Mellow, J. D., and Stanley, K. 2001. "Alternative accounts of developmental patterns: Toward a functional-cognitive model of second language acquisition." In K. A. Smith and D. Nordquist (eds.), *Proceedings of the Third Annual High Desert Linguistics Society Conference*, 51-65. Albuquerque, N.M.: High Desert Linguistics Society

Author Affiliations:
J. Dean Mellow, Simon Fraser University, Burnaby, B.C. CANADA
Karen Stanley, Central Piedmont Community College, Charlotte, N.C. U.S.A

Contact Address:
Dean Mellow
Department of Linguistics
Simon Fraser University
Burnaby, B.C. CANADA V5A 1S6
e-mail: dmellow@sfu.ca

ACKNOWLEDGMENTS
We are grateful for the many useful comments which we have received from Doug Biber, Joe Collentine, Kevin Gregg, Jan Hulstijn, Brian MacWhinney, Paul McFetridge, William O'Grady, the audience at HDLS, and, especially, Nick Ellis. The paper has been improved substantially as a result of the detailed comments of the reviewers. We would also like to thank Mike Long for pointing out that something is moving in the bushes.

Note: As presented here, page breaks correspond to the breaks in the published version. In addition, dashed numbers in square brackets indicate the end of each page in the published version.

1. DIFFERENT ACCOUNTS OF DEVELOPMENTAL PATTERNS IN SECOND LANGUAGE ACQUISITION.

Longitudinal studies of first and second language acquisition have often revealed specific developmental patterns that include *acquisition orders* across language elements and *developmental sequences* within elements (Larsen-Freeman and Long 1991; R. Ellis 1994; Braidi 1999). We believe that at least five different types of explanations for such developmental patterns in language acquisition have been proposed in the literature (cf. Brown 1973; O'Grady 1987: 194-200, 1997: 307-328). The first two types of explanations are external to human cognition and the remaining three types involve very different assumptions about the nature of cognition. The first type of explanation is environmentalist, with learning attributed to input frequency, opportunities for language use, and contextualization of language use (cf. Long 1996). The second type is compositionist, with learning attributed to the formal and functional properties that comprise the language elements or mappings being learned (cf. grammatical, semantic, and cumulative complexity proposed by Brown 1973; and the grammatical explanation proposed by O'Grady 1987: 195).

The third type of explanation is connectionist, with learning attributed to simple associative learning processes and not due to prespecified cognitive architecture, modules, or mechanisms (cf. Gasser 1990: 190; N. Ellis 1998; Elman *et al.* 1998: 35-42). The fourth type is general nativist, with learning attributed to innate cognitive mechanisms and modules that are not language-specific (O'Grady 1987, 1996, 1997: esp. 308, 1999). In contrast to connectionism, general nativism proposes innate modules and mechanisms which are self-contained cognitive units that perform relatively complex functions. Within a connectionist approach, these complex cognitive behaviors are thought to be epiphenomenal: They emerge as a result of "relatively simple developmental processes being exposed to a massive and complex environment" (N. Ellis 1998: 644). Using a somewhat more inclusive definition of general nativism, the information-processing approach, with the various mechanisms that it includes, is considered here to be general nativist (cf. McLaughlin and Heredia 1996 and section 4 below). The fifth type of explanation is special nativist, with learning attributed to innate, language-specific cognitive capacities (e.g., Krashen 1985; Pienemann and Johnston 1987; Zobl and Liceras 1994; Pienemann 1998).

The three different types of cognitive explanations can be ordered as in (1) below, with the simplest, most general, and most parsimonious explanation on the left of the continuum.

(1) connectionist < general nativist < special nativist

This view of theoretical simplicity is informed by the high value that O'Grady (1997: 307) placed upon general nonlinguistic cognitive processes, by the high value that McLaughlin and Heredia (1996: 222) placed upon a reduction in the number of learning mechanisms, and by the high value that N. Ellis (1998: esp. 645) placed upon the use of the simplest, most basic learning processes. Following this view of theoretical simplicity, we adopt an approach to second language acquisition (SLA) research in which we first seek explanations using the most general cognitive factors. Less general explanations would then be utilized only when the simpler explanations have been exhausted and found to be inadequate. Specifically, in order to account for four past time developmental patterns, we propose a functional-cognitive (or FC) model that, in addition to environmentalist and connectionist explanations, utilizes only a connectionist cognitive explanation.

In contrast to the high value that we place upon theories that use more general cognitive factors, many acquisition researchers have adopted special nativist positions. In order to account for acquisition orders such as those found across English morphemes (such as progressive *-ing* preceding articles and articles preceding third person singular non-past *-s*), Krashen (1985: 3, 21) adopted the innatist position proposed by Chomsky (1975). Similarly, Meisel, Clahsen, and Pienemann (1981) and Pienemann and Johnston (1987) accounted for a wide array of acquisition orders in German and English by adopting a transformational syntactic analysis that presupposed special nativist linguistic mechanisms (for further discussion, see Mellow 1996a; Pienemann and Johnston 1996). Subsequent to transformational syntax, White (1989: 30-31) argued that Universal Grammar, when manifested as Government and Binding (GB) theory, accounts for certain acquisition order phenomena, but does not account for the order of English morpheme acquisition. Later, Zobl and Liceras (1994) accounted for acquisition orders in English morphemes using the constructs related to innate functional categories within GB theory. More recently, Pienemann (1998: esp. 23-24, 32-33, 93-98) has carefully combined the special nativism of Lexical Functional Grammar with general nativist cognitive constructs.

It is beyond the scope of this paper to compare the explanatory adequacy of these special nativist accounts to the account provided by our FC Model. Instead, our purposes in this paper are (i) to outline the FC Model, which utilizes connectionist explanations of developmental patterns within past time expression, and (ii) to distinguish the constructs of the FC Model from one type of general nativist account, the information-processing approach.

2. THE DATA: ACQUISITION ORDERS AND DEVELOPMENTAL SEQUENCES IN THE SLA OF ENGLISH PAST TIME MAPPINGS.

The FC Model accounts for four specific patterns in the longitudinal SLA of past time form-function mappings (i.e., of simple past, present perfect, and past perfect). These four previous findings are based upon analyses of written texts produced longitudinally by English as a Second Language (ESL) learners (Bardovi-Harlig 1994, 1997; Mellow and Stanley 1998). After exemplifying the ESL use of these mappings, the four patterns are described.

2.1 ESL EXAMPLES OF PAST TIME MAPPINGS: SIMPLE PAST, PRESENT PERFECT, AND PAST PERFECT.

Examples of how past time mappings are expressed in ESL writing are provided in (2).

(2) a. I *when* home to relax. When I *got* home somebody <u>call</u> me and (<u>let</u>) massege in the answer machine.

b. One of the most important decision that I **have made** in whole my life *was* when I *decided* to (came) to U.S.A.

The meaning of the italics, underlining, bolding, and parentheses used in these examples are indicated in (3).

(3)

Native-like contexts for Simple Past:	*Italics*
Native-like contexts for Past Perfect:	<u>Underlined</u>
Native-like contexts for Present Perfect:	**Bold**
Non-native-like overgeneralizations of Simple Past:	(Parentheses)

The simple past is a mapping that pairs morphological forms such as suffixation (of *-ed*), internal change, or suppletion (or partial suppletion) with the expression of completed events or states in the past (the many other possible meanings of simple past and other past time forms are discussed by Binnick 1991; Celce-Murcia and Larsen-Freeman 1999, among many others). Native-like contexts for simple past in these three passages are italicized. Native-like uses of this mapping are *got* in (2a) and *was* and *decided* [52]

in (2b). A non-native-like use of this mapping is *when* (a spelling which suggests a non-native-like form of *went*) in (2a). In these passages, simple past forms have also been overgeneralized to contexts where they are non-native-like: These contexts are enclosed in parentheses. In (2b) *to came* is an infinitival form that is unmarked in native-like English. In (2a), a simple past form has also been overgeneralized to a context for past perfect, as discussed below.

The past perfect mapping (also known as the pluperfect) uses a syntactic structure along with morphological marking. The past participle of a main verb is preceded by *had*, the partially suppletive form of the auxiliary *have*. The past participle is formed through either suffixation or suppletion. These forms are paired with the expression of a situation in the past that occurred prior to another situation in the past. Passage (2a) includes two native-like contexts for past perfect: These contexts are underlined. The events referred to by the verbs *call* and *leave* took place prior to the event referred to by *get home*. These two forms are non-native-like. There is no auxiliary *had* preceding *call* and *call* is unmarked morphologically. The word *let* appears to be a misspelling of *left*, a partially suppletive form that is either the simple past form or the past participial form. In addition, there is no auxiliary *had* preceding *let*, and the possibility of ellipsis of *had* is eliminated because there is no auxiliary preceding *call*. Consequently, *let* is interpreted to be a simple past form overgeneralized to a past perfect context and is enclosed in parentheses.

The present perfect mapping also uses a syntactic form along with morphological marking. The auxiliary *have* or its partially suppletive form *has* precedes the participial form of a verb. The participial form is marked by either suffixation or suppletion. These forms are paired with the expression of a situation in the past that has current relevance or is viewed from the perspective of present time. Passage (2b) includes a native-like context for past perfect: This context is in bold. This example, *have made*, is a native-like use of this mapping, expressing a completed action in the past that maintains relevance to present time.

The FC Model, as discussed below, is primarily concerned with four patterns in the development of these three past time mappings. However, data from two other past time mappings, reverse-order-reports and present perfect progressive, are discussed as well. Reverse-order reports are sequences of clauses that are not presented in the chronological order in which they occurred. The following example is from Bardovi-Harlig (1994: 244): *John entered college in 1980. He had graduated from high school five years earlier.* Bardovi-Harlig (1997: 380) indicated that "the present perfect progressive combines the meaning of the present perfect with the notion of a continuous event of process" and provided the following example: *She has been practicing law for 5 years.*

2.2 FOUR PATTERNS IN THE SLA OF ENGLISH PAST TIME MAPPINGS

The first pattern in the longitudinal SLA of past time form-function mappings is an acquisition order in which more complex past time mappings only emerged in production data after the simple past exhibited a high level of suppliance. Bardovi-Harlig (1994: 265) found that when the learners first produced the past perfect (or pluperfect), their appropriate use of the simple past ranged from 78% to 100% and averaged 87%. When these learners first produced the present perfect, their appropriate use of the simple past ranged from 68% to 93% and averaged 85.9% (Bardovi-Harlig 1997: 390). When these learners first produced reverse-order-reports, their appropriate use of the simple past ranged from 37% to 100%, but averaged 84% (Bardovi-Harlig 1994: 265). Mellow and Stanley (1998) found that *post-threshold* texts, those with greater than 70% suppliance in obligatory contexts (SOC) of simple past, exhibited significantly more contexts for past perfect and present perfect mappings than did *pre-threshold* texts, those with less than 70% SOC of simple past.

The second pattern is an acquisition order in which certain complex past time mappings only emerged in production data after other complex past time mappings had already emerged. Bardovi-Harlig (1994: 264, 1997: 417) found that past perfect emerged at the same time as or after reverse-order-reports and present perfect had emerged. Past perfect was also found to appear relatively late in Klein (1995: 47, 50). In contrast, Mellow and Stanley (1998) found that past perfect emerged at least as early as present

perfect. Finally, Bardovi-Harlig (1997: 390) found that the present perfect progressive emerged only after the present perfect had emerged. These two findings are summarized in Figure 1.

Insert Figure 1 about here

FIGURE 1: A SUBSET OF LOGICAL POSSIBILITIES OF PHASES AND SUBPHASES IN THE SECOND LANGUAGE ACQUISITION OF PAST TIME MAPPINGS

We have characterized these past time findings by distinguishing between two types of groupings of language mappings that develop at similar times, *phases* and *subphases*. A phase includes a set of interrelated mappings that develop at a relatively similar time and which do not emerge in production until after the mapping(s) within the previous phase have achieved a high strength of cognitive representation (or strength of neural connectivity), as indicated by a high level of suppliance. In contrast, a subphase includes a set of interrelated mappings that develop at a very similar time and that may not emerge until after the mapping(s) in the previous subphase have emerged (if a previous subphase exists within that phase). These two categories of results are represented in Figure 1, with simple past in Phase *p*, with reverse-order-reports and present perfect in Subphase *p*+1+.1, and with past perfect and present perfect progressive in Subphase *p*+1+.2. Because of the contradictory findings noted above, a question mark has been placed beside the past perfect in Subphase *p*+1+.2.

The third pattern is a developmental sequence in which overgeneralizations of the simple past mapping increased significantly after the simple past exhibited a high level of suppliance. Mellow and Stanley (1998) found that all overgeneralizations of the simple past mapping were significantly more frequent when the mapping exhibited a high level of suppliance, greater than 70% SOC. These overgeneralizations were to target-like contexts for present perfect and for past perfect, as well as to target-like contexts for non-past time mappings, including infinitives and after modal verbs.

The fourth pattern is a pattern of overgeneralizations in which the emerging, more complex past time forms were often produced within target-like contexts for the simple past mapping and in which the simple past forms were used in contexts for the emerging mappings. Bardovi-Harlig (1997: 400-402) found that when present perfect forms were overgeneralized (N = 65), 63.1 % of the overgeneralizations were in contexts for simple past (cf. the similar finding reported by Klein 1995: 47), 23.1% were in contexts for past perfect (or pluperfect), and 10.8% were in contexts for the present tense. In addition, when other forms were overgeneralized in contexts for the present perfect (N = 35), 43% were present tense forms, 37% were simple past forms, and 20% were past perfect forms. These patterns of overgeneralization were confirmed for the present perfect and extended to the past perfect in the data reported in Mellow and Stanley (1998). Of the uses of and contexts for present perfect (N = 8), two (25%) were present perfect forms overgeneralized in simple past contexts and two (25%) were simple past forms overgeneralized in present perfect contexts. Of the uses of and contexts for past perfect (N = 17), one (6%) was a past perfect form overgeneralized in a simple past context and eight (44%) were simple past forms overgeneralized in past perfect contexts.

3.0 THE FC MODEL OF ESL PAST TIME DEVELOPMENT

Using only connectionist, environmentalist, and compositionist explanatory factors, the FC Model accounts for these four empirically-attested patterns in the longitudinal SLA of past time form-function mappings. The FC Model begins with the four primary theoretical commitments of

the Competition Model (MacWhinney 1997; MacWhinney and Bates 1989). The first commitment is that language and interlanguage systems are hypothesized to be composed of form-function mappings. In addition, following Sag and Wasow (1999), the FC Model conceptualizes language as form-function mappings in which phonological (or orthographic) features are paired with semantic and syntactic features. The second commitment is that language learning is thought to be incremental, resulting from associative (i.e., connectionist) learning processes. The third commitment is that language processing is thought to be restricted by capacity limitations in terms of short-term verbal memory. The fourth commitment is that developmental patterns are hypothesized to result from the frequency in input and functional properties of the mappings being learned (i.e., an empiricist or data-driven, rather than nativist position). The FC Model has also been formulated in order to be consistent with the developmental patterns reported in Cazden (1968), Huebner (1979, 1983a, 1983b), Barrett (1986), and Plunkett, Sinha, Moller, and Strandsby (1992). In accordance with these commitments**,** the past time patterns, including acquisition orders and overgeneralizations, are interpreted as manifestations of expansions in neural connectivity and modifications of connection strengths, changes that result from the associative learning that occurs during the processing of a large number of exemplars. The Model is explicated in more detail in Mellow and Stanley (1998), also providing an account of two patterns of task variation.

3.1 EXPLANATORY FACTORS WITHIN THE FC MODEL

The FC Model accounts for the findings summarized in Figure 1 using only connectionist, environmentalist, and compositionist explanatory factors. Rather than relying upon cognitive modules or mechanisms that are either general to human cognition or specific to language, one of the main assumptions of the FC Model is that that key aspects of the development of past time mappings result from associative learning processes. Thus, language learning is not explained through the use of complex, self-contained cognitive units. Instead, language learning is characterized as changes in patterns of connections and activation between forms and functions. These changes can be represented and simulated by connectionist models (e.g., MacWhinney 1989, 1997; Broeder and Plunkett 1994; N. Ellis 1998, 1999; Kempe and MacWhinney 1998). More specifically, a connectionist approach to development (e.g., Elman et al. 1998) assumes that learning is a consequence of repeated neural network activation, in conjunction with learning algorithms such as backpropagation and Hebbian learning, that results in stronger and more easily activated connections.

In addition, the FC Model assumes that certain aspects of the development of past time mappings are affected by environmental factors. Long (1996) provides a detailed review of the role of environmental factors in SLA. One environmental factor that the FC Model includes is the frequency of items in input (e.g., Larsen-Freeman 1976; Gathercole 1986; Barlow 1996; MacWhinney 1997; N. Ellis 1998). To a certain extent, aspects of the acquisition order in Figure 1 may be due to frequency in input, with simple past presumably occurring more than present perfect and past perfect in the input to a learner. A second environmental factor is the frequency of opportunities and/or need for language use in output (Swain 1993). Although Bardovi-Harlig (1994, 1997) found that developmental patterns in past time expression were not affected by instruction, a third environmental factor included in the FC Model is the ways in which language use is contextualized and made meaningful, including salience-enhancement and instruction (Schmidt and Frota 1986; Sharwood Smith 1993; Schmidt 1994; VanPatten 1995).

In addition, to explain the past time findings, we utilize an explanation that we refer to as compositionist, expressed as the principle in (4).

(4) The Compositionist Principle of Acquisition Orders:
Form-function mappings will develop in a specific order according to the properties of which they are composed, including: (i) the aggregate processability of their formal and functional properties; and (ii) the cumulative ordering that results from the developmental interrelations of the forms and functions within each mapping.

The principle builds upon explanatory accounts of acquisition orders proposed by Brown (1973), Slobin (1982: 150-53), Johnson (1985), Gathercole (1986), O'Grady (1987: 194-198, 1997: 349), Radford (1990: 263-68), Cho and O'Grady (1995: 446), VanPatten (1995), and Bardovi-Harlig (1997: 412), among others. The first part of this principle proposes that acquisition orders across mappings occur because the aggregation of specific formal and functional properties makes a mapping relatively more or less difficult to process in comprehension or production. Because connectionist models propose that development results from the network associations that occur during the processing of masses of exemplars, mappings that are easier to process will presumably be processed more often and hence learned earlier. The formal properties that make mappings difficult to process include, but are not limited to, low perceptual salience and complex structural properties. Low perceptual salience may result when (i) a form is a bound morpheme, rather than a free morpheme; (ii) a morpheme is an unstressed syllable; or (iii) a morpheme is only a one-consonant phoneme. Complex structural properties include (i) a greater quantity of required morphological or syntactic forms (e.g., Brown, 1973; Givón, 1984); (ii) allomorphic variation and/or uses of different word formation structures by different lexical subcategories to encode the same meaning (e.g., affixation and suppletion alternatively used to express past tense); (iii) homophony with a form used to express another meaning; and (iv) syntactic dependency on a non-adjacent element, such as the preposing of a *wh*-pronoun that is the object complement of a verb.

The functional properties that make mappings difficult to process include, but are not limited to, low functional load and complex functional load. A low functional load may occur when there is (i) frequent or absolute discoursal or syntagmatic redundancy (Mellow and Cumming 1994; VanPatten 1995; Mellow 1996b); (ii) paradigmatic redundancy (i.e., items in free variation that express the same meaning); and (iii) absence of cue contrast availability, low cue simple reliability, and low cue conflict reliability (MacWhinney 1997). A complex functional load may occur when there is (i) abstract, non-prototypical, or less 'relevant' semantic content (e.g., Blakemore, 1992; Plunkett et al. 1992; Andersen and Shirai 1994); (ii) subtle social or emotional meaning; (iii) indirect speech acts; (iv) complex semantic content that is a combination of semantic features (e.g., Brown 1973; Bardovi-Harlig 1997); and (v) polyfunctionality of meaning (i.e., multiple meanings at grammatical, referential, pragmatic, and/or social levels; Mellow 1996b).

As indicated by the second factor specified in the Compositionist Principle of Acquisition Orders, a crucial assumption is that mappings that are sequentially related to each other within the order are interrelated and dependent upon each other (cf. Brown 1973; Borer and Wexler 1987: 126; O'Grady 1987: 195-198; Radford 1990: 268-270). If the Compositionist Principle of Acquisition Orders only made reference to the aggregation of properties of processability, then mappings could be assigned to different phases simply because one mapping has relatively more aggregate properties that impede processing and hence delay acquisition; however, the order would be neither coherent nor meaningful because there would be no linguistic relationship between the mappings. For example, the plural suffix on nouns (*-s*) appears to have fewer properties that hypothetically delay acquisition than does the past perfect marking on verbs, which has relatively more complex syntactic (auxiliary verb) and morphological (affixation or suppletion) components. Although this may lead to the prediction that the plural mapping will be acquired before the past perfect mapping, there is no overlap in either the form or function of these mappings and therefore no reason to place these two mappings within the same acquisition order. Indeed, the lack of theoretical relation between ordered elements has been one of the main criticisms of previous models of acquisition orders (e.g., Brown 1973: 407; Larsen-Freeman and Long 1991: 91; Zobl and Liceras 1994; Mellow 1996a).

In contrast, in the FC Model, the mappings within an acquisition order will share (during interlanguage development, although perhaps not in the target system) formal and/or functional properties, with the earlier acquired mappings having forms and/or meanings that are relatively more easily processed and learned (cf. Brown 1973; Bardovi-Harlig 1997; Andersen and Shirai 1994). Building upon Brown's (1973: 185-187, 368-379, 404-409) 'law of cumulative complexity', we describe this as a *cumulative ordering* within an acquisition order: certain linguistic forms or functions must have

already emerged or achieved stability before a mapping that includes (or builds upon) the form or function can emerge.

A cumulative ordering with respect to some of the primary meanings of the past time form-function mappings is indicated by the following feature analysis. In her analysis of interlanguage data, Bardovi-Harlig (1997; cf. Binnick 1991: esp. 102) proposes that simple past primarily encodes the semantic feature [+ anterior] (i.e., it indicates that an event or situation took place prior to the time of speaking), but that present perfect may also encode both [+anterior] and the semantic feature of [+current relevance]. In addition, because a frequently occurring function of the past perfect is to encode an "action completed in the past prior to some other past event" (Celce-Murcia and Larsen-Freeman 1999: 116), past perfect can encode both [+anterior] and a feature that we tentatively refer to as [+ prior to point of reference] (following Reichenbach 1947, as discussed in Binnick 1991: 110-118). Using these semantic features and following the notion of cumulative semantic complexity proposed by Brown (1973), Table 1 provides a hierarchy of the semantic features for these meanings of these three mappings.

Mapping	Semantic Features
simple past	+ anterior
present perfect	+ anterior, + current relevance
past perfect	+ anterior, + prior to point of reference

TABLE 1: A HIERARCHY OF THE SEMANTIC FEATURES OF A SUBSET OF THE MEANINGS OF THREE PAST TIME MAPPINGS.

As indicated in Table 1, the cumulatively complex meanings of these past time mappings correspond to the empirically attested acquisition order summarized in Figure 1, with simple past in Phase *p* and present perfect and past perfect in Phase *p+1*. By including the Compositionist Principle of Acquisition Orders, the FC Model is able to explain these orders as being a consequence of difficulty of processing.

3.2 AN EXPLICATION OF THE FC MODEL

The FC Model was created to account for the past time findings while adhering to the theoretical commitments and explanatory factors described above. The FC Model is composed of the following constructs: (i) mapping *phases* that characterize a subset of acquisition orders across mappings; (ii) mapping *subphases* that characterize an additional subset of acquisition orders across mappings; (iii) a Compositionist Principle of Acquisition Orders that accounts for the placement of mappings in phases (or subphases); (iv) four *stages* that characterize the developmental sequence within a specific mapping: emergence, pre-threshold, post-threshold, and near target-like; (v) two *substages* that allow for two subparts of overgeneralization (increases in overgeneralization and retreat of overgeneralization) within the pre-threshold, post-threshold, and near target-like stages; (vi) an important '*threshold*' boundary between the second and third stages of a mapping, with the actual threshold SOC value varying according to the attentional requirements of task, among other possible factors; (vii) a post-threshold stage that occurs after a *developmental shift* and is characterized by a significant increase in overgeneralizations; (viii) a post-threshold stage that occurs after a *developmental shift* and is characterized by its co-occurrence with the emergence of mappings in the subsequent phase; and (ix) a specification of the domains of overgeneralization at each stage, with several important domains of overgeneralization linked to the Compositionist Principle of Acquisition Orders.

The FC Model is illustrated in Figure 2 with respect to the development of two mappings that express past time, simple past and present perfect.

Insert Figure 2 about here

FIGURE 2: A SUBSET OF LOGICAL POSSIBILITIES OF STAGES, SUBSTAGES, AND PHASES OF THE SLA OF PAST TIME FORM-FUNCTION (F-F) MAPPINGS WITHIN THE FC MODEL, INCLUDING OVERGENERALIZATIONS BETWEEN MAPPINGS IN ADJACENT PHASES.

In Figure 2, increases in overgeneralization are abbreviated as ↑OvG and the retreat of overgeneralization is abbreviated as ↓OvG. In addition, the domain of the overgeneralization is specified and abbreviated in parentheses, with the first variable indicating the phase of the form that is overgeneralized and the second variable indicating the phase of the context to which the form is generalized. For example, ↑OvG ($p \rightarrow p_{+1}$) describes increases in overgeneralizations of a form from a mapping in phase *p* to the context for a mapping in phase *p+1*.

The horizontal dimension in Figure 2 indicates increases in interlanguage complexity. Thus, the horizontal axis indicates an acquisition order of phases across form-function mappings, with a subset of possible past time mappings indicated as mapping phase *p*, which includes simple past, and mapping phase *p+1*, which includes present perfect. Representing only a subset of the English mappings that express past time, Figure 2 includes only two past time mappings and does not indicate the *subphases* of mappings that were developed in Figure 1.

Vertically, Figure 2 represents developmental sequences within each mapping, with each mapping potentially going through four stages (Emergence, Pre-threshold, Post-threshold, and Near Target-like) and with important substages within three of those stages (increases in overgeneralizations, followed by decreases or retreat of those overgeneralizations). The 'vertical' stages and substages within a specific mapping may overlap to various degrees. In addition, the combination of the horizontal and vertical dimensions results in time being represented diagonally, beginning in the top left and moving toward the bottom right.

4.0 THE NATURE OF GRADUAL INCREASES AND DEVELOPMENTAL SHIFTS: INFORMATION-PROCESSING (GENERAL NATIVIST) VS. CONNECTIONIST ACCOUNTS

Clearly, the FC Model is very different from special nativist accounts of developmental patterns, both in terms of units of linguistic analysis (e.g., mappings of form and function vs. parameters, functional projections, and movement) and explanatory factors. In this section, we discuss the less obvious distinction between the FC Model's connectionist account and one type of general nativist account, the information-processing approach. Information-processing does not assume language-specific cognitive mechanisms, but does assume that humans are composed of separate information-processing mechanisms, including perceptual systems, output systems, memory systems, attention capacities, and several learning processes, including automatization and restructuring (McLaughlin and Heredia 1996). In contrast, a connectionist account assumes only a massively interconnected neural network, with behaviors due to the nature of connection patterns and with learning being the adjustment of those patterns of connectivity in response to the continual processing of linguistic (and other) exemplars.

Within the past time findings, two seemingly different types of learning patterns appear to be occurring in the development of mappings such as the simple past. The first pattern is the gradual increase in suppliance of target-like forms in obligatory contexts (during Stage 2, Pre-threshold). Slow and gradual development is a pattern that has often been reported in longitudinal SLA studies of past time and other grammatical mappings (e.g., Hakuta 1976; Klein 1995; Mitchell and Myles 1998: 119; cf. L1 acquisition: Brown 1973: 257, 410).

The second pattern is a more complex developmental shift and is comprised of three co-occurring patterns: (i) the achievement of high levels of suppliance of simple past; (ii) the emergence of the more complex past time mappings, and (iii) a significant increase in overgeneralizations of simple past (during Stage 3, and corresponding to Stage 1 of a more complex mapping). Many studies of first and second language acquisition have reported similar patterns that are relatively sudden and appear to involve a qualitative change in the learner's production or comprehension. These similar patterns have been characterized as restructuring (e.g., Lightbown 1985; McLaughlin 1990), sudden discontinuous shifts (McLaughlin 1990: 119), qualitative changes in internal representation (McLaughlin 1990; McLaughlin and Heredia 1996), the crossing of a threshold (Mellow 1988; for very different SLA uses of the term threshold level of development, see Cummins 1984 and van Ek 1987), the attainment of acquisitional prerequisites (Bardovi-Harlig 1994, 1997; cf. Pienemann 1984; Pienemann and Johnston 1987), the commencement of active engagement in the acquisition of a specific structure (Morgan, Bonamo, and Travis 1995; Saxton 2000), burst patterns (or marked acceleration) (Elman et al. 1998: 182), and spurts (or fundamental advances) (Plunkett et al. 1992).

In order to account for these two different patterns, the information-processing approach has proposed two different types of learning processes: automatization and restructuring (McLaughlin 1990; McLaughlin and Heredia 1996; Mellow 1996b; Segalowitz, Segalowitz, and Wood 1998). Automatization accounts for gradual increases in the suppliance of forms. Restructuring accounts for relatively sudden shifts that appear to involve qualitative changes in a learner's internal system. Within the FC Model, these two patterns are accounted for by only one process. Thus, although a developmental shift may not be as gradual as increases in SOC, these shifts are also interpreted to be the manifestation of cumulative, incremental, associative learning (changes in patterns of network connectivity) (cf. O'Grady 1987: 199; Barlow 1996). In the remainder of this section, we will explain how these two patterns can be accounted for with the same associative learning process. The discussion will summarize connectionist accounts of rapid changes and overgeneralizations, re-analyze the properties of the two apparently different developmental patterns, and then discuss the nature and operationalization of a threshold.

4.1 CONNECTIONIST ACCOUNTS OF RAPID CHANGES AND OVERGENERALIZATIONS.

Incremental associative learning has provided a plausible account of gradual patterns in SLA (Rumelhart and McClelland 1986; Schmidt 1994; N. Ellis and Schmidt 1997, 1998; MacWhinney 1997: esp. 129; N. Ellis 1998, 1999; Elman et al. 1998). These gradual changes can be attributed to the strengthening of the cognitive representation of those mappings, interpreted within connectionist models as the strengthening of patterns of connectivity. However, connectionist models have indicated that cumulative, incremental development is not always slow, gradual, and linear. Indeed, connectionist and mathematical models have indicated that a sudden 'readiness to learn', accelerations in slope (i.e., apparent discontinuities), U-shaped learning, and qualitatively different changes in behavior (especially dynamical changes in which later behavior depends on earlier behavior) can be accounted for by the processing of sufficient masses of exemplars in combination with relatively continuous rather than discontinuous equations and models (e.g., van Geert 1991; N. Ellis and Schmidt 1997, 1998; N. Ellis 1998; Elman et al. 1998: esp. 173-238). For example, the connectionist simulation of concept-formation and vocabulary growth reported by Plunkett et al. (1992) exhibited a developmental pattern that resembled a vocabulary spurt. This spurt occurred only after a prolonged period of training (cf. the discussion of spurts or bursts in Elman et al. 1998: 124-129, 181-186).

In addition, overgeneralizations can be accounted for by using incremental associative learning in conjunction with the use of form-function mappings as the unit of linguistic analysis. Overgeneralizations can be interpreted as changes in the interconnections within a learner's neural network. As a result of the associative learning that occurs during the processing of exemplars, learners develop patterns of connectivity between multiple forms and multiple functions. From the perspective of the target language, these interconnections may increase in such a way that the forms and functions of one mapping become connected to the forms and functions of another mapping or other mappings. Overgeneralizations then result when these 'overlapping' mappings are activated. Many of these overgeneralizations would be expected to occur only later in the development of a mapping: As the patterns of connection for a mapping become strong and less variable (and achieve a threshold strength of connectivity), learners are presumably able to begin processing meanings and structures that are increasingly and cumulatively complex. Therefore, overgeneralization patterns occur and increase as learners' neural networks expand and begin to regularly include related, more complex forms and functions. Importantly, in the connectionist simulation reported by Plunkett et al. (1992, discussed above), the associative learning resulted in a developmental pattern in which overgeneralizations (or over-extensions) primarily occurred only later in training, a result that is remarkably parallel to the third past time finding reported in section 2.2. In this way, behavior that might have been attributed to an overgeneralized rule is not rule-governed, but instead results from specific patterns of activation or weightings of connections between forms and functions.

4.2 RE-CHARACTERIZING THE PROPERTIES OF GRADUAL INCREASES AND DEVELOPMENTAL SHIFTS.

Although gradual increases and developmental shifts appear to have very different properties, a reanalysis of their properties reveals that they can be accounted for with a single learning process, associative learning. Building partially from McLaughlin (1990: 121), and accounting only for the findings with respect to past time mappings, we have characterized two 'seemingly' different types of patterns not as automatization and restructuring, but instead as (i) incremental increases in the suppliance of a form in its obligatory contexts; and (ii) sequential multi-staged shifts in the use of form-function mappings. There are two apparent differences between these types of developmental patterns: (i) the first type is clearly cumulative, incremental and gradual, whereas the second type appears to involve a change that is sudden and therefore may be discrete rather than continuous (cf. McLaughlin 1990: 120); and (ii) the first type does not involve the addition or deletion of forms or functions, whereas the second involves changes to interlanguage mappings so that the mappings overlap (or cease to overlap) with respect to forms and/or functions. However, a connectionist analysis of these apparent differences reveals that

neither of these differences is the result of distinct learning processes. Instead, the two types of developmental patterns are not distinct but are both manifestations of the same associative learning process.

The first apparent difference, suddenness or discreteness, is likely to result from the nature of the analyses and from the nature of the longitudinal data that are considered. As indicated by Huebner's (1979, 1983b) careful analysis of stages of overgeneralizations, a detailed analysis of the use of form-function mappings may reveal a series of small systematic changes that are not observed without such a fine-grained analysis (see also Preston 1996: 250; Bardovi-Harlig 1997: 415). In addition, a small number of data points may provide only a 'snapshot' of developmental changes, resulting in the interpretation that changes are relatively abrupt. In contrast, an extensive number of longitudinal data elicitation sessions may suggest that changes are gradual (for further discussion, see McLaughlin 1990: 118, 120). The data that motivated the FC Model suggest large but non-discrete changes in production patterns. For example, in Mellow and Stanley (1998), the pre-threshold texts exhibited a small number of instances of contexts of past perfect and present perfect (N=5), as well as a small number of simple past overgeneralizations (N=12). In contrast, the post-threshold texts had a significantly larger number of instances of contexts of past perfect and present perfect (N=18), as well as a significantly larger number of simple past overgeneralizations (N=34). Although these differences are statistically significant, our interpretation of these numbers is that they do not suggest discrete or entirely distinct stages. These findings of non-discrete changes are likely due to the moderately large number of sampling sessions which limits the snapshot effect. Thus, the specific temporal and linguistic analyses of the past time mappings suggest that the developmental shifts in those data, although less gradual than earlier changes, are continuous and incremental rather than discrete and sudden.

The second apparent difference between these types of patterns is that only shifts are associated with changes in other mappings. However, as indicated by the nature of overgeneralizations within connectionist models (section 4.1), associative learning can account for changes in overlapping patterns of connectivity between forms and functions: A developmental shift resulting in overlapping mappings is simply a later stage in the development of a mapping. In other words, the two types of patterns are different stages of one longer, complex developmental path that results incrementally from associative learning. Patterns of connectivity constantly change as a result of processing exemplars, with the part of the network associated with past time (or other) forms and functions first strengthening (exhibiting increasing SOC) and then expanding to related and more complex forms and functions (exhibiting overgeneralizations). In addition, the very earliest development of a mapping (Stage 1 and the early parts of Stage 2) may also exhibit overgeneralizations, overlapping with forms and functions that are part of a previously acquired mapping. Thus, a complete longitudinal perspective on the development of a mapping may reveal that shifts associated with changes in other mappings occur both in the early and late stages of development.

4.3 The nature and operationalization of a threshold

One final aspect of developmental shifts that warrants discussion is the timing of the shift. In the FC Model, we proposed that, because one of the co-occurring patterns is high SOC scores, the strength of connectivity of the simple past forms and functions must reach a *threshold level* before the shift occurs and the co-occurring patterns appear. The construct of a threshold level implies that increases in overgeneralizations and the development of related, more cumulatively complex language mappings are significantly facilitated when less complex mappings have reached a certain strength of cognitive representation. In other words, the expansion of a learner's network to include additional complex forms and functions occurs only when simpler forms and functions have achieved a strength or consistency of network connectivity (cf. Plunkett et al. 1992: esp. 307; Elman et al. 1998: 128-129). Because not all mappings will exist in such a cumulatively complex relationship with each other, a precise model of development will need to specify a set of developmental relationships. These important theoretical issues

are addressed by the constructs of phases and subphases of mappings, constructs which were developed in Figure 1 in response to the past time data, as well as by the notion of cumulative ordering.

For the purposes of measurement, the construct of a *threshold* level for change may be operationalized within a study as a specific percentage of obligatory suppliance of a form in its functional context. For example, for a range of grammatical phenomena, active engagement in acquisition was hypothesized to occur at 50% of grammatical accuracy in Morgan et al. (1995) and Saxton (2000). Similarly, increases in overgeneralizations and the emergence of complex forms were hypothesized to occur at 70% SOC of simple past in Mellow and Stanley (1998). In Bardovi-Harlig (1994, 1997), in reference to the appropriate use of simple past, reverse-order-reports emerged at an average of 84.6%, pluperfect (past perfect) emerged at an average of 87%, and present perfect emerged at an average of 85.9%. The use of these specific operationalized values or levels suggests a division of development into discrete stages. However, our view, following Mellow (1988), is that a threshold level is not a single value or point. Instead, achievement of the threshold is a continuous, although fairly rapid, process. For example, the threshold level in Mellow and Stanley (1998) might have been operationalized at 65% SOC or at the range of 70% through to 73% SOC. An investigation of the narrowness of the threshold will require a larger data set than that analyzed in Mellow and Stanley (1998). In addition, the specific level at which a developmental shift occurs will vary across different ways of coding native-like or 'accurate' use, different learning opportunities, different individuals, different language mappings, and, especially, different task conditions in which language is used.

In sum, the construct of a threshold level provides an account of when and why these developmental changes occur. However, until some of the variables that affect development and use are better understood, the construct has limited predictive power. Overall, the connectionist simulations, in conjunction with an analysis of the distinctive properties of shifts in past time mappings, reveal that these developmental shifts can be accounted for with associative learning processes. In addition, the construct of prerequisite strength of connectivity also explains why patterns of overgeneralization increase late in the development of a mapping, a result reported both in the past time findings and in connectionist simulations. Following Mellow and Stanley (1998), in the FC Model the threshold level that defines the boundary between Stages 2 and 3 has been tentatively set at 70% SOC.

5.0 CONCLUSION.

In this paper, we have attempted to demonstrate that acquisition orders across form-function mappings, as well as developmental sequences within mappings, especially those related to stages of overgeneralization, can be accounted for with connectionist and compositionist explanations. The FC Model has been motivated by a desire for theoretical simplicity in a cognitive theory of language acquisition: Before postulating the need for innate cognitive mechanisms, we wish to determine whether patterns of development can be accounted for with simpler cognitive processes. As such, the FC Model contrasts sharply with the many previous special nativist accounts of acquisition orders. In addition, the FC Model is different from a general nativist approach, such as the information-processing approach, because complex developmental facts are accounted for with a single learning process. Although we are optimistic that the FC Model can be expanded to account for additional aspects of SLA, the true test of the explanatory adequacy of such a model will only come with analyses of additional and more complex linguistic phenomena.

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