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CHAPTER 17

Individual Differences in Sentence Processing

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1 Introduction

Language comprehension is a complex task that involves constructing an incremental interpretation of a rapid sequence of incoming words before they fade from immediate memory, and yet the task is typically carried out efficiently and with little conscious effort. Given the complexity associated with extracting intended meaning from an incoming linguistic signal, it is perhaps not surprising that multiple cognitive and perceptual systems are simultaneously engaged during the process. One ramification of the multifarious nature of online language comprehension is that individuals tend to vary greatly in terms of their processing skill. Indeed, considerable by-subject variability in performance on syntactic processing tasks has been observed in numerous studies over the past two decades (e.g., King and Just, 1991; MacDonald, Just, and Carpenter, 1992; Novick, Trueswell, and Thompson-Schill, 2005; Pearlmutter and MacDonald, 1995; Swets et al., 2007), and yet debate still exists in regard to both the sources and the nature of this documented variability.

This chapter explores some potential sources of variability in online comprehension skill. First, we briefly discuss the proposed role that verbal working memory plays during syntactic processing, followed by the exploration of an alternative hypothesis that reassesses the effects of verbal working memory in terms of individual differences in learning-based, experiential factors. Subsequently, we consider the degree to which variability in "cognitive control" has the potential to account for variability in syntactic processing tasks, and then we touch on, briefly, the influence of variability of perceptual systems on processes related to language comprehension. The literature on individual differences in syntactic processing is vast, and it is not possible to cover all of it in the small number of pages allotted to this chapter. Instead, we hope that the information contained here will help guide those with burgeoning interests in the area of individual differences research toward some of the current topics and debates within the field.

Before discussing factors that may account for variability in online syntactic processing, however, it must be noted that the information provided here is presented largely under a framework heavily influenced by constraint-based theories of online language comprehension, which have been the dominant mainstream theories since the mid 1990s (e.g., MacDonald, Pearlmutter, and Seidenberg, 1994; Tanenhaus and Trueswell, 1995; Whitney, 1998). Under these accounts, comprehenders use all salient and reliable sources of information, as soon as possible, to guide their interpretation of an incoming linguistic signal. Indeed, many factors, including (but not limited to) referential context (e.g., Altmann and Steedman, 1988; Tanenhaus et al., 1995), frequency (e.g., Trueswell, 1996), phonological regularities (e.g., Farmer, Christiansen, and Monaghan, 2006), and plausibility (e.g., Garnsey et al., 1997) may influence how an incoming string of words is processed.

One key phenomenon within the domain of sentence processing that these theories help explain is the so-called *garden-path effect*. Sentences such as, "The horse raced past the barn fell" are difficult to process because, at least temporarily, multiple possible structural representations exist (see Bever, 1970). In this example, *raced* could either signal the onset of a reduced relative clause, equivalent in meaning to *The horse that was raced past the barn…*, or *raced* could be interpreted as the main verb of the sentence, such that the horse is the entity that was willfully racing. If *raced* is initially interpreted as the main verb, then processing difficulty is experienced upon encountering the word *fell* because it requires the less- or nonactive reduced relative clause interpretation. It is this kind of processing difficulty that is classically referred to as the garden-path effect. Constraint-based theories argue that in the face of such ambiguity, each of the possible syntactic interpretations of the sentence is partially active. The multiple sources of information integrate *immediately* to determine the amount of activation provided to each of the competing alternatives. In this framework, garden-path effects arise because the incorrect syntactic alternative wins much of the competition during the early portion of the sentence, and then nonconforming information from the latter portion of the sentence induces a laborious reversal of that activation pattern. The degree to which the incorrect alternative had been winning the competition early on affects the degree to which the reversal of that activation pattern will be protracted and difficult.

The competition-based resolution of temporarily ambiguous sentences is highlighted here due to the fact that it is the model of ambiguity resolution that is most amenable to explaining individual differences in performance on processing tasks. Indeed, some of the earliest instantiations of a competition-based approach to language learning were designed in order to account for the fact that both languages, and the people who process them, are highly variable (e.g., Bates and MacWhinney, 1989), and thus can help explain why people seem to exhibit such high levels of variability in online comprehension tasks. These accounts propose that the availability and reliability of relevant cues drives the analysis of incoming linguistic input, and indeed, more formally specified competition-based models have been proposed to account for the manner in which multiple cues (or constraints) can integrate over time to influence, for example, competition between syntactic alternatives in the face of ambiguity (McRae, Spivey-Knowlton, and Tanenhaus, 1998; Spivey and Tanenhaus, 1998). Crucially, however, the degree to which cues are reliable, and thus useful, for individuals during language processing is determined by an individual's unique experience with those cues over time, thus emphasizing a strong continuity between language acquisition and processing in adulthood (Seidenberg, 1997; Seidenberg and MacDonald, 2001). Implicit in such claims is the fact that an individual's linguistic experience may be shaped not just by exposure to the regularities of a language over time, but also by the unique nature of the cognitive systems specific to that individual. That is, individual variability in factors such as memory, attention, perceptual systems, reading skill, and so forth may interact with a person's experience with language to produce vastly different patterns of performance on syntactic processing tasks. Flexible frameworks such as the functionalist multiple constraint-based approaches detailed previously provide a unified account of how variability in cognitive skill and linguistic experience influence language acquisition and processing. Accordingly, it is for this reason that we approach the topic of individual differences in language comprehension from this perspective.

2 Verbal working memory versus the role of linguistic experience

A longstanding account of variability in online syntactic processing is that performance on language comprehension tasks varies primarily as a function of verbal working memory capacity (Caplan and Waters, 1999; Just and Carpenter, 1992; Waters and Caplan, 1996). However, a thorough review of research on the relationship between language processing and verbal working memory capacity is beyond the scope of this present paper (but see Chipere, 2003; Daneman and Merikle, 1996; Friedman and Miyake, 2004; MacDonald and Christiansen, 2002 for summaries of relevant literature). What therefore follows is an abbreviated and highlighted treatment of findings relevant to key accounts in the literature.

Within a capacity-based approach to individual differences in online syntactic processing, Just and Carpenter (1992) argued that the systems supporting syntactic processing are reliant upon a single pool of working memory resources, and that such a resource pool exists independent of linguistic knowledge (viz., the hypothesized working memory resource pool exists outside of the systems that are directly responsible for syntactic processing). Just and Carpenter also argued, in accordance with many more recent constraint-based accounts of syntactic processing (MacDonald et al., 1994; McRae et al., 1998), for a highly interactive processing system whereby the many processes related to language comprehension occur in parallel.

Given the large number of demands placed on the highly interactive processing architecture, it perhaps makes sense to propose the existence of a system-external pool of memory resources. Such a resource pool can serve as a sort of support mechanism for the comprehension system when processing becomes too cumbersome for the system to support on its own. Accordingly, Just and Carpenter argued for a systematic trade-off between processing and working memory resources in such a way that as memory resource demands increase, processing becomes more difficult, and vice versa. The impact of verbal working memory capacity on language processing tasks can be evidenced through patterns of Reading Times (RTs) on syntactically complex sentences, compared to their simpler counterparts (see example [1]).

(1A) The reporter that attacked the senator admitted the error. (subject relative)
(1B) The reporter that the senator attacked admitted the error. (object relative)

In example (1), sentences with a head noun (*the reporter*) that is the object of the embedded verb (*attacked*), as in (1B), are famously more difficult to process than sentences in which the head noun is the subject of the embedded verb, as in (1A), as evidenced by increased RTs on the main verb (*admitted*) of the object – as opposed to the subject-embedded relative clauses sentences (e.g., King and Just, 1991 – though see Reali and Christiansen, 2007).

When encountering syntactically complex sentences such as those containing object-embedded relative clauses, King and Just (1991) found that subjects with low scores on a test of verbal working memory ability produced longer RTs on the difficult regions of these sentences and were also less accurate on related comprehension questions than their high-span counterparts. Purportedly, the smaller amount of working memory resources available to low-span subjects became more quickly taxed, given the object-subject ordering of the object-embedded relative clause, making these subjects subsequently more sensitive to the increased processing demands of syntactically complex sentences. It is necessary to note, however, that the Just and Carpenter view does not exist unchallenged. Indeed, Caplan and Waters (1999) argue against the existence of a single pool of working memory resources responsible for language comprehension in favor of a multiresource theory. They assert that one pool of working memory resources is accessed during online interpretive processing whereas a separate pool of resources is accessed during offline postinterpretive processing. What is important about this and the other memory-based account cited, however, is that they both rely on access to working memory resources hypothesized to exist outside of the systems responsible for language processing.

Based on the data detailed earlier, MacDonald and Christiansen (2002) proposed that reading span tasks – the tasks used to measure verbal working memory, as in the Just and Carpenter studies – are actually better conceptualized as measuring language comprehension skill. Indeed, over the past two decades, the Daneman and Carpenter (1980) reading span task has been the most frequently used measure of "verbal working memory resources." The task requires individuals to read out loud progressively longer sets of sentences while simultaneously retaining the final word of the sentences for later recall. So, although memory is one component of the task, its main component requires lower-level reading skills and the ability to process phonological, syntactic, and semantic information. In light of this fact, it is not unreasonable to argue that tasks of this nature measure, to some degree, language processing skill (which is presumably, although imperfectly, correlated with linguistic experience).

To evaluate an experience-based hypothesis whereby accrued linguistic experience over time substantially influences sentence processing, MacDonald and Christiansen trained a series of neural networks to predict the next word in syntactically simple versus syntactically complex sentences. They trained ten simple recurrent networks (SRNs; Elman, 1990) on sentences from a context-free grammar with grammatical properties inherent to English such as subject-verb agreement, present and past tense verbs, and so forth. Importantly, many of the training sentences contained simple transitive and intransitive constructions, and a small number of the training sentences contained subject- (1A) or object- (1B) embedded relative clause constructions. To assess the role of experience on the network's ability to learn, they examined the networks after one, two, and three training epochs. After each epoch, the networks were tested on novel training sentences containing object- and subject-embedded relative clause constructions in order to examine average performance as a function of experience.

After each of the three epochs, average performance of the networks was the same across all regions of the simpler subject-embedded relative clause sentences. However, on the more difficult object-embedded relative clause sentences, an effect of experience was elicited. Early in training, the network produced more errors on the main verb of the object-embedded relative clause constructions than it did after three epochs of training. The initial disparity in the processing of embedded object- and subject-relative clauses occurred due to the fact that the syntactic structure of the subject-embedded relative clauses was very similar to that of many of the other simple training sentences. Thus, whereas the networks quickly learned to process subject-embedded relative clauses via generalization from the subject-object ordering common to simple transitive sentences, direct experience with the object relative clauses was needed to deal with the reverse ordering of subjects and objects. Such a demonstration can be seen as an example of the accumulated effects that linguistic experience can exert on phenomena such as the frequency x regularity interaction.

Indeed, when comparing the performance of the SRNs presented by MacDonald and Christiansen to the working memory data presented by King and Just, a striking pattern emerges. The networks that were examined after the first epoch in training strongly matched the performance of individuals measured to have low verbal memory span in King and Just, with higher error rates (commensurate to higher RTs at the critical region of the sentence) on the object- than on the subject-embedded relative clause sentences. After training, however, the networks exhibited a decrease in the error rate difference between the two sentence conditions, and such a pattern maps onto the decreased difficulty exhibited by high-span individuals in the King and Just study. The simulations provided by MacDonald and Christiansen, then, provide computational support for the role that linguistic experience may play in capturing variability in online syntactic processing, while calling into question whether verbal working memory span tasks measure a system-external working memory capacity. Instead, given the strong language-related task demands, these tasks very well may be an index of an individual's overall processing skill, driven by interactions between the cognitive architectures and linguistic experiences of an individual.

The emphasis placed on linguistic experience is in line with a relatively large literature on the degree to which variables that may logically correlate with linguistic experience can account for variability in language comprehension skill. For example, Stanovich and West (1989) operationally defined reading experience in terms of the coarse-grained variable they called "print exposure." As a measure of print exposure, the authors created the Author Recognition Test (ART), in which participants are presented with a list of names – some which are the names of real authors and some which are not – and are asked to place a checkmark next to the names they believe to be real authors. The overarching idea motivating the creation of this task, obviously, was that people who spent more time reading would also be more likely to have a better knowledge of the set of popular authors spanning multiple genres. Indeed, scores on this task significantly correlated with scores on measures of various reading-related processes. Likewise, education level, another probable correlate of reading experience, has also been shown to influence overall comprehension ability. Dabrowska (1997) found, for example, that those with higher education levels were better able to accurately identify the meaning of sentences with complex syntactic structures (see also Chipere, 2003; Dabrowska and Street, 2006).

Although it is the case that individual differences in variables that might act as "proxies" to linguistic experience do seem to account for some of the variability in language comprehension, such an approach is naturally limited due to the fact that such variables are not direct indicators of linguistic experience. In a more direct test of the effects of accrued experience over time, a training study by Wells et al. (2009) systematically manipulated participants' exposure to relative clause constructions over the course of three thirty- to sixty-minute experimental sessions spanning nearly a month. During the three training sessions, an experimental group of participants was exposed to equal amounts of subject and object relatives. A control group, however, received an equivalent amount of reading, but without the inclusion of embedded relatives (i.e., they read complex sentential complements and conjoined sentences). Both groups were matched beforehand on reading span (i.e., verbal working memory) scores (which were fairly low). Importantly, after training, the two groups' processing of relative clauses diverged such that the RTs of the experimental group resembled the pattern for high-span individuals noted before, whereas the control group showed the kind of RT profile associated with low-span individuals. Together, these two studies argue for a crucial role of experience in relative clause processing and against the notion of verbal working memory as a parameter varying independently from processing skills.

While Wells et al. hypothesized that statistical learning may be an underlying mechanism for mediating these effects of experience, a further study by Misyak, Christiansen, and Tomblin (2009) empirically investigated this idea, using a within-subjects design to assess syntactic processing performance for subject-object relatives in relation to statistical learning ability. Statistical learning (see Gómez and Gerken, 2000; Saffran, 2003, for reviews) has been a proposed mechanism for acquiring probabilistic knowledge of the distributional regularities governing language structure, and is theoretically compatible with the constraint-based framework assumed herein regarding the rapid online application of learned, statistical constraints in linguistic processing. Misyak et al. found that individual differences in the statistical learning of artificial nonadjacent dependencies were associated with variations in individuals' processing for the same types of embedded relative clause sentences discussed earlier in the chapter. Specifically, better statistical learning skill correlated with reduced processing difficulty at the main verb regions of these sentence types. Additionally, when participants were classified into "high" and "low" statistical learning groups based on performance on the statistical learning task, the language performance of these two groups reproduced the key reading time patterns documented in the literature for those characterized as having "high" or "low" verbal working memory spans, respectively. That is, "low"-performing statistical learners (compared to "high"-performing statistical learners) exhibited slower overall reading times as well as substantially greater difficulty for processing object relatives versus subject relatives at the main verb. These results suggest that individual differences in statistical learning may be a largely overlooked contributor to language processing variation, and moreover, may mediate experience-based effects on relative clause performance that had been traditionally attributed to working memory differences.

Despite disputes regarding interpretation, scores on verbal working memory tasks sometimes account for a statistically significant amount of variance in dependent measures thought to index syntactic processing skill. However, it is worth pointing out that even recent studies employing rigorous psychometric approaches while exploring a constellation of traits involving working memory leave a substantial amount of variance unaccounted for (e.g., Swets et al., 2007). Next, we therefore consider what other factors might contribute to differential language performance at the level of the individual.

3 The role of cognitive control

Another factor that likely influences language comprehension-related phenomena, such as syntactic ambiguity resolution, is that of attentional/control mechanisms. In the broader cognitive literature, several terminological and descriptive variations of cognitive control have been postulated. Accordingly, it has also been called *suppression ability*, *cognitive inhibition*, *executive function*, and *attentional control*. In some cases, these labels connote potentially broader or narrower categories of operation (e.g., executive function and suppression ability, respectively), or have somewhat different emphases (e.g., "inhibitory control" as the suppression of irrelevant information, versus "selective attention" as the sustained focus on relevant information). Such skills could theoretically specify a unitary architectural component, although in other cases, researchers have posited distinct subcomponents or component processes (behaviorally and/or neurally; e.g., Dreher and Berman, 2002), and in other accounts, the conflict resolution processes corresponding to cognitive control are subsumed under the activities of one among other anatomically distinct attentional networks (Fan et al., 2005; Fan et al., 2002; see also the overview by Raz and Buhle, 2006).

However, analogous to the discussion of working memory, the more idiosyncratic details for these hypothetical formulations do not concern us here. Central to all these conceptualizations is the notion of effectively resolving competing or conflicting internal representations, especially under conditions requiring one to override a biased response pattern or otherwise maintain task-relevant information online. Further, despite a wide literature on this construct, current work has only begun to explore more rigorously its contribution to normal online language processing. As standard tasks for assessing cognitive control are mutually employed throughout these studies (i.e., the Eriksen flanker task, the Go/No-go task, the Stroop interference task, and related variants of these such as the item/letter recognition task used by Novick et al., 2005), we will more conservatively reference the skills tapped by the aforementioned tasks and the basic concept of internal conflict resolution as constituting our provisional notion of cognitive control.

Within the adult language comprehension literature, the notion of "suppression mechanisms" figures prominently in Gernsbacher's (1993, 1997; Gernsbacher and Faust, 1991) work on discourse processing. Gernsbacher identified *suppression* as attenuated or dampened activation of a mental representation, which she distinguished from either inhibition (as akin to blocking activation at the onset) or to interference (an activated but irrelevant representation). Differential performance of more-skilled and less-skilled readers in language comprehension was attributed to the latter's weaker suppressive skills. Gernsbacher reported experiments in which less-skilled readers had greater difficulty rejecting isolated test words (e.g., *ace*) as unrelated to a previously presented sentence in those cases where the meaning of the test word was consistent with the inappropriate, alternate meaning suggested by the final polysemous word of the sentence (e.g., *He dug with the spade*, where *spade* on its own could ambiguously refer to either a garden tool or a playing card). Specifically, for less-skilled readers, on probes where a test word's meaning was related to the irrelevant meaning of the sentence-final word, the contextually inappropriate meaning still remained activated a second later, in contrast to the performance of more-skilled readers who did not retain activation of the inappropriate meaning. (Activation is inferred as the difference in response latencies from test probes after sentence-final homographs versus after sentence-final nonhomographs.) Analogous findings were also obtained for: a) homophones; b) when sentences were replaced with scenic arrays (in which the test probe described an item that was either present *or* that was absent but prototypical of the scenic array); c) and when sentences were replaced with a word superimposed over a picture (and test probes consisted of either related item pictures or words).

More recently, Novick et al. (2005) proposed that individual differences (and developmental differences) in cognitive control may influence syntactic parsing commitments, particularly with regard to garden-path recovery abilities. By their account (in line with constraint-based and interactive theories), multiple levels of information continuously conspire towards an interpretation as one processes a garden-path sentence – that is, when disambiguating, countervailing information is encountered, cognitive control mechanisms are required to suppress the inappropriate analysis and to recharacterize the input towards settling appropriately into a new correct analysis. They supported their view by presenting neuroscience evidence implicating the posterior left inferior frontal gyrus (LIFG), including Broca's area (Brodmann Areas 44 and 45) specifically, in the detection and recruitment of control mechanisms for resolving incompatible information that conflicts with situational demands. They predicated involvement of the LIFG for only ambiguous constructions that activated conflicting information (or generated indeterminacy among multiple interpretations), and *not* for ambiguous or complex constructions more generally (in cases where information nonetheless reliably converges towards the correct analysis). The attentional shifts required for biasing against a competing inappropriate representation and for maintaining attentional focus were thus hypothesized by definition to occur at an internal/representational level, rather than a more response-based level of conflict.

Following these claims, January, Trueswell, and Thompon-Schill (2009), in a functional magnetic resonance imaging (fMRI) study, reported colocalization of conflict resolution with BA 44/45 within each participant on a sentence comprehension task and a modified Stroop task. In the sentence comprehension task, participants heard ambiguous and unambiguous sentences describing actions to be carried out upon objects in photographs, and were instructed to vividly imagine performing the action. Ambiguous sentences contained a prepositional phrase (e.g., *Clean the pig **with the leaf***), and were accompanied with a visual reference scene that parametrically varied in composition so as to modulate the amount of contextual support for either the instrument or modifier interpretation of the verb. That is, the visual scenes afforded weaker or stronger conflict for interpreting the sentences, and thus trials varied in their cognitive control demands. Additionally, two different types of parametric series were used whereby the scene was appropriately altered so as to manipulate the degree of either *syntactic* or *referential* conflict.

Results of January et al.'s (in press) study showed that activation in LIFG (BA 44/45) increased for trials where greater cognitive control was hypothesized to be required (stronger conflict trials) in the syntactic conflict condition. This activation was also in the same area as for trials generating representational conflict in the nonsyntactic Stroop task. Increased activation in LIFG was not observed, however, for the referential conflict condition. As they reasoned, either the ambiguity manipulation here was potentially too weak/transient, or LIFG may be involved in representational conflict that is linguistic in nature (though not syntactically specific, given that Stroop task performance also generated activation in this area). These results appear compatible with constraint-based sentence processing theories, rather than serial modular accounts in which an initial representational structure is constructed from a syntactic parse alone. This claim cannot be conclusively based from the fMRI time-signal data, but is supported from previous eyetracking studies investigating syntactic ambiguity phenomena with the same or similar contextual factors and demonstrating rapid contextual influences modulating sentence interpretation (see Spivey and Tanenhaus, 1998; Tanenhaus et al., 1995).

The studies briefly detailed here seem to implicate cognitive control as a potential source of variability in online comprehension skill, with the underlying assumption being that those with more control ability may learn language and process language differently than those with less cognitive control. The influence of cognitive control on sentence processing skill, and the development of it is, with few exceptions, a burgeoning area of interest. It is likely that future research on the relationship between cognitive control and language processing will more explicitly pin down the role that cognitive control plays in sentence processing-related phenomena such as syntactic ambiguity resolution.

4 Perceptual and perceptuo-motor related factors

In this final section, we briefly consider the degree to which variability in lower-level perceptual processes can account for variability in online language processing skill. This class of individual difference sources is vast, and could include basically any faculty that plays a role in any type of perception. Here, we consider a small number of studies that have aimed to illuminate the effects of various perceptual processes, and variability associated with them, on language comprehension skill and the development of it.

Competing speech demands are typical in real-world environments, but the effect of such noise is rarely investigated in standard language processing experiments conducted under well-controlled laboratory settings. However, there is some evidence suggesting that not only are such influences on language performance substantial, but that individual differences may also exist here in this regard. Thus, Leech et al. (2007) surveyed a wide body of evidence in atypical and developmental literatures indicating that the influence of perceptual processing deficits (or underdeveloped perceptual skills) on language processing is substantial. For example, young children are more greatly affected by both attentional and perceptual distractors in processing speech, and follow a protracted developmental trajectory towards adult-like performance. More generally, under conditions when two or more perceptual and attentional stressors are present, normal individuals display linguistic performance patterns mirroring those observed in developmental or acquired language disorders.

In line with these observations, Dick and colleagues (2001) have reported that under situations of "cognitive stress" induced by perceptually degraded speech *and* increased attentional demands, normal adults have greater difficulty comprehending object-cleft and passive sentences, but that simpler constructions, namely subject-cleft and active sentences, are not affected. They hypothesize that the greater robustness of the simpler constructions in these cases might be due to regularity and frequency properties. That is, object-clefts (e.g., *It's the cow that the dog is biting*) and passives (e.g., *The cow is bitten by the dog*) are sentence types with low microstructural (and absolute) frequency in English, whereas subject-clefts (e.g., *It's the dog that is biting the cow*) contain microstructurally more frequent properties, despite being less frequent in absolute occurrence. Additionally, active sentences (e.g., *The dog is biting the cow*) are highly common in type and instantiate canonical word order.

In a study systematically manipulating perceptual, attentional, and external semantic demands on language processing, Leech et al. (2007) administered a spoken sentence comprehension task to 348 normally hearing children and sixty-one normally hearing adults, spanning a continuous age range from five to fifty-one years. Perceptual, attentional, and semantic interference were modulated by combinations of distractors (energetic perceptual masking, speech-like noise applied to one ear, and competing semantic content, respectively) across four speech conditions: different ear/backward speech (attentional interference), different ear/forward speech (attentional and semantic interference), same ear/backward speech (perceptual and attentional interference), and same ear/forward speech (perceptual, attentional, and semantic interference). Sentence types comprised actives, passives, and subject- and object- clefts.

Overall, a gradual, nonlinear, and protracted developmental trajectory towards adult performance levels was observed. Perceptual (but not attentional or semantic) interference significantly reduced comprehension for the more difficult constructions in adults relative to a baseline no-competition speech condition, whereas comprehension of simple sentence types was impervious to this form of interference. Inspection of the provided scatterplots indicates considerably larger individual differences in adults for comprehending passives under the perceptual interference conditions. Lexical production efficiency (word reading efficiency), general speed of processing (reaction time to auditory nonlinguistic sound signals), and chronological age were significantly associated with language comprehension, and predicted the most variance for the difficult constructions (object-clefts and passives).

Related work has additionally shown that perceptual efficiency is related to reading proficiency (cf. Plaut and Booth, 2000), the latter of which encompasses both accuracy and speed (Geva, Wade-Woolley, and Shany, 1997). And in young adult readers (ages sixteen to twenty-four) who were administered a comprehensive battery of tasks, individual differences in reading speed and literal comprehension correlate strongly and positively (Braze et al., 2007). In a study investigating individual differences in speed of processing on spoken idiom comprehension, Cacciari, Padovani, and Corradini (2007) split participants into fast/slow groups on the basis of processing speed and assessed responses to idiomatic targets embedded in sentential contexts that either biased interpretation towards the idiom's literal or idiomatic meaning. They observed differences among the participants such that those with slow speed of processing also required more perceptual information from the sentence before identifying the idiomatic meaning. Thus, individual differences in perceptual processing have been linked to both reading ability and spoken language comprehension.

In these aforementioned cases, perceptual interference and sentence comprehension appear interrelated through the recruitment of phonological representations. Indeed, within MacDonald and Christiansen's (2002) proposal that observed variations in language processing among individuals were attributable to both differential experiential and biological factors, they discussed evidence suggesting that there may be intrinsic differences in the precision of phonological representations formed by individuals. Consistent as well with MacDonald and Christiansen's proposal then, perceptually related processes (e.g., integrity of phonological representations and robustness to noise) and "efficiency" (faster/slower activation in transmitting informational signals) could be encompassed more or less within the computational resources/processes of a singular system, and thus be an interwoven part of the language architecture.

5 Conclusion

Performance on measures of language comprehension skill is notoriously variable, a fact that is not terribly surprising once one considers the large number of perceptual and cognitive systems engaged during linguistic processing. In order to account for such variability, working memory and other memory-related principles have traditionally received the largest amount of attention within the language processing literature. Although we have no doubt that memory plays an important role in online language processing, studies that find links between variability in verbal working memory capacity and variability in processing skill only account for a small proportion of the variance. Accordingly, we additionally discussed other factors that may help account for the variance left unexplained by studies of verbal working memory effects, such as by-individual variation in cognitive control/attentional mechanisms and perceptual processes, along with the interaction of those factors with variability in the linguistic experiences of individuals and the ability of individuals to learn from these experiences via statistical learning. More generally, individual differences research can aid in advancing the architectural specification of the systems responsible for language, thus fostering more mechanistic explanations of the processes underlying language comprehension. Such an advantage is not to be taken lightly, for it has large repercussions for many theories spanning the entire spectrum of the language sciences, from domains such as online language processing, to acquisition processes, to the understanding of language-related disorders and the development of interventions to attenuate them.

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