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The declarative/procedural model and the shallow structure hypothesis

Clahsen and Felser (CF) have written a beautiful and important paper. I applaud their integrative empirical approach, and believe that their theoretical account is largely correct, if not in some of its specific claims, at least in its broader assumptions. CF directly compare their shallow structure hypothesis (SSH) with a model that my colleagues and I have proposed for aspects of the neurocognition of first and second language: the "declarative/procedural" (DP) model. Although some of CF's discussion accurately depicts the DP model and its relation to the data, they also make a few critical errors. Here, I first summarize the DP model in both first language (L1) and adult-learned second language (L2), in order to be able to contrast it with the SSH, and then address the relevant problems in CF. For further details on the DP model and L1, see Ullman (2001a, 2001c, 2004) and Ullman et al. (1997). For the model as it applies to L2, see Ullman (2001b, 2005).

THE DP MODEL

The basic premise of the DP model is that language depends on two well-studied brain memory systems that have been implicated in nonlanguage functions in animals and humans. The *declarative memory* system subserves the learning, representation, and use of knowledge about facts and events (Eichenbaum & Cohen, 2001; Mishkin, Malamut, & Bachevalier, 1984; Squire & Knowlton, 2000). The knowledge learned in this system is at least partly (but *not* completely; Chun, 2000) explicit, that is, available to conscious awareness. Medial temporal structures consolidate new memories, which eventually depend largely on neocortical regions, particularly in the temporal lobes (Eichenbaum & Cohen, 2001; Hodges & Patterson, 1997; Martin, Ungerleider, & Haxby, 2000; Squire & Knowlton, 2000). Other brain structures play a role in declarative memory as well, including ventrolateral prefrontal cortex, which underlies the selection or retrieval of declarative memories (Buckner & Wheeler, 2001). The molecular bases of declarative memory have also been studied. For example, declarative memory function can be enhanced by estrogen (Sherwin, 1988), perhaps via the modulation of the neurotransmitter acetylcholine (Packard, 1998). The *procedural memory* system underlies the implicit (nonconscious) learning of new, and the control of long-established, motor and cognitive "skills" and "habits," especially those involving sequences (Mishkin et al., 1984; Squire & Knowlton, 2000; Willingham, 1998). (Note that the term procedural memory is used here to refer *only* to one type of implicit, nondeclarative, memory system, Squire & Zola, 1996, *not* to all such systems.) The system is composed of a network of interconnected brain structures, and is rooted in frontal/basal ganglia structures, including premotor regions and Brodmann area 44 (BA44; Ullman, 2004, in press). The neurotransmitter dopamine plays a particularly important role in aspects of procedural learning (Harrington, Haaland, Yeo, & Marder, 1990; Nakahara, Doya, & Hikosaka, 2001). The two memory systems interact, yielding both cooperative and competitive learning and processing (Packard & Knowlton, 2002; Poldrack & Packard, 2003; Ullman, 2004). First, the two systems can complement each other in acquiring the same or analogous knowledge, including knowledge of sequences. Thus, declarative memory may acquire knowledge initially, thanks to its rapid acquisition abilities, whereas the procedural system gradually learns analogous knowledge. Second, animal and human studies suggest that the two systems also interact competitively. This leads to a "see-saw effect" (Ullman, 2004), such that a dysfunction of one system results in enhanced learning in the other, or that learning in one system depresses the function of the other.

According to the DP model, each of the two memory systems plays analogous roles in its nonlinguistic and linguistic functions. In *L1* the distinction between declarative and procedural memory largely parallels the distinction between the mental lexicon and the mental grammar. Declarative memory underlies the lexicon, which contains (at least) all idiosyncratic word-specific knowledge, including the sounds and meanings of words, and whether a word takes a morphologically irregular form, although the lexicon can *also* contain other information, including memorized complex forms. The procedural memory system subserves aspects of the mental grammar, which underlies the rule-governed sequential and hierarchical computation of complex linguistic structures. The procedural system plays computationally analogous roles across grammatical subdomains, including morphology and syntax, and may be especially important in grammatical structure building. The two systems are predicted to interact both cooperatively and competitively in the acquisition and use of language. For example, young children should initially learn both idiosyncratic and complex forms in declarative memory, while the procedural system gradually acquires the grammatical knowledge underlying rule-governed combination.

The DP model makes a somewhat different set of claims and predictions for *late-learned L2*. In L2, the acquisition of grammatical/procedural knowledge is expected to be relatively more problematic than the acquisition of lexical/declarative knowledge, compared to language learning in young children. This can be explained by one or more factors that directly or indirectly affect one or both brain systems, including the attenuation of procedural memory and the enhancement of declarative memory. Whereas motor skill learning associated with the procedural system may be subject to early critical period effects, declarative memory improves during childhood, with a possible plateau in adolescence (Di Giulio, Seidenberg, O'Leary, & Raz, 1994; Fredriksson, 2000; Siegler, 1978; Wolansky, Cabrera, Ibarra, Mongiat, & Azcurra, 1999). The changes in both procedural and declarative memory may be at least partly explained by the increasing levels of estrogen that occur during childhood/adolescence in both genders (Calabresi, Centonze, Gubellini, Pisani, & Bernardi, 2000; Sherwin, 1988; Ullman, 2004, 2005). Finally, competitive interaction between the two memory systems (see above) suggests that the improvements in declarative memory during childhood may be accompanied by an attenuation of procedural learning abilities.

Thanks to their relative facility at declarative compared to procedural learning, L2 learners should tend to rely heavily on declarative memory, even for functions that depend upon the procedural system in the L1. Thus, L2 learners should tend to memorize, as chunks, complex linguistic forms (e.g., *walked; the cat*) that are generally computed compositionally by L1 speakers (e.g., *walk + -ed; the + cat*). They may also depend heavily on stored schemas or constructions (e.g., of the sort proposed by construction grammar; Fillmore, Kay, & O'Connor, 1988), and may memorize transition probabilities between words, particularly when adjacent words co-occur frequently in the same syntactic frame. Productivity in the L2 may involve associative generalization over similar forms or structures stored in lexical memory, the computation of conceptual–semantic relations among items, or the use of "rules" learned in declarative memory.

These strategies should lead to a fairly high degree of proficiency, the level of which should vary according to a number of factors, including the amount and type of L2 exposure, and individual subject differences regarding declarative memory abilities. However, not all types of "grammatical" knowledge should be equally learnable in declarative memory. For example, complex forms that are shorter or more frequent should be particularly easy to remember. Constructions that cannot be easily memorized, such as those that involve long-distance dependencies, should cause particular difficulties. The limitations of lexical/declarative memory lead to the expectation that this system cannot supply all functions subserved by the grammatical/procedural system in L1, and thus cannot provide nativelike proficiency in all aspects of grammar. Crucially, however, the complete dysfunction of the grammatical system in L2 is *not* expected. Rather, in accordance with multiple studies of the adult acquisition of nonlinguistic skills by procedural memory (Schacter & Tulving, 1994; Squire & Zola, 1996), practice should lead to procedural learning and improved performance. Thus, with sufficient experience with L2, the language should become L1-like in its grammatical dependence on the procedural system, with the potential for a high degree of proficiency. Whether or not a given individual acquires a given set of grammatical knowledge in the procedural system will depend on factors such as the type of grammatical knowledge being learned, the nature of the L2 exposure, and characteristics of the learner, such as intrinsic procedural learning abilities.

THE DP MODEL AS DISCUSSED BY CF

The DP model differs from Paradis' perspective

CF seem to suggest substantial equivalence between the DP model and the view espoused by Paradis (1994, 1995, 1999, 2004). Like the DP model, Paradis suggests a greater dependence on declarative than procedural memory in L2 compared to L1, and in low-proficiency L2 compared to high-proficiency L2. However, *unlike* the DP model, which emphasizes the parallels between the lexicon/grammar distinction and the dichotomy between the declarative and procedural brain memory systems, Paradis seems to assume a direct correspondence between explicit knowledge (available to conscious awareness) and declarative memory, and between implicit knowledge (not available to conscious awareness) and procedural memory. That is, for Paradis, all that is conscious is declarative, and all that is nonconscious is procedural. Thus, the two models focus on very different distinctions and parallels. Indeed, Paradis discusses the increased reliance on procedural memory, in *both* L1 and high-proficiency L2, largely in terms of greater automatization and implicitness *across* various domains of language, including both lexicon and grammar. Paradis also diverges somewhat from the DP model with respect to neuroanatomy. Paradis focuses only on medial temporal lobe structures for declarative memory, and on the basal ganglia, cerebellum, and neocortex for procedural memory; particular neocortical regions do not appear to be implicated, other than left "perisylvian areas" (Paradis, 1999, 2004). Finally, unlike the DP model, Paradis does not seem to make further predictions based on independent knowledge of the two memory systems, such as modulation by sex hormones. In sum, the DP model makes a different set of predictions from Paradis, allowing the two perspectives to be empirically distinguished.

A comparison of the DP model and the SSH

The SSH and the DP model both posit a lack of L1-like grammatical processing in L2 speakers, who instead rely on other mechanisms, in particular, those that involve lexical and semantic knowledge and processes. However, the two perspectives differ crucially in at least three ways. First, whereas the DP model posits that experience with the L2 eventually leads to proceduralization of grammar, resulting in L1-like grammatical processing, the SSH denies such a qualitative change over time. Unfortunately, CF do not seem to acknowledge the fact that such a shift is expected by the DP model. Second, whereas the DP model posits that low-experience (but not high-experience) L2 speakers differ from native speakers both in syntax *and* morphology, the SSH argues that only syntax differs between L1 and L2, and that, in fact, L2 morphology is processed in much the same ways as in L1. Third, whereas the SSH limits its purview to processing, and indeed is relatively specific in this respect, the DP model makes claims and predictions at numerous neurocognitive levels, from the molecular level on up through brain structures to acquisition, representation, and processing. Such a level of detail is possible because the DP model's assertions about language are derived from and constrained by not only language studies, but also our *independent* knowledge of the two well-studied memory systems. In contrast, the SSH is apparently motivated only by psycholinguistic evidence, and thus is limited in the nature of its claims. It is certainly not the case, as CF suggest, that the DP model suffers from a "vagueness of notions such as 'less available' and 'more dependent.'" In fact, the DP model specifies both *why* and *how* language may depend less on procedural memory and more on declarative memory in low-experience L2 speakers, compared to both L1 and high-experience L2 speakers. Ironically, although CF critique the DP model as being vague in defining the notion of less available, they themselves provide virtually no detail as to why or in what way L1-like grammatical processing is absent in L2. Moreover, it should be pointed out that CF's shallow structure account appears to rely largely on formulations that have either previously been incorporated into the DP model (e.g., chunking), or are entirely compatible with the basic premises of the model (e.g., L2 learners compute representations that "capture thematic roles and other aspects of lexical–semantic structure").

The neurocognitive data

Although CF accurately present a wide range of data, they mischaracterize or omit certain important findings. A comprehensive examination of the neurological, neuroimaging, and event-related potential (ERP) data, as well as of psycholinguistic findings on morphology, paints quite a different picture than that depicted by CF, and in fact, supports the DP model and is inconsistent with aspects of the claims of both CF and Paradis. (For further details and discussion, see Ullman, 2001b, 2005.)

Neurological studies. Patients with left frontal/basal ganglia lesions show greater grammatical impairments in L1 than L2, *as well as* in more proficient L2 compared to less proficient L2. However, these lesions do *not* appear to lead to differences in *lexical* performance between L1 and L2, or between high- and low-proficiency L2s (Fabbro, 1999; Fabbro & Paradis, 1995; Ullman, 2001b). This pattern is predicted by DP and is at least partly problematic for both Paradis and the SSH.

Neuroimaging studies (positron emission tomography and functional magnetic resonance imaging). Tasks that involve only *lexical/conceptual processing* have not elicited more activation in the L2 than the L1 (Chee, Tan, & Thiel, 1999; Illes et al., 1999; Klein, Milner, Zatorre, Zhao, & Nikelski, 1999; Pillai et al., 2003), suggesting a common neurocognitive basis, or have elicited more activation in the L2 than the L1 in regions that may reflect the greater demands of the less well-learned L2 on articulation, working memory, or lexical retrieval/selection (Chee, Hon, Lee, & Soon, 2001; De Bleser et al., 2003; Klein, Milner, Zatorre, Meyer, & Evans, 1995; Klein, Zatorre, Milner, Meyer, & Evans, 1994). In contrast, *sentence comprehension* tasks generally elicit greater activation in the L2 than the L1 in temporal lobe regions, especially in medial temporal structures, suggesting a greater dependence on declarative memory in the L2 than the L1 (Dehaene et al., 1997; Perani et al., 1996; Perani et al., 1998). High experience and proficiency with the L2 seems to diminish or eliminate this L2/L1 difference (Chee et al., 1999; Perani et al., 1998), although confounds between age and length of exposure complicate these findings. Finally, syntactic processing of an adult-learned artificial language elicited medial and neocortical temporal lobe activity at low proficiency, whereas by the time subjects had reached high proficiency this activation had decreased while activation increased in BA44 (Opitz & Friederici, 2003). This finding directly supports the DP model's prediction of a shift from the declarative to the procedural system in grammatical processing during late L2 learning, and is not consistent with the SSH.

ERP studies. Lexical/semantic processing in the L2 as well as the L1 consistently elicits N400s (Hahne, 2001; Hahne & Friederici, 2001; McLaughlin, Osterhout, & Kim, 2004; Weber-Fox & Neville, 1996), which have been linked to the declarative memory system (Ullman, 2001b). In contrast, most studies of syntactic or morphological violations in L2 speakers have failed to find left anterior negativities (LANs; Hahne, 2001; Hahne & Friederici, 2001; Hahne, Muller, & Clahsen, 2003; Weber-Fox & Neville, 1996), which have been linked to the grammatical/procedural system (Ullman, 2001b). Instead, one finds no negativities at all, or even an N400-like component, consistent with a reliance on declarative memory for grammatical processing in L2 (Osterhout & McLaughlin, 2000; Ullman, 2001b; Weber-Fox & Neville, 1996). LANs have been found in only two experiments of later learned language: in a study of *syntactic* violations in adults acquiring an artificial language to high proficiency (Friederici, Steinhauer, & Pfeifer, 2002) and in a finding cited by CF as problematic for the DP model, in which a LAN was elicited by the inappropriate addition of a regular past-participle affix to an irregular verb (Hahne et al., 2003). Importantly, the subjects in this study were also highly proficient, as expected by the DP model.

Psycholinguistic studies of morphology. Contrary to the expectations of the SSH, Brovetto and Ullman (2001) found past tense frequency effects for regular past tense forms in lower experience L2 speakers but not in native speakers, suggesting that the former but not the latter retrieve these forms from memory; both groups showed frequency effects for irregulars. In contrast, Birdsong and Flege (2001) reported an L1-like pattern in high-experience L2 subjects, with frequency effects for irregular but not regular inflected forms.

SUMMARY AND CONCLUSION

The DP model constitutes a well-specified theory of the neurocognitive bases of both L1 and L2. It gives an account of both the whys and hows of the differences and commonalities of L1 and low- and high-experience L2, at various neurocognitive levels. The model is similar in certain respects to both Paradis' perspective and the SSH, although it also differs from both in crucial and testable ways. The extant neurocognitive data are largely compatible with the DP model, and are at least partly problematic for Paradis' proposal as well as for the SSH claims that L2 sentence processing is never L1-like, whereas morphological processing in the L2 and L1 do not differ.

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