a digit load to simulate deficits in domain-general working memory. Against Miyake et al. (1994), who simulated receptive agrammatism in normal subjects with speeded visual stimuli, C&W do not find specific effects on "hard" sentence types as a function of digit load or memory span. We have replicated C&W's results, but we have also replicated those of Miyake et al., and we believe that C&W have moved too fast in reaching their broad conclusions about the autonomy of grammatical processing. Using a broader range of structures, languages, and patient groups, with controls tested under a broader range of adverse processing conditions, we conclude that *specific deficits in grammar can be explained without recourse to a domain-specific resource or processing device.* Our interpretation differs from that of Miyake et al., but it is similar in spirit.

First, the same hierarchy of difficulty (actives, subject relatives > passives, object relatives) has been observed in several languages and in many different populations, including Broca's aphasics, Wernicke's aphasics, anomics without expressive agrammatism, and individuals in the early stages of first- or second-language acquisition. The pattern is not unique to any form of aphasia or to any lesion site (Dick et al. 1998; Naucler et al. 1998).

Second, other facets of receptive agrammatism (deficits in the use of function words and grammatical inflections) have been observed in a broad range of patient populations as well as in normals subjected to a broad range of stressors. Published and unpublished studies from our laboratory have simulated selective deficits in morphology (with relative sparing of word order) in college students processing under a digit load, a partial noise mask, low-pass filtering, and/or auditory compression. These results hold true, in varying degrees (depending on the strength of each information type under normal conditions), in English, Italian, and German (Bates et al. 1994; Blackwell & Bates 1995; Kilborn 1991).

Third (and most relevant to C&W's claim), selective deficits in the processing of passives and object clefts have been demonstrated in English college students, but under conditions different from those adopted by C&W. Because they failed to demonstrate effects of digit load or working-memory capacity on the above sentence hierarchy, C&W conclude that syntactic processing is affected only by deficits within a syntax-specific pool of processing resources and not by reductions in working memory outside this domain (as claimed by Miyake et al., based on results with speeded presentation). We have shown that C&W and Miyake et al. are both right: college students tested under a digit load (a task that disrupts computation of subject–verb agreement and other inflectional phenomena in our laboratory) are unimpaired in their ability to process passives and object clefts (replicating C&W), but students tested under perceptual degradation and/or temporal compression are selectively impaired on precisely those sentence types (replicating Miyake et al. in the auditory modality). Furthermore, students tested with *both* compression and perceptual filtering produced superadditive results, greater than those we would expect from adding separate effects of compression and degradation alone, and identical to results for aphasic patients in the same paradigm (similar error rates and similar patterns of individual variation in a cluster analysis) (Dick et al. 1998).

We conclude that the specific challenges posed by passive and object relatives are not unique to a single aphasia type and can be explained without recourse to syntax-specific mechanisms or to damage involving specific lesion sites. We propose a domain-general account of the specific difficulties posed by low-frequency syntactic structures that differs from the working-memory proposal of Miyake et al., reflecting the effects of structural frequency on *encoding* (activation of stimuli) rather than *memory* (maintenance of stimuli in working memory). Grammatical morphemes are vulnerable to stressors of either type (including digits); low-frequency word orders are vulnerable at encoding but form solid memory traces that are mnemonically robust if they make it over the encoding threshold. This would explain why patients with working memory deficits do not show the predicted pattern, but it does not permit C&W to leap to a much stronger conclusion, namely, that syntactic deficits reflect damage to an autonomous processor, independent from the processing resources used by other cognitive systems. Our account makes differential predictions for the fate of complex sentence types under stress in cross-linguistic comparisons, results that are supported by preliminary findings for German and Italian.

ACKNOWLEDGMENTS

This work was supported by National Institute on Deafness and other Communication Disorders grant 2-R01-DC00216 and National Institute of Neurological Disorders and Stroke grant NS22343.

Fractionated working memory: Even in pebbles, it's still a soup stone

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Abstract: We agree with Caplan & Waters that there are problems with the single-resource theory of sentence comprehension. However, we challenge their dual-resource alternative on theoretical and empirical grounds and point to a more coherent solution that abandons the notion of working memory resources.

Caplan & Waters (C&W) argue for the inadequacy of the single-resource theory of verbal working memory in sentence comprehension. We are sympathetic to this position and see two approaches to developing an improved account. One is the approach that C&W adopt: dividing the single working memory resource into two independent resources, each dedicated to a particular processing module. The other is to reject the construct of a limited processing resource; Navon (1984) clearly articulated this position and likened the notion of processing resources to a theoretical "soup stone," contributing no explanatory power to theories of cognition. We have elsewhere advocated this position for theories of language comprehension and have argued that the abandonment of the notion of verbal working memory provides a superior account of the individual differences in sentence-comprehension abilities that C&W review (MacDonald & Christiansen 1998). We see C&W's dual-resource account as nothing more than cracking the superfluous soup stone into pebbles. Instead, we suggest that individual differences emerge from interactions between variations in linguistic experience (e.g., some people read more than others) and processing architecture (e.g., some people have more accurate phonological representations than others). Thus, individual differences in working memory tasks correlate with language comprehension not because there is a separate resource constraining these tasks but rather because the same architectural and experiential constraints that shape the accuracy of language comprehension also affect skill in performing verbal working memory tasks.

C&W have noted that understanding a sentence and following instructions are not the same thing, a point that no one would wish to dispute. They have reified this observation into a claim about separate working memories, however, and this move is an unfortunate one for a theory of cognitive processes. The motivation for the fractionated working memory is that performance in the two arenas is not particularly well correlated. By this logic, any two poorly correlated tasks should be constrained by separate working memories; the proliferation of working memories would be enormous. Indeed, it is not at all clear why C&W propose only two working memories for language; segmenting the speech stream,

activating lexical semantics, parsing, and pronominal reference interpretation are very different processes, and probably abilities in these areas are not perfectly correlated, yet C&W assume that these processes are all part of one "interpretive" working memory. Thus, the decision to have one vs. two vs. twenty working memories is unprincipled.

A serious concern with all resource theories is that they are nearly impossible to falsify, because there is no theory of how reductions in resource availability will affect the myriad processes that purportedly draw on the same resource. By dividing this resource into two pools each constraining many processes, C&W have not made this concern go away; they have compounded it. C&W suggest that current data do not yield the complex interactions predicted by the single-resource theory, but in fact they review almost every conceivable pattern of data (including those with the putatively crucial interactions) and conclude that no result is inconsistent with their account. It is always possible to invent a scenario in which comprehenders allocate resources to tasks in a way that accounts for the data, especially if the sizes of the two "independent" resource pools are positively correlated, as C&W imply.

Whereas C&W go to great lengths to explain away conflicting data from studies with young normal adults, they may appear to be on firmer ground with data from patient populations. We suspect that this situation is merely an artifact of the paucity of on-line studies of language comprehension and working memory in these populations. Contrary to C&W's claims, our work with patients with Alzheimer's disease (AD) has shown that these patients' on-line sentence processing is impaired compared to that of controls (Almor et al. 1998). Patients appear equivalent to normal individuals in cross-modal naming only when the stimuli are constructed in such a way that subjects can ignore all but a few words in the sentence (typically the last few) and still perform the task accurately. Moreover, Almor et al. (1998) found that AD and normal subjects' accuracy producing and interpreting pronouns correlated well with performance on putatively "post-interpretive" working memory measures. Thus C&W's claim that patients with impaired "central executive functioning" have normal syntactic processing is not supported by studies that carefully manipulate the on-line processing demands of the stimuli. Instead, the ability to develop a discourse representation, a key part of "interpretive processing" in C&W's account, is related to performance on "post-interpretive" working memory tasks.

Much of the confusion in C&W's account stems from a narrow view of sentence processing and a failure to appreciate that notions of working memory are inseparable from views of processing architecture. C&W make several mistakes in their discussion of sentence-processing theories, including (1) an inconsistent blending of constraint-based and reanalysis approaches to ambiguity resolution and (2) questioning the lack of reading effects in ambiguous sentence regions for ambiguities in which no theory predicts any effects in this region. At the architectural level, C&W's account (as well as the single-resource theory) incorporates the assumption that sentence comprehension consists of building syntactic representations word by word as the basis for semantic interpretation. Working memory resources are needed for storage of partial processing results. The constraint-based account that we advocate holds that sentence comprehension involves the parallel application of multiple probabilistic constraints from sentential and discourse context. In connectionist instantiations of this view, there is no distinction between storage of linguistic knowledge, comprehension processes, and working memory resources. An individual's "capacity" to process language is realized as the efficiency of passing activation through a network and is constrained by the interaction of network architecture and experience. Including the notion of working memory resources adds nothing to this account.

Distinguishing interpretive and post-interpretive processes

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Abstract: A separation between interpretive and post-interpretive processes is central to Caplan & Waters's theory of language comprehension. This commentary raises some issues that are intended to help sharpen the distinction.

Caplan & Waters (C&W) present an excellent overview of their research. Their work demonstrates that differences in working memory capacity do not affect sentence-interpretation processes themselves but may influence operations performed on the output of those processes. I find the general approach the authors take convincing, but a number of questions can be raised concerning the distinction between interpretive and post-interpretive events during sentence comprehension. Let me begin by acknowledging that C&W do go some way toward providing clarification on this point in their section 4, entitled "Discussion: Fractionating verbal working memory." There they suggest that interpretive processes include accessing words, computing prosody, assigning thematic roles to syntactic constituents, establishing coreference (although presumably not coreference relations that rely extensively on real-world plausibility), and determining a sentence's focus-presupposition structure.

What strikes me as requiring more justification are the authors' assumptions about what constitutes post-interpretive processes. Likely everyone would agree that it is not really language that tells us that if Harvey used to sell junk bonds and now he sells pencils on a street corner he likely lost money, but some of the other processes labeled as post-interpretive seem more controversial. For instance, C&W seem to assume that events involved in sentence reanalysis are post-interpretive. The examples they give include *We hated the cheap hotel room because of all the bugs we saw in it; We realized our conversations would not be private;* and *The aggressive trial lawyer questioned in minute detail by the judge hesitated.* The first presumably involves lexical reanalysis and the second syntactic reanalysis. The problem here is that certainly not all cases of either require post-interpretive processing. For example, the sentence *The team defeated in the Super Bowl vowed revenge next season* might require repair once *vowed* is encountered, but re-analysis does not seem to require more than the basic interpretive processes of the sentence-comprehension system. Indeed, recently Fodor and Inoue (in press) proposed a theory of syntactic revision that is deliberately designed to keep reanalysis internal to the sentence-interpretation mechanism. In their theory, when a word cannot be incorporated into the current syntactic phrase marker (*vowed* in the Super Bowl example above), it is "attached anyway," and then the parser faces the syntactic consequences of that attachment by moving right to left through the tree, making necessary adjustments. Therefore, it seems that C&W should say much more about what sorts of repair processes might be post-interpretive and what sorts are not.

Another question concerns C&W's assumption that sentences with more than one proposition invoke post-interpretive processing. First, I do not understand how the sentences they give as examples contrast in number of propositions; second, I do not see why number of propositions by itself should matter. The authors devote several paragraphs in the article to their argument that the processing of multi-propositional sentences interacts with resource limitations because such sentences require post-interpretive processing, but they do not really spell out how this is supposed to work. Let us take an example from the beginning of the paper that is meant to illustrate the contrast:

1. The boy hugged the girl and the baby.
2. The boy hugged the girl and kissed the baby.