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CHAPTER 4

How does syntactic priming experience support language development?

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Syntactic priming effects are argued to reflect the mechanisms that underlie language acquisition. This chapter explores the predictions of key models for such learning via syntactic priming and discusses the extent to which behavioural evidence is consistent with these predictions. Specifically, the chapter examines whether the timecourse of priming effects in research with children reflects lasting effects of syntactic experiences, and what between-group and between-individual variation in priming effects, predicted by the error-based nature of the learning mechanism, might be expected. The chapter also considers whether learning via priming might be located in comprehension and – or production processes. The chapter finishes by making recommendations for how future research may build on existing findings to further test these models, including discussing methodological implications.

Keywords: long-term priming, implicit learning, mechanisms, timecourse, variation, prediction

1. Introduction

Much of the syntactic priming research with children has focussed on the question of what priming effects show about the syntactic representations that children are acquiring, whether those children are monolingual learners of one language (e.g. Huttenlocher, Vasilyeva, & Shimpi, 2004; Savage, Lieven, Theakston, & Tomasello, 2003), bilingual learners of two or more languages (e.g. Vasilyeva et al., 2010) or children with delayed language acquisition (e.g. Allen, Haywood, Rajendran, & Branigan, 2011; Garraffa, Coco, & Branigan, 2015). In particular, syntactic priming has often been used to address the question of whether young children's syntactic representations are abstract or item- (e.g. verb) specific, in response to long-standing debates on the development of syntax in the developmental literature. Such research was a natural extension to early models of priming which characterised priming effects as transient activation of representations of syntactic structure (Pickering & Branigan, 1998; see also Branigan & Pickering, 2017). However, the adult priming literature identified that priming effects do not just reflect transient activation of static representations, rather they appear to indicate long-lasting effects of prior experience on speaker's representation and processing of syntactic structures (e.g. Bock & Griffin, 2000). These long-lasting

effects have been characterised as implicit learning of syntactic choices, with the weighting for a particular choice being shifted when a prime structure is processed. This weight-change increases the likelihood of a syntactic choice being used in the immediate- and, crucially, the longer-term.

Subsequent models of syntactic priming have therefore faced the challenge of embedding such learning effects into the mechanisms of syntactic priming. One influential model specifically relates these learning effects to the learning architecture that supports child language acquisition (Chang, Dell, & Bock, 2006) making it particularly relevant to child syntactic priming. Indeed, this conception of priming creates a new challenge for the child priming literature – to explore the predictions of such implicit learning models of syntactic priming and to discover whether the behavioural evidence for syntactic priming in children supports the predictions of models of syntactic priming as implicit learning. In this sense, developmental syntactic priming evidence can play a critical role in determining the mechanisms and architecture of human language that support syntactic priming, but that also therefore underlie broader language processes, such as language acquisition. In this chapter, we outline the predictions of such models and the kind of evidence required to support them; we also review how well the current evidence-base supports them and make suggestions for future research directions in this area.

2. Syntactic priming as implicit learning

Bock and Griffin (2000) demonstrated that syntactic priming effects persist beyond the immediate priming trial. In their study, adult participants produced primed syntactic structures when up to ten intervening fillers were placed between the prime trial and the target response. These results are supported by other demonstrations of long-lasting priming effects of abstract syntactic structure, that is, priming in the absence of lexical overlap between the prime and target items. For example, adults tend to produce more primed structures following increased exposure to that structure both within and across experimental sessions, (Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008; Kaschak, 2007; Kaschak, Kutta, & Schatschneider, 2011; Kaschak, Loney, & Borreggine, 2006). By contrast, when there is lexical repetition between prime and target sentences, the lexical boost to priming that occurs (the increased magnitude of priming with lexical repetition) is typically a short-lived effect (Branigan & McLean, 2016; Hartsuiker et al., 2008). As Bock and Griffin concluded, different mechanisms may therefore support the lexical boost to priming with repeated words and the priming of abstract structure. One account for these differences is that more explicit, short-term memory systems support the former whereas long-term, implicit learning mechanisms support the latter (Branigan & McLean, 2016; Chang, Janciauskas, & Fitz, 2012; Dell & Chang, 2014). Such learning mechanisms are characterised as shifting weightings of the representations of alternative syntactic structures which influence the likelihood

of a particular structure being selected in subsequent language processing. A more recently processed structure will be weighted more strongly leading to its higher likelihood of reuse for subsequent utterances (that is, priming effects). As such, in this instance, the 'learning' that leads to priming effects is not learning of new syntactic structures, rather it is moment-by-moment tuning of the language system to reflect the preferences or statistics of the current discourse, in essence, learning to match or align the structural choices of the speaker (or writer) during that discourse.

Different models for these learning effects have been proposed. Some model these effects as unsupervised learning based on increased activation of representations within short- and long-term memory (Malhotra, Pickering, Branigan, & Bednar, 2008; Reitter, Keller, & Moore, 2011). Other models propose that learning through priming is related to prediction processes, via a rational learning mechanism (Jaeger & Snider, 2013) or a supervised learning mechanism (Chang et al., 2006). This latter model of syntactic priming roots short- and long-term priming effects in adults within the architecture that underlies child language acquisition. This model proposes that the implicit learning of structural preferences that is observed as immediate and long-lasting priming effects in adults is in fact a vestige of the mechanism that learns the syntactic structures of the language from the early years. Chang et al. (2006) proposed a prediction-driven, error-based implicit learning model of language acquisition, processing and priming. As speakers listen to language input they actively predict upcoming words based on predicted structures – learning occurs as the model compares its predictions to the actual input and adjusts its weighting for different structures to reflect the actually-experienced structure. Because this error-based adjustment increases the weighting of a structure, it makes that structure more likely to be re-used until further evidence to adjust that weighting is experienced, hence immediate and long-term syntactic priming effects.

These prediction-based accounts therefore locate learning within the comprehension process: as children listen, they make predictions about upcoming words (Chang, et al., 2006) or structures (Jaeger & Snider, 2013), and then use the discrepancy between these predictions and the actual input to make long-term adjustments in the strength of their syntactic representations, which subsequently affect their syntactic choices in production and comprehension. As such, implicit learning accounts of syntactic priming imply a close relationship between the input language that children hear and process and the language that they produce within immediate interactions but also more generally across their language development. Broadly speaking, there is good evidence that children's language development closely reflects the input they receive in the long-term: the quality and quantity of input that caregivers provide corresponds to the quantity and range of language that children subsequently acquire and use (Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010). Children who experience more varied language develop larger vocabularies and more

efficient lexical processing, as well as better comprehension of syntax and more varied production of sentence structures (Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Weisleder & Fernald, 2013). One possible explanation for this close correspondence between input and output, is that processing syntactic structures for comprehension in immediate interactions does indeed provide implicit learning of syntactic structure, via the same mechanisms that create immediate syntactic priming effects.

Such learning would therefore be visible as immediate priming effects in the short-term. As covered in the other chapters of this volume, there is ample evidence that children are susceptible to immediate syntactic priming and will repeat the language input that they hear within an immediate interaction. These effects are prevalent across a wide range of ages, varied languages and structures and even modalities. These short-term experiences of syntactic structures would yield immediate adjustments to their syntactic representations (and corresponding immediate changes to their likelihood of using those structures), which in turn lead to long-lasting learning for how to use different structural choices in the language being acquired – in the manner described by implicit learning accounts of syntactic priming.

If it is the case that an implicit (error-based) learning mechanism underlies syntactic priming, we would expect certain patterns of priming to emerge within the behavioural evidence. First of all, the timecourse of priming effects should be consistent with an implicit learning mechanism: abstract syntactic priming effects should be long-lasting in children in the same way as they are in adults, since instances of priming should lead to long-lasting changes in children's representations of structures as they do in adults. Moreover, such effects should accumulate: since each exposure to a syntactic structure involves the process of error-based learning through predicting and adjusting representations, successive experiences of an unpredictable structure should lead to successive increases in its weighting, over time gradually increasing its weighting and therefore the likelihood of its use. As such, the overall likelihood of using a syntactic structure should become greater with accumulated experiences of priming. Conversely, lexically-mediated priming effects should be short-lived if they are not supported by the implicit learning mechanism.

Moreover, models of implicit syntactic learning that incorporate an error-based learning mechanism predict systematic variations in syntactic priming effects as a function of both age and structure type. This is because the extent to which a syntactic experience affects subsequent behaviour depends on features of learners themselves – their prior experience with language and their individual propensity to learn language. Learning rate[1] reflects individual propensity to learn

[1] Note that we use the term here to describe variability in individuals. Whilst within the error-based connectionist model of learning, 'learning rate' refers to the parameter that determines whether priming occurs via prediction error (Chang et al., 2006), it has subsequently also been used to characterise the biological, age-dependent learning parameter, with

language and is assumed to vary at both the individual and group level, so that it varies between individuals but overall is larger at the start of language learning and decreases with age as an individual's language experience and knowledge comes to reflect the adult language state. Prediction error is the discrepancy between expected vs actual input and will itself reflect an individual's previous syntactic experience and knowledge – speakers with less experience with the target language are more likely to make prediction errors when processing input (Branigan & McLean, 2016; Chang et al., 2006; Jaeger & Snider, 2013). Based on these features, children are predicted to be more susceptible to effects of syntactic experience in general, for example in comparison to adults, (via a higher learning rate), and when exposed to structures for which they have less robust representations (via a higher prediction error), such as later acquired and – or disfavoured structures (e.g., verb structures compared to noun structures; passives compared to actives). Such effects should even be increased in younger children who are at an earlier stage in their language development. Consequently, because of younger children's higher learning rate and likely greater prediction error, there should be group-level differences between younger and older children, as well as between children and adults, in the magnitude of priming. Equally, within an age group, syntactic priming effects may vary between individuals, depending on – and in relation to – individual children's learning rate and previous syntactic experience.

Lastly, if learning occurs during comprehension of syntactic structures, then long-lasting effects of priming should depend primarily on comprehension experiences and should not be related to participants' own production of syntactic structures. Whilst in principle, children may learn from their language production, this is unlikely to be due to error-based learning as the likelihood of any prediction error – the mechanism that drives priming and learning – during language production processes would be low.

In summary, this model of syntactic priming as implicit learning leads to a number of expectations about how syntactic priming effects should manifest in children, with regard to the timecourse of priming effects, between- and within-group differences in the magnitude of priming, and the locus of learning. To summarise:

i. Abstract syntactic priming effects should be long-lasting and cumulative, and lexically-mediated priming effects should be short-lived, in children as in adults, since only abstract priming is hypothesised to rely on an implicit learning mechanism.
ii. Priming effects should be stronger in young children than in older children, and in older children than in adults since learners are likely to be more susceptible to the type of prediction error that leads to adjustments (learning). The strength of priming may also

younger speakers having a higher learning rate than older speakers, that explains changes in language learning with time (Janciauskas & Chang, 2018; Peter et al., 2015).

vary according to the syntactic structures being manipulated and how likely they are to generate prediction error.

iii. Priming effects should vary within groups based on individuals' language experience and learning rate.

iv. Learning should, under this model, occur primarily during comprehension rather than production since learning occurs through prediction when processing input sentences.

In the following sections, we will review how well the existing behavioural evidence supports these predictions, and, as such, implicit learning models of syntactic priming. We will also consider what evidence is still needed to understand whether syntactic priming mechanisms reflect implicit learning for syntactic structure in children.

3. The timecourse of syntactic priming effects in children

There is some evidence that syntactic priming effects persist beyond the immediate prime in young children. Huttenlocher et al. (2004) demonstrated that children who had heard a block of either dative or passive picture description primes before describing another block of pictures would reproduce the structure they had heard across the block of target pictures. Kidd (2012b) similarly demonstrated that children continued to produce passive descriptions in a post-test following a block of passive prime-target trials, and their production of passives remained above baseline levels (see Gámez & Shimpi (2016) for similar results in Spanish). Savage, Lieven, Theakston, and Tomasello (2006) found that children who were primed with a short block of passive primes were more likely to reuse the passive to describe similar pictures both immediately, after a week and, if re-tested after a week, one month later as well. Thus, young children who have recently experienced a syntactic structure in a previous discourse will re-use this structure in subsequent discourse demonstrating lasting effects of syntactic primes. This evidence is, however, limited in important ways. First of all, the children who showed priming in these studies were all relatively old (around five years of age) – if the implicit learning mechanism that supports priming is a mechanism for language acquisition, then evidence of long-term priming should emerge at younger ages. Secondly, the priming in these studies was from a block of the same prime structure – it is not clear whether long-term priming would have arisen in these studies if priming was not blocked. Thirdly, such studies were too short (in terms of the number of items) to measure whether priming effects were cumulative.

Other evidence does however address these issues: a handful of studies have tested priming with younger children and when children's linguistic experience varied between different syntactic choices. Branigan and McLean (2016) demonstrated that 3- to 4-year-old children show lasting priming across two filler trials between the prime and target. Children were more likely to produce

passive descriptions when they had heard a passive prime than when they had heard an active prime, even when this priming event occurred two picture descriptions earlier. Messenger (2021) demonstrated that 3- to 4-year-old children who heard a mixture of active and passive primes in a priming phase continued to produce passives in a post-test phase, whether that occurred immediately after the priming phase or after a short, 1-2 minute delay. Fazekas, Jessop, Pine, and Rowland (2020) found that 5- to 6-year-old children produced more dative sentences in a post-test after hearing dative primes that mis-matched the verbs' structural biases. These studies suggest that effects of syntactic priming from mixed exposure to different syntactic structures persist in younger children over short lags within an experiment session. Furthermore, Branigan and McLean (2016) used a larger than typical number of items and demonstrated that priming effects accumulated across the experiment: when measured over children's correct and errorful responses, children produced more passives as the experiment progressed and as they heard more passives (see also Kidd, 2012b). By using a multi-session study design, Branigan and Messenger (2016) showed that priming effects accumulated across two sessions (which included both active and passive primes) separated by a week: children produced more passives in the second priming session than in the first. Though children experienced the prime input in both sessions, meaning the relative contributions of short- and long-term priming effects is not easily distinguished, the increased production of target structures across all priming trials in the second session, irrespective of the prime condition, implies a lasting effect of the first session. These results are consistent with a mechanism of priming in which priming experiences constitute learning about syntactic choices which leads to both immediate re-use of experienced structures and lasting changes to representations of those structures.

Nonetheless, the evidence remains limited. There is scope for further research testing priming as implicit learning at younger ages (cf. Foltz, Knopf, Jonas, Jaecks, & Stenneken, 2020) or the durability of priming effects for languages other than English (cf. Gámez & Shimpi, 2016; Hsu, 2014b, 2019) and syntactic structures other than passives (cf. Fazekas, et al. 2020). The English passive has proved a useful tool in syntactic priming research (see Chapter 5) as it is late acquired and infrequent – it is particularly suited therefore to production experiments measuring priming in older children. Evidently, however, if the mechanisms behind priming are fundamental to the process of language acquisition, then such patterns of priming should be more widely observed across other English structures and across other languages and at earlier stages of development. Within any language, children should show a propensity to repeat recently experienced syntactic structures and to be more likely to reuse them in the long-term with sufficient exposure. Moreover, by comparing priming effects across different structures, we can not only gain a clearer understanding of the generalisability of priming effects and the mechanisms that underlie them, we

can also test predictions regarding the magnitude of priming and learning, based on the frequency of particular structures (see section 5 below). There has been more published research on *immediate* priming effects with different structures (such as datives, (Buckle, Lieven, & Theakston, 2017; Peter, Chang, Pine, Blything, & Rowland, 2015; Rowland, Chang, Ambridge, Pine, & Lieven, 2012); noun phrases, (Branigan, McLean, & Jones, 2005; Foltz, Thiele, Kahsnitz, & Stenneken, 2015); possessives, (Skarabela & Serratrice, 2009); and auxiliary inclusion, (Krok & Leonard, 2018; Rissman, Legendre, & Landau, 2013)), or with a limited range of other languages (e.g. German, (Foltz et al., 2020); Mandarin Chinese, (Hsu, 2014a); Spanish, (Gámez & Shimpi, 2016; Gámez, Shimpi, Waterfall, & Huttenlocher, 2009); and Russian, (Vasilyeva & Waterfall, 2012). However, there is a clear need for further cross-structure and cross-linguistic research that also examines the longevity of syntactic priming effects and thereby the mechanisms that support learning via priming.

Lastly, if priming effects are evidence of long-term learning about syntactic structures, the effect of this experience should be observable in children's language regardless of context. That is, priming experience should be at least partly context-independent, such that experience of a structure in one situation (e.g., a specific interaction) facilitates subsequent use of that structure in a different situation. Research with adults suggests that long-lasting priming effects are not context-dependent (Kutta & Kaschak, 2012), however to date, child priming studies have focused on effects within one experimental task and hence have not examined the extent to which syntactic learning from priming is context-independent. Investigating the extent to which experiencing a structure in one context encourages its later use in the same vs. a different context will help to elucidate the mechanisms underlying experience-based syntactic learning, and whether such learning is wholly context-independent, or instead involves a context-dependent component (e.g. Branigan & McLean, 2016; Chang et al., 2006).

4. Between-group differences in the magnitude of priming

Error-based learning accounts predict that such learning should be greater in those, for example, children, who have a higher learning rate but less accurate or robust representations and who therefore experience greater error in predicting upcoming words and structures. Greater prediction error should entail greater shifting in the weighting of representations, which should be visible in a greater magnitude of priming. A clear prediction of such accounts is therefore that young children at earlier stages of language acquisition should demonstrate larger syntactic priming effects than older children or adult speakers. Whilst many priming studies with children focus on children only (e.g. Huttenlocher et al., 2004; Kidd, 2012a, 2012b; Savage et al., 2003, 2006; Shimpi, Gámez, Huttenlocher, & Vasilyeva, 2007), a number of studies have directly compared

priming effects in young child and adult participants or older children within the same task (Branigan & McLean, 2016; Branigan & Messenger, 2016; Buckle et al., 2017; Messenger, 2021; Messenger, Branigan, & McLean, 2011; Messenger, Branigan, McLean, & Sorace, 2012; Peter et al., 2015; Rowland et al., 2012). None, however, have reported finding the critical interaction between age and syntactic priming that would suggest that one group experienced a greater degree of priming than another. The most promising evidence comes from a pair of studies that targeted priming of dative structures in English and compared younger and older children and adults (Peter et al., 2015; Rowland et al., 2012). These studies report larger effect sizes of the prime condition for younger children than adults though there were no differences in the actual magnitude of priming effects. But generally, in this regard, the evidence that would support implicit learning accounts of syntactic priming remains inconclusive.

However, before we reject such models on this basis, it is worth considering that studies comparing syntactic priming in children and adults have tested samples that span wide age ranges: all but one reported samples ranging in age from 19 to 23 months (the other sample was 12 months), with the average age span being 20 months (Branigan & McLean, 2016; Branigan & Messenger, 2016; Messenger, 2021; Messenger et al., 2011; Messenger, Branigan, McLean, et al., 2012; Peter et al., 2015; Rowland et al., 2012). Most of these studies focus on children between the ages of 3 and 5 years of age; Peter et al., (2015) and Rowland et al., (2012) also tested a group of 5- to 6-year-olds. These studies do not in general test whether this age range relates to performance in the priming task; two studies by Messenger and colleagues found that including age as a predictor did not improve the model fit, though sample sizes in those studies were probably too small to detect reliable relationships (16 and 20/24 children respectively; Messenger et al., 2011; Messenger et al., 2012). Whilst age is not a perfect proxy measurement for stage of language development, it is nonetheless clear that such wide-spanning samples may include children at different stages of language learning. Children at the younger end of the range are likely to be at an earlier stage in their acquisition of syntactic representations and therefore to have a higher learning rate and to have less robust representations, whereas at the upper end of the age limit, children's learning rate may have significantly decreased as their language experience has grown and their representations of syntactic structure have become more adult-like. As such, the two factors that are predicted to modulate priming effects, learning rate and error rate, are likely to vary widely in samples of children spanning such large age ranges. This may be one reason why between-group differences in the magnitude of priming effects have not clearly emerged – the groups being compared to adults included both children more likely to be primed and those less likely to be primed.

For the same reason, previous research may not have observed cumulative effects of priming because of the large age ranges tested: younger children may be more likely to show

cumulative priming effects within a session as the build-up of experience with a structure strengthens a fledgling representation, whereas older children with greater experience of a structure may show weaker cumulative effects alongside strong immediate effects. This may add complexity to comparisons with adults who, given their lower learning rates and greater language experience, may show limited learning effects despite reliable immediate priming.

Whether such between-group differences emerge will also depend on the syntactic structure being primed. This is in part because children's ability to produce a given structure will determine the strength of priming that is observable (see section 7 for further discussion) but also because different syntactic structures are typically in acquisition at different ages/stages. For example, English-speaking children understand the difference between simple intransitive and active transitive structures by their second birthday (e.g. Gertner, Fisher, & Eisengart, 2006) but their understanding of the passive transitive does not emerge until around their third (e.g. Ibbotson, Theakston, Lieven, & Tomasello, 2010; Messenger & Fisher, 2018) and their comprehension and production of passives remains errorful until quite late in development (e.g. Marchman, Bates, Burkardt, & Good, 1991; Messenger, Branigan, & McLean, 2012; Turner & Rommetveit, 1967). The existing research targeting passive priming in English-speaking children may not have shown the expected differences in the magnitude of priming between children and adults because it relied on samples of children that encompassed those at earlier (three-year-olds) and those at later (five-year-olds) stages of acquisition. Within English, children at earlier stages of acquiring the structure, such as three-year-olds, should be more likely to be primed than older children, such as five-year-olds, whose representation is more stable and adult-like. These younger children, upon experiencing passive primes should be more likely to experience error-based learning and therefore show greater priming effects for passives. Targeting priming studies at the appropriate age for the structure being investigated is therefore critical for testing predictions of implicit learning models of syntactic priming.

An alternative approach would be to test sufficiently large samples across a broad range of ages to examine whether the expected relationship between priming magnitudes and developmental age can be observed. It is worth noting that one study based on a large sample of children (122; Kidd, 2012b) found that age did not relate to priming effects but that older children produced more passive forms than younger children. Children in this study were older (mean age 5;7, range 4;5 – 6;11) than in studies comparing passive priming in children and adults (e.g. the studies by Messenger and colleagues which had child samples with mean ages of 4;1/4;2, range 3;1 – 4;11) and thus did not include children at the earliest stages of acquisition. At this older age, passive representations may be more robust hence why age may not have been a good predictor of priming.

Further cross-linguistic work would also be particularly useful in this area. For example, cross-linguistically, when passives are acquired varies widely: in Bantu languages such as Sesotho, where the structure is more frequently spoken, children tend to understand the structure at earlier ages (Demuth, Moloi, & Machobane, 2010) whereas in other languages, such as English, German and Danish, children do not reliably understand passives until they are five, or even later, in the case of Hebrew, Lithuanian and Catalan (Armon-Lotem et al., 2016). The fact that acquisition of syntax varies in line with the frequency and the complexity of the structure in the target language input is consistent with implicit learning accounts. Correspondingly we would predict child speakers of different languages to show particular sensitivity to priming of passives at different ages – based on their experiences, a five-year-old child acquiring Sesotho would be more likely to correctly predict a passive in their language, and therefore less likely to show large priming effects for passives. By contrast, a five-year-old child learning Hebrew or Catalan, for whom passives are less frequent, would be less likely to have acquired a full representation for passives and less likely to predict passives during comprehension, and therefore more likely to show large priming effects for passives. Cross-linguistic comparisons would therefore provide a useful tool in evaluating models of priming as implicit learning.

It is worth noting, however, that in existing evidence, children learning Spanish, a language in which the periphrastic (*fue*-) passive is very rarely spoken, show limited priming of the form even at six years of age: priming only occurred when the prime was repeated before a target was described (Gámez & Shimpi, 2016). Without repetition, Spanish-speaking children were instead primed to produce the more frequent, subjectless (*se*-) passives following periphrastic passive primes (Gámez et al., 2009). Thus, children experienced priming of information structure and some elements of syntax (the *by*-phrase) if not of exact constituent structure. Similarly, younger 3-year-old children learning English, sometimes show reliable priming only after repeating the prime (Shimpi et al., 2007). This evidence may indicate that children must have enough experience with a target structure to have acquired a suitably robust representation for priming effects to occur (Whitehurst & Novak, 1973); alternatively, it is possible that some proficiency with enlisting that representation for production is also required, as we discuss below. This further implies that group differences in priming may only emerge in early but not the earliest stages of acquisition.

Consequently, in order to accurately test the predictions of implicit learning models of syntactic priming, and thereby gain an understanding of the mechanisms underlying language acquisition and priming, further research will need to target samples of children at appropriate ages for the structures being tested. By comparing priming effects for different structures within a language at different ages, and priming effects for similar structures across languages at appropriate ages, it should be possible to build up a body of evidence for whether children show the predicted

sensitivity to syntactic experiences and contrast this with participants who should be less sensitive, that is, adults and older children in order to better understand the nature of the implicit learning mechanisms underlying syntactic priming.

5. Between-individual variation in syntactic priming

Implicit learning models suggest that learning from syntactic priming is related to an individual's learning rate and prior experience of the language. This means that an individual should show consistent priming effects for a given structure across tests but also that within a group of similar individuals, there may be between-individual variation in priming: an individual with a higher learning rate will show greater priming than an individual with a lower learning rate. Between-individual variation in priming rates is well observed in the literature, but only one study, to our knowledge, has investigated consistency of priming within individuals, testing children and adults on two syntactic priming tasks separated by a week (Branigan & Messenger, 2016). This study showed the expected pattern of results, with each group showing the same overall magnitude of priming in each session, and clear correlations between the degree to which individuals primed in each session. As with other priming research, the evidence base remains very limited in its scope, however.

Furthermore, this model predicts a consistent propensity to prime for different structures: an individual's propensity to prime, as determined by their learning rate, should be consistent across structures leading to correlations between priming effects for different structures, even though knowledge and experience of different structures may vary, meaning that the magnitude of priming for a given structure may also vary. To the best of our knowledge, this has not been tested with child learners and so this would be an important avenue for future research to explore, in order to further our understanding of the mechanisms behind syntactic priming as implicit learning.

In our above discussion we have proposed that age is a likely indicator of the factors, learning rate and prior language experience, that should predict individual variation in priming effects: an individual's prior experience of the language will at a basic level be related to their age – older children will have more experience of the language than younger children. And implicit learning models of priming set higher learning rates in earlier stages to model young children's rapid learning of syntactic representations and lower learning rates in later stages to model phenomena such as the end of a critical period for language acquisition (Janciauskas & Chang, 2018) and the development of verb biases for structures (Peter et al., 2015).

But age is not a perfect proxy for developmental stage – within any age group there will be substantial variation in syntactic knowledge and language production skills between children. To gain a better understanding of the mechanisms underlying child priming and language acquisition, it

would be beneficial to consider how learning rate, as well as the role of language experience, can be more precisely indexed in order to test predictions of the implicit learning account. It has been suggested that the learning rate that supports grammatical development is not language specific but a more general learning parameter (Janciauskas & Chang, 2018), thus learning in other domains may relate to syntactic learning and thus syntactic priming effects (see also Hsu & Bishop, 2014). Kidd (2012a) reports evidence to support this: a large study of individual variation in syntactic priming showed that performance on an implicit statistical learning task predicted long-term syntactic priming effects, though not immediate priming, for passives in 5- to 7-year-olds; Kidd (2012b) found that the tendency to show immediate but not long-term priming was related to children's non-verbal ability, specifically non-verbal reasoning (which we assume to be related to learning rate). Further research replicating and extending these findings to younger children and ruling out alternatives would help to elucidate whether the learning that supports priming and syntactic development is indeed based on a more general learning parameter.

Other research, albeit few of the available priming studies, has examined whether markers of language experience relate to priming with mixed findings. For example, Messenger et al. (2011) found that receptive vocabulary scores did not improve models of passive priming effects, and Allen et al., (2011) similarly found no correlation between receptive vocabulary score and passive priming effects, while Messenger et al. (2012, Experiment 2) reported that the best fitting model included receptive vocabulary though this was not itself a significant predictor. By contrast, Kidd (2012b) reported that both receptive vocabulary and grammar knowledge scores predicted the degree of priming, and Garraffa et al., (2015) found similar effects for receptive grammar knowledge. Messenger (2021) found that children's productive vocabulary showed a marginal correlation with their individual priming effect for passives and a significant correlation with the frequency of target structures they produced in a priming phase, irrespective of priming condition. Foltz et al. (2015) reported that productive syntactic skills did not improve model fit for priming of relative clauses in young children whereas Foltz et al. (2020) reported that these did predict priming of transitive structures. In addition, both studies by Foltz and colleagues also report that working memory abilities (as measured by a digit span task) predicts priming, albeit only in younger children in the case of transitive priming. Evidently, further work is needed to establish which markers of prior language experience are systematically related to syntactic priming effects and whether this pattern supports implicit learning accounts.

6. The locus of implicit learning

Implicit learning models suggest that learning primarily takes place during comprehension processes (Branigan & McLean, 2016; Chang et al., 2006; Dell & Chang, 2014; Peter & Rowland,

2018; Reitter et al., 2011) and at least one model assumes no role for children's production experiences in their syntactic learning (Chang, et al., 2006). As children listen, they make predictions about upcoming structure, and then use the discrepancy between these predictions and the actual input to make long-term adjustments to the strength of their syntactic representations.

There is good developmental evidence that children use prediction in their language processing (Pickering & Gambi, 2018). Young children are able to predict upcoming words in a sentence based on the semantic features of the utterance (e.g. Borovsky, Elman, & Fernald, 2012). They are also able to make predictions about upcoming referents based on morphosyntactic features of the utterance, for example expecting two items after a plural verb (*are*) than after a singular (*is*; Lukyanenko & Fisher, 2016) or expecting an item labelled by a noun with feminine gender after a feminine marked article (*la*; Lew-Williams & Fernald, 2007). Children can also make syntax-based predictions: they use structural information to predict the upcoming referent for a patient of an active sentence (Gambi, Pickering, & Rabagliati, 2016) or predict the referent of the post-verbal argument of a dative sentence following syntactic priming (Thothathiri & Snedeker, 2008). As such, it is clear that children are able to make predictions about the upcoming structure of sentences in real time (though see Rabagliati, Gambi, and Pickering (2016) for further discussion). Whilst these studies do not provide evidence for error-based learning from this prediction-based processing, evidence is beginning to emerge that children can indeed learn from their predictions: Fazekas et al. (2020) showed that when 5-6 year old children's experiences of syntactic structures mis-matched their expectations, because the sentence verb was biased to a different structure, they were more likely to subsequently use the unexpected structure (see also Peter et al., 2015). This provides strong, though preliminary, support for prediction and error-based learning from sentence processing.

Other, particularly strong, evidence to support the notion that children learn via comprehension processes more generally comes from a longer-term study in which children listened to stories that contained a large proportion of passive sentences over a period of two weeks (Vasilyeva, Huttenlocher, & Waterfall, 2006). Measurements of their pre- and post-intervention comprehension and production of passives indicated that children's ability to correctly understand and produce this target structure improved following this period of increased input. Since children never produced passives during the intervention, this study provides strong evidence that listening experience leads to lasting effects on a speaker's syntactic representations (see also Hesketh, Serratrice, & Ashworth, 2016; Serratrice, Hesketh, & Ashworth, 2015). Clearly, however, there is scope for more research examining the effect of children's processing of individual experiences of syntactic structure and the extent to which this generates syntactic learning. As above, there is a

distinct need for this research to broaden the evidence base to other structures, languages and contexts too.

Perhaps as a consequence of the prediction driven error-based implicit learning model, there has been much less consideration of how *producing* an utterance may also support syntactic learning. But a number of language processing models, including the error-based learning model, link production and comprehension processes, specifically connecting prediction processes with language production mechanisms (Dell & Chang, 2014; Pickering & Gambi, 2018; Pickering & Garrod, 2007). Within the error-based learning model, however, production derives from prediction – the model learns to predict first and such abilities transfer to production, ruling out a role of production experience in supporting (initial) learning (Dell & Chang, 2014). By contrast, other accounts suggest that prediction processes, which are available early in language acquisition, can be supported by production mechanisms (Pickering & Gambi, 2018; Pickering & Garrod, 2007). Even if production abilities lag comprehension skills in development, such that children are not able to accurately carry out all stages of production (Pickering & Garrod, 2007), the underlying production mechanism can be recruited to support prediction generation during comprehension, though the extent to which young children do this may be less than in adults (Pickering & Gambi, 2018). This suggests that production experience could have a role in supporting the predictive processes by which language is acquired.

Existing research examining syntactic priming in children, including studies that examined whether priming leads to long-term persistence, typically uses a comprehension-to-production paradigm (but see Chapter 5) in which children listened to primes and produced target responses. Whilst their comprehension experience may have been the source of priming and implicit learning, it is not possible with such designs to rule out a possible contribution of their target sentence production to syntactic persistence. Indeed, some studies with children also involved the child repeating the prime sentence before producing their target response (Bencini & Valian, 2008; Huttenlocher et al., 2004; Kidd, 2012a, 2012b; Savage et al., 2003; Shimpi et al., 2007) and as noted above, in some cases, for example with younger children, reliable priming effects have only been observed when children repeated the primes (Shimpi et al., 2007). In other priming studies, children's production of primed target structures in later tests has shown a positive correlation to their primed production of the structure during earlier priming (Branigan & Messenger, 2016; Messenger, 2021). Other research demonstrates that turn-taking in conversations is more important for language development than just adult language input (Zimmerman et al., 2009). Thus, the evidence suggests that production experience may indeed be important.

This also highlights the relevance of competence/performance distinctions in development: children's comprehension experience when processing language may play an important role in

developing their competence as it provides an opportunity to learn and strengthen representations. By contrast, production experience, producing primed structures, may have a more important and distinct role in supporting performance. It is possible that producing an utterance might involve procedural learning of formulation processes, for example coordinating lexical retrieval with grammatical encoding (Levelt, 1989). Production processes require speakers to formulate grammatically accurate and complete utterances to convey a message – research with adult language learners suggests that rehearsing this process may be critical for learning (Hopman & MacDonald, 2018); the same may well be true for child learners (see e.g. Mani and Huettig, 2012). The possibility that such experience also feeds back into comprehension processes merits further attention as it has important implications for teasing apart different models of language processing and acquisition. As such, future research that distinguishes the relative contributions of each type of experience would help to further our understanding of which aspects of syntactic priming support (which aspects of) syntactic learning.

Moreover, as introduced above, the modality of children's language experiences may exert different influences at different stages of development: younger children may benefit from comprehension experience to develop nascent representations, but also from production experience to support the act of producing new sentence forms and to support learning via prediction during comprehension. As children get older and have developed robust formulation mechanisms, this production experience may be less important for eliciting primed responses but they may still benefit from comprehension and production experience to strengthen representations. Therefore, there is scope for systematic investigations that disentangle the relative contributions of comprehension and production experience in syntactic priming for implicit learning at different stages of development.

7. Methodological issues

So far, we have considered how well the existing evidence supports the predictions of implicit learning models of syntactic priming. Whilst there is clear evidence for immediate priming and learning from this experience in children, albeit within a limited range of contexts, a number of the more specific predictions about the magnitude or locus of priming are not as well-supported by the current literature. One issue worth considering when assessing evidence from priming studies is how priming is measured. Traditionally, syntactic priming is measured as the increased use of target structures on target trials following prime trials with that structure, relative to prime trials with an alternative structure. This approach is particularly relevant to answering questions about the nature of the syntactic representations that support syntactic priming (e.g. Messenger et al., 2011; Messenger, Branigan, McLean, et al., 2012; Rowland et al., 2012) because such immediate priming

effects indicate an underlying representation of syntax (Branigan & Pickering, 2017; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995).

The studies that have compared priming across different age groups have also typically used this measure of priming; however, it may not be the most appropriate for making this between-group comparison. The magnitude of priming is the difference between target structures produced on target prime and alternative prime trials, thus if a participant produces a high number of target structures on the alternative prime trials (in addition to on target prime trials), in ways that might reflect cumulative learning within the session, the measurable priming effect will actually be reduced. Such carry-over of priming effects to alternative prime trials is not uncommon: for example, Messenger (2021) compared a baseline group who never heard active or passives primes to a priming group who heard both active and passive primes. The baseline group produced a negligible number of passive targets (<1% transitive responses); by contrast, the priming group produced passive targets on both passive (27% transitive responses) and active (13% transitive responses) trials. The difference in their frequency of production of passives between active prime and baseline trials strongly suggests that priming effects carry over different trials. Similarly, Branigan and Messenger (2016) observed a cumulative effect of priming across two experimental sessions that manifested as an overall increase in passives in the second session relative to the first, not as a greater priming effect, that is, more passives following passive primes than active. Indeed, this behaviour is in line with an implicit learning explanation of priming in which priming effects accumulate across experience: as experience of a structure increases (e.g. across an increasing number of prime trials), this leads to an increased likelihood of producing that primed structure, independently of the immediately preceding prime.

But this has clear implications when examining the difference between passive and active trials in order to compare the magnitude of priming in different groups. A clearer measure of the degree to which children show priming for a given structure would be to compare their production of target structures following primes with the target structure and baseline (unrelated) primes. Based on the underlying assumption that the priming manipulation leads to weight adjustments that increase participants' production of the target structure across the experiment, not just on target trials, examining participants' production of a target structure during a priming phase relative to a baseline phase (see e.g. Hurtado & Montrul, 2021; Kaschak et al., 2006 for examples of such analyses in the second language acquitision and adult literature respectively) may provide a clearer picture of the effect of priming experience and may help to distinguish between-group differences in the magnitude of this effect. However, no child studies that tested between-group comparisons have included this (cf. Messenger, 2021, in which groups that experienced priming were compared to a baseline group that did not).

Alternatively, it may be appropriate to consider differences between groups irrespective of prime condition, that is, participants' overall production of a target structure during a priming phase (essentially, the evidence of cumulative priming effects), as evidence of greater learning from priming. For instance, some studies that compared priming in children and adults showed a main effect of age group whereby children produced more target structures, in these cases – passives, than did adults (Branigan & Messenger, 2016; Messenger et al., 2011; Messenger, Branigan, McLean, et al., 2012; cf. Messenger, 2021); although other studies did show a main effect of age group, but it was the adults that produced more target structures (datives) than the children (Peter et al., 2015; Rowland et al., 2012). Thus, in considering whether patterns of priming effects in children support models of syntactic priming as implicit learning, it may in fact be important to look at other measures, such as overall group production and comparisons to baseline data, not just primed production.

Another important consideration when examining predictions of syntactic priming as implicit learning, is that children's responses in such studies are often errorful or incomplete (in ways that may reflect shortcomings in performance rather than competence). This means that the number of trials on which attempts to produce the target (even if not fully accurate or complete) were made, and which may indicate priming, will differ from the number of trials on which fully accurate and complete responses were recorded. These incomplete or inaccurate trials are likely to be informative as to the actual magnitude of priming effects in children, even if the outcome of the priming is not a fully formed target structure, as an attempt to produce the target structure implies an influence from the primes. Yet the extent to which this has been reported in previous research is highly mixed. Some studies do report a lenient or lax coding of the data, and that it either decreases the number of 'other' responses (Peter et al., 2015) or increases the number of target structures (Branigan & McLean, 2016; Kidd, 2012a; Messenger, 2021). Whilst many report that the pattern of results was not changed by the inclusion of incomplete or inaccurate responses (e.g. Messenger, Branigan, McLean, et al., 2012), Branigan and McLean (2016) found significant cumulative priming only when considering children's correct *and* errorful responses. In conjunction with the above considerations of what measures and effects may be most informative about the incidence of syntactic priming, measures that include children's attempts to produce a primed target may be critical for fully understanding the strength and timecourse of priming in child populations, and therefore for gaining a better understanding of the mechanisms underlying priming.

On the other hand, investigations of *learning* via syntactic priming evidently require a modified testing approach to priming on immediate trials, in order to measure the lasting effect of priming. Adult research has typically tested the longevity of priming by either inserting unrelated filler items between prime and targets (Bock & Griffin, 2000; Hartsuiker et al., 2008) or by

measuring the use of a target structure in a test phase that followed a priming phase (Kaschak, 2007). Child research has largely adopted the latter approach as the former is less practical in developmental research, (Huttenlocher et al., 2004; Kidd, 2012a; Messenger, 2021; Savage et al., 2006; cf. Branigan & McLean, 2016). That is, studies with children typically measure the persistence of priming effects in a post-priming phase, compared to performance in a pre-test (Kidd, 2012b, 2012a) or a baseline group (Messenger, 2021). Learning is indicated by an increased usage of a target structure following priming of that target structure (which frequently involves blocked presentation of a single target structure (Huttenlocher et al., 2004; Kidd, 2012b, 2012a; Savage et al., 2006; cf. Messenger, 2021). In such studies, priming is therefore measured as the frequency of target structures produced in a given experimental phase or group, as such, these measures are not susceptible to the issue of carryover effects across conditions but it would still be relevant to test the data from different scorings, and, as identified across this chapter, to extend this methodology to test different language learners and different syntactic structures. Moreover, it is important to test whether use of a target structure generalises beyond the specific context of the experimental task to other contexts, in order to demonstrate broader learning.

7. Conclusion

In this chapter, we have considered how child syntactic priming research can inform our understanding of the nature of the mechanisms that support syntactic priming, and the extent to which these relate to broader mechanisms of language learning. Implicit learning models of syntactic priming make important connections between more general language processing effects (such as prediction and priming) and processes such as language production and learning. These models imply that syntactic priming effects can provide evidence beyond the nature of children's syntactic representations; this research can also evidence the nature of the mechanisms that support language learning and development. As such, research in this area can have important implications for our understanding, not just of how syntactic priming manifests in language learners, but also of how language is processed and acquired more broadly.

But it is clear from the discussion in this chapter that further work is required to develop this understanding in child speakers. We finish here with some recommendations for future research: foremost, it is clear that there is much work still to do to understand how syntactic priming supports children's learning of different structures in different languages. Further research with new structural alternations and different languages will not only test the generalisability of existing findings and associated explanations, it will, as discussed above, allow further predictions about when in development children should be particularly susceptible to learning via priming, to be tested. More work to understand the contexts in which such learning occurs, and the extent to which

learning is bounded by context, will also serve to extend our understanding of the mechanisms underlying syntactic priming. Lastly, closer attention to methodological features would ensure that future research provides a clearer picture about children's learning from priming: more targeted participant samples for the structure being tested, increased numbers of items and the inclusion of baseline conditions, and more in-depth analysis of different possible effects of syntactic priming would increase our understanding of how such effects provide implicit learning of language structures. These developments will help to resolve long-standing and fundamental questions about the way in which children are able to learn language and the role that their individual experiences of language might play in this process.

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