties when it comes to understanding other people in conversation. To the extent that understanding implies predicting, a low level of confidence in one's own higher-level predictions will make understanding harder. Figuring out what the speaker wants to say may be incredibly hard, especially because most neurotypical conversations are highly open-ended and imprecise.

A linguistic processing style that assigns a lower level of confidence to the predictions about the interlocutor's output is likely to engender several consequences for autistic individuals, especially in terms of language comprehension, and in particular, when non-literal or non-explicit language is involved. As a consequence, linguistic comprehension in autistic individuals may be characterized by *higher uncertainty* about their own predictions compared to neurotypicals. Given the higher weight assigned to incoming signals, linguistic input ends up being processed in the here-and-now, thereby making any violation or imprecision appear more puzzling and salient (similarly to what happens perceptually, see Allenmark et al. 2021).[5] In

[4] This is in turn an articulation of the idea of "analysis by synthesis" (Bever and Poeppel 2010) taken up by PP in the form of the generative model. Recently, some proposals regarding sentence processing have also been advanced within the PP paradigm (Michel 2019; Rappe 2019).

[5] If this is correct, autistic individuals should display a preference for maximal precision in conversation. Some phenomena that have been discussed in the literature point in this direction. Examples include the search for neologisms and perfectionism – e.g., intolerance of other people's linguistic errors, the use of overly specific and idiosyncratic terms – as well as the violation of Gricean maxims of informativeness by offering too many details or by being too specific (Roberts et al. 2007; Paul et al. 2009; Volden and Phillips 2010).

the following section we discuss the case of metaphors to flesh out how the hypothesis would work in more detail.

5 Literal Comprehension: the Case of Metaphors

In this section we focus on a possible PP explanation behind the literalist bias observed in many autistic individuals in the case of *metaphor comprehension*. There is sufficiently robust evidence that autistic individuals experience difficulties in understanding metaphors (Vulchanova et al. 2015; Kalandadze et al. 2018), with a documented tendency towards literal interpretation (Vicente and Falkum 2023; Chahboun et al. 2016; Morra 2016). As further evidence of such difficulties, several intervention programs are specifically designed to support autistic individuals in the process of recognizing metaphors and facilitating their comprehension (Melogno and Pinto 2022; Melogno et al. 2017). That said, such difficulties are at times not directly apparent in the context of empirical studies, possibly as a consequence of specific experimental designs and type of metaphors selected (see Section 5.2). Although some researchers have suggested that issues with figurative language in autism may be rather indicative of issues with language *tout court* (Norbury 2005; Gernsbacher and Pripas-Kapit 2012), more recent evidence indicates that autistic individuals with intact language abilities show a delay in metaphorical processing (Chahboun et al. 2017) as well as a tendency to interpret figurative language literally (Walenski and Love 2017).

From a PP perspective, difficulties with figurative language may derive from its paradigmatically open-ended character. As we mention above, difficulties with figurative language (and with metaphors in particular) usually take two different forms: (a) comprehension issues *simpliciter* – i.e., having a hard time understanding a metaphor or idiom; (b) literal interpretation – i.e., interpreting a metaphor or idiom literally as opposed to figuratively. Here we suggest that (a) and (b) may arise from different processes, and we offer an explanation as to why they are typically observed in different populations – i.e., individuals with developmental language disorders or clinical as well as nonclinical conditions affecting structural language (e.g., being a L2 learner) and autistic individuals, respectively. These two processes may be summarized as follows.

Comprehension issues may arise because, upon hearing a non literal expression, the hearer expects a certain feature (or kind of feature) that does not appear. For instance, upon encountering the metaphor "that boy is a turtle", the hearer expects certain features to appear in the predicate (e.g., features that apply to persons), and is surprised by a predicate whose more salient features are not the expected ones. She may then try to retrieve said features, but lack of world knowledge, issues with linguistic development and/or abilities, or issues with analogical thinking may hinder her efforts. In such cases, the outcome will probably be that she cannot understand the metaphor altogether. In these cases, not understanding a figurative expression requires the hearer to stick to her prior prediction – e.g., that a sentence such as "That boy is…" would be followed by a predicate that applies to persons. In *literalism* cases, literal interpretation may instead arise from individuals overweighting

incoming signals at the expense of prior experiences. Literal interpretation may then be the safest bet after detecting an unexpected semantic clash. Neurotypicals would usually have higher confidence in their predictions, which in turn would make it easier to select features that are applicable to the subject of the utterance while suppressing the rest (e.g. slow, in the case of "that boy is a turtle"). By contrast, autistic individuals would display lower confidence in their higher-level predictions, thereby experiencing uncertainty concerning the features they had predicted the predicate would have. In that case, they may end up not suppressing any feature of the predicate, trying to make sense of the whole utterance assuming a literal interpretation of the metaphorical vehicle.[6]

The PP explanation that we are sketching may thus allow us to disambiguate the difference between not understanding a metaphorical expression and interpreting it literally. The former usually implies abiding by the prediction concerning features that are nonetheless not found in the linguistic stimulus. The individual holds onto their expectation of a certain semantic feature in the predicate; then, not being able to select an interpretation that has such a feature, they give up the attempt at making sense of the utterance. Thus, the interpretation of an utterance such as 'the boy is a turtle' ends up being something like: "the boy is something that turtles also are". The literalist interpretation, in contrast, *revises* the prediction concerning the semantic features of the predicate. In the "turtle" example, the prediction that ends up being revised is that the predicate's semantic features are features that apply to agents. As a result of such a revision, the hearer will entertain the possibility that the boy literally *is* a turtle. To further illustrate such a difference, consider the case of a L2 speaker who first encounters the non-literal use of the verb 'to sit', as in: "two whales sat underneath our boat the whole time we were anchored", or in "Nicole sat in Bruttig for weeks" (Fraser 2022). It is reasonable to assume that they might not fully understand what 'sit' means in such cases, though most likely they will be aware that it does not refer to being in a sitting position, since literal uses of 'sit' are not compatible neither with whales sitting nor with people sitting for weeks. Although the L2 speaker may not be able to guess the non-literal meaning conveyed by 'sit' in either example, they will not try to force a literal interpretation. The reason, we suggest, is that they would operate under a set of (stable) higher-level assumptions that make it possible to understand that the relevant sentence requires a non-literal interpretation.

Notably, the ability to represent higher level priors per se is not sufficient: in fact, autistic individuals surely possess some higher-level priors such as the assumption that some sentences can be interpreted metaphorically (see Morra 2016, for some first-person reports). As we will see in the next section, autistic individuals do not seem to experience difficulties in producing metaphors, which means that metaphors

[6] Different kinds of metaphors may engender different experiences in this respect. For instance, metaphors in subject position (referential metaphors), or any metaphorical expression that is uttered as the beginning of a phrase (e.g., 'the autumn of life') requires that the interpreter readjust her predictions differently. The hearer expects a continuation involving certain semantic features that do not appear. Low confidence in such expectation might be beneficial, but only provided that higher-order predictions about general intelligibility of what speakers say are sufficiently stable.

in themselves are not alien to them. However, priors also need to be *stably represented* (i.e., trusted) in the face of unexpected events: e.g., the hearer should not question whether the speaker really has the intention to express a metaphor.

Further, to pick out the proper non-literal interpretation among many possibilities, other stable priors – such as the ones about general conversational context – need to be present. As we suggest, those priors might also be unstable for an autistic individual, especially when having a conversation with neurotypical people. Consider again the example: "The boy is a turtle". In this case, it is the overall context that determines whether this sentence should be interpreted literally. For instance, the sentence *could* be interpreted literally in the context of a fictional story where a boy turns into a turtle and a girl into a rabbit. In another context, such as when we are talking about certain traits of a real-world boy, the sentence is better interpreted metaphorically. Now in this latter case, the context also determines how exactly to interpret the metaphor: it could be interpreted as the boy being slow, or as living an isolated and overly sheltered life. Overall, there is a good number of predictions involved in interpreting any utterance that is not literal and/or explicit, such that a diminished confidence in any of said predictions may result in retreating to the literal interpretation.

In what follows, we argue that appealing to uncertainty concerning predictions about speaker's production can explain two puzzling facts: the comprehension-production asymmetry observed in autistic individuals, and the mixed results obtained in the lab versus the experience of many autistic individuals in real life situations.

5.1 The Comprehension-Production Asymmetry

A puzzling general asymmetry between comprehension and production has been repeatedly observed in autism. Kanner (1943) already noted that otherwise hypersensitive children seemed to be unconcerned with loud sounds as long as they were the ones producing them: "the child himself can happily make as great a noise as any that he dreads and move objects about to his heart's content" (p. 245). This passage suggests that sounds produced by the individuals themselves would be easier to process as opposed to the ones coming from the environment. In the domain of language, another dominant idea has been that autistic individuals would experience fewer issues in production than in comprehension, thereby reversing a pattern usually observed in neurotypicals (Davidson and Weismer 2017).

With respect to metaphor production, autistic individuals have been found to perform comparably to – and in some cases better than – neurotypicals. Indeed, a series of studies by Kasirer and colleagues show that autistic individuals, while having difficulties with metaphor comprehension, are able to produce novel and creative metaphors (Kasirer and Mashal 2016; Kasirer et al. 2020). First-person accounts also substantiate this point: as reported by Morra's analysis of a series of threads in the Wrong Planet forum (Morra 2016), 63% of respondents report using metaphors often, whereas only 37% of them perceive their metaphor comprehension as "unproblematic". See the following for some examples: "[…] I am perfectly capable of cocking my brain and throwing [metaphors and analogies]

out, not always so good at catching them"; "I've had trouble understanding common metaphors (like kill two birds with one stone), but I'm really good at figuring out literary metaphors and creating metaphors"; "i can construct metaphors, but i can not understand many metaphors that i did not create" (pp. 135–137).

How can we explain this puzzling asymmetry between comprehension and production? Drawing on the PP framework outlined above, it is reasonable to think that in cases of linguistic production the overall degree of uncertainty will be reduced. Barring other structural forms of linguistic disability, linguistic production is more controlled and guided in nature than linguistic comprehension: one may plan what to say next, which kind of words and grammatical construction to use, how far to depart from literal meaning, etc. All this does not involve the processing of external sensory information, which may inhibit the development of stable and precise higher-level priors if they are given excessive weight. In this sense, the degree of uncertainty involved in linguistic production is less overwhelming compared to comprehension.

Notably, increased certainty about knowing what to say or what is coming next might even trump uncertainty in being understood by others. Indeed, there seem to be several situations in which autistic individuals seemingly disregard context and/or their interlocutor. For example, they may break Gricean maxims of relevance or quantity (Paul et al. 2009), deliberately speak in a different language or heavily employ neologisms and overly specific terms (Llorente et al. 2022), which violates the requirement of looking for common lexicons (Clark 1996). The production of creative metaphors reported by Kasirer and Mashal (2014, 2016) and Kasirer et al. (2020) appears to be consistent with this idea. Once a fitting metaphor has been identified, the autistic speaker seems to be more focused on reproducing it *as is* than on determining whether such an expression would belong to the common ground with their interlocutor. Some first-person accounts reported by Morra (2016) also stress the difficulty in being understood by others when using figurative language. See for instance the following exchange:

> Speaker A: "I understand metaphors just fine and use them quite often […]";
> Speaker B: "Same here, but sometimes they aren't caught by others";
> Speaker C: "I try to use metaphors to help them understand. Unfortunately, using motorcycle metaphors is lost on most people".

This linguistic behavior becomes less puzzling if we assume that attention in production may be more focused on knowing what to say and how to say it – e.g., on carefully choosing one's words – as opposed to other aspects of linguistic and social communication – e.g., being understood by one's conversational partners. As we mention above, focusing on these other aspects would require the mobilization of massive background knowledge as well as a stable representation and selection of the contextually appropriate high-level priors, which might be particularly challenging for autistic individuals. In the next section we tackle yet another gap that has been observed in the studies on figurative language and autism, namely the discrepancy between results obtained in laboratory settings and daily life experiences.

5.2 Mixed Results in the Lab and Daily Life Experience

As mentioned, most laboratory studies on non-literal uses of language in autism yield mixed results. Here we want to explain at least part of such variability. We begin by summarizing some of these mixed results and then we move on to highlight one factor that we think is relevant to account for the gap between laboratory and everyday settings. In line with the rest of the section, this factor concerns potentially relevant differences in the degree of predictability and control displayed by these different contexts.

Kissine et al. (2015) and Marocchini et al. (2022), find that autistic children can perform just as neurotypicals in understanding conventional indirect speech acts (i.e., knowing that "Can you pass me the salt?" counts as a request even if it has the form of a yes/no question). Yet, previous work by Paul and Cohen (1985), and Ozonoff and Miller (1996) found that autistic participants exhibited difficulties in grasping indirect speech acts appropriately. Even the derivation of scalar implicatures (e.g., understanding 'some' as expressing 'some but not all') appears to be difficult according to some studies (Pastor-Cerezuela et al. 2018; Schaeken et al. 2018; Mazzaggio et al. 2021), but not in several others (Chevallier et al. 2010; Su and Su 2015; Hochstein et al. 2018; Pijnacker et al. 2009). Studies concerning metaphor comprehension yield similarly mixed results. Norbury (2005), in her seminal study, suggested that, if matched on structural language, autistic and typically developing children performed just as well in a forced choice metaphor task. Her view, as mentioned above, has given rise to the idea that metaphor understanding is related to structural language development, which means that autistic children may experience a delay in metaphor understanding that corresponds to the more general delay they experience in language acquisition. However, Vulchanova and colleagues find a literalist bias in metaphor comprehension in a series of studies (see references above). In turn, Kasirer and Mashal (2014, 2016) and Kasirer et al. (2020) report difficulties with conventional metaphors, but not with novel metaphors.

There seems to be more agreement concerning irony and sarcasm. Many studies have found strong difficulties in irony comprehension (Deliens et al. 2018; Happé 1993; Kaland et al. 2002; MacKay and Shaw 2004; Martin and McDonald 2004; Saban-Bezalel et al. 2019). Some studies have found delays rather than difficulties, thereby suggesting a compensatory picture, as shown by implicit measures such as response times and eye gaze (Pexman et al. 2011) or brain imaging techniques (Colich et al. 2012; Wang et al. 2006; Williams et al. 2013). Still, if the task reduces demands, some autistic individuals seem to experience fewer difficulties (Glenwright and Agbayewa 2012).

To some extent, these mixed results can be explained by appealing to autism's heterogeneity and the fact that experimental groups can be relatively small. Thus, it may be that responses to the same task may vary considerably from one experimental group to another. However, experimental design also has an obvious influence. In one of the most comprehensive reviews on the topic, Kalandadze et al. (2019) identifies several dimensions that may affect performance in metaphor comprehension

tasks, such as experimental design and setting.[7] An interesting dimension that we want to highlight here relates to the extent to which some tasks are more *structured* – and, as a consequence, more predictable – than others. For instance, while Kasirer and Mashal (2014, 2016) use a forced choice task with possible explications of a metaphorical Noun + Adj expression, Chahboun et al. (2017) use a lexical priming task. These two ways of testing metaphor comprehension and the literalist bias exhibit many differences. To begin with, the former is about selecting paraphrases and guessing which one is better, with little time constraints, while the latter is about making quick decisions on the basis of associations. The task employed by Kasirer and Marshal is a quite structured, multiple choice task that offers the possibility to ponder possible responses. A lexical priming task, in contrast, is much more demanding and unstructured: it is a "game" about reacting quickly to a word or non-word stimulus. Similarly – as emphasized by Kalandadze et al. (2019) – multiple-choice and non-verbal enactment tasks (i.e., acting out a metaphor with toys after having heard a story containing such metaphor) are more structured – and thus arguably less demanding – than tasks centered around verbal explanation, such as answering open questions about metaphors heard in a story (Rundblad and Annaz 2010).

The study by Paul and Cohen (1985) is also a good example of how experimental designs can have a strong influence on results. Paul and Cohen evaluated comprehension of indirect speech acts in two different cases. In both cases, participants had to color circles either in blue or red following indirect requests such as: "I'll be happy if you color this circle blue". However, in the first case, participants were explicitly informed that they would be presented with requests, while in the second, requests were made as part of a conversation held between experimenter and participant while participants were drawing. In both cases, autistic participants performed worse than controls matched by verbal mental age, but they performed clearly better in the first case than in the second, arguably because the task demands were more explicit and left less room for uncertainty.

This suggests – in line with the PP approach outlined above – that more structured and predictable tasks may be more amicable to autistic participants. Now, think about daily life conversations, which are paradigmatically more unpredictable and involve a greater number of variables. Sometimes uncertainty about how a metaphorical utterance should be understood is due to the metaphor not being sufficiently embedded in a context. For instance, a sentence such as: "My sister was a rock" could be understood in any of the following senses: my sister was solid, reliable, or she was indestructible, or even in some situations she was stupid or stubborn (Pouscoulous 2014, p. 246). A clearly structured conversation would facilitate comprehension in such cases: for instance, contextual elements may be highlighted and reinforced, so that hearers can be more confident about the relevant properties

[7] Notably, it has been already observed that experimental design and setting affect performance in metaphor comprehension both in neurotypical and schizophrenic populations (see Pouscoulous 2011 and 2014 and Rossetti et al. 2018 respectively).

of the abovementioned metaphor – e.g., reliability or strength. Yet, typical conversations lack such a structured form.

More generally, it is virtually impossible to predict whether a given conversation would involve non-literal language, be it in the form of direct or indirect requests, metaphors or idioms, implicatures, or irony and sarcasm. Some of these linguistic forms do not display a specifically recognizable structure, thereby making it harder to identify them in a given stretch of conversation. By contrast, some of the studies discussed above – e.g., forced choice tasks – structure the environment in a way that makes it apparent that some specific linguistic forms will appear, or at least that one correct answer will be presented along with some distractors. This option is hardly ever present in everyday conversations, where participants are left on their own to figure out how to interpret their interlocutor's utterances. A similar pattern may be detected in studies that explore cognitive flexibility and task switching, where observed behavioral difficulties rarely reflect inflexibility measures collected in the lab (Geurts et al. 2009). Also in this case, many laboratory tasks tend to be quite compartmentalized and structured (e.g., Wisconsin Sorting Cards Task), making it difficult to replicate the complexity and degree of uncertainty that people encounter in everyday situations. Geurts et al. (2009) made an important claim with respect to a lack of correspondence between laboratory results concerning cognitive flexibility and observed cognitive flexibility difficulties in the autistic population. We suggest that there may be a similar lack of correspondence between what we observe in structured tasks in the laboratory settings and difficulties that arise in much more unstructured situations in daily life conversations.

In the next section we briefly explore literalism in other forms of figurative language beyond metaphors, also trying to corroborate a PP-style explanation that would accommodate the complex and often unpredictable character of everyday communication.

6 Literalism Beyond Metaphors

A PP approach can also be endorsed to explain the difficulties of autistic individuals related to the comprehension of other non-literal uses of language. We already mentioned some of these uses, such as indirect speech acts. Ideally, a PP approach should offer a unified treatment of the literalist bias in autism observed in all non-literal uses, including those that are currently indisputably related to ToM issues, or to "social pragmatics" more generally, namely, typically, irony and sarcasm (Andrés-Roqueta and Katsos, 2017, 2020). In this section, we focus on implicatures, since recent work by Wilson and Bishop (2019, 2021, 2022) has already related difficulties with implicatures in the autistic population to uncertainty. We then conclude with some speculations concerning irony.

Research into implicature processing by autistic individuals is still limited. While there is work on *some-but-not-all* scalar implicature derivation, significantly less work has been conducted on other forms of scalar reasoning (e.g., ad hoc implicatures), and particularly scarce work exists about conversational implicatures. Concerning ad hoc implicatures, Mazzaggio et al. (2021) found that autistic children

have difficulties with both scalar and ad hoc implicatures. In the case of ad hoc implicatures, autistic children experienced more difficulties than their typically developing peers inferring from: "My bed is the one with a teddy bear" that the speaker refers to the bed with only a teddy bear and not to the bed with a teddy bear and a doll. The authors suggest that the difficulties with those types of implicatures in autistic children is determined by an impaired capacity to determine what the relevant alternatives are in each context, which would also be predicted by the PP account of autism. In this case, however, there would be no impairment as such; rather, autistic children would be unsure about whether the speaker is being maximally informative. Concerning conversational implicatures, we find the pioneering work conducted by Wilson & Bishop particularly interesting. In a series of papers, Wilson and Bishop (2019, 2021, 2022) develop a 7-task battery of tests to investigate whether core language skills and pragmatic abilities can be teased apart and, thus, whether they can be said to result from different cognitive underpinnings. Focusing on their Implicature Comprehension Test (ICT), featuring particularized conversational implicatures, they observe that autistic individuals are twice as likely to choose a "non-normative" interpretation of an implied meaning, and five times as likely to select "I don't know" as an answer when asked about the presence of an implicated meaning (Wilson and Bishop 2021).

In Wilson & Bishop's ICT, participants watch short animated cartoons featuring two characters, Tom and Sally, who participate in a dialogue. After each dialogue, a robot appears on a different screen and asks whether the implicature can be derived. In their 2021 study, the participant can reply "yes", "no" or "don't know". In their design, the task directly inquires about the implicature, which makes the generation of the implicature an explicit act. In 36 items, the participant needs to process the implicature to answer the question correctly. "Yes" is the "normative" answer in half of the items, and "No" in the other half. This is one of the examples:

Sally: Can the two of us sit here?
Tom: The children just went to find the toilet.
Robot: Do you think Tom and Sally can sit there?
→ No

7 Conclusion

In this paper we show how a PP-style explanation may be productively applied to a range of issues concerning pragmatic difficulties exhibited by many autistic individuals. Prominent PP explanations have already been proposed to account for several autistic traits, including hypersensitivity (Van de Cruys et al. 2019), repetitions, adherence to routines, and preference for structured environments (Lawson et al. 2017). Most of these explanations rely on the idea that the autistic brain assigns more weight to incoming signals at the expense of prior predictions. As a consequence, a lower degree of confidence ends up being assigned to each prediction, thereby generating higher uncertainty. Here we show how a similar hypothesis may shed some light on the literalist tendency frequently observed in the autistic

population. We start by drawing on some recent accounts (Pickering and Gambi 2018, Ferreira and Chantavarin 2018) to establish that predictions play a key role in everyday comprehension, where errors and violations are systematically ignored in favor of predictions. If understanding implies predicting, higher uncertainty with respect to one's own predictions is likely to make comprehension significantly harder. We then illustrate how such clashes may occur by discussing the case of metaphor comprehension, which tends to showcase the literalist bias observed in many autistic individuals. According to our hypothesis, when it comes to understanding metaphors – e.g., "that boy is a turtle" – autistic individuals experience *more uncertainty* concerning the features they had predicted the predicate would have – e.g., features related to human beings. As a consequence, they may end up not suppressing any feature of the predicate, trying to make sense of the whole utterance through a literal interpretation – i.e., the boy literally *is* a turtle.

Our hypothesis has two main advantages. First, it allows us to make sense of a puzzling set of data concerning the apparent asymmetry between metaphor comprehension and production in the autistic population. Indeed, empirical studies (Kasirer and Mashal 2016; Kasirer et al. 2020) and first-person accounts (Morra 2016) converge on the idea that autistic individuals are able to produce novel and creative metaphors. In our view, this depends on the fact that the overall degree of uncertainty is reduced in linguistic production, given that the speaker is in control of what comes next. The comprehension difficulties highlighted by the literature may therefore not be due to metaphors per se, but to a higher degree of uncertainty with respect to one's own predictions. This is likely to generalize to other aspects of linguistic communication beyond the scope of this paper – such as irony, indirect speech acts, etc. One may wonder whether a similarly high degree of uncertainty could also apply to linguistic production. In our view, less uncertainty in production results from a higher value being placed on "knowing what to say" (e.g., to minimize anxiety), combined with a diminished focus on being understood by others. Some linguistic behaviors observed in autism – such as the violation of Gricean maxims or the frequent use of neologisms – suggest that an imbalance of this sort might occur (see Section 5.1).

Second, our hypothesis offers a sensible explanation of the gap we observe between empirical results – which often struggle to identify specific difficulties – and everyday situations, where literalism is widely reported as an issue that autistic people experience. Generally speaking, studies conducted in laboratory settings tend to be more structured and predictable, thereby drastically reducing uncertainty. By contrast, daily life conversations are significantly more unpredictable and involve a greater number of variables. The observed gap between laboratory results and daily life experiences may therefore reflect the different degree of structure and predictability of these two environments. This point also applies more generally, given that the gap between laboratory results and daily life experiences extends to several areas of autism research. The very nature of the phenomena of study – e.g., conversational abilities, social and language skills – often makes these traits resistant to being captured by studies conducted exclusively in laboratory settings. A more complete picture could be obtained by combining results obtained in the lab with more observational measures – such as recorded conversations – and with the qualitative

analyses of first-person reports, in order to detect possible discrepancies across contexts and conditions. This suggests, in line with several recommendations (see for instance Eigsti and Schuh 2016) that research should orient itself towards ecologically more valid paradigms.

Given the results obtained, and especially the fact that autistic individuals are five times as likely to select "I don't know" as an answer when asked about the presence of an implicated meaning, Wilson and Bishop (2021) speculate that the "I don't know" answer may suggest a cognitive preference for certainty and explicit communication.[8] We find Wilson and Bishop's work particularly interesting because of the role they assign to intolerance of uncertainty. According to them, difficulties with implicature derivation may relate to how uncomfortable the individual feels when communication is not explicit. However, as we have explained above, discomfort with uncertainty may be an epiphenomenon generated by a higher level of experienced uncertainty. Choosing "I don't know" responses, as well as failing to derive an implicature for lack of confidence, seem to be a result of higher uncertainty, not of intolerance of uncertainty. That is, the choice of 'I don't know' responses may reveal that autistic individuals are unsure about whether their expectation (i.e., the response has to be "yes" or "no") has been satisfied.

What about irony? In the case of irony, the hearer often needs to interpret a sentence as expressing the opposite of what is literally expressed. Importantly, depending on the context, the sentence *can* also be unproblematically interpreted and comprehended literally (unlike what happens with most metaphors).[9] For instance: "This is a great friend" can in principle be interpreted both literally and ironically in different contexts. Due to its features, irony therefore places a higher demand on context comprehension (especially social context comprehension, see Fabry 2021). We suggest that irony may be a particularly difficult case, given that the uncertainty related to higher order priors probably plays an even larger role in comprehension. Indeed, while one can perfectly recognize a metaphor without understanding what exactly it means – precisely because its literal meaning is in most cases hard to work out – one might get stuck more easily with the literal meaning of an ironic sentence. What also increases uncertainty in the case of irony is that, while "easy" metaphors tend to have a more or less recognizable structure ("X is Y"), potentially every utterance may be interpreted ironically. This makes it particularly difficult to identify possible patterns and to successfully predict when irony is going to occur within a conversation. The lack of a proper context representation, possibly due to the overweighting of incoming stimuli at the expense of higher-level priors, may lead to not recognizing the irony or to being highly uncertain about whether irony is being employed. Although there is evidence that irony comprehension is, generally speaking, challenging for autistic individuals (Barzy et al. 2022), some results are intriguing. For

[8] Note also that the kind of implicatures tested by Wilson and Bishop belong to what Jary (2013) labeled 'material implicatures', whose derivation does not require reflecting about the interlocutors' mental states (see Abbot-Smith et al. 2022 for empirical support).

[9] Note that some metaphors *can* also be interpreted literally. For instance: "This surgeon is a butcher" may be legitimately interpreted as: "The person, who is a butcher, is (also) a surgeon [= she has two professions]". Yet, literally interpretable metaphors are the exception rather than the rule.

instance, Panzeri et al. (2022) found an interesting bimodal distribution of results when testing three groups of children – one autistic group and two typically developing groups of different ages – for irony comprehension. While the majority of the autistic group performed worse than controls, a minority performed at ceiling. More research is therefore needed to determine whether a PP explanation may also be successfully applied to irony comprehension, and we aim to develop such an explanation in future work.

Acknowledgements The authors want to express their gratitude to all Lindy Lab members for their comments, and in particular to Elena Castroviejo and Isabel Martín González for their valuable feedback. Versions of this paper were presented at the 2022 PLM conference in Warsaw, the 2023 Logos 30th Anniversary Conference in Barcelona, and the 2023 IPrA conference in Brussels. We are grateful to audiences in these events for their feedback. Special thanks are due to Nicholas Allott and Ingrid Lossius Falkum. Thanks also to three reviewers from RoPP and to editor Derek Ball for helping us shape up the paper and clarify our views.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature. Research for this paper was funded by the following grants: (1) BBVA Foundation Grant for Scientific Research Projects 2021 (RILITEA) funded AV and VP (The Foundation takes no responsibility for the opinions, statements and contents of this project, which are entirely the responsibility of its authors). (2) Agencia Estatal de Investigación (AEI) and Ministry of Science and Innovation, grant number PID2021-122233OB-I00 (AV and VP). (3) The Basque Government, grant number IT1537-22 (AV and VP). (4) Agencia Estatal de Investigación (AEI) and Ministry of Science and Innovation, grant numbers PID2021-128950OB-I00 and IJC2020-043408-I (VP).

Data Availability Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

References

Abbot-Smith, K., C. Schulze, N. Anagnostopoulou, M. Zajączkowska, and D. Matthews. 2022. How do 3-year-olds use relevance inferencing to interpret indirect speech? *First Language* 42 (1): 3–21.

Allenmark, F., Z. Shi, R.L. Pistorius, L.A. Theisinger, N. Koutsouleris, P. Falkai, H.J. Müller, and C. M. Falter-Wagner. 2021. Acquisition and use of 'priors' in autism: Typical in deciding where to look, atypical in deciding what is there. *Journal of Autism and Developmental Disorders, 51*(10), 3744–3755.

American Psychiatric Association. 2022. *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision*. (DSM-5-TR).

Andrés-Roqueta, C., and N. Katsos. 2020. A distinction between linguistic and social pragmatics helps the precise characterization of pragmatic challenges in children with autism spectrum disorders and developmental language disorder. *Journal of Speech, Language, and Hearing Research* 63 (5): 1494–1508.

Arthur, T., S. Vine, G. Buckingham, M. Brosnan, M. Wilson, and D. Harris. 2022. Testing predictive coding theories of autism spectrum disorder using models of active inference. PsyArXiv; 2022. https://doi.org/10.31234/osf.io/zyfkn.

Barzy, M., R. Filik, D. Williams, and H.J. Ferguson. 2022. Emotional processing of ironic vs. literal criticism in autistic and non-autistic adults: evidence from eye-tracking. *Autism Research*, 13 (4): 563–578. ISSN 1939–3792.

Bendtz, K., S. Ericsson, J. Schneider, J. Borg, J. Bašnáková, and J. Uddén. 2022. Individual differences in Indirect Speech Act Processing found outside the Language Network. *Neurobiology of Language* 3 (2): 287–317.

Bervoets, J., D. Milton, and S. Van de Cruys. 2021. Autism and intolerance of uncertainty: an ill-fitting pair. *Trends in Cognitive Sciences* 25 (12): 1009–1010.

Bever, T.G., and D. Poeppel. 2010. Analysis by synthesis: a (re-) emerging program of research for language and vision. *Biolinguistics* 4 (2–3): 174–200.

Boulter, C., M. Freeston, M. South, and J. Rodgers. 2014. Intolerance of uncertainty as a framework for understanding anxiety in children and adolescents with autism spectrum disorders. *Journal of Autism and Developmental Disorders* 44: 1391–1402.

Bühler, D., A. Perovic, and N. Pouscoulous. 2018. Comprehension of novel metaphor in young children with Developmental Language Disorder. *Autism & Developmental Language Impairments* 3: 1–11, 2396941518817229.

Cai, Z.G., N. Zhao, and M.J. Pickering. 2022. How do people interpret implausible sentences? *Cognition* 225: 105101.

Carleton, R.N., M.K. Mulvogue, M.A. Thibodeau, R.E. McCabe, M.M. Antony, and G.J. Asmundson. 2012. Increasingly certain about uncertainty: intolerance of uncertainty across anxiety and depression. *Journal of Anxiety Disorders* 26 (3): 468–479.

Chahboun, S., V. Vulchanov, D. Saldana, H. Eshuis, and M. Vulchanova. 2016. Can you play with fire and not hurt yourself? A comparative study in figurative language comprehension between individuals with and without autism spectrum disorder. *PloS One*, 11(12): e0168571.

Chahboun, S., V. Vulchanov, D. Saldana, H. Eshuis, and M. Vulchanova. 2017. Can you tell it by the prime? A study of metaphorical priming in high-functioning autism in comparison with matched controls. *International Journal of Language & Communication Disorders* 52 (6): 766–785.

Chevallier, C., D. Wilson, F. Happé, and I. Noveck. 2010. Scalar inferences in autism spectrum disorders. *Journal of Autism and Developmental Disorders* 40: 1104–1117.

Chrysaitis, N.A., and P. Seriès. 2022. 10 years of Bayesian theories of autism: a comprehensive review. *Neuroscience & Biobehavioral Reviews 145*:1–17, 105022.

Clark, H.H. 1996. Communities, commonalities. In *Rethinking linguistic relativity*, ed. J. Gumperz and S.C. Levinson, 324–355. Cambridge University Press.

Colich, N.L., A.T. Wang, J.D. Rudie, L.M. Hernandez, S.Y. Bookheimer, and M. Dapretto. 2012. Atypical neural processing of ironic and sincere remarks in children and adolescents with autism spectrum disorders. *Metaphor and Symbol* 27 (1): 70–92.

Davidson, M.M., and S. Ellis Weismer. 2017. Reading comprehension of ambiguous sentences by school-age children with autism spectrum disorder. *Autism Research* 10 (12): 2002–2022.

Deliens, G., F. Papastamou, N. Ruytenbeek, P. Geelhand, and M. Kissine. 2018. Selective pragmatic impairment in autism spectrum disorder: indirect requests versus irony. *Journal of Autism and Developmental Disorders* 48: 2938–2952.

Dugas, M.J., P. Gosselin, and R. Ladouceur. 2001. Intolerance of uncertainty and worry: investigating specificity in a nonclinical sample. *Cognitive Therapy and Research* 25: 551–558.

Dugas, M.J., K. Buhr, and R. Ladouceur. 2004. The Role of Intolerance of Uncertainty in Etiology and Maintenance. In *Generalized anxiety disorder: Advances in research and practice*, ed. R.G. Heimberg, C.L. Turk, and D.S. Mennin, 143–163. The Guilford Press.

Eigsti, I.M., and J.M. Schuh. 2016. Language acquisition in autism spectrum disorders: beyond standardized language measures. In *Innovative investigations of Language in Autism Spectrum Disorder*, ed. L. Naigles. Berlin, Germany: APA/Walter de Gruyter.

Fabry, R.E. 2021. Getting it: a predictive processing approach to irony comprehension. *Synthese* 198 (7): 6455–6489.

Ferreira, F., and S. Chantavarin. 2018. Integration and prediction in language processing: A synthesis of old and new. *Current Directions in Psychological Science* 27 (6): 443–448.

Ferreira, F., and M.W. Lowder. 2016. Prediction, information structure, and good-enough language processing. In *Psychology of learning and motivation*, vol. 65, 217–247. Academic.

Ferreira, F., K.G. Bailey, and V. Ferraro. 2002. Good-enough representations in language comprehension. *Current Directions in Psychological Science* 11 (1): 11–15.

Fraser, K. E. 2022. The literal/non-literal divide synchronically and diachronically: The lexical semantics of an English posture verb. Doctoral Dissertation. University of the Basque Country – UPV/EHU.

Gambi, C., U. Cop, and M.J. Pickering. 2015. How do speakers coordinate? Evidence for prediction in a joint word-replacement task. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior* 68: 111–128.

Gernsbacher, M.A., and S.R. Pripas-Kapit. 2012. Who's missing the point? A commentary on claims that autistic persons have a specific deficit in figurative language comprehension. *Metaphor and Symbol* 27 (1): 93–105.

Geurts, H.M., B. Corbett, and M. Solomon. 2009. The paradox of cognitive flexibility in autism. *Trends in Cognitive Sciences* 13 (2): 74–82.

Glenwright, M., and A.S. Agbayewa. 2012. Older children and adolescents with high-functioning autism spectrum disorders can comprehend verbal irony in computer-mediated communication. *Research in Autism Spectrum Disorders* 6 (2): 628–638.

Happé, F.G. 1993. Communicative competence and theory of mind in autism: a test of relevance theory. *Cognition* 48 (2): 101–119.

Happé, F., and U. Frith. 2006. The weak coherence account: detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders* 36 (1): 5–25.

Hochstein, L., A. Bale, and D. Barner. 2018. Scalar implicature in absence of epistemic reasoning? The case of autism spectrum disorder. *Language Learning and Development* 14 (3): 224–240.

Hodgson, A.R., M.H. Freeston, E. Honey, and J. Rodgers. 2017. Facing the unknown: intolerance of uncertainty in children with autism spectrum disorder. *Journal of Applied Research in Intellectual Disabilities* 30 (2): 336–344.

Jary, M. 2013. Two types of implicature: material and behavioural. *Mind & Language* 28 (5): 638–660.

Jenkinson, R., E. Milne, and A. Thompson. 2020. The relationship between intolerance of uncertainty and anxiety in autism: a systematic literature review and meta-analysis. *Autism* 24 (8): 1933–1944.

Kaland, N., A. Møller-Nielsen, K. Callesen, E.L. Mortensen, D. Gottlieb, and L. Smith. 2002. A new advanced test of theory of mind: evidence from children and adolescents with Asperger syndrome. *Journal of Child Psychology and Psychiatry* 43 (4): 517–528.

Kalandadze, T., C. Norbury, T. Nærland, and K.A.B. Næss. 2018. Figurative language comprehension in individuals with autism spectrum disorder: a meta-analytic review. *Autism* 22 (2): 99–117.

Kalandadze, T., V. Bambini, and K.A.B. Næss. 2019. A systematic review and meta-analysis of studies on metaphor comprehension in individuals with autism spectrum disorder: do task properties matter? *Applied Psycholinguistics* 40 (6): 1421–1454.

Kanner, L. 1943. Autistic disturbances of affective contact. *Nervous Child* 2 (3): 217–250.

Karimi, H., and F. Ferreira. 2016. Good-enough linguistic representations and online cognitive equilibrium in language processing. *Quarterly Journal of Experimental Psychology* 69 (5): 1013–1040.

Kasirer, A., and N. Mashal. 2014. Verbal creativity in autism: comprehension and generation of metaphoric language in high-functioning autism spectrum disorder and typical development. *Frontiers in Human Neuroscience* 8: 615.

Kasirer, A., and N. Mashal. 2016. Comprehension and generation of metaphors by children with autism spectrum disorder. *Research in Autism Spectrum Disorders* 32: 53–63.

Kasirer, A., E. Adi-Japha, and N. Mashal. 2020. Verbal and figural creativity in children with autism spectrum disorder and typical development. *Frontiers in Psychology* 11: 559238.

Kissine, M., J. Cano-Chervel, S. Carlier, P. De Brabanter, L. Ducenne, M.C. Pairon, and J. Leybaert. 2015. Children with autism understand indirect speech acts: evidence from a semi-structured act-out task. *PLoS One* 10 (11): e0142191.

Lawson, R.P., C. Mathys, and G. Rees. 2017. Adults with autism overestimate the volatility of the sensory environment. *Nature Neuroscience* 20 (9): 1293–1299.

Llorente, M., J. Martos, R. Ayuda, S. Freire, A. Gonzaléz, and I. Gutierréz. 2022. *Inflexibilidad en Los Niños Con Tea*. Ciencias de la Educación Preescolar y Especial. CEPE.

Löhr, G., and C. Michel. 2023. Conceptual engineering, predictive processing, and a new implementation problem. *Mind & Language,* 1–19. https://doi.org/10.1111/mila.12471.

MacKay, G., and A. Shaw. 2004. A comparative study of figurative language in children with autistic spectrum disorders. *Child Language Teaching and Therapy* 20 (1): 13–32.
Marocchini, E., S. Di Paola, G. Mazzaggio, and F. Domaneschi. 2022. Understanding indirect requests for information in high-functioning autism. *Cognitive Processing* 23: 129–153.
Martin, I., and S. McDonald. 2004. An exploration of causes of non-literal language problems in individuals with Asperger syndrome. *Journal of Autism and Developmental Disorders* 34: 311–328.
Mashal, N., and A. Kasirer. 2011. Thinking maps enhance metaphoric competence in children with autism and learning disabilities. *Research in Developmental Disabilities* 32 (6): 2045–2054.
Mazzaggio, G., F. Foppolo, R. Job, and L. Surian. 2021. Ad-hoc and scalar implicatures in children with autism spectrum disorder. *Journal of Communication Disorders* 90: 106089.
McDougal, E., D.M. Riby, and M. Hanley. 2020. Teacher insights into the barriers and facilitators of learning in autism. *Research in Autism Spectrum Disorders* 79: 101674.
Melogno, S., and M.A. Pinto. 2022. Devising trainings to enhance the capabilities of children with Autism Spectrum disorder to cope with metaphor: a review of the literature. *Frontiers in Communication*, 7: 1–6, 915873.
Melogno, S., M. A. Pinto, and M. Orsolini. 2017. Novel metaphors comprehension in a child with high-functioning autism spectrum disorder: a study on assessment and treatment. *Frontiers in Psychology* 7: 2004.
Michel, C. 2019. The Liar Paradox in the predictive mind. *Pragmatics & Cognition* 26 (2–3): 239–266.
Mol, J. 2020. Autistic in times of Covid-19. *Professionally Autistic*. Posted on April 25th, 2020.
Morra, L. 2016. Raising awareness of how Asperger persons perceive their capacity to use metaphors. *Medicina & Storia* XVI (9–10): 129–146.
Mottron, L., M. Dawson, I. Soulières, B. Hubert, and J. Burack. 2006. Enhanced perceptual functioning in autism: an update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders* 36: 27–43.
Neil, L., N.C. Olsson, and E. Pellicano. 2016. The relationship between intolerance of uncertainty, sensory sensitivities, and anxiety in autistic and typically developing children. *Journal of Autism and Developmental Disorders* 46: 1962–1973.
Norbury, C.F. 2005. The relationship between theory of mind and metaphor: evidence from children with language impairment and autistic spectrum disorder. *British Journal of Developmental Psychology* 23 (3): 383–399.
Ozonoff, S., and J.N. Miller. 1996. An exploration of right-hemisphere contributions to the pragmatic impairments of autism. *Brain Language* 52 (3): 411–434.
Palmer, C.J., A.K. Seth, and J. Hohwy. 2015. The felt presence of other minds: predictive processing, counterfactual predictions, and mentalising in autism. *Consciousness and Cognition* 36: 376–389.
Palmer, C.J., R.P. Lawson, and J. Hohwy. 2017. Bayesian approaches to autism: towards volatility, action, and behavior. *Psychological Bulletin* 143 (5): 521.
Panzeri, F., G. Mazzaggio, B. Giustolisi, S. Silleresi, and L. Surian. 2022. The atypical pattern of irony comprehension in autistic children. *Applied Psycholinguistics* 43 (4): 757–784.
Pastor-Cerezuela, G., Tordera Yllescas, J.C. González-Sala, F. Montagut-Asunción, and M.I. Fernández-Andrés. 2018. Comprehension of generalized conversational implicatures by children with and without autism spectrum disorder. *Frontiers in Psychology* 9: 272.
Paul, R., and D.J. Cohen. 1985. Comprehension of indirect requests in adults with autistic disorders and mental retardation. *Journal of Speech and Language Hearing Research* 28 (4): 475–479.
Paul, R., S. Miles Orlovski, H. Chuba Marcinko, and F. Volkmar. 2009. Conversational behaviors in youth with high-functioning ASD and Asperger Syndrome. *Journal of Autism and Developmental Disorders* 39: 115–125.
Pellicano, E., and D. Burr. 2012. When the world becomes 'too real': a bayesian explanation of autistic perception. *Trends in Cognitive Sciences* 16 (10): 504–510.
Petrolini, V., M. Jorba, and A. Vicente. 2023. What does it take to be rigid? Reflections on the notion of rigidity in autism. *Frontiers in Psychiatry* 14. https://doi.org/10.3389/fpsyt.2023.1072362.
Pexman, P.M., K.R. Rostad, C.A. McMorris, E.A. Climie, J. Stowkowy, and M.R. Glenwright. 2011. Processing of ironic language in children with high-functioning autism spectrum disorder. *Journal of Autism and Developmental Disorders* 41: 1097–1112.
Pickering, M.J., and C. Gambi. 2018. Predicting while comprehending language: a theory and review. *Psychological Bulletin* 144 (10): 1002.
Pickering, M.J., and S. Garrod. 2013. An integrated theory of language production and comprehension. *Behavioral and Brain Sciences* 36 (04): 329–347.

Pickering, M. J., and S. Garrod. 2021. *Understanding dialogue: Language use and social interaction*. Cambridge University Press.

Pijnacker, J., P. Hagoort, J. Buitelaar, J.P. Teunisse, and B. Geurts. 2009. Pragmatic inferences in high-functioning adults with autism and Asperger syndrome. *Journal of Autism and Developmental Disorders* 39: 607–618.

Pouscoulous, N. 2011. ï»¿Metaphor: for adults only? *Belgian Journal of Linguistics* 25 (1): 51–79.

Pouscoulous, N. 2014. The elevator's buttocks. Metaphorical abilities in children. In D. Matthews (Ed.), *Pragmatic development in first language acquisition*, 239–259.

Rappe, S. 2019. Now, never, or coming soon? Prediction and efficient language processing. *Pragmatics & Cognition* 26 (2–3): 357–385.

Roberts, J., G. Martin, L. Moskowitz, A. Harris, J. Foreman, and L. Nelson. 2007. Discourse skills of boys with fragile X syndrome in comparison to boys with Down Syndrome. *Journal of Speech Language and Hearing Research* 50: 475–492.

Rossetti, I., P. Brambilla, and C. Papagno. 2018. Metaphor comprehension in schizophrenic patients. *Frontiers in Psychology* 9: 670.

Rundblad, G., and D. Annaz. 2010. The atypical development of metaphor and metonymy comprehension in children with autism. *Autism* 14 (1): 29–46.

Saban-Bezalel, R., D. Dolfin, N. Laor, and N. Mashal. 2019. Irony comprehension and mentalizing ability in children with and without autism spectrum disorder. *Research in Autism Spectrum Disorders* 58: 30–38.

Schaeken, W., M. Van Haeren, and V. Bambini. 2018. The understanding of scalar implicatures in children with autism spectrum disorder: dichotomized responses to violations of informativeness. *Frontiers in Psychology* 9: 1266.

South, M., and J. Rodgers. 2017. Sensory, emotional and cognitive contributions to anxiety in autism spectrum disorders. *Frontiers in Human Neuroscience* 11: 20.

Su, Y., and L.Y. Su. 2015. Interpretation of logical words in Mandarin-speaking children with autism spectrum disorders: uncovering knowledge of semantics and pragmatics. *Journal of Autism and Developmental Disorders* 45: 1938–1950.

Tager-Flusberg, H., R. Paul, and C. Lord. 2005. Language and Communication in Autism. In *Handbook of autism and pervasive developmental disorders: Diagnosis, development, neurobiology, and behavior*, ed. F.R. Volkmar, R. Paul, A. Klin, and D. Cohen, 335–364. Wiley.

Van de Cruys, S., K. Evers, R. Van der Hallen, L. Van Eylen, B. Boets, L. de-Wit, and J. Wagemans. 2014. Precise minds in uncertain worlds: predictive coding in autism. *Psychological Review* 121 (4): 649.

Van de Cruys, S., K. Perrykkad, and J. Hohwy. 2019. Explaining hyper-sensitivity and hypo-responsivity in autism with a common predictive coding-based mechanism. *Cognitive Neuroscience* 10 (3): 164–166.

Vasa, R.A., N.L. Kreiser, A. Keefer, V. Singh, and S.H. Mostofsky. 2018. Relationships between autism spectrum disorder and intolerance of uncertainty. *Autism Research* 11 (4): 636–644.

Vicente, A., and I.L. Falkum. 2023. Accounting for the preference for literal meanings in autism spectrum conditions. *Mind & Language* 38 (1): 119–140.

Vicente, A., and I. Martín-González. 2021. The literalist bias in the autistic spectrum conditions: review of existing accounts. *Studies in Psychology* 42 (2): 298–333. https://doi.org/10.1080/02109395.2021.1909248.

Volden, J., and L. Phillips. 2010. Measuring pragmatic language in speakers with autism spectrum disorders: comparing the children's communication checklist-2 and the test of pragmatic language. *American Journal of Speech-Language Pathology* 19 (3): 204–212.

Vulchanova, M., J.B. Talcott, V. Vulchanov, and M. Stankova. 2012. Language against the odds, or rather not: the weak central coherence hypothesis and language. *Journal of Neurolinguistics* 25 (1): 13–30.

Vulchanova, M., D. Saldaña, S. Chahboun, and V. Vulchanov. 2015. Figurative language processing in atypical populations: the ASD perspective. *Frontiers in Human Neuroscience* 9: 24.

Walenski, M., and T. Love. 2017. The real-time comprehension of idioms by typical children, children with specific language impairment and children with autism. *Journal of Speech Pathology & Therapy* 3 (1): 1–22.

Wang, A.T., S.S. Lee, M. Sigman, and M. Dapretto. 2006. Neural basis of irony comprehension in children with autism: the role of prosody and context. *Brain* 129 (4): 932–943.

Williams, D.L., V.L. Cherkassky, R.A. Mason, T.A. Keller, N.J. Minshew, and M.A. Just. 2013. Brain function differences in language processing in children and adults with autism. *Autism Research* 6 (4): 288–302.

Wilson, A.C., and D.V. Bishop. 2019. If you catch my drift… ability to infer implied meaning is distinct from vocabulary and grammar skills. *Wellcome open Research* 4: 68.

Wilson, A.C., and D.V. Bishop. 2021. "Second guessing yourself all the time about what they really mean…": cognitive differences between autistic and non-autistic adults in understanding implied meaning. *Autism Research* 14 (1): 93–101.

Wilson, A.C., and D.V. Bishop. 2022. Stage 2 registered report: investigating a preference for certainty in conversation among autistic adults. *PeerJ* 10: e13110.

Wilson, D., and R. Carston. 2006. Metaphor, relevance and the 'emergent property issue. *Mind & Language* 21 (3): 404–433.

Wood, R., and F. Happé. 2021. What are the views and experiences of autistic teachers? Findings from an online survey in the UK. *Disability & Society* 1–26.