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The Role of Language Processing in Language Acquisition

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Abstract
Language processing research is changing in two ways that should make it more relevant to the study of grammatical learning. First, grammatical phenomena are re-entering the psycholinguistic fray, and we have learned a lot in recent years about the real-time deployment of grammatical knowledge. Second, psycholinguistics is reaching more diverse populations, leading to much research on language processing in child and adult learners. We discuss three ways that language processing can be used in the service of understanding language acquisition. Level 1 approaches ("Processing in learners") explore well known phenomena from the adult psycholinguistic literature and document how they play out in learner populations (child learners, adult learners, bilinguals). Level 2 approaches ("Learning effects as processing effects") use insights from adult psycholinguistics to understand the language proficiency of learners. We argue that a rich body of findings that have been attributed to the development of the grammar of anaphora should instead be attributed to limitations in the learner's language processing system. Level 3 approaches ("Explaining learning via processing") use language processing to understand what it takes to successfully master the grammar of a language, and why different learner groups are more or less successful. We explore the role of language processing in why some grammatical phenomena are mastered late in children and not at all in adult learners. We examine the feasibility of the idea that children's language learning prowess is directly caused by their processing limitations ("less is more": Newport, 1990). We conclude that the idea is unlikely to be correct in its original form, but that a variant of the idea has some promise ("less is eventually more"). We lay out key research questions that need to be addressed in order to resolve the issues addressed in the paper.

1. Introduction

Language processing research is changing in at least two ways that should make it more interesting to people whose concerns involve successful and unsuccessful learning of grammars. First, grammatical phenomena are re-entering the psycholinguistic fray after a period of partial exile. We have learned a lot in recent years about the real-time deployment of grammatical knowledge. Second, psycholinguistics is reaching more diverse populations, such as child and adult learners, in addition to the college-age monolinguals who are the staple diet of psycholinguists. These changes are driven in part by the lower price of entry to the experimental tools. But little of the research depends on recent technological advances, and it mostly depends on identifying new questions.

Our aim here is to give an (opinionated) sketch of how language processing should be harnessed in the service of understanding language learning. We do not want to simply generate a lot of complicated data by throwing new(ish) experimental measures at our favorite population of learners. Rather, we want to use an understanding of real time grammatical computation to understand how and when learning succeeds in young children, and why it is generally less successful in later learners. As psycholinguists, we welcome the increased attention from language acquisition experts in what we do. But we are often dismayed by the focus on learning new technical skills, rather than on the central problems that should be driving our field(s).

We see at least three ways that language processing can be used in the service of understanding language acquisition. They vary in the degree to which they engage with the central questions of the field.

Level 1 approaches: Processing in Learners. Research at this level explores well known phenomena from the adult psycholinguistic literature and documents how they play out in different populations (child learners, adult learners, bilinguals), and asks whether there are differences. For example, do children resolve syntactic ambiguities in the same way that adults do? Most existing research on language processing in learners falls into this category. It addresses the abilities of language learners, but it does not directly address questions about learners' ultimate successes and failures. We survey key findings in this area in Section 3.

Level 2 approaches: Learning Effects as Processing Effects. Research at this level draws on insights from adult psycholinguistics to understand the language proficiency of learners. It asks whether findings that have been attributed to incomplete grammatical learning should instead be attributed to limitations in the learner's language processing system. In Section 4 we explore one area where findings about adult real time grammatical computation illuminates otherwise mysterious aspects of children's learning profiles.

Level 3 approaches: Explaining Learning via Processing. Research at this level seeks to understand what it takes to successfully master the grammar of a language, and what language processing abilities are needed to reach that level. It seeks to understand whether language processing limitations might be to blame for cases of incomplete learning and for *critical periods* or *maturational constraints*. This type of work directly addresses the learning problem. This is the focus of Section 5, where we discuss the seductive but counter-intuitive idea that children's cognitive limitations are the cause of their success ("Less is more": Newport, 1990). We argue that this idea is unlikely to be correct in its original form. But we also suggest that a variant of the idea has some promise, taking into account some key recent findings about the details of language processing mechanisms. The key connection that we explore involves a possible link between predictive processing mechanisms and the learner's ability to test detailed hypotheses about the language.

We focus here on the learning of sentence-level grammatical phenomena. This is because it is the area where we think that the most progress has been made in understanding child language processing. Sentences are relatively extended in time, and so it is possible to gain useful insights about the time course of syntactic processing using relatively coarse-grained measures that are suitable for use with children. In other domains of language, our key questions involve processes that operate on shorter time scales and that develop at earlier ages, when children are less easy to work with.

In order to discuss language processing in learners, we first need to outline what (we think) we know about the language processing mechanisms that support grammatical computation in monolingual adults. This population provides the gold standard for rapid use of grammatical knowledge, so they are a valuable benchmark.

2. Language Processing Essentials for Learners

2.1 Preliminaries: What We're Trying to Explain

Looking from the outside, one could be forgiven for thinking that language processing research is all about ways of confusing speakers using garden path sentences or hard-to-process structures such as object relative clauses. Much of the language comprehension literature is concerned with quantifying difficulty, and much influential work attempts to make detailed predictions about the degree of difficulty of each incoming word in a sentence (e.g., Gibson, 1998; Levy, 2008). The language processing literature is also dominated by research on relatively simple linguistic phenomena that may hold limited interest for language acquisition experts, and so the relevance may appear limited.

For our purposes, though, the goal is not to explain what is easy or hard, but to understand what representations are constructed in real time, how comprehenders figure out which representations are possible, and how tightly those representations are constrained by a speaker's grammatical knowledge. One tradition in psycholinguistics assumes that comprehenders build rough-and-ready representations that bear only a loose relation to what their grammar sanctions (e.g., Ferreira & Patson, 2007; Townsend & Bever 2001). That is worrying for language learners, if true, as it suggest that learners might systematically misperceive crucial input for learning. Fortunately, we think that there is good evidence that comprehenders quickly build grammatically accurate representations. Many studies show that comprehenders make effective use of their syntactic and semantic knowledge (e.g., Frazier, 1999; Kazanina et al., 2007; Phillips, 2006; Traxler & Pickering, 1996; for review see Phillips et al., 2011). In electrophysiological studies, rapid sensitivity to grammatical errors is so commonplace that it is news only when speakers fail to quickly notice a violation of a linguistic constraint (e.g., Wang et al., 2012; Xiang et al., 2009).

We can ask about the representations that are built during comprehension at multiple grains of analysis. In addition to descriptions in the standard terms of linguistic analysis, we can ask how the representations are encoded at a finer level of detail, as objects in short-term memory or as neural encodings. Much of our group's effort in recent years has been devoted to exploring how structures are encoded in memory, how grammatical information is used in memory access operations and how do all of this fast enough to comprehend words at a rate of 3-5 words per second. Thinking about how grammatical information is used in memory access and in generating linguistic predictions has raised many questions that are relevant to learners.

2.2. Accurate Parsing

Comprehenders need to assign the intended structure and meaning to sentences incrementally, rather than waiting to the end of a phrase or sentence. To do this, they need to be able to use the grammatical constraints of the language, in order to avoid building unintended structures and meanings.

Each word or phrase in a sentence structure forms relations with other words and phrases in the sentence, e.g., selection/thematic relations, agreement relations, coreference relations, scope relations. Therefore, each word introduces a set of requirements that need to be satisfied, either by accessing an item in memory, or by waiting for some future item in the sentence (agreement relations, thematic relations, scope relations, focus relations, etc.). These various requirements call for a comprehension system that is able to keep track of many different needs at the same time. The system should be able to identify the right type of item at the right location in memory, without being distracted by similar items in structurally inappropriate locations. And it needs to manage multiple demands simultaneously.

The more that we learn about language processing, the clearer it becomes that successful comprehension requires sophisticated time and resource management. A new word appears roughly every 200-400 milliseconds, yet the time needed to carry out sensory, phonological, lexical, syntactic, and semantic processing likely adds up to longer than the duration of each word. Hence many different processes must operate in parallel, without interfering with each other. Any attempt to build an explicit model of real-time sentence comprehension quickly reveals that parsing is a highly skilled process that requires rapid switching between sub-tasks. There has been much recent interest in the notion of a *bilingual advantage*, the suggestion that bilinguals enjoy general cognitive benefits, due to the demands on cognitive control of managing two grammars and two lexicons (Costa et al., 2009; Kroll & Bialystok, 2013). But once we spell out what is required for monolingual comprehension, we quickly see that resolving competing plans and choices is something that everybody does, all the time.

2.3. Reanalysis

If the comprehender is successful in rapidly parsing the input, then it is very likely that he will need to make revisions along the way, since language is filled with temporary ambiguities. Successful revision requires that the comprehender recognize the problem, diagnose how it could be repaired, inhibit the initial parse, plus any interpretive commitments that arose from that parse, and build a new parse that is consistent with the input. Studies in the lab show that this task is not always easy: when an initial parse fails, the cue that the parse failed provides few clues to what went wrong and how to fix it. The small literature on easy vs. hard reanalyses suggests that reanalysis is something that adults can often do, but they are not especially good at it (Ferreira & Henderson, 1991; Sturt, 2007). Even when successful re-parsing occurs, new beliefs that were created based on the mis-parse are not retracted (Christianson et al., 2001; Sturt, 2007).

Reanalysis abilities are, in theory, important for language learners, as they are necessary for correctly apprehending the input. Therefore, when we find that children are especially bad at reanalysis, this raises the danger that they systematically misperceive the properties of the language around them. But the fact that we can document reanalysis difficulties in the lab is no guarantee that they play an important role in real life or in language acquisition. It could be that the situations that we concoct in the lab are very rare indeed in the wild. An important task for understanding the relation between language processing and language acquisition is to figure out when and where reanalysis abilities are needed in everyday language use.

2.4 Prediction

There is a lot of current interest in psycholinguistics in how good adults are at predicting upcoming material. We share this interest. But our main goal here is to examine how these abilities might be essential for language learning. Our group’s recent work has moved from demonstrations that prediction occurs to the question of how it occurs, and this has led us to find that we might not be as good as we thought at using rich linguistic constraints in prediction. We suspect that this might be very relevant for learning.

Predictive processes encompass category predictions that are very reliable, e.g., the determiner *the* signals that a noun is coming soon, and some that are probabilistic, e.g., the verb *whisper* is often but not always followed by a complement clause, and lexical predictions that vary greatly in their reliability, e.g., the sequence *the prize that the athlete* … is likely to be continued with the verb *won*.

The notion that comprehenders are 'active' participants in the parsing process is best known from research on comprehending unbounded dependencies ('filler-gap' dependencies in psycholinguistic parlance; Fodor, 1978; Frazier & Flores D’Arcais 1989; Phillips & Wagers, 2007; Stowe, 1986). Comprehenders posit gaps associated with fronted *wh*-phrases ahead of unambiguous evidence for the gap site. But it is now clear that active comprehension is a pervasive property of the mature comprehension system (DeLong et al., 2005; Dikker et al., 2009; Lau et al., 2006; Staub, 2006; van Berkum et al., 2005). Active comprehension mechanisms might reflect the engagement of production mechanisms (Federmeier, 2007; Phillips, 1996; Pickering & Garrod, 2007).

Predictive mechanisms are likely important for the robustness of language understanding, such as in noisy settings or when listening to an unfamiliar accent or non-native speech. Prediction may also play a key role in learning, since it can provide valuable information that would otherwise be unavailable to the learner. If a learner accurately parses and interprets a sentence, then he has evidence that the sentence is possible in the target language. But this provides little information about why that sentence was used in that context to convey that meaning. But if a learner can use his current knowledge of the language (together with the context of the utterance) to predict how the sentence will unfold, then the comparison of what he expects with what actually occurs could provide valuable additional information. The idea that predictions can provide a key source of feedback for language learners has been explored in a number of learning models (e.g., Chang et al., 2006; Elman, 1993), but we suspect that this area may be even more fruitful, based on some recent findings about the successes and failures of predictive mechanisms.

2.5 Fast and Slow Predictions

We now need to briefly dive into the weeds of electrophysiology, as we suspect that some recent findings that are not easy to digest may hold valuable clues for understanding language learning mechanisms.

The most widely known generalization about the electrophysiology of language is very likely wrong. In 1980 Kutas and Hillyard reported that semantically anomalous sentences like *I drink my coffee with cream and socks* elicit a characteristic ERP response that came to be known as the N400 (Kutas & Hillyard, 1980). They also showed that other types of linguistic anomalies did not elicit the same response. This finding it is very reliable, but it is less clear how to interpret this finding. An early view was that the N400 reflects the ease or difficulty of combinatorial semantic interpretation. This view has taken hold in the broader consciousness, but it has fallen out of favor among ERP specialists, based on a wealth of further evidence.

A widespread view in the ERP literature nowadays is that the N400 more closely reflects lexical access mechanisms, and specifically the ease of recognizing a word in context (Deacon et al., 2004; Kutas & Federmeier, 2000; Lau et al., 2008; van Berkum, 2009). Studies using magnetoencephalography (MEG) suggest that the N400 is generated in posterior temporal brain areas that are more commonly associated with lexical processing (Halgren et al., 2002; Helenius et al., 1999; Lau et al., 2008; Pylkkänen et al, 2007). N400 amplitudes are modulated by variables that are typically associated with lexical access, such as word frequency and priming (Holcomb et al., 2002; Kutas et al., 2006; Lau et al., 2013; van Petten & Kutas, 1990). And in sentence contexts, inappropriate words that are associated with highly expected words elicit surprisingly small N400 effects, suggesting lexical priming effects (Federmeier & Kutas, 1999).

Although very many studies have shown that N400 amplitude to a word is tightly linked to the word's cloze probability, some important studies have shown that N400 amplitudes appear to reflect superficial lexical associations between the words in a sentence (Fischler et al., 1983; Nieuwland & Kuperberg, 2008; Urbach et al. 2008). For example, in the sentence *A robin is not a {bird* | *tree}* the word *bird*, which is closely associated with *robin* elicits a smaller N400 than *tree*, despite the fact that the completion with *bird* is a false statement (Fischler et al., 1983). This further supports a connection between N400 and lexical processing, specifically the degree to which the current word is predicted in context. But it also raises the puzzle of why lexical predictions are sometimes based on low-level associative relations, and sometimes based on more sophisticated use of the semantic and pragmatic context (Nieuwland & Kuperberg, 2008). Recent work in our group, led by Wing Yee Chow and Shota Momma, points towards a solution to this puzzle.

The cloze probability of a word in a context is typically the product of many different sources of information: word associations, argument roles, discourse context, etc., and we know little about how these are combined to generate predictions about upcoming words. Chow and Momma found ways to isolate the contribution of specific types of predictive information, and determine how quickly they could be exploited, using verb-final sentences in English, Chinese, and Japanese. In (1a-b) the sentence-final verb is very unlikely in both sentences, but for different reasons. In (1a) the verb is unlikely simply because evicting events don't involve landlords and cats. In (1b) the verb is unlikely because of the semantic roles of the two arguments, which are the reverse of their typical configuration. Chow found that these two constraints had different impacts on N400 amplitudes: manipulations of cloze probability via lexical associations, as in (1a), had an immediate effect on N400s, but equally strong manipulations of cloze probability via argument role reversals, as in (1b), had no effect on N400s (Chow et al., submitted b).

1a. Which cat did the landlord evict?
b. Which landlord did the tenant evict?

In other studies, using Mandarin Chinese, Chow found that cloze manipulations due to role reversals do affect N400s, but only when there is sufficient time between the arguments and the verb (Chow et al., submitted a). Momma found a similar effect of argument-role related predictions in Japanese (Momma et al., in prep.). Importantly, in none of these cases did we find that speakers showed delayed sensitivity to the anomaly: they always noticed the problem, as reflected in P600 effects. This shows that when the verb arrived in the input, speakers could easily recognize the anomaly. What varied was only the N400, which we take to reflect comprehenders' expectations immediately before the verb appeared in the input.

We find these results interesting because they suggest that different sources of information affect linguistic predictions on different time scales, that it is possible to study the time course of these different effects, and that we may soon be able to understand why some sources of information can be used more readily than others. One suggestion for why argument role information has delayed effects on prediction is that it is difficult to directly probe memory representations based on complex cues. For example, the memory query "what type of events involve landlords?" might be easier to carry out than the memory query "what type of events involve landlords as patients?" It suggests that it is too coarse-grained to ask whether a given learner group is good or bad at linguistic prediction.

2.6 Learning Relevance: Input, Intake, and Missed Opportunities.

Based on this brief survey, we can imagine at least 3 ways that a learner's language processing abilities could aid or hinder learning.

First, a learner could simply fail to assign a coherent parse to an input sentence, perhaps because the sentence is too complex or arrives too quickly. This kind of failure would slow learning, but it would not actively impede learning, as it would not lead the learner to draw incorrect generalizations.

Second, a learner could systematically mis-parse a certain type of input sentence, e.g., due to parsing biases and/or reanalysis failure. This type of failure is potentially more disruptive, as it could lead a learner to see evidence for structural generalizations that are not in fact true of the target language. There is a long tradition of worrying about how informative is the input to learners ('poverty of the stimulus' arguments: Berwick et al., 2011; Lidz et al., 2003; Perfors et al., 2011; Phillips, 2013; Pullum & Scholz, 2002) and whether the input contains misleading information due to speech errors (Newport et al, 1977). But even if the input is both informative and impeccable, there is a danger that learners might themselves introduce errors, as their 'intake' might diverge in systematic ways from the input. This is a topic that our colleagues Jeff Lidz and Akira Omaki have paid much attention to in recent years (Lidz & Gagliardi, 2014; Omaki, 2010; Omaki & Lidz, 2014).

Third, a learner who successfully parses an input sentence could extract more or less information from that sentence, depending on his ability to predict ahead of time how the sentence will unfold. If the learner can make more sophisticated predictions about the what will be said when, then he may be able to learn more complex contingencies in the language.

3. Level 1 Accounts: Processing in Learners

Research at our first level of analysis takes findings about adult monolingual language processing and asks whether child or adult learners perform similarly. This work does not directly address learning questions, but it is a critical first step in understanding the relevance of language processing in language acquisition.

3.1 Analysis & Reanalysis in Children

We know surprisingly little about children's ability to assign detailed and accurate analyses to incoming sentences. They must be doing something right, since they grow up to have a grammatically sophisticated adult processing system. Our main source of evidence for children's processes of analysis is the meanings they assign to sentences they hear. But although children do relatively well at understanding intended meanings, we do not know how they arrive at these, nor whether they use the same syntactic and semantic representations as adults. Contrasting children's interpretations of ambiguity -- both true and fake -- lets us ask whether children access all and only the meanings that adults allow.

In the domain of true ambiguities, a lot of attention has been devoted to children's interpretation of simple prepositional phrase (PP) attachment ambiguities, as in *Put the frog on the napkin in the box*, where the PP *on the napkin* could be understood as the goal argument of the verb *put* or as a modifier of the direct object *the frog*. Adults show a bias for the argument parse of the PP (Rayner et al., 1983; Tanenhaus et al., 1995). Children show the same bias, but more strongly (Trueswell et al., 1999). Children are able to access the alternative, modifier parse of the PP under some circumstances (Snedeker & Trueswell, 2004), but they are less able than adults to integrate multiple cues that might lead them to that parse (Engelhardt, 2014; Hurewitz et al., 2000; Snedeker & Trueswell, 2004; Weighall et al., 2008).

In studies on globally ambiguous wh-questions, such as (2), we found that children show the same bias as adults to construe the wh-phrase *where* with the first verb that they encounter (Omaki et al., 2014). We are confident that the bias is based on order/timing, rather than on structure or plausibility, as the preferences reversed between English (2a) and Japanese (2b), which have sharply different word orders. English speakers took the question to be about location of telling, Japanese speakers took the question to be about the location of catching. In those studies, children's bias for the first-verb interpretation was so strong that we worried that they might systematically fail to notice that an alternative parse is available, leading to a mistaken view of the grammar of their language. Omaki (2010, Chapter 6) contains a detailed discussion of this danger, in which he examines a large corpus of child-directed wh-questions and asks whether the attested distributions would be seriously distorted once filtered through a child parser. He concludes that distortion would indeed occur, but that the truly ambiguous input data is rare enough that the child would be saved by unambiguous evidence. But such arguments need to be considered in many linguistic domains.

2a. Where did Lizzie tell somebody that she was going to catch butterflies?
b. Doko-de Yukiko-chan-wa chouchou-o tsukamaeru-to itteta-no?
where-at Yukiko-dim-top butterfly-acc catch-comp was-telling-Q
'Where was Yukiko telling someone that she will catch butterflies?'

'Fake' ambiguities are cases where the adult grammar allows only one interpretation, but where an alternative interpretation might be available if the child violates a grammatical constraint. There are many studies that suggest that preschoolers do well at using grammatical constraints to avoid fake ambiguities (e.g., Conroy et al., 2009; Crain & Thornton, 1998; de Villiers & Roeper, 1995). But we find other cases where children seem to violate simple grammatical constraints to arrive at non-adultlike interpretations. For example, studies on children's interpretation of non-canonical word orders suggest that they might systematically ignore case-marker cues, e.g., reversing agent and patient roles in *dog.acc chased cat.nom* (MacWhinney et al., 1984). Similarly, many studies have found that children often misinterpret passive sentences, reversing the roles of the arguments (Bever, 1970; Huang et al., 2013; Maratsos et al., 1985; Pinker et al. 1987)

In more subtle cases of true or fake scope ambiguity, there are concerns that children may either undershoot or overshoot what the target grammar allows. In cases of true scope ambiguity a recurring finding is that children show strong biases for one interpretation, generally the same interpretation that adults favor (Lidz & Musolino, 2002), though not always (Goro & Akiba, 2005; Unsworth et al., 2008). Given sufficient contextual support, children allow the dispreferred interpretation, but this requires more work than it does for adults (Gualmini, 2008; Lidz, 2014; Viau et al., 2010). More worryingly, in cases of fake ambiguity, we find cases where children allow scope interpretations that are disallowed in the adult language (Goro, 2007). These cases are worrying for learning theories, as they suggest that children could perceive that they are seeing evidence for grammatical possibilities that are not, in fact, available in the target language.

It is perhaps surprising that most of the research that we cite here comes from studies that pay little attention to the time course of interpretation. More time-sensitive measures such as reading times, eye-tracking, or event-related brain potentials (ERPs) have played a smaller role in studies with children, in part because of difficulty, but also because they rarely show anything different than slower (and simpler) measures of interpretation. This is because of children's acute difficulty with reanalysis.

The clearest finding about child sentence processing is that children are very poor at reanalysis (Trueswell et al., 1999). This contrasts with adults, who often show relatively easy recovery from initial mis-parses (Sturt et al., 1999). Children's difficulty with reanalysis has been confirmed many times in subsequent research (Choi & Trueswell, 2010; Kidd et al., 2011; Lassotta et al., submitted; Weighall, 2008). Therefore, a rather robust generalization about child parsing is that children's first interpretation is their only interpretation.

It is widely assumed that children's difficulty with reanalysis is not a language-specific limitation, but instead reflects more general limitations in children's cognitive control abilities (Novick et al., 2005; Mazuka et al., 2009). Children show broad difficulties in revising initial action plans, and this is commonly attributed to the delayed maturation of the frontal lobe, the primary home of executive function abilities (Davidson et al., 2006). As such, this aspect of children's sentence processing abilities is maturational in nature, and should be unrelated to language proficiency in general.

For detailed reviews of child sentence processing research at this level, see Snedeker (2013) and Omaki & Lidz (2014).

3.2 Analysis & Reanalysis in L2ers

In adult learners we can ask the same questions as we asked about children: do they analyze incoming sentences accurately, and how well are they able to recover from misanalyses? Both of these are relevant to the question of what evidence learners actually perceive ("intake") about the grammar of the target language.

Whereas children show acute difficulties with reanalysis, this appears to be much less of a problem for adult learners. That is consistent with the view that children's reanalysis difficulties are related to language-independent maturational constraints.

The question of how accurately adult learners parse input sentences has received a good deal of attention, and with mixed results. We know more in this domain than we do about children, though the findings are complicated by the fact that adult learners are so much more heterogeneous than child learners.

Many studies on L2 parsing have focused on questions such as how ambiguity resolution biases might transfer from the L1 to the L2. For example, this is the motivation for studies on PP-attachment ambiguities in L2 learners (Dussias, 2003; Felser et al., 2003; Fernández, 2003; Hopp, 2014;

Papadopoulou & Clahsen, 2003). We have little to say about these here, as they tell us less about the question of how learners analyze key evidence that contributes to learning the target grammar.

Our knowledge of how accurately L2 comprehenders parse incoming sentences owes much to the *Shallow Structure Hypothesis* (Clahsen & Felser, 2006), which argues that L2 learners rely on lexical and conceptual associations to guide interpretation, rather than using structural cues to build detailed and accurate syntactic representations. This could lead to widespread misanalysis on-line, even if learners' ultimate interpretations are correct. SSH struck a nerve in the L2 community, which succeeded in eliciting a host of supporting and contradictory evidence.

The evidence for or against SSH generally involves demonstrations of L2ers' sensitivity or insensitivity to structural cues that native speakers attend to in parsing, rather than evidence that L2ers are more strongly guided by lexical and conceptual associations. For example, in the domain of wh-dependency formation, Marinis et al. (2005) argued that L2ers do not build long-distance dependencies in the same way as native speakers. This was based on a failure to find in L2ers a reading facilitation effect that Gibson and Warren (2004) had found in L1ers, and had attributed to the breaking of long dependencies into multiple shorter dependencies. One limitation of findings like this is that it is rather easy to fail to replicate L1 findings in the noisier data of L2 speakers, especially when those findings depend on statistical interactions. Arguing for the opposite position, Omaki and Schulz (2011) and Aldwayan et al. (2010) argue that L2ers parse wh-dependencies in a nativelike fashion, based on online sensitivity to island constraints (Felser et al. (2012) present similar findings, though they arrive at a different conclusion). Other studies have made similar arguments involving L2ers' sensitivity to constraints on anaphora (Rodriguez, 2008). In the domain of case and agreement inflection processing, findings are highly varied, ranging from the claim that L2ers are highly insensitive to inflectional information (Jackson & Dussias, 2009; Jiang, 2004) to the claim that they can achieve native-like proficiency (Hopp, 2010).

Less is known about adult learners' susceptibility to considering grammatically illicit dependencies as parsing progresses. In subject-verb agreement, where native speakers show fleeting interference effects ('attraction') from structurally inappropriate 'lure' nouns, it seems that L2 comprehenders are no less susceptible to error (Tanner et al., 2012). In closely related domains where native speakers fail to show attraction effects, such as the processing of reflexive pronouns (Dillon et al., 2013), there is some evidence that L2ers do show attraction effects (Felser & Cunnings, 2012). This suggests that L2ers may be susceptible to more mis-parses than native speakers, but this is less of a concern than it is for children (see Section 3), because L2ers appear to be better reanalyzers than children.

The evidence we have cited is somewhat mixed: some studies claim that learners lean on conceptual association to guide on-line sentence comprehension, others focus on learners' ability to use native-like syntactic representations. Learners certainly appear to be able to form detailed structural parses in processing, but their success on-line depends on the speed with which processing takes place, the availability of transfer from L1, and proficiency. That is, while the ability to build accurate sentence representations on-line may not be maturationally constrained, it seems that the ability to do so quickly is a function of maturation. However, where mis-parses take place, they are probably less disastrous for adult L2 than for child L1 learners: there is little evidence in the adult L1 parsing literature that reanalysis poses problems for adults, and we presume that reanalysis difficulties therefore have less of an impact in L2 parsing than in child learners.

3.3 Prediction in Children

Predictive mechanisms are most useful for learners if they are able to (i) act on diverse predictive cues, preferably combinations of cues, and (ii) do so quickly. Predictions are most useful when they are generated in advance of the external input. Therefore, in assessing what is known about prediction mechanisms in children and adult learners, we need to look beyond the binary question of whether learners are able to use predictions, to the specifics of what they are able to do, and how quickly. In these terms, very little is known at present. For child and adult learners alike, there is evidence of some facilitation from prediction, but also evidence that they are not as good as native speaking adults. Unsurprisingly.

A number of studies with children have used demonstrations of anticipatory looks in a simple visual scene as evidence of predictive linguistic processing. This includes studies where verbs trigger looks to likely direct objects in 2-10 year olds (Borovsky et al., 2012; Mani & Huttig, 2012; Nation et al., 2003), and where gender-marked determiners in Spanish facilitate looks to a gender-matching objects in 3-year olds (Lew-Williams & Fernald, 2007). However, these involve very simple relations between words and their syntactic sisters in simple situations containing a very small number of visual targets, and so we should be cautious in generalizing from these findings.

In a tougher test of predictive processing involving wh-dependencies, 5-year olds lagged behind adults (Atkinson et al., 2013). Following a story children listened to wh-questions such as *Can you tell me what Emily was eating a cake with?*, or yes-no questions such as *Can you tell me if Emily was eating the cake with a fork?* Although the wh-question queried the instrument, the main interest in the study was the looks to the direct object *cake* upon hearing the verb. Increased fixations to a picture of the cake in the wh-question relative to the yes-no question were taken as evidence of anticipatory interpretation of the question as a direct object question. Adults showed this pattern at the verb, but children did not. This suggests that although children have basic predictive abilities at an early age, they are less good at acting quickly on more complex cues. In the wh-question setting the predictive fixations depend on retrieving the wh-phrase, combining its interpretation with the verb and then directing looks to relevant objects in the display.

A different source of evidence for delayed development of predictive mechanisms in children comes from ERP studies that show that children reliably detect syntactic anomalies, but that they lack the earlier (E)LAN response component often observed in adults (Hahne et al., 2004; Oberecker & Friederici, 2006; Silva-Pereyra et al. 2005). If those early components are reflections of predictive processes (Dikker et al., 2009; Lau et al., 2006), then their absence might be informative about predictive mechanisms, but the argument is indirect, and the components are not consistently elicited even in adults.

Clearly, we still know relatively little about children's predictive abilities. Much more needs to be learned in this area, especially if we hope to link these abilities to hypothesis testing and recovery from overgeneralization in learning.

3.4 Prediction in L2ers

There is little work that directly compares prediction in child and adult learners. It is easier to directly compare adult learners with adult native speakers.

In a follow-up to their study with Spanish-speaking children, Lew-Williams and Fernald (2010) found that adult learners of Spanish were unable to use gender on a determiner to anticipate an upcoming noun. This suggests a possible case where child parsing abilities might outstrip adults, but extreme caution is needed, as it could simply be that the adults were tested at a phase when they were less familiar with the noun genders than were the children.

An ERP study by Martin et al. (2013) also found evidence of reduced predictive processing in adult learners, using a design adapted from DeLong et al. (2005). A sentence like *It was a windy day so the boy decided to go out to fly …* creates a strong expectation for a a continuation with the noun *kite*. Therefore the determiner *a* is more expected than the determiner *an* (as in *… an airplane*). DeLong and colleagues showed that adult native speakers detect evidence against their prediction already at the determiner *an*. But Martin and colleagues found no corresponding sensitivity in L2ers to the mismatch at the determiner , despite their flawless knowledge of the alternation in determiner forms.

We saw that children's predictive processes fell short of adults in processing wh-questions, as reflected in a lack of active wh-dependency formation effects in a visual world task (Atkinson et al., 2013). We know of no direct comparison with L2 speakers, but there are a number of L1-L2 comparisons of active wh-dependency formation in adults, and these include evidence that L2ers construct dependencies at the same point as native speakers (Omaki & Schulz, 2011)

Therefore, we find evidence of limitations in L2ers' prediction abilities, but we do not find clear evidence that L2ers lag behind children in their prediction abilities.

3.5 Summary

Level 1 studies are most useful for understanding learning when they provide clues to what information learners can extract from the sentences that they hear. For this reason, we focused primarily on the questions of whether learners build accurate analyses of incoming sentences, and whether they have the predictive abilities that could help them to extract much more information from the input. The clearest finding is that children are not good at reanalysis, and this makes it more important that their initial parses be correct. For adult and child learners we find mixed evidence on the grammatical accuracy of their parses. Some evidence suggests that they do very well, while other evidence points to serious risk of misanalysis. Future work will need to figure out how seriously the parsing failures found in the lab transfer to real-life situations. Meanwhile, prediction is poorly understood in learners, in part because it is treated monolithically. Learners can exploit some predictive information, but they struggle in more complex cases. We hope that future work will build on the developments in the adult L1 literature to dig more deeply into these abilities.

A more general conclusion from the Level 1 studies is that children's language processing gives them no obvious advantage over adult learners.

4. Level 2 Accounts: Learning Effects as Processing Effects

In this section we give an example of a Level 2 account, which uses sentence processing findings to explain phenomena that have typically been attributed to stages in children's grammatical development. We review striking parallels that emerge from independent literatures in language acquisition and language processing on the effects of constraints on anaphora, though the effects operate on different time scales.

4.1 Starting point: universal vs. language-specific constraints on backwards anaphora.

Our starting point involves a surprising finding about a little known constraint on anaphora in Russian, which creates a minimal contrast with English. English allows backwards anaphora (3a), but not when the pronoun c-commands the name (3b). The Russian counterparts are both unacceptable under the coreference reading. (3b) and (4b) reflect a cross-linguistically robust constraint, Principle C (Chomsky, 1981), whereas (4a) is ruled out by a more specific constraint that applies only to specific combinations of subordinators, aspect, and thematic roles (Avrutin & Reuland, 2004; Kazanina, 2005). We refer to the Russian constraint as the *poka*-constraint, based on the subordinator that most strongly gives rise to the effect.[1]

3a. While he was reading the book, Pooh ate an apple.
b. *He ate the apple while Pooh was reading the book.

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[1] Related effects can be seen in null subject languages, but we regard those as different, reflecting constraints on the use of overt pronouns. Russian is not a null subject language.

4a. *Poka on$_i$ chital knigu, Pooh$_i$ s'el yabloko.
while he was reading.imp the book Pooh ate.perf the apple
b. * On$_i$ s'el yabloko, poka Pooh$_i$ chital knigu.
he ate.perf the apple while Pooh was reading.imp the book

Young children show mastery of the contrast as early as it has been possible to test them, using Truth Value Judgment Tasks (TVJT) in 3-6 year olds (Crain & McKee, 1985; Crain & Thornton, 1998), and preferential looking tasks in children as young as 30 months (Lukyanenko, Conroy, & Lidz, 2014). This has been taken as compelling evidence that Principle C, a cross-linguistically robust constraint, is known innately.

Nina Kazanina tested Russian children's interpretations of sentences like (4) (Kazanina & Phillips, 2001). Her findings were very clear: 6-year olds performed similarly to adults, disallowing coreference in both Principle C contexts and *poka*-constraint contexts. But the youngest group of Russian children, aged 3 years, performed remarkably similarly to the English-speaking 3-year olds in Crain & McKee's study, allowing coreference in (4a), but not in (4b). 4-5 year olds showed an intermediate profile.

These findings have an attractive interpretation in terms of grammatical development: children master universal constraints at a very early age, but closely related language-particular constraints develop later. But we were also troubled by how Russian children could ever learn the constraint, and why it should take them 5-6 years to do so. We explored the possibility that the blame lies with children's knowledge about verbal aspect, but this appeared not to be the problem (Kazanina & Phillips, 2007). We also considered the possibility that the *poka*-constraint is learned late because the relevant evidence in the input is very sparse. But if sparse input is to blame, then we should encounter a lot of variability in when children master the constraint: if it takes some children 6 years to hear enough relevant evidence, then some children might never see enough relevant input. Finally, we were troubled by the fact that Russian children need to move from a more permissive to a less permissive grammar: they need to somehow figure out that they are wrong to assume that coreference is possible in sentences like (4a). We return to this puzzle below.

4.2 Principle B (pronouns) in children

Principle B effects in children present an interestingly different puzzle. One of the most impressive cases of developmental findings influencing theoretical linguists is the finding that preschoolers allow interpretations that violate Principle B in sentences with referential antecedents (5a), but adhere to Principle B in sentences with quantificational antecedents (5b) (Chien & Wexler, 1990; Thornton & Wexler, 1998).

5a. Mama Bear washed her.
b. Every bear washed her.

Our interest in this area was triggered by a provocative claim by Paul Elbourne that the Quantificational Asymmetry in children's mastery of Principle B is an experimental artifact, due to poorly-matched materials (Elbourne, 2005). We took Elbourne up on his challenge, in an effort to prove him wrong. We implemented his experimental fixes, and made a number of further improvements. He turned out to be less wrong than we expected. Once we more closely matched the quantificational and referential conditions, the quantificational asymmetry did indeed go away. But, to our surprise, our improvements also got rid of the Delay of Principle B Effect (DPBE). Children allowed non-adultlike interpretations in only around 12% of trials (Conroy et al., 2009).

Puzzled by the fact that children in our study had performed so well, we analyzed around 30 previous studies on DPBE revealed an interesting picture. Across studies, there was very large variation in the proportion of non-adultlike interpretations, ranging from as low as 10% (Kaufman, 1988) to a high of 82% (McKee, 1992). This variability was more than one would expect based simply on measurement error, and it appeared to be linked to experimental design issues. Experiments that made a non-adultlike interpretation less accessible tended to elicit higher error rates from children.

Importantly, we did not simply take away from this variability that we had found a great design that revealed children's true abilities where others had failed. We took the variability to indicate that in applying Principle B, children are very fragile. Especially striking is a contrast reported by McKee (1992). McKee's study has one of the highest rates of non-adultlike interpretations in the Delay of Principle B literature, and a look at the experimental design suggests why. In that experiment, the pronoun interpretation that would reflect adherence to Principle B was barely relevant at all in the example scenario. But the most interesting feature is that McKee ran the same experiment with Italian children, using clitic pronouns instead of the full pronouns used in English. And the Italian children did great, allowing the non-adultlike interpretation in only 15% of trials. This is consistent with other evidence that children do not show a DPBE with clitic pronouns (Baauw et al., 1997; Varlokosta, 2000). What we took to be the most interesting finding was that whereas children show great fragility in implementing Principle B with full pronouns, they showed very little fragility in implementing Principle B with clitic pronouns. We are not aware of fragility in the literature on children's mastery of Principle C. In all three cases we see evidence that the adult constraint is in place, but children showed selective fragility in their ability to demonstrate this knowledge. This is reminiscent of a similar pattern of "selective fallibility" that we had been starting to observe elsewhere.

4.3 Principle C Effects in Adult Parsing

In independent work with adults, we were interested in the effects of grammatical constraints – preferably obscure ones – on real-time language comprehension. This was motivated by an interest in the nature of grammatical knowledge and its relation to moment-by-moment processes (Phillips, 1996; Phillips & Lewis, 2013; Lewis & Phillips, 2015). Principle C turns out to be a parade case of grammatical faithfulness in language processing.

We can test the online effects of Principle C by creating instances of backwards anaphora in English, and asking whether comprehenders temporarily consider an interpretation where the pronoun corefers with an NP that should be excluded by Principle C.[2] We can test where people attempt coreference using a gender mismatch paradigm: in any structural position where speakers attempt coreference, manipulation of the gender match between the pronoun and the potential antecedent should lead to processing disruption (van Gompel & Liversedge, 2003). Our findings for Principle C were very clear: we found gender mismatch effects in positions that satisfy the constraint (6a), but not in positions that violate the constraint (6b). We found the same contrast across three self-paced reading experiments involving different syntactic configurations (Kazanina et al., 2007), and the finding appears to be robust across languages and labs (Aoshima et al., 2009; Fedele & Kaiser, 2014; Pablos et al., submitted; Rodriguez, 2008; Yoshida et al., 2014).

[2] Some readers may be concerned about the possibility that Principle C is a tenuous or epiphenomenal constraint (Ambridge et al., 2014). Objections come from cases where instances of supposedly acceptable backwards anaphora are rated as little better than Principle C violations (Gordon & Hendrick, 1998), or from cases where apparent Principle C violations are clearly acceptable (Harris & Bates, 2002). We do not think that these facts undermine the grammatical generalization, though they certainly illustrate the importance of careful discourse controls in studies of cataphora. See Kazanina (2005) for more detailed discussion.

6a. While she was taking classes full time, Kathryn|Russell was working two jobs ...
b. She was taking classes full time while Kathryn|Russell was working two jobs ...

It appears that interpretations that violate Principle C simply do not occur to people, even when we probe using time sensitive measures. In more technical terms: interpretations that violate Principle C are not merely illicit, they are beyond the generative capacity of the language system.

The child-adult parallel that we saw with Principle C is just the first among a list of similar parallels that we have observed.

4.4 Principle A (local reflexives)

4-5 year old children perform well in tests of the locality constraint on reflexives like *herself* or *themselves*, which requires (roughly) that a reflexive find an antecedent in the same clause (Principle A: Chomsky, 1981). Some studies have shown relatively high rates of illicit interpretations (Chien & Wexler, 1990), but those errors reflect a failure to attend to gender marking (*himself, herself*). Once that problem is taken care of, children perform quite well (Zukowski et al., 2008).

We also know a lot about the real-time effects of Principle A in adults, thanks to a recent debate about the generality of "retrieval interference effects" in parsing (Dillon, 2014). We know that speakers frequently make errors in producing subject-verb agreement, incorrectly agreeing with a structurally inappropriate noun ("agreement attraction"), as in (7) (Bock & Miller, 1991; Eberhard et al., 2005; Vigliocco & Nicol, 1998). In the comprehension version of agreement attraction, speakers fail to notice the same errors, and those effects have been attributed to noisy memory retrieval mechanisms: in attempting to retrieve a feature-matching noun from the subject position, comprehenders may sometimes mistakenly retrieve a feature-matching noun from a different position (Wagers et al., 2009). Interpreting a reflexive should be similar: it should require retrieval of a feature-matching noun from the subject position. We might therefore expect to find corresponding "reflexive attraction" effects, but in general we do not. A particularly useful case is due to Brian Dillon, who created closely matched tests of agreement and reflexive attraction (8). He found strong agreement attraction effects, but no reflexive attraction effects (Dillon et al., 2013). This is consistent with numerous other findings of a lack of attraction effects with reflexives (Clackson et al., 2011; Clifton et al. 1999; Nicol & Swinney, 1989; Sturt, 2003; Xiang et al., 2009).[3]

7a. * The key to the cabinet(s) <u>are</u> on the table.
b. * The runner(s) who the driver <u>see</u> every day never forget to wave.

8. * The new manager [who oversaw the middle manager(s)] ...
… apparently <u>were</u> dishonest about the company’s profits.
… apparently <u>doubted</u> themselves on most major decisions.

[3] Here we focus on facilitatory attraction effects in otherwise ungrammatical sentences, which are consistently found in agreement processing, and which provide the clearest evidence of retrieval of an inappropriate antecedent. We know of only two studies that found facilitatory effects with reflexives. Cunnings & Felser (2012) report such effects in a low memory-span subgroup of participants. Parker & Phillips (2014) replicated the standard no-attraction finding in materials where the structurally appropriate NP mismatches the reflexive in just one feature, but found strong facilitatory attraction effects in experiments where the structurally appropriate NP mismatched the reflexive in two features, e.g., gender + number. Some studies have found small inhibitory interference effects in grammatical sentences (Chen et al., 2012; Kush & Phillips, 2014; Patil et al., 2011)

Principle A has parallel effects in children and adults: children successfully avoid illicit interpretations in off-line tasks of acceptability and interpretation; adults successfully avoid illicit interpretations in on-line measures.

4.5 Principle B (pronouns) in adults

We already saw that preschool aged children seem to know Principle B, but show extreme fragility in implementing the constraint. We find the same thing when we turn to adult on-line processing. Well, almost. Studies on Principle B in adult parsing certainly show varied and conflicting results, reminiscent of the variability that we find in children. A number of studies have concluded that adults successfully avoid pronoun interpretations that violate Principle B (Clifton et al., 1997; Lee & Williams, 2006; Nicol & Swinney, 1989), and a number of other studies have reached the opposite conclusion (Kennison, 2003; Runner et al., 2003). The most well known of these comes from a paper by Badecker & Straub (2002) that used a variant of the gender match paradigm that we saw above. Badecker and Straub tested whether the presence of two nouns that matched the gender of the pronoun would lead to competition and hence slowdown in reading times, even when one of the nouns is a clausemate of the pronoun, making it an illicit antecedent (9). They found clear slowdowns ("multiple match effect") in their first two experiments, and concluded from this that Principle B does not remove potential antecedents from consideration during parsing.

9. John thought that {Bill | Beth} owed him another chance to solve the problem.

Based on these past results, it appears that Principle B neatly fits our pattern. Children's off-line interpretations show sensitivity to the constraint, but in a fragile fashion. Adults on-line interpretations show similar fragility. Our main reservation about this summary is that studies in our group attempted to replicate and manipulate the presence of fleeting on-line Principle B violations, and they were uniformly unsuccessful. Across seven studies, including one that was a direct copy of Badecker & Straub's materials and procedures, we consistently failed to find the multiple match effect that would suggest on-line Principle B violations (Chow, Lewis, & Phillips, 2014). We tried many different strategies for replicating Principle B violation effects, but none of them worked. In light of this difficulty in eliciting the fleeting Principle B violations that others have found, we must proceed with caution. But if we take previous results at face value, then it seems that adults and children consider the same illicit interpretations, except that in adults those interpretations are evident only in rapid on-line measures.

4.6 Russian Backwards Anaphora (again)

In light of the child-adult parallels in other constraints on anaphora, it is worthwhile to return to the Russian *poka*-constraint that we started with, to find out what Russian adults do with the constructions where young children showed non-adultlike interpretations. Our findings on adult comprehension place the child findings in a new light (Kazanina & Phillips, 2010). Russian adults read sentences in which a potential antecedent for a pronoun appeared in three different configurations relative to the pronoun: one where coreference is possible for Russian adults (10a), one where coreference is impossible due to Principle C (10b), and one where coreference is impossible due to the *poka*-constraint (10c).

10a. Posle togo kak on_i procital knigu, $Ivan_i$ s'el jabloko. [no constraint]
after he read book Ivan ate apple
“After he read the book, Ivan ate an apple.”

b. On$_i$ cital knigu, poka Ivan$_i$ el jabloko. [Principle C]
he read book while Ivan ate apple
"He read a book while Ivan ate an apple."

c. Poka on$_i$ cital knigu, Ivan$_i$ s'el jabloko. [*poka*-constraint]
while he read book Ivan ate apple
"While he read the book Ivan ate an apple."

The reading profiles for (10a-b) were as in English: there was a gender mismatch effect in (10a), reflecting an attempt to resolve coreference, and no corresponding effect in (10b), indicating that Russians do not attempt interpretations that violate Principle C. But in (10c), where Russian adults also disallow coreference, we found a (delayed) gender match effect, i.e., slower reading times when the gender of the name matched the pronoun. We take this to mean that Russian adults do initially consider the illicit coreference relation, and that the effect of the *poka*-constraint kicks in after some delay, leading to disruption in the gender-match condition.

These adult results cast the child findings in a new light. If Russian adults temporarily consider interpretations that violate the *poka*-constraint, and then quickly inhibit those interpretations, perhaps young Russian children do the same thing, except that they fail at the point where the adults manage to inhibit the illicit interpretation. This would suggest that the children know more than their judgments reveal, and that the developmental pattern that we saw from ages 3-6 might reflect changes in the children's ability to inhibit inappropriate parses, rather than changes in their grammar *per se*.

4.7 Additional antecedent effects in reconstruction (reflexives)

The final stop in this survey involves a case where children's interpretations diverge from adults in a way that it is hard to make sense of unless we invoke language processing limitations. We have already seen that English-speaking children and adults implement that locality constraint on reflexives rather well. An interesting twist on the locality constraint arises when a reflexive is embedded inside a larger phrase, such as the noun phrase in (11) or the predicate phrase in (12). When the phrase containing the reflexive occupies its canonical position, interpretive possibilities are exactly as expected: only a clausemate antecedent is possible (11a, 12a). But when the phrase containing the reflexive undergoes *wh*-fronting, a surprising contrast emerges. NP-fronting creates an additional antecedent for the reflexive (11b). It can still be interpreted as referring to the subject of the embedded clause (the 'reconstruction' interpretation), but it now can also be understood as referring to the subject of the main clause. But fronting a predicate does not have the same effect: in (12b) the fronted reflexive still only allows the embedded clause subject as its antecedent. The contrast is interesting fodder for linguistic analysis (Heycock, 1995; Huang, 1993), but the effects in language acquisition are even more striking.

11a. John$_i$ knew that Bill$_j$ saw the picture of himself$_{*i,j}$.
b. John$_i$ knew which picture of himself$_{i,j}$ Bill$_j$ saw.

12a. John$_i$ knew that Bill$_j$ was very proud of himself$_{*i,j}$.
b. John$_i$ knew how proud of himself$_{*i,j}$ Bill$_j$ was?

In a TVJT using sentences like (13) Leddon and Lidz (2006) found that children gave adultlike interpretations, with one exception. In (13b) they correctly allowed only the embedded clause antecedent, and in (13a) they also allowed the main clause antecedent. But in (13a) they surprisingly rejected the embedded clause antecedent, which we might expect to be the more 'basic' interpretation. Since it is unlikely that those children have a grammar in which reflexives disallow local antecedents, the most natural interpretation of these findings is that children adopt the first available grammatical interpretation of the reflexive, and that once they have adopted an interpretation they stick with it, even when additional antecedents appear. In the NP-fronting sentence in (13a) the first grammatical interpretation of the reflexive takes the main clause subject as an antecedent. In the predicate fronting sentence in (13b) the main clause subject is not a grammatical antecedent, and therefore the subordinate clause subject is the first antecedent that they consider.

13a. Miss Cruella figured out which picture of herself Janie put up.
b. Mr Monkey figured out how proud of himself Andy was.

In a later series of adult studies we probed the word-by-word interpretation of similar sentences (Omaki et al., 2007). We found that adult parsing respects the contrast between NP fronting and predicate fronting. That is perhaps unsurprising in light of the child findings, but it is not so straightforward to see the effect of the contrast. Using a gender mismatch paradigm, it is easy to show that upon reaching the fronted reflexive in (11b) adults immediately interpret it as coreferring with the main clause subject, since that is the only potential antecedent at that moment in time. However, in our initial study we found a similar gender mismatch effect in both the NP-fronting and predicate fronting conditions, suggesting that on-line interpretation ignored the contrast that was so clear in acceptability judgments. Further investigation revealed that adults comprehenders were not ignoring the grammatical constraint, but were making full use of available possibilities.

It is, in fact, grammatically possible for a reflexive in a fronted predicate to corefer with the main clause, because the reflexive may take the embedded clause subject as its antecedent, and that subject could be a pronoun that corefers with the main clause subject, as in (14).

14. John_i figured out how proud of himself_i he_i must have seemed to his_i boss.

Therefore, comprehenders who encounter the reflexive in (14) might be willing to interpret it as coreferring to the main clause subject, because of the possibility of a subsequent pronoun, and this might lead them to anticipate a pronoun. The same expectation for a pronoun should not arise in NP-fronting examples like (11b), where the reflexive can directly link to the main clause subject. We tested this in two further experiments. In the first, we simply gave people sentence fragments that extended as far as the reflexive, e.g., *John knew {which picture of* | *how proud of} himself* …, and asked them to provide a written completion. Pronoun completions were far more common in the predicate-fronting conditions (82%) than in the NP-fronting conditions (50%). The second experiment used self-paced reading to test what comprehenders expect to see after they have already encountered a fronted reflexive that matches the main clause subject. In NP-fronting conditions (15a) they should have no specific expectations, and we found no gender mismatch effect to the embedded subject. But in predicate fronting conditions (15b) they should expect to encounter a subsequent matching noun, and we found a gender mismatch effect following the embedded clause subject.

15a. {Patrick | Rachel} found out which story about {himself | herself} the alcoholic ...
b. {Patrick | Rachel} knew how proud of {himself | herself| the alcoholic ...

Thus, children show knowledge of the contrast between argument fronting and predicate fronting, but they exhibit one surprising gap in the interpretations that they allow. That gap is naturally linked to independent limitations in children's ability to revise initial parses. Meanwhile, adult on-line processing also shows evidence of the contrast between argument fronting and predicate fronting.

4.8 Summary: adult on-line studies reveal source of child errors.

The moral of this section is that we can learn a lot about learners' linguistic abilities by looking at real-time processes in adult native speakers. Using five constraints on anaphora as a test case, we saw that adults' first interpretation corresponds to children's only interpretation. There is much evidence that children have great difficulty in revising their initial parses, and this may be due to independent limitations in children's cognitive control abilities (Omaki & Lidz, 2013; Snedeker, 2013; Trueswell et al., 1999). The contrasts between children's mastery of different constraints on anaphora would be mysterious if we tried to understand them as a case of uneven grammatical development. Thanks to the link with adult on-line parsing profiles, the challenge for grammatical learning theories changes. Rather than needing to explain why children show severe delays in learning some constraints on anaphora, we instead are left with the task of explaining the uneven profile in the online effects of grammatical constraints in adults (cf. Phillips et al., 2011).

5. Level 3 Accounts: Explaining Learning via Processing

At this level, the aim is to go beyond documenting how language processing gives rise to specific effects during child or adult learning. The aim is to ask how language processing contributes to an understanding of learning success in children, or ultimate attainment in adult learners. This is not straightforward, since the most salient finding about language processing in learners is that they are limited in various ways and prone to errors. Therefore we minimally want to understand why the learners' processing limitations do not jeopardize their chances of success. And if we are particularly optimistic, then we might hope that their processing abilities could somehow contribute to explaining their learning outcomes, including an understanding of why children outperform adults.

Unlike the previous section, which was built around a synthesis of clearly related empirical findings, this section is more speculative: we discuss the ways in which language processing findings *might potentially* contribute to an understanding of learning outcomes. The key elements here involve observations about that age at which children outperform adults, and the possible role of rich predictive processing mechanisms.

5.1 Where is Language Processing Relevant to Learning?

Language processing is clearly relevant to language learning. The more information the learner is able to extract from the input, the more successful he is likely to be.

As a first step, the learner minimally needs to be able to accurately analyze sentences that he encounters in the target language. Without this, it is difficult to see how learning could ever succeed. As we have seen above, there are number of ways that learners might frequently misanalyze the input. How much this matters depends on how learning proceeds. If learners rely on key encounters with informative examples in their language input, and are relatively insensitive to distributional information, then they may be relatively unaffected by mis-parses. But if learners instead rely on observing distributional patterns in the input, then systematic mis-parsing has the potential to wreak havoc with learning, as it could change the distributions. Distributional learning is widely assumed to be important in many current learning theories (e.g., Lidz & Gagliardi, 2014; Pearl & Sprouse, 2013; Perfors et al. 2011; Saffran, 2003; Yang, 2002), and it is probably the only viable option in cases where the learner must retreat from an over-general hypothesis.

Various of the studies reviewed above highlight the potential dangers of systematic mis-parsing, which can lead to discrepancies between "input" and "intake" (Omaki & Lidz, 2014). It currently is unclear how much of a danger this presents for learners. It is one thing to mis-parse sentences in controlled laboratory settings, and it is another thing to systematically mis-parse crucial experience in everyday life.

In order to assess the seriousness of the danger, we need to know (i) what distributional information about sentences is crucial for learners, (ii) whether mis-parsing is a real danger in the uncontrolled settings where children naturally encounter those sentences, and (iii) how much the distributional information in the input is therefore likely to be distorted. (See Omaki (2010) for further discussion.)

As a second step, language learners might be able to extract valuable additional information from their experience if they can compare predicted input with actual input. A learner who simply passively analyzes incoming sentences can recognize whether he is able to parse each sentence as it arrives, and this is informative when he encounters a sentence that he cannot parse. But for this passive learner most input is relatively uninformative. In contrast, a more active learner who generates expectations as a sentence unfolds, predicting upcoming categories and words, potentially gains a lot more information about the language input. If the active learner not only makes predictions, but tracks the source of those predictions, then he can use confirmed and disconfirmed predictions as feedback that either reinforces or weakens learned generalizations, allowing retreat from overgeneralizations. In other words, *a predictive parser is a hypothesis testing device*.

An active learner that can act on complex cues to generate predictions could potentially learn about complex contingencies in the language. But in order to do that, the learner must first be able to recognize and integrate complex cues in order to initiate predictions. This is an ability that may be beyond the reach of beginning learners, and certainly beyond the reach of early child learners. We have seen in Section 3.1 that children have difficulty integrating multiple cues to ambiguity resolution (Engelhardt, 2014; Snedeker & Trueswell, 2004; Trueswell et al., 1999), and so it is unlikely that they can use complex cues to generate predictions.

Also, an active learner can use predictions to generate feedback only if he can generate the predictions quickly enough to “get ahead of” the input. We currently know little about how quickly different types of predictions can be generated, but as we saw in Section 2.5, we are starting to learn that some types of predictions are generated only slowly.

However, one clear obstacle to drawing a close connection between parsing and learning is that we know that children are more successful language learners than adults. Yet young children are not especially good parsers. This suggests that we should not want to rely too heavily on language processing abilities for ensuring learning success. But of course this is at odds with a rather well known claim in the language acquisition literature, namely that children are better language learners precisely because of their cognitive limitations (Newport, 1990). We now turn to look more closely at this claim, which seems rather implausible, based on what we now know about how children’s limitations impact their language processing.

5.2 Maturational Constraints - Possible Sources

There is a small number of leading ideas about why children are more successful language learners than adults. (We are surely blurring some important distinctions here, in the interest of space.)

Language-specific maturational constraints. One possibility is that language is an independent cognitive system (an ‘instinct’), and that language learning mechanisms are governed by an biological clock that somehow makes them less effective after puberty (Bley-Vroman, 1990; Clahsen & Muysken, 1986; Hawkins & Chan, 1997). Under this view, children’s cognitive limitations are irrelevant to explaining their language learning prowess. This view is sometimes framed as the claim that children have access to Universal Grammar and adults do not, but that is a more specific version of the claim. (Note that this approach does not exempt us from paying close attention to children’s language processing abilities. Even if language processing abilities play no role in explaining why children outperform adults, we still need to know how children succeed despite their limitations as language processors.)

Less is more. Under the second view, children are better learners precisely because they are more cognitively limited (Newport, 1990). The idea is that children's limitations might help them to recognize generalizations that adults miss. We discuss this approach in more detail in the next subsection.

Entrenchment and transfer. An alternative view is that children don't fare better than adults because they are younger, but because they do not already know another language. Under this view, knowledge of the first language is 'entrenched', and this creates a barrier to learning another language system (Bialystok, 1997), especially with continued use of L1 (MacWhinney, 2004). It's certainly the case that adult learners experience interference from their first language ('transfer'), but this is unlikely to be the whole story. Age does seem to matter. Children who start learning a second language well before puberty typically learn quite well, and can achieve apparently native-like proficiency. (This includes the second author of this paper, who started learning English at age 6, and who is functionally a native speaker.) And children who start learning their first language too late certainly struggle, as seen especially in cases of deaf learners who are first exposed to a sign language later in life (Newport, 1990).

Nothing to explain here. A fourth approach is to dispute the claim that there is an age-related decline in the ability to learn grammar, and to argue that adults are entirely successful language learners. We will not dwell upon that one here, as it strikes us as a non-starter, although it is certainly possible that individual phenomena may show no age effects.

Neuroplasticity - a non-account. A final approach is to appeal to changes in brain plasticity with age. Children's brains are more flexible, and hence they learn better than adults (Penfield & Roberts, 1959, Lenneberg, 1967, Long, 1990). We also have little to say about this view, because it is essentially a restatement of the problem, rather than an explanation: it simply says that children can learn better, which is the fact that we're trying to explain. A more articulated version would need to draw specific links between neural changes and specific language abilities.

5.3 Less is More. Maybe.

One of our key concerns is the danger that learners' sentence processing limitations might derail their ability to successfully master the grammar of their language. But this contrasts with the counterintuitive but attractive idea that learners' limitations might actually facilitate learning, and that children's linguistic prowess might be a direct consequence of their limitations. According to this "less is more" proposal, adults fail because they are too smart (Newport, 1990), and learners with limited resources should enjoy better outcomes (Elman, 1993). This idea has attracted a great deal of attention – as we write this, Newport and Elman's articles each show 1243 citations in Google Scholar – but surprisingly little critical discussion. A strength of Newport and Elman's claims is that they are backed up by computational simulations, but a closer look at the models shows that they mostly avoid the problems that most concern us here.

Newport's argument is supported by a computational model of morphological learning. Goldowsky and Newport (1993) present a model of how learners figure out the correspondence between morphemes and meanings in complex words that they encounter. For example, the learner must discover that the word unhelpful has three morphemes, and what the meaning/function of each is (16), i.e., it learns pairwise correspondences.

16.	un	help	ful
	Neg	'aid'	adj

For each word that it encounters, the learner considers multiple potential correspondences. As it accumulates more experience, it builds up in memory a matrix of potential correspondences, and it uses this to identify the reliable correspondences. Its main task is to separate the true correspondences, e.g., un=neg from spurious correspondences, e.g., ful=neg+aid. Goldowsky and Newport show that the model's performance is limited by the large number of spurious correspondences that it stores, and that performance improves when the model's memory encoding is limited, so that on each trial it stores only one or two potential correspondences.

Rohde and Plaut (2003) is one of very few studies to engage with the specifics of Goldowsky and Newport's model. They argue that an alternative learning algorithm fares far better than Goldowsky and Newport's algorithm, and removes the benefit of limited memory.

A more important question about the Goldowsky and Newport simulations is whether their assumptions are applicable to the challenge of learning syntax and semantics. In particular, their model takes as its starting point a perfect encoding of the form units and meaning units that need to be learned, e.g., the morphemes and the syntactic/semantic chunks in (16) are exactly the right ones. The model's only task is to figure out which of the correct form pieces is associated with which of the correct syntactic/semantic units. (The model also considers that combinations of form units might be linked to particular meanings, but this does not greatly affect the model's task.) The effect of limited memory for the model is to impose a bias for encoding correspondences of approximately the right grain size. Similarly, other recent demonstrations of "less is more" effects in word segmentation models succeed because the model is forced to make plausible assumptions about the size of the lexicon of the target language (Hitzcenko & Jarosz, 2014; Pearl et al., 2010). See Perfors (2012) for useful discussion of the relation between memory limitations and learning biases.

The challenge in learning syntax and semantics is rather different. The learner's task is to discover what are the structural units of the target grammar, and what semantic units they correspond to. But both of these are hard to observe, and prone to misclassification. The structural units are not transparently reflected in sentence forms, so they must be inferred from unreliable evidence. And the semantic units are also not at all transparently observable. Even if we make the generous assumption that learners can perfectly infer a speaker's intent with a sentence, that is very different than knowing which parts of that intent are mapped onto semantic units in the sentence, and which are left to pragmatic inference (for a useful discussion see Lewis, 2013). Therefore, the main problem in learning syntax and semantics is the immense ambiguity of the evidence, and this is the part of the problem that is largely treated as pre-solved in Goldowsky and Newport's morphological learning model. Their model starts with a set of generally plausible hypotheses, and the effect of resource limitations is to focus attention on more likely hypotheses. But in learning syntax and semantics the greatest danger is that learners could mis-analyze the syntactic and semantic units in the input. And the effect of resource limitations can only increase this danger, by making mis-analyses more likely.

Elman (1993) presents a different computational demonstration of the "importance of starting small" that is closer to the syntax/semantics learning problem. Elman's neural network model uses a simple recurrent network to predict the next word in sequences of pseudo-English. In order to do this, it needs to implicitly learn the grammar. The focus of the model is on correctly learning subject-verb agreement relations, even when the subject and verb are separated by intervening relative clauses. Elman argues that the model learns best when it is initially restricted, either via limited memory or via simplified input. The conclusions about the benefits of starting small are disputed by Rohde and Plaut (1999), who claim that Elman's results do not replicate across a variety of model configurations. But perhaps more important is that the syntactic domain that Elman focuses on is unrepresentative of the task that real learners face. Subject-verb agreement is represented in almost every clause of every sentence that learners encounter. So learners enjoy an abundance of evidence about subject-verb agreement, and the relation between subject properties (number/person) and agreement properties (number/person) is relatively straightforward. This is not representative of the problems that are most challenging to child learners. And it is also probably not an area that is most affected by critical periods.

In sum, it is not clear that existing demonstrations of the benefits of limited resources have much to offer for understanding children's success in learning syntax and semantics. Even setting aside the modeling concerns about the original computational arguments, the benefits of limited resources are not magical. They may be useful in linguistically simple domains where a constraint like “don’t memorize too much” is sufficient to point the learner in the right direction. But that is not what makes learning syntax and semantics so hard. The difficulty in these domains is different: the problem is that there are too many potentially misleading analyses of the structure and meaning of any incoming sentence, and so the learner needs more specific constraints on his hypothesis space. So we are skeptical of the standard version of “less is more” as a contributor to grammar learning. But this does not mean that we have given up on the idea entirely, as we shall see shortly.

5.4 Nature of the child advantage: When do children shine?

In order to understand why children outperform adults in learning sentence-level grammar, we need to know when children outperform adult learners. Put simply, if children already outperform adults at age 2, then we need an account that can capture how 2-year olds notice generalizations that adults miss, despite their acute limitations. But if children do not outperform adult learners until a later age, we need a different kind of account.

In order to figure out when and where children outperform adult learners, we need to first know what language phenomena cause the greatest difficulty for adult learners, and then find out when children master those phenomena. This is easier said than done, as it is hard to find a consensus on the things that adult learners fail to master.

Adults are poorer learners than children in (at least) two ways. They are slower, even for things that they do eventually master. This is surely important, though we have less to say here about speed. And there are things that adults typically fail to learn, even after many years of immersion. It is not easy to come up with a definitive set of phenomena that adults fail to learn. In part this is because different adult learners have trouble with different linguistic phenomena, depending on the relation between their L1 and their L2. But this is also made difficult by the fact that it is hard to distinguish slow learning from failed learning. If we are most concerned about the things that late learners have the most difficulty with, then we need to look at very advanced learners, i.e., at the question of “ultimate attainment” (Abrahamsson & Hyltenstam, 2009; Birdsong, 2004; Coppieters, 1987; DeKeyser, 2005; Montrul & Slabakova, 2003).

A common claim about advanced adult learners is that they fare well on the learning of obligatory syntactic rules, and robust word order patterns, but that they have the greatest difficulty with forms that are used optionally, especially if the optionality is semantically conditioned (Coppieters, 1987; Sorace, 2011).

It is clear that much more needs to be learned about where the most advanced adult learners fail, but our impression is that the phenomena that adults struggle with the most are not things that children typically master at a very young age. Children appear to know a great deal about the word order and morphology of the target language at an early age, e.g., by age 3 or 4 (e.g., Guasti, 2002; Phillips 1995/2010; Snyder, 2007), but there are many things that children do not master until later, and these often involve semantically- or pragmatically-conditioned formal choices (e.g., de Villiers, 2005; Goro, 2007; Kazanina & Phillips, 2007; Speer & Ito, 2009; Weckerly, Wulfeck, & Reilly, 2004)

Here is a critical part of our case: if the domains where adults fall short are ones that children master relatively late, when their cognitive and language processing resources are sharply improving, then this undermines the notion that children outperform adults specifically because they are so cognitively limited. If the limitations were the cause of children’s success, then surely children would shine at an earlier age. (That might be the case in some domains of language, such as speech articulation, but it does not seem to be the case for syntax and semantics.) So the next step in our argument is to address why the things that are learned slowest are so difficult.

We should note that a potential source of inspiration for understanding where children outperform adults should be controlled studies using artificial grammar learning paradigms. But unfortunately these studies tend to show the opposite, that adults outperform children (e.g., Ferman & Karni, 2010). This could be because artificial grammar learning tasks favor ‘explicit learning’ over ‘implicit learning’ mechanisms (DeKeyser, 2003), giving the edge to adults. Alternatively, it could just be that the kinds of phenomena that can feasibly be tested in the scope of a lab-based study are too simply to allow children to shine.

5.5 What Makes the Hard Stuff so Hard?

So what is special about the linguistic phenomena that cause the greatest difficulty for learners? In particular, what is distinctive about the things that children learn late, and that adults may never master? We start with the question of why these phenomena might be so hard to learn, and then proceed to the question of why children fare better than adults.

One tempting explanation for things that children learn late is that they are rare phenomena that children simply do not receive much evidence for. Learning is slow because children must wait to accumulate sufficient evidence. A concern about this line of reasoning is that blaming sparse input data for late development should predict enormous variability in when children master a given phenomenon. If the relevant input data is so sparse that a typical child must wait for 6 years to accumulate enough evidence, then perhaps some children would never encounter enough evidence and would fail to learn, and some other children might get lucky and see enough evidence to learn much earlier. In this scenario, variation in learning schedules should be linked to learners’ experience, and not to their learning abilities, so we should expect major variability in outcomes, unrelated to children’s general cognitive or linguistic talents. To our knowledge, we do not find cases like this, and so we are skeptical of accounts that blame delayed development of *specific linguistic phenomena* on mere sparse input. (This is to be contrasted with the effect of overall limited input, which may have severe consequences for language development in general (Hart & Risley, 1995).)

An alternative that we find more promising is that there are internal changes in learners that allows them to recognize evidence in their surroundings that they were blind to before. This change could happen because learners start to encode some feature of their experience that they were not previously encoding. For example, independent development of social cognitive abilities might lead children to recognize semantic/pragmatic regularities that they were not aware of earlier. Alternatively, learners might notice new evidence in their surroundings because their language processing abilities develop in a way that allows them to test more complex hypotheses about contingencies in the input. For example, if they become able to generate predictions based on complex cues, integrating information across domains, this could allow them to confirm or disconfirm regularities that they were previously unable to test. Under either of these scenarios, variation in learning speed should be tied to individual learners’ abilities, rather than to properties of their language input.

This leads to a potential link between the development of language processing abilities and the mastery of hard-to-learn linguistic generalizations.

i. Complex contingencies, especially involving the integration of information across multiple levels of encoding, e.g., syntax and pragmatics, may be among the hardest things to learn.
ii. In the domain of structural ambiguity resolution, children show difficulty in rapidly integrating different sources of information to guide their parsing choices.
iii. Learning complex contingencies often draws on predictive mechanisms, which allow the learner to test hypotheses. (This is especially relevant in cases where the learner needs to retreat from overgeneralization.)
iv. In the domain of linguistic prediction, some types of linguistic constraint generate predictions more slowly than others (see Section 2).
v. Generating predictions based on combined information from multiple domains may be particularly difficult, and may be a late-developing ability.

Among these points (i) is moderately well motivated; (ii) is relatively uncontroversial; (iii) is more speculative, but we do not know of better ways of testing hypotheses and retreating from overgeneralizations; (iv) is not a well-established finding, but we are seeing more and more evidence that it is true; and (v) is something that we have no direct evidence for, though it seems eminently plausible if (ii-iv) are true.

Clearly the link that we are suggesting here involves a number of uncertain steps, so further work would be needed to confirm or reject it. But first we need to turn to an even more pressing concern: how could this hope to explain why children fare better than adults?

5.6 Why Children Shine, and How Less Could (Eventually) be More

Even if it is true that late developing language processing abilities are essential for children's learning success, we still need to know why adults fare less well. Shouldn't they be able to learn using exactly the same mechanisms that children rely on?

We could, of course, argue that adult learners might never attain the language processing abilities that a typical primary school child develops. For example, if it is true that the key to learning complex linguistic phenomena involves complex predictive mechanisms, perhaps adults never get to be as good as children. But we are not optimistic about this approach, as it would require that even the best adult learners should have worse language processing abilities than relatively poor child learners. We regard that as unlikely.

As far as we know, adults have the basic cognitive abilities that should allow them to process incoming sentences just as proficiently as children do.

We saw that younger children show limitations in initial analysis and reanalysis, especially in the ability to revise their initial interpretations. A standard view is that this is not a language-specific problem, but instead reflects the slow maturation of cognitive control abilities. If this indeed reflects a maturational constraint, then we should expect adult learners to do better than children at an earlier stage of learning. And this does appear to be the case, specifically in the domain of reanalysis.

In contrast, we assume that children's limitations in predictive processes reflect proficiency rather than maturation. Children develop better prediction mechanisms as they learn more about their language. If predictive mechanisms are tied to proficiency, then they should develop similarly in child and adult learners.

So why should adults, who do not obviously lag behind children at any stage in the basic abilities that underlie sentence processing, wind up as inferior learners?

It is possible that adult learners' deficits at other levels of language processing, such as sounds and words, do lag behind even young children, and that the consequences of this are so severe that they hold back sentence processing abilities. But we do not think that we have good evidence for such a claim.

An alternative possibility, which is probably the most speculative piece of our already speculative argument, is that advanced adult learners do have the same basic sentence processing abilities that advanced child learners have, but that they are held back by what they learned at earlier stages of learning the language. Adult learners should, in principle, be able to analyze input sentences in the same way that advanced child learners do, and they should be able to use their predictive mechanisms to generate and test complex contingencies involving information from different linguistic domains. But perhaps the 'toxic combination' is that adult learners' early successes -- at a stage when they are relatively good (re)analyzers but not yet good predictors -- somehow lock them into sentence processing routines that make them less sensitive to the new information that should become available to them later, once they become more effective predictors.

But if adult learners' problem is that their early processing successes damage them, and make them less receptive to later insights, why shouldn't children have exactly the same problem? We do not have a good answer to this, but can offer some suggestions for where to look. (i) Children's immature memory mechanisms might make them less committed to what they learn initially, and hence more receptive to later insights, once they have the improved processing abilities needed to gain those insights. (ii) Children's inferior (re)analysis abilities might give them less confidence in their initial learning. (iii) It could be that predictive abilities develop earlier in adult learners than in children, in a way that might give rise to differential learning. But the evidence about predictive abilities in learners is currently far too limited to draw any conclusions about this.

Summarizing, our speculation is that adult learners might be held back precisely because their early learning prevents later progress. So this brings us surprisingly close to a "less is more"-style account. But instead of proposing that children outperform adult learners because their information processing limitations lead directly to more accurate insights, we instead propose that their limitations might help them to avoid damage, making it possible for them to eventually outperform adults, once their processing resources become more fluent. In other words, our suggestion could be summarized as "less is eventually more".

6. Conclusion

Our main goal here was to advocate for a specific type of relation between language acquisition and language processing research, especially at the syntax/semantics level. It is easy enough to take ideas from the adult L1 psycholinguistics literature and port them to learner populations. But although this can teach us a lot about the learners, it is less clear how it helps us in understanding learning. And that is presumably our primary aim. We described some ways in which language processing research could actually contribute to accounts of how learning succeeds, and how it fails. In discussing the key components of parsing abilities, we emphasized components that might be essential for learners' grammatical parsing of the input, and that go beyond the standard menu of ambiguity resolution phenomena. This included some new findings about the the speed of different types of predictive process, which could turn out to be important for language learning, because predictive processing helps the learner to do hypothesis testing. We gave one extended example of how language processing mechanisms can shed light on some old chestnuts in language learning. And finally we made some conjectures about how specific language processing abilities might contribute to the success of child learning, and perhaps even to maturational constraints on learners. We argued that "less is not more", at least in the way that the Less is More view has generally been understood, but suggested that a "less is eventually more" approach might show promise.

Over the course of the article, we tried to pull together findings from disparate areas that we think could be relevant to our main aim. But the reader will have noticed that in doing so we had to make many leaps of faith, to compensate for gaps in current knowledge. A second goal of this paper was to highlight some topics that we need to know a lot more about, if we are to understand successful and unsuccessful learning. We need to a lot more research that compares adult and child learners. In particular, we need to know more about the specific areas where children outstrip adult learners. We need to know a lot more about how predictive mechanisms can be deployed in adults: psycholinguists have repeatedly demonstrated that these mechanisms exist, but we are only now beginning to learn about how they might work in more detail. And if we can understand those mechanisms better, it could become feasible to link a more detailed understanding of those mechanisms to the advanced stages of language learning.

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