entreviSta: Michael Ullman

por Ingrid Finger (UFRGS)

In this issue of EntreviSta, we interview Dr. Michael Ullman, who received his BA in Computer Science from Harvard University (1988) and his PhD in Brain and Cognitive Sciences from MIT (1993). His main area of research is the relationship between language, memory, and the brain. Ullman is a Professor in the Department of Neuroscience at Georgetown University, and holds secondary appointments in the Departments of Neurology, Psychology and Linguistics. He is the director of the Brain and Language Lab, which investigates the neural and psychological bases of both first and second language, as well as the neurocognition of group and individual differences in language and memory (e.g., sex differences, handedness, and genetic variability). He and his colleagues use both behavioral and neuroimaging techniques (mainly EEG/ERPs and fMRI). His lab also works with developmental disorders (including developmental language and reading impairments, autism, Tourette syndrome, and ADHD) and acquired brain disorders (including aphasia, amnesia, and Alzheimer's, Parkinson's and Huntington's diseases). Together with Ingrid Finger (Federal University of Rio Grande do Sul, Brazil), Kara Morgan-Short (University of Illinois at Chicago, USA) and Sarah Grey (Georgetown University), Ullman is the author of a recently published ground-breaking article, entitled *Second language processing shows increased native-like neural responses after months of no exposure*, which was widely featured in the press, including in the New York Times. A squib of this article has been included in this issue of Revista LinguiStica.

EntreviSta[1]: Michael, it is a real pleasure to interview you for Revista LinguíStica. Let's start with a hot topic. Generative Grammar established a tradition for over half a century that the recursive, infinite, generative language engine works independently from memory. Memory is then treated as an irrelevant condition to the system. Your research since 2001 seems to defy this concept. In what ways?

Ullman: The type of memory that you are referring to is working memory, which is very different from the kind of memory I work with. Whereas working memory is a temporary store, the two

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memory systems that I am primarily interested in – declarative memory and procedural memory – are long-term memory systems, in which the linguistic knowledge is actually learned. Most linguistic knowledge must be learned and stored in some type of long-term memory in the brain, even if some knowledge has an innate basis. The kind of grammatical knowledge that is the focus of Generative Grammar seems to be learned mainly in procedural memory, but can also be learned in declarative memory. In other words, the theoretical model we have proposed (the declarative/procedural model of language) specifies what long-term memory systems underlie language learning and processing, and how.

EntreviSta: What is the difference between the declarative memory and the procedural memory systems, biologically speaking?

Ullman: Traditionally these two memory systems were often defined in terms of their functional characteristics, particularly in terms of the differences between explicit and implicit knowledge. Declarative memory was pretty much defined, and still is for a fair number of researchers, in terms of the memory system or type of memory that underlies the learning of explicit knowledge, that is, knowledge that is available to conscious awareness. In contrast, procedural memory was generally defined in terms of implicit knowledge (not available to conscious awareness), for example, all memory that is not explicit.

This is not the way we talk or think about these memory systems. For us, as implied in your question, we are trying to define these systems according to their biological bases – that is, the biological underpinnings of all of their functions, from learning and consolidation through long-term storage and retrieval and processing. Declarative memory is rooted in medial temporal lobe structures, including the hippocampus and nearby structures. However, it also involves neocortical regions (towards the outside of the brain), particularly in the temporal lobe, but also in frontal cortex, in particular Brodmann Areas (BA) 45 and 47. Each of these structures play different and complementary roles. For example, the medial temporal lobe structures underlie learning and consolidation of new knowledge, whereas that knowledge is eventually stored largely in temporal neocortex, and the frontal regions underlie retrieval of the knowledge.

So, one thing to point out is that we are defining the two memory systems somewhat differently from traditional memory researchers, not just because we are not defining them in terms of implicit or explicit knowledge, but also because we are defining them regarding not only their roles in learning new knowledge, but also in terms of where that knowledge is eventually stored and processed, in the longer term. This is because we want to understand the role of these memory systems not just in how language is learned, but also where and how it is eventually stored and processed.

A brief comment concerning the issue of explicit and implicit knowledge: even though declarative memory does appear to underlie explicit knowledge, it does not seem to underlie *only* explicit knowledge. Going back to the late 1990's, researchers such as Marvin Chun and Elizabeth Phelps showed that some tasks that involve implicit knowledge also seem depend on declarative memory brain structures. Thus, it is reasonable to think about declarative memory as underlying both explicit *and* implicit knowledge. Indeed, it was never the case that evidence suggested that declarative memory did not underlie any implicit knowledge (which would be very difficult to show), but rather just that it did underlie explicit knowledge.

EntreviSta: Now how about procedural memory?

Ullman: First of all, evidence suggests that there are a number of different memory systems in the brain that underlie implicit knowledge, including declarative memory, as I've just mentioned. Procedural memory is just *one* of these memory systems that subserve implicit knowledge. Although procedural memory is less well studied and understood than declarative memory, we do have some understanding of its neural bases. It seems to be rooted in frontal-basal ganglia circuits, though it also involves other structures, including the cerebellum. The basal ganglia are a set of subcortical structures that are heavily connected to frontal cortex. But not all of the basal ganglia and frontal cortex underlie procedural memory. Rather, portions of each of these structures plays a role in procedural memory, including premotor regions and BA 44 (which is part of traditional Broca's area) in frontal cortex.

EntreviSta: What do these two memory systems actually do, what are their functions? And how do they interact?

Ullman: Whereas declarative memory is specialized for learning arbitrary bits of information and associating them, that is, binding them together, procedural memory seems to be specialized for structures, sequences, and rules. But it's important to emphasize that we don't understand procedural memory as well as declarative memory, and we don't yet understand exactly what it is specialized for. Now moving to the second part of your question: these two memory systems do indeed interact in a few ways. First, they both appear, at least to some extent, to be able to learn and process the same kind of information, although in very different ways. That is, they are redundant to some extent to each other. On the one hand, what I just mentioned, the learning of arbitrary bits of information and binding them together, seems to be something that *only* declarative memory can do. But there is evidence that the kinds of tasks and functions that I said that procedural memory can perform, like dealing with sequences and rules, can *also* be done by declarative memory -- although in different ways, at least to some extent, than procedural memory. For example, you can learn sequences implicitly in procedural memory or you can learn sequences explicitly in declarative memory. And it may even be the case that you can learn sequences implicitly in declarative memory as well. And evidence from rodents suggests that they can navigate using two completely different strategies, each of which depends on one of the two memory systems – "response strategies", which depend on geometric cues, rely on brain structures of procedural memory, whereas "place strategies" , which depend on landmarks, rely on declarative memory brain structures. So they can solve navigational problems with either system, although in different ways. Humans may show the same distinction for navigation. Thus, the first important way that the two systems "interact" is that many problems, tasks, and functions can be solved by either system, though in quite different ways.

Another way the two systems interact is in what is sometimes called "competitive interaction", which we call "the see-saw effect": the worse you are at one system, the better you are at the other. For example, when one system is dysfunctional, the other system may actually get better. It is not clear what mechanisms underlie this, and in fact it could be a variety of different mechanisms. One possible mechanism may be estrogen[2], or its underlying molecular systems. Evidence from rodent studies suggests that estrogen enhances declarative memory, while it may inhibit or suppress the functionality of procedural memory, that is, the function of the basal ganglia. These are just some examples of interactions between the two systems.

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2. Estrogen is the main sex hormone in women. It is manufactured mostly the ovaries and it is essential to the menstrual cycle, despite the fact that it is also found in men, in much smaller amounts. Estrogen is the key factor in the establishment of secondary sex characteristics in women, including breasts, a widened pelvis, more fat in the thighs and hips, less facial hair and smoother skin than that in men. Estrogen regulates women's menstrual cycle. After menopause, women experience a reduction in estrogen and this has been related to a number of consequences including memory problems (note of the editor).

EntreviSta: And how does this difference impact language processing?

Ullman: Since all bits of arbitrary information and the relations among them seem to necessarily rely on declarative memory, our prediction is that anything that is arbitrary, idiosyncratic in language, including all word-specific knowledge, should have to be learned and processed at least in part by declarative memory. This is quite a strong prediction. As for rule-governed implicit aspects of grammar, including in syntax, morphology, phonology, we would expect that, to a large extent, these should rely on procedural memory – although much of this could also be carried out by declarative memory as well (which could learn rules, store chunks of complex forms, etc.). In other words, we predict that grammar is typically learned and processed in procedural memory but it can *also* rely on declarative memory. Which system is more important, more relied on, for learning and processing grammar should depend on various factors, including which system is more available. For example, if an individual is particularly good at declarative memory, they should rely more on this system for those aspects of grammar that can depend on either memory system, than an individual who might not be so good at declarative memory, or who might be better at procedural memory.

EntreviSta: What are the roles of declarative memory and procedural memory in second language learning?

Ullman: Essentially the same as in first language, but with a different reliance on the two memory systems. Let's talk, first of all, about how the two memory systems change from early childhood, when one learns a first language (or an early-learned second language), to later in life, when second languages are often learned. Declarative memory is not very strong in early childhood. That's why you can't remember much from your first few years of life. Then it gradually improves during childhood, and plateaus in adolescence and one's early 20s (after which it declines). Although the developmental trajectory of procedural memory is less well understood, learning in this system seems to be pretty well established early in childhood, and then it might possibly even decline, though that is not certain (and during adulthood and into old age there appear to be further declines). The upshot is that early in childhood, learning in declarative memory is weak, while procedural memory may be relatively strong, whereas as one gets older during childhood and into adulthood, declarative memory gets stronger while procedural memory may become weaker.

As a consequence, a child learning grammar (whether in his or her first *or* second language) should depend largely on procedural memory, whereas a young adult should depend substantially on declarative memory (relative the early learner). Thus, early and later learned languages should depend differentially on the two memory systems for grammar. In contrast, arbitrary linguistic knowledge (lexical knowledge) should always be learned in declarative memory, in first and second language, since that's apparently the only system that can learn it.

Finally, it's not the case that young adults have no learning ability in procedural memory. It's just possibly less available than in childhood, especially as compared to declarative memory. But a 20 year old can certainly learn in procedural memory, for example to ride a bike and type. Therefore we expect that grammar should be proceduralizable, that is, learnable with time and practice (perhaps the right kind of practice) in procedural memory. So, contrary to strong versions of the critical period hypothesis, we predict that grammar can in fact become quite native language-like in adult second language learners – at least in its underlying neurocognitive mechanisms (which is a different issue than how *well* this system learns and processes the grammar, which may still be less well than native

speakers, so that their proficiency itself is still not native-like). We have performed a number of experiments and written reviews of the literature examining these various predictions, and we believe that the evidence largely supports at least the basic predictions of this view, that is, for the declarative/procedural model of second language. See various papers on our website, brainlang.georgetown.edu.

EntreviSta: What is the role played by sex differences in language processing and how do these differences connect with memory?

Ullman: The answer to this question relates to what I was saying before – which memory system, declarative or procedural, is relied on more depends on which one is more available - at least, for performing those tasks and functions, including grammar, than can be subserved by either system. And the evidence suggests that indeed there are sex differences in these memory systems, at least in declarative memory. Females appear to have an advantage over males at declarative memory (and much more as well, but let's not go into that, or else as a male I'll just give up), over multiple domains, including verbal and spatial aspects of cognition. This advantage appears to be modulated at least in part by estrogen, which of course is generally found at higher levels in females, even in children. So we expect that females should not only be better at declarative memory, and lexical knowledge within language, but also should rely more on declarative memory for grammar (and for other functions that can depend on either memory system, such as navigation), whereas males should depend more on procedural memory. At least some neurocognitive evidence supports these predictions, as we've reported in a number of papers (e.g., see Ullman, Miranda and Travers, 2008, as well as other papers, on our website).

EntreviSta: Your lab has also conducted research on developmental disorders, such as SLI (Specific Language Impairment), ADHD, dyslexia and autism. What role does memory play in these disorders?

Ullman: We have hypothesized that a number of developmental disorders, which in fact often co-occur with each other, involve abnormalities of brain structures underlying procedural memory, including the basal ganglia, the cerebellum, and portions of frontal cortex. These disorders seem to include at least SLI, dyslexia, ADHD, autism, and Tourette syndrome. The brain abnormalities and ensuing procedural memory and related dysfunctions are somewhat different in each of these disorders. In some cases, including most clearly SLI, but probably also some of the other disorders, declarative memory can play an important compensatory role for those functions that both systems can subserve, such as grammar. Hence, in SLI for example, individuals not only have grammar impairments, but also rely on declarative memory for learning and processing grammar. Indeed, this compensation may help explain why the grammatical abilities of children with SLI gradually improve with age, since their declarative memory based compensation may gradually take over. A number of our papers in this area can be found on our website.

One last fun and interesting point, which ties our work with developmental disorders with our work with sex differences. We also believe that the procedural system dysfunction in these disorders might at least partially account for the sex differences in the prevalence of these disorders. All of these disorders are more prevalent, that is, more common, in males than females. People don't really know why. We think it may be at least partially explained as follows. If (1) procedural memory is dysfunctional in these disorders, (2) declarative memory can compensate for many if not most of the functions of procedural memory, such as grammar and navigation, and (3) females are better

than males at declarative memory, then it follows that at least some of the dysfunctions should be more obvious, more detectable, more identifiable, in males than females -- since the latter are more successful at compensating with declarative memory. Therefore the sex differences in the prevalence of at least some of these disorders might be at least partly explained simply by who one notices has the disorder. Since girls should compensate better than boys, the problems should be more noticeable in boys, so they should be diagnosed more, even if in fact the underlying abnormalities are not more common in boys than girls.

So that's some of the work that we're doing, and some of the issues we're interested in. Thanks for spending the time to interview me, Ingrid! I appreciate it.