Theory Development in Applied Linguistics: Toward a Connectionist Framework for Understanding Second Language Acquisition

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This paper builds upon the Competition Model to create a broad framework that can inform a connectionist approach to second language acquisition research. After adopting three types of explanations for second language acquisition and outlining criteria for evaluating theories, the paper summarizes the Competition Model, a theory that utilizes those three types of explanations. The paper then summarizes findings regarding the longitudinal development of past time expression. To account for these patterns, the paper introduces additional constructs that are consistent with the Competition Model. Integrating "the competition of forms for expressing functions" with the notion of "cumulative complexity" (Brown, 1973), these new constructs are combined in the Sign-based, Connectionist, Environmentalist, and Compositionist (SCEC) Framework. The past time patterns 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.

INTRODUCTION TO THEORY DEVELOPMENT

A number of researchers have recently presented arguments for and against the potential of connectionist models of learning for providing a theory of second language acquisition (SLA) (e.g., Broeder & Plunkett, 1994; N. Ellis, 1998, 1999; N. Ellis & Schmidt, 1997, 1998; Fantuzzi, 1992, 1993; Gasser, 1990; MacWhinney, 1989a; Mitchell & Myles, 1998; Ney & Pearson, 1990; Shirai, 1992; Shirai & Yap, 1993; Sokolik, 1990; Sokolik & Smith, 1992; Yap & Shirai, 1994). In order to contribute to SLA theory development, this paper attempts to extend connectionist principles to three dominant issues in SLA research: (i) developmental sequences within language elements; (ii) acquisition orders across language elements; and (iii) task variation. Responding to Mitchell and Myles' (1998, p. 99) observation that "at the moment, the route followed by L2 learners is not convincingly explained by such [cognitive] approaches," this paper proposes specific, falsifiable constructs that can account for existing findings related to developmental patterns in second language (L2) grammar.

As explained in N. Ellis (1998), connectionism is one of a range of theoretical

Issues in Applied Linguistics ISSN 1050-4273

Vol. 13 No. 1, 3-39

approaches which assume that complex linguistic representations are learned as a result of simple learning mechanisms being exposed to extensive language data as part of the social environment. This range of similar approaches has been described as emergentist (N. Ellis, 1998) and empiricist (MacWhinney, 1997). Among these approaches, the connectionist approach to development (e.g., Elman et al., 1998) provides computational tools for modeling or simulating the process of acquisition. Language acquisition is characterized as changes in patterns of connectivity and activation that can be represented and simulated by connectionist models. Learning is assumed to be a consequence of repeated neural network activation that results in stronger and more easily activated connections, in conjunction with learning algorithms such as backpropagation and Hebbian learning.[1] These learning algorithms are rules that adjust the connection strengths between the units in the network "in such a way as to decrease the discrepancy between the network's actual output and its desired output" (Elman et al., p. 66).

The framework developed in this paper adopts the connectionist assumption that the cognitive processes that result in SLA are relatively simple, associative processes that are not specific to language learning. In contrast, *general nativist* approaches propose *innate* modules and mechanisms which are self-contained cognitive units that perform relatively complex functions and which contribute to the learning of many different types of abilities (O'Grady, 1987, 1997; see also Mellow & Stanley, 2001). *Special nativist* approaches propose innate cognitive capacities that are only used in language learning and which perform highly complex learning or processing functions. Because the connectionist approach assumes only a relatively simple and limited cognitive contribution to language learning, this approach must rely extensively on two other types of explanations for SLA. First, in an *environmentalist* explanation for developmental patterns, learning is attributed to properties of the linguistic environment in which learners use language (Long, 1996; Mellow & Stanley, 2001). Environmentalist explanatory factors include input frequency, opportunities for language use, and contextualization of language use. Second, in a *compositionist* explanation, learning is attributed to the formal and functional properties that comprise the linguistic elements being learned (Brown, 1973; Mellow & Stanley, 2001; see later section on explanatory factors for developmental patterns).

In addition, connectionist approaches to cognition do not assume that representations of language involve rules. Instead, as pointed out by Broeder and Plunkett (1994) and N. Ellis (1998, 1999), connectionist approaches are compatible with linguistic approaches that consider language to be mappings or pairings between form and function. One precise representation of a form-function mapping is the *sign* (Pollard & Sag, 1994; Saussure, 1915/1959). Given these different assumptions about representations and explanations for learning, this paper discusses the value of a connectionist explanation in relation to a general framework of assumptions that we call the Sign-based, Connectionist, Environmentalist, and Compositionist Framework, or SCEC Framework. In Mellow and Stanley (2001), a preliminary

version of this framework of assumptions was named the Functional-Cognitive (or FC) Model.

In this paper, the SCEC Framework is developed in relation to four criteria that SLA researchers have used to develop and evaluate theories: source, definitional adequacy, presence of empirical support, and scope (e.g., R. Ellis, 1994; Long, 1993; McLaughlin, 1987; Mitchell & Myles, 1998; Schumann, 1993, 1995). In this view, theory construction is fundamentally shaped by the source of theoretical constructs. Source disciplines such as generative linguistics, cognitive science, functional linguistics, and sociolinguistics often provide very different assumptions that lead to highly distinct (and perhaps even non-comparable) theories of SLA. After adopting assumptions, theories must meet two initial standards: definitional adequacy (clarity, specificity, and falsifiability) and presence of empirical support. The fourth criterion is the relative scope of a theory in terms of the range of empirical and logical issues that are addressed. These criteria may operate in a cyclic fashion. For example, after adopting foundational commitments and achieving definitional adequacy and empirical support, a theory may expand in order to account for additional empirical phenomena (i.e., increase its scope). The new constructs will need to remain consistent with the original source assumptions and will need to achieve definitional adequacy and have empirical support.

In order to illustrate this cyclic application of these criteria in the development of the SCEC Framework, the paper begins by summarizing the Competition Model, a well-developed theory that makes sign-based, connectionist, environmentalist, and compositionist assumptions about representations and learning processes. Next, the paper critiques the limitations of the Competition Model, especially with respect to its scope. The paper then summarizes a set of empirical findings regarding the longitudinal development of past time expression, including acquisition orders across sign networks and developmental sequences within sign networks. To account for these patterns, the paper introduces additional SLA constructs and findings that are consistent with the Competition Model. To achieve definitional adequacy, these new constructs are presented in a specific, falsifiable manner. An instantiation of the constructs provides a precise analysis of the past time findings. The SCEC Framework is comprised of the theoretical commitments of the Competition Model, as well as the new inter-related constructs. In the final section of the paper, the constructs and assumptions of the SCEC Framework are critically evaluated.

THE COMPETITION MODEL

An Overview of the Competition Model

The Competition Model is one of the most established models of SLA (cf. Braidi, 1999; Cook, 1996; Gass & Selinker, 1994; and esp. Correman & Kilborn, 1991; N. Ellis, 1999, p. 26; R. Ellis, 1994, pp. 377-378, 387; Segalowitz & Lightbown, 1999, p. 47). As specified by MacWhinney (1997), the Competition Model makes four major theoretical commitments. These assumptions reflect the source

of the theoretical constructs: cognitive science and functional linguistics.

The first major assumption of the Competition Model is that language learning is incremental, resulting from simple associative learning processes. Researchers have used connectionist models to create computationally explicit accounts of acquisition (Kempe & MacWhinney, 1998; MacWhinney, 1989a, 1997, 2000). The second major assumption of the Competition Model is that language and interlanguage systems are composed of form-function mappings. The Competition Model has, since its earliest formulations (e.g., Bates & MacWhinney, 1982; MacWhinney, Bates, & Kliegl, 1984, p. 128), emphasized the importance of using form-function mappings, rather than rules, as the units of analysis (McLaughlin & Harrington, 1989; cf. Selinker, 1972).

The third major assumption of the Competition Model is that language processing is restricted by capacity limitations. Although "virtually all models of language processing assume processing limits" (MacWhinney, 1997, p. 132), one strength of the Competition Model is the specific ways in which capacity limitations have been integrated into accounts of language performance and development. The fourth major assumption of the Competition Model is that developmental patterns result from the frequency in input (an environmentalist explanation) and from functional properties of the mappings being learned (compositionist explanations). In this input-driven approach to learning, "the basic claim of the Competition Model is that the system of form-function mappings embodied in language processing networks is acquired in accord with a property we will call *cue validity*" (MacWhinney, 1997, p. 122). In general, a cue (such as subject position) is a good or valid cue for a meaning (such as indicating the agent of a verb) if there is a high probability that the cue corresponds to the meaning. Cue validity is comprised of a number of cue distribution dimensions that include frequency and several functional properties of cues, including whether a cue such as singular subject-verb agreement morphology is contrastive in reference to other agreement marking (contrast availability; e.g. *The cat chases the dogs*) and whether a cue leads to the right functional choice whenever it is present (simple reliability).

Evaluation of the Competition Model and Connectionism

One of the strengths of the Competition Model is that its precise components can be tested and falsified (N. Ellis, 1999, p. 26; R. Ellis, 1994, p. 377; MacWhinney, 1997; Segalowitz & Lightbown, 1999, p. 47; cf. Gibson, 1992). In numerous empirical studies, the constructs of the Competition Model have been supported (for overviews, see MacWhinney, 1997, in press). Thus, the Competition Model meets our two initial standards of definitional adequacy and presence of empirical support.

In some of the critiques of the Competition Model and connectionism, many criticisms appear to be due to the source of the author's theoretical assumptions (e.g., Gibson, 1992). Mitchell and Myles (1998, p. 80), in comparing connectionism to Universal Grammar approaches, have suggested that the absence of "rules"

within connectionist models "goes against everything that linguists have taken as a starting point, namely that language is a set of rules (syntax, morphology, phonology) … and that the task facing language learners is to extract those rules from the language around them in order to build up their own mental set of those rules." Mitchell and Myles' comments indicate that many SLA analyses have been framed within structural approaches to linguistics, with their emphasis on rules (see also N. Ellis & Schmidt, 1997, 1998; McLaughlin & Harrington, 1989; Rumelhart & McClelland, 1986a). As noted above, the Competition Model is not informed by linguistic approaches that use rules as linguistic representations.

Other critiques of the Competition Model and connectionism relate to four limitations of scope and reflect the nature of the empirical data that Competition Model studies have typically considered. First, although the Competition Model provides certain information about development over time (e.g., MacWhinney, 1997, pp. 118, 120-121, 129; and esp. the cross-sectional analyses in Kempe & MacWhinney, 1998), it has not yet provided extensive accounts of longitudinal phenomena such as acquisition orders and developmental sequences (N. Ellis, 1999, p. 26). Recently, MacWhinney (in press) reviewed a number of mental processes that might apply to language learning and discussed the importance of tracking the details of individual patterns of language learning.

Second, the linguistic scope of the Competition Model has been limited (e.g., Gibson, 1992). The Competition Model has tended to focus on the identification of the thematic role of agent, although some studies have considered other grammatical phenomena such as direct objects, pronominal assignment, and case marking (Kempe & MacWhinney, 1998; MacWhinney, 1997, pp. 116, 124).

Third, the Competition Model has tended to examine comprehension data rather than production data (Kempe & MacWhinney, 1998, p. 581; MacWhinney, 1997, p. 132; but see Bates & Devescovi, 1989; Sridhar, 1989). Fourth, the Competition Model has often studied the comprehension of relatively simple forms that may be ungrammatical, and has often utilized somewhat artificial tasks (R. Ellis, 1994, p. 378; Gibson, 1992; MacWhinney, 1997, pp. 124, 128-129, 131; McLaughlin & Harrington, 1989; see also the discussions of the use of artificial data in N. Ellis, 1999, pp. 32-33; N. Ellis & Schmidt, 1997; Hulstijn, 1997; Schmidt, 1994). Similarly, Mitchell and Myles (1998, p. 84) suggested that connectionist models "have been concerned with the acquisition of very simple, often artificial data, far removed from the richness and complexity of natural languages, and it is still questionable how much we can learn from these experiments about language learning in 'real' situations."

To overcome these limitations of scope, this paper summarizes data that are different than those typically addressed by the Competition Model and connectionist simulations: authentic, longitudinal, production data. To account for these data, the paper introduces additional SLA constructs and findings that are consistent with the Competition Model, resulting in the specific set of constructs that comprise the SCEC Framework.

ADDITIONAL DATA TO BE ACCOUNTED FOR: THE DEVELOPMENT OF PAST TIME EXPRESSION

Past Time Sign Networks

The scope of the Competition Model is extended in this paper by considering developmental patterns in the expression of past time. To represent these patterns, the construct of the form-function mapping has been formulated as a sign. Originally proposed by Saussure (1915/1959), signs have been developed considerably within Head-driven Phrase Structure Grammar (HPSG) (e.g., Pollard & Sag, 1987, 1994; Sag & Wasow, 1999). Because the representations used in the Competition Model have indicated connections between different units of linguistic information and have been informed by Construction Grammar, Lexical Functional Grammar, and the work of Carl Pollard (MacWhinney, 1987, esp. pp. 264, 303; 1989b, esp. pp. 64, 76; in press), our use of HPSG is, in many respects, a continuation of these earlier representations.

Building from Pollard and Sag (1994, p. 15), Krieger and Nerbonne (1993), Krieger (1994), and De Kuthy (2002), signs are conceptualized in the SCEC Framework as structured complexes of phonological, morphological, syntactic, semantic, discourse, and phrase-structural information. Because the SCEC Framework utilizes a connectionist explanation of learning, it attempts to avoid or reduce the modularity of linguistic knowledge. Thus, one assumption of the SCEC Framework is that similar (although not identical) principles constrain word structure, sentence structure, and discourse structure. Therefore, utilizing ideas proposed in Krieger and Nerbonne and Krieger, signs in the SCEC Framework include bound morphemes as well as words and phrases. Within the SCEC Framework, language is conceptualized as a very complex network of signs, as well as a number of principles for the syntagmatic combination of signs into larger units. The SLA of some of these combinatorial principles was discussed by Mellow and Bae (2001).

HPSG representations of linguistic information stand in opposition to the types of rules and representations used in some special nativist theories. In particular, HPSG does not include representations that refer to phonologically abstract units or structure-destroying operations such as movement (Webelhuth, Koenig, & Kathol, 1998). In addition, HPSG sign analyses are especially appropriate because HPSG is neutral with respect to the cognitive explanation that is presumed to underlie grammatical knowledge (i.e., connectionism vs. special nativism: Sag & Wasow, 1999, p. 227). Thus, the assumption of connectionist learning principles may be consistent with the linguistic formalisms in HPSG.

The SCEC Framework accounts for English past time expressions that we describe as: (i) simple past, (ii) present perfect, and (iii) past perfect. Within the sign-based framework that is developed in this paper, the simple past is a network of signs that pair morphological forms such as suffixation (of *-ed*) with the expression of completed events or states in the past. In her analysis of interlanguage

data, Bardovi-Harlig (1997) proposes that simple past encodes the semantic feature *anterior* (i.e., it indicates that an event or situation took place prior to the time of speaking). Consequently, one sign that is part of the simple past network is represented in Figure 1. Following Krieger (1994), the features that are present are a subset of those that are required for a sign that is of the type affix.

Figure 1

affix	
PHON	*-ed*
SEM	anterior
ACAT	suffix
SUBCAT	verb

A sign that includes a subset of the features that are connected in the representation of an affix. Abbreviations: PHON - phonology; SEM - semantics; ACAT - affix category; SUBCAT - subcategorization.

The form or structure within this sign is a linear string of phonological units (i.e., the PHON feature). For simplicity of representation, the value of this feature is presented here as an orthographic string: *-ed*. The function or meaning within this sign is a semantic feature (SEM): anterior. In addition, we have specified two morphological features and their values: affix category (ACAT; prefix or suffix) and the part of speech for which the affix is subcategorized (SUBCAT).

As noted above, the simple past is best considered as a network of signs. The network includes many related structures, including the allomorphs [t], [d], and [d], as well as other morphological processes, including internal change and suppletion (although the output of highly idiosyncratic processes may best be represented in the lexical entries of the verb stems, cf. Pollard & Sag, 1987, p. 213). The simple past network also includes many related functions or semantic features; for example, Greenbaum (1996, p. 257) has pointed out that some meanings involve distancing, a metaphorical use of pastness. (For further discussion of the many past time functions, see Andersen & Shirai, 1994; Bardovi-Harlig, 1997; Binnick, 1991; Celce-Murcia & Larsen-Freeman, 1999; Comrie, 1976; Dahl, 1985; Klein, 1992, among others). The many combinations of these forms and functions comprise a complex network of signs. In the discussions that follow, we use the term *sign network* when we are emphasizing a set of related signs within a learner's overall interlanguage network (i.e., a paradigmatic set of connections between features). In contrast, we use the term *sign* to describe a specific feature structure that has been produced syntagmatically. This usage is similar to the distinction between a phoneme and an (allo)phone or between a morpheme and an (allo)morph. Because a sign network such as the simple past is also related to other sign networks (such as past perfect and present perfect), the boundaries between these sign networks will overlap and could even be delimited in different ways depending upon the

focus of investigation.

Examples of how these past time sign networks are expressed in English as a second language (ESL) writing are provided in (1) (the examples are from Stanley, 1998).

(1) a. I *when* home to relax. When I *got* home somebody *call* 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 (2).

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

Within the ESL examples provided, native-like uses of simple past are *got* in (1a) and *was* and *decided* in (1b). A non-native-like use is *when* (a spelling which suggests a non-native-like form of *went*) in (1a). In these passages, simple past forms have also been overgeneralized to contexts where they are non-native-like. In (1b) *to came*, the past time form *came* is overgeneralized to an infinitival form that is morphologically unmarked in native-like English. In (1a), the simple past form has been overgeneralized to a context for past perfect, as discussed below. These overgeneralizations indicate that non-native-like signs had been activated in the learner's interlanguage network: The learner paired forms with functions in non-native-like ways. From the perspective of the Competition Model, a non-native-like form has prevailed in the competition for expressing this function. Given this perspective, we use the term *overgeneralization* in a relatively broad manner, referring to the use of any form, not just well-developed forms, in contexts other than obligatory contexts.

The present perfect network of signs uses both syntactic forms and morphological forms. The auxiliary *have* or its partially suppletive form *has* precedes the past participial form of a verb. The past participial form is marked by either suffixation or suppletion. These forms can be paired with the expression of a situation in the past that has current relevance or is viewed from the perspective of present time. According to Bardovi-Harlig (1997, following Suh, 1992; cf. Binnick, 1991, esp. p. 102), the present perfect may encode two semantic features: *anterior* and *current relevance*. Consequently, examples of the phonological and semantic features that are part of the present perfect network are represented in (3).

(3) PHON *have VERB-ed*
SEM anterior, current relevance

Although not discussed here, the native-like English present perfect network also includes a number of other signs.

Within the ESL examples provided, passage (1b) includes an obligatory context for present perfect. This example, *have made*, is a native-like sign, expressing a completed action in the past that maintains relevance to present time. The past perfect (also known as the pluperfect) network of signs also uses both syntactic forms and morphological forms. 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 can be paired with the expression of an action completed in the past prior to some other past event (Celce-Murcia & Larsen-Freeman, 1999, p. 116). Thus, 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, pp. 110-118). Consequently, examples of the phonological and semantic features that are part of the past perfect network are represented in (4).

(4)	PHON	*had VERB-ed*
	SEM	anterior, prior to point of reference

Although not discussed here, the native-like English past perfect network also includes a number of other signs.

Within the ESL examples provided, passage (1a) includes two contexts for past perfect. 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. This overgeneralization indicates that a non-native-like sign had been activated in the learner's interlanguage network: The learner paired a form and a function in a non-native-like manner.

Using the semantic features described above and following the notion of cumulative semantic complexity proposed by Brown (1973), Table 1 provides a hierarchy of the semantic features of these meanings of the three sign networks.

Although this feature analysis is simplified, this cumulative complexity analysis of some of the primary meanings of these sign networks provides a useful springboard to understanding developmental relations.

Findings Regarding the SLA of Past Time Sign Networks

Within the many studies of the L2 expression of past time events or situations (e.g., Andersen & Shirai, 1994; Bailey, 1989; Giacalone Ramat, 1992; Hakuta, 1976;

Table 1
A hierarchy of the semantic features of a subset of the meanings of three past time sign networks.

Sign Network	Semantic Features
Simple Past	Anterior
Present Perfect	Anterior, current relevance
Past Perfect	Anterior, prior to point of reference

Klein, 1995; Meisel, 1987; Schumann, 1987), the longitudinal studies reported in Bardovi-Harlig (1994, 1997, 2000) and Mellow and Stanley (2002) may provide insight into the development of these three English past time sign networks. In particular, the findings reported in these longitudinal studies can be used to expand the scope of the data typically considered by the Competition Model. Bardovi-Harlig (1994, 1997, 2000) reported the results of analyses of a longitudinal corpus comprised of written and spoken data produced by 16 adult learners of English of four different first language backgrounds (Arabic, Japanese, Korean, and Spanish) for periods of time varying from 6 to 13.5 months. Mellow and Stanley (2002), a reanalysis of Stanley (1998), also reported the results of analyses of past time expression. Using a design that considered task variation and permitted inferential statistical tests, Mellow and Stanley (2002) replicated and extended Bardovi-Harlig's findings, investigating development of past time expression during a 4-month period on four parallel written free narrative tasks for six adult learners whose L1s were Chinese, Greek, Korean, Spanish, and Vietnamese. The texts produced by these learners were categorized into two groups: post-threshold texts comprised of 11 texts with greater than 70% simple past *suppliance in obligatory contexts* (SOC) and pre-threshold texts comprised of 10 texts with less than 70% simple past SOC. Mellow and Stanley (2002) also investigated the nature of ESL use on two different written tasks (for five learners of varying L1s), comparing the free narratives to narrative retellings of a silent film.

Five Patterns in the SLA of Past Time Sign Networks

These longitudinal studies yielded five patterns that can be accounted for within the SCEC Framework. The first pattern was a consistent acquisition order in which relatively more complex past time sign networks (past perfect, present perfect, reverse-order reports) did not appear in a learner's production data until the simple past exhibited high levels of native-like suppliance.[2] Specifically, Bardovi-Harlig (1994, p. 265) reported that when the learners first produced the past perfect (referred to by Bardovi-Harlig as the 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 86% (Bardovi-Harlig, 1997, p. 390). When these

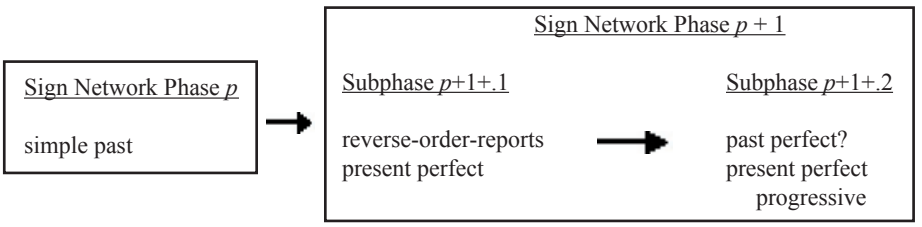
learners first produced reverse-order-reports, their appropriate use of the simple past ranged from 37% to 100%, but averaged 85% (Bardovi-Harlig, 1994, p. 265). Bardovi-Harlig (1994, pp. 264, 273; 1997, pp. 377, 412, 414) interpreted the data to indicate that the use of the simple past needs to be stabilized or that certain acquisitional prerequisites must be attained before the more complex mappings can appear. The data reported in Mellow and Stanley (2002) supported these findings. In that study, the post-threshold texts exhibited significantly more contexts for past perfect and present perfect than did the pre-threshold texts.[3] Although these studies reported similar results, the coding and analyses were somewhat different. Bardovi-Harlig (1997, pp. 390, 397-8; 2000, pp. 141-2, 160, 167) reported the first use or production of past perfect and present perfect forms (potentially including overgeneralizations and ill-formed structures) in comparison to the rate of appropriate simple past use (potentially including ill-formed structures, but excluding overgeneralizations). In contrast, Mellow and Stanley (2002) reported the numbers of past perfect and present perfect contexts, whether or not the correct forms were used, in comparison to the rate of native-like suppliance of simple past in obligatory contexts.

The second pattern was a (slightly less consistent) acquisition order in which certain complex past time sign networks (past perfect, present perfect progressive) did not appear in a learner's production data until other complex past time sign networks (present perfect, reverse-order reports) had already appeared. Specifically, Bardovi-Harlig (1994, p. 264; 1997, p. 417) found that past perfect was first produced at the same time as or after reverse-order-reports and present perfect were first produced. Past perfect was also found to appear relatively late in Klein (1995, pp. 47, 50). In contrast, Mellow and Stanley (2002) found that past perfect appeared at least as early as present perfect. Finally, Bardovi-Harlig (1997, p. 390) found that the present perfect progressive appeared only after the present perfect had appeared.[4] Because the appearance of these latter developing sign networks followed only after the prior initial *appearance* of other sign networks (not after the prior exhibition of high levels of suppliance) and because there may be some variation in these orderings, these results suggest that these orders are of a different kind than that found between simple past and the more complex past time sign networks.

Building upon the representations of acquisition orders proposed in Krashen (1977), Dulay, Burt, and Krashen (1982), Pienemann and Johnston (1987), and Giacalone Ramat (1992), these two types of acquisition orders are represented in Figure 2.

To distinguish and specify the two different types of developmental prerequisites (high levels of suppliance vs. initial appearance), Figure 2 illustrates our proposal that there are two types of groupings of sign networks that develop at similar times, *phases* and *subphases*. A phase includes a set of interrelated sign

Figure 2



A summary of the attested acquisition orders across past time sign networks.

networks that do not appear in production until after the sign network(s) within the previous phase have achieved a high strength of cognitive representation, as indicated by a high level of suppliance. In contrast, a subphase includes a set of interrelated sign networks that may not appear until after the sign network(s) in the previous subphase (if a previous subphase exists within that phase) have appeared in the interlanguage system, as indicated by initial appearance in production. An additional difference is that the orderings between phases appear to be quite certain, but the orderings between the subphases may be less certain or even subject to variation. These two categories of results are represented in Figure 2, 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 indicates the uncertainty of the placement of the past perfect in Subphase *p*+1+.2.

The third pattern was a developmental pattern in which all overgeneralizations of simple past forms were significantly more frequent when the sign network exhibited a high level of suppliance, greater than 70% SOC (Mellow & Stanley, 2002). These overgeneralizations were to obligatory contexts for present perfect and for past perfect, as well as to contexts for non-past time signs, including infinitives and after modal verbs.

The fourth pattern was that there appeared to be distinctive patterns in the overgeneralizations that occurred with the newly developing, more complex sign networks. Specifically, when present perfect forms were overgeneralized in Bardovi-Harlig's (1997, pp. 400-402) data (N = 65), 63.1 % of the overgeneralizations were to contexts for simple past (a similar finding was reported by Klein, 1995, p. 47), 23.1% were to contexts for past perfect (or pluperfect), and 10.8% were to contexts for the present tense. In addition, when other forms were overgeneralized to contexts for the present perfect (N = 35), 43% were present tense forms, 37% were simple past forms, and 20% were past perfect forms.

In the data reported in Mellow and Stanley (2002), these patterns of overgeneralization were confirmed and expanded to overgeneralizations related to past perfect. Of the eight uses of or contexts for present perfect, two were present perfect forms overgeneralized to simple past contexts and two were simple past forms overgeneralized to present perfect contexts. Of the 17 uses of or contexts

for past perfect, one (6%) was a past perfect form overgeneralized to a simple past context and eight (44%) were simple past forms overgeneralized to past perfect contexts. These results reveal that a large number of the early uses of present perfect and past perfect involve overgeneralizations from or to simple past, indicating an interaction between the developmentally ordered sign networks that have been placed in phases *p* and *p*+1.

The fifth pattern was one of task variation in which the SOC of simple past was significantly higher in free narratives than in narrative retellings (Mellow & Stanley, 2002). On the free narrative task, the mean simple past SOC score was 95%. In contrast, the mean simple past SOC score was 72% on the narrative recall task.

An Integrated Interpretation of These Five Patterns

An integration of these results suggests the construct of a *developmental shift* that occurs once the simple past achieves a high strength of cognitive representation. This developmental shift of the simple past (Phase *p*) is characterized by the co-occurrence of high SOC scores, a significant increase in all types of overgeneralization of simple past forms, and the appearance of more complex past time sign networks, including present perfect, past perfect, and reverse-order-reports (Phase *p*+1). Because one of the co-occurring patterns is high SOC scores, our interpretation of these data is that the strength of cognitive representation of the simple past must reach a *threshold level* before the shift occurs and these patterns appear. Although the high strength of cognitive representation is inferred from high SOC scores, the level of suppliance of the simple past does appear to vary according to the type of elicitation task. As a result, the influence of task variation will need to be accounted for within the specification of the construct of a threshold level. The results also reveal that a large number of the early uses of present perfect and past perfect involve overgeneralizations from or to simple past. These patterns of overgeneralization led Bardovi-Harlig (1997, pp. 399, 415) to conclude that these past time expressions are fundamentally interrelated in their development, with learners gradually acquiring and distinguishing these related forms and meanings.[5]

ADDITIONAL CONSTRUCTS AND FINDINGS CONSISTENT WITH THE COMPETITION MODEL

In order to account for these five patterns and extend the scope of the Competition Model, this paper introduces additional SLA constructs and findings that are consistent with the Competition Model. To maintain theoretical coherence, the four primary theoretical commitments of the Competition Model (connectionism, form-function mappings, capacity limitations, and input-driven learning) are retained. Combining the assumptions of the Competition Model with additional SLA constructs permits the integration of two well-known concepts in acquisition

research into the framework. The first concept is Brown's (1973, p. 186) notion of cumulative complexity: Within certain coherent acquisition orders, later developing elements are composed of earlier developing elements. In other words, a sign network composed of '*x* + *y*' is more complex than either *x* or *y* alone and should be acquired only after *x* and *y* have been acquired. This notion corresponds to the acquisition orders illustrated in Figure 2 and is discussed in the section below on explanatory factors for developmental patterns. The second concept is the Competition Model's notion of competition, in production, of forms for expressing functions (i.e., functions are mapped onto either native-like or non-native-like forms). This notion corresponds to the types of overgeneralizations reported as the fourth finding and is discussed in the sections below on the longitudinal development of individual sign networks and on the interrelationships between sign networks. Before discussing how these concepts can be integrated into the framework, the next section provides an account of task variation and its effect on interlanguage use. To achieve definitional adequacy, these new constructs are presented in a specific, falsifiable manner that permits a precise instantiation of past time findings.

Capacity Limitations and Task Variation

The past time findings suggest that SOC is affected by task properties (the fifth finding reported above). This variation affects the accurate quantification and operationalization of hypothesized threshold values for developmental shifts. Consequently, the SCEC Framework specifies aspects of processing capacity limitations that are consistent with those specified in the Competition Model. In considering production data, the SCEC Framework characterizes certain types of task variation as due to capacity limitations (or limited attentional resources) and the strength of network connectivity (or degree of automatization).

In previous SLA studies, certain aspects of the systematically variable nature of L2 use have been attributed to the different cognitive demands of the tasks in which language data are elicited. In particular, researchers have reported that the SOC or Target-like Use[6] of grammatical forms is higher on tasks in which greater amounts of attention may be focused on the production of those sign networks (R. Ellis, 1987, 1994; Hulstijn, 1989; Hulstijn & Hulstijn, 1984; Mellow, 1996; Salaberry & Lopez-Ortega, 1998). In addition, Mellow and Cumming (1994), in a study of the ESL use of plural morphology, found that tasks such as writing, in which learners have relatively abundant attentional resources available for focusing on signs, result in different interlanguage production patterns than those exhibited on other tasks in which learners have relatively limited attentional resources, such as spoken tasks involving attention to content (cf. VanPatten, 1995). Mellow (1996), a study of ESL article use, further argued that production patterns on different tasks are affected by both the availability of attentional resources and the degree to which sign networks are automatized (cf. McLaughlin & Heredia, 1996; Segalowitz & Lightbown, 1999). These results are consistent with the result in Mellow and Stanley (2002), reported above, in which simple past forms were

supplied in a significantly more native-like manner in written free narratives than in written narrative retellings.

Although these previous accounts of task variation utilize the constructs of an information-processing perspective on cognition (e.g., Hulstijn, 1989; McLaughlin & Heredia, 1996), these findings may also be interpreted within a connectionist perspective. Specifically, limited attentional resources may be considered to be one type of capacity limitation, and although connectionist models may lack explicit attentional mechanisms, Rumelhart and McClelland (1986b, pp. 114-118) argued that connectionist models are capable of exhibiting attentional phenomena (see also Shirai, 1992, pp. 107-108). In addition, degree of automatization may be considered a reflection of strength of connectivity or the utilization of "a relatively permanent set of associative connections in long-term storage" (McLaughlin & Heredia, 1996, p. 214). Thus, strength of cognitive representation or connectivity may be very similar to the construct of automatization.

Building upon the Competition Model's assumption of capacity limitations, upon these previous studies of interlanguage variability, and upon the past time findings of Mellow and Stanley (2002), the Principle of Task Variation below accounts for the effects of the availability of attentional resources during the performance of a task.

> Principle of Task Variation:
> L2 learners will exhibit greater suppliance of a form in its obligatory functional contexts when the learners are able to (i) use signs in contexts or for meanings that are strongly and consistently represented in interlanguage networks, and (ii) use those signs when large amounts of limited attentional capacities need not be focused on other aspects of communication.

The principle proposes that sign networks will have higher SOC scores in language tasks that allow learners to use those signs in specific contexts or for specific meanings that, for the learner, are often used and have a high strength of connectivity (or are relatively automatized) (Barlow, 1996; Bruner, 1983; Sinclair, 1991). In addition, the principle proposes that forms will be supplied more often in language tasks when learners do not need to allocate large amounts of their limited attentional capacity to other aspects of communicating the intended meaning, especially recalling, organizing, and formulating new and complex content (Mellow & Cumming, 1994; Shirai, 1992, p. 110). Thus, tasks with a choice of content and/or text structure, compared to tasks with less or no choice, are likely to result in interlanguage use in which forms are supplied more often in obligatory functional contexts (see also Selinker, 1972).

It is important to point out that variations in the strength of connectivity between native-like forms and functions are hypothesized to be manifested in two types of language patterns: (i) variation in SOC scores (discussed further in the

section below on longitudinal development), and (ii) task variation (see also MacWhinney, 1997, esp. pp. 133-135). First, if native-like connections are not strong, then production will exhibit a low SOC. From the perspective of the Competition Model, the interlanguage system may have non-native-like cue validity for a sign network because there is competition between native-like and non-native-like forms for expressing functions. A cue that is obligatory for native speakers may not consistently be available for a learner's production. Second, if native-like connections are not strong enough to be automatic, then tasks that allow or encourage more attention to particular signs will have higher SOC scores than tasks that allow or encourage less attention to those signs.

Explanatory Factors for Developmental Patterns

As noted in the overview above, the Competition Model assumes that developmental patterns result from the frequency in input and functional properties of the mappings being learned (i.e., cue validity). In order to account for the past time production data, the SCEC Framework includes additional connectionist, environmentalist, and compositionist explanatory factors that are consistent with the Competition Model. With respect to a connectionist explanation, the SCEC Framework assumes that the types of learning curves exhibited in the past time findings result from associative learning processes (as discussed in the following two sections).

Frequency in input, an environmentalist factor, is likely to have contributed to the orders of acquisition across phases summarized in Figure 2, in which simple past develops before present perfect and past perfect. In their analysis of a 20-million word corpus of authentic English use, Biber et al. (1999, pp. 456-461) reported that simple past occurred 5 to 20 times more frequently than present perfect, depending upon register. In addition, simple past occurred 10 to 70 times more frequently than past perfect, depending upon register (Biber et al., 1999, pp. 456-461).

The past time findings are also consistent with the formal and functional properties that comprise the linguistic sign networks being learned. As developed in Mellow and Stanley (2001), this compositionist explanation includes the constructs of *aggregate processability* and *cumulative ordering*. Aggregate processability is the hypothesis that acquisition orders across sign networks occur because the aggregation of specific formal and functional properties makes certain signs relatively more 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, signs that are easier to process will presumably be processed more often and hence learned earlier. In brief, the aggregation of formal and functional properties impedes processing and hence delays acquisition.

The formal properties that make signs difficult to process include, but are not limited to: (i) low perceptual salience; and (ii) complex structural properties, including quantity of required morphological or syntactic forms (e.g., Brown, 1973; Givón,

1984). The functional properties that make signs difficult to process include, but are not limited to: (i) low functional load, including frequent or absolute discourse or syntagmatic redundancy (Mellow, 1996; Mellow & Cumming, 1994; VanPatten, 1995); and (ii) complex functional load, including abstract, non-prototypical, or less relevant semantic content (e.g., Andersen & Shirai, 1994; Plunkett, Sinha, Moller, & Strandsby 1992).

Building upon Brown's (1973) "law of cumulative complexity" (cf. O'Grady, 1987, pp. 195-198; Radford, 1990, pp. 268-270), cumulative ordering is the hypothesis that acquisitional orders result when it is necessary for certain linguistic forms or functions to have already appeared or achieved stability before a sign network that includes or builds upon that form or function can appear. In this way, sign networks that are interrelated and dependent upon each other are expected to be sequentially related within the acquisition order. Cumulative ordering does not make predictions about the acquisition order of elements that are not in a cumulative complexity relationship to each other.[7] These two hypotheses have been combined into the The Compositionist Principle of Acquisition Orders.

> The Compositionist Principle of Acquisition Orders:
> Sign networks 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 components; and (ii) the cumulative ordering that results from the developmental interrelations of the forms and functions within each sign network.

The compositionist explanation is consistent with the orders of past time acquisition (the first and second findings summarized in Figure 2 and reported in the section on five patterns in the SLA of past time sign networks). One order of acquisition across phases, simple past developing before present perfect, is likely to have been affected by formal and functional processability properties and by cumulative ordering. With respect to the processability property of structural complexity, simple past is expressed by an inflected verb, but the present perfect is more complex because it requires both an inflected auxiliary verb and an inflected participle. In addition, the low perceptual saliency of the auxiliaries *have* and *has*, when contracted,would also make the present perfect more difficult to process (Brown, 1973, pp. 375-376, 409-410). With respect to complexity of functional load, the simple past may express the semantic feature *anterior*, whereas the present perfect may express two features, *anterior* and *current relevance*. Thus, with respect to processability properties, present perfect is more difficult to process and therefore this may partially account for its later acquisition.

With respect to cumulative ordering, these same functional properties (i.e., anterior only vs. both anterior and current relevance) may also rank the simple past before the present perfect. The structural properties are less clear, but the inflected simple past form is often identical to the past participle in the present perfect, sug-

gesting a cumulative ordering in which the inflected verb form must be acquired before the structurally more complex present perfect can appear.

An additional order of acquisition across phases, simple past developing before past perfect, can also be accounted for by the same properties of processability (structural complexity, perceptual salience, and semantic complexity) and by a similar cumulative ordering. Simple past is expressed by an inflected verb, but past perfect is more complex because it requires both an inflected participle and an inflected auxiliary verb that may be contracted. With respect to semantic complexity, the simple past may express the semantic feature *anterior*, whereas the past perfect may express both *anterior* and *prior to point of reference*. In sum, these sign networks indicate how compositionist factors may contribute to acquisition orders.

The Longitudinal Development of Individual Sign Networks: Stages

The SCEC Framework includes constructs that account for the development of sign networks longitudinally, in four stages from emergence through to mastery. This longitudinal development is included in the Framework because the past time findings suggested: (i) that there is a link between the first appearance of some sign networks (e.g., present perfect, past perfect) and the mastery of other sign networks (e.g., simple past) as in the first finding reported above; and (ii) that the early development of a sign network may be characterized by certain types of overgeneralizations, whereas the later development of a sign network may exhibit different types of overgeneralizations (the fourth finding reported above).

Following the seminal longitudinal acquisition research of Cazden (1968), the SCEC Framework includes stages within the acquisition of a single sign network, specifying changes in the amount and type of overgeneralizations. In analyzing the L1 acquisition of plural inflections by three children (Adam, Eve, and Sarah), Cazden divided longitudinal development into four periods: Period A, the absence of the inflection; Period B, occasional production with neither errors nor overgeneralizations; Period C, marked increases in production, with errors and overgeneralizations; and Period D, attainment of the arbitrary criterion of 90 per cent correct use.

By following Cazden's analysis of L1 acquisition and incorporating the full longitudinal development of a sign network into the SCEC Framework, the Framework includes three different perspectives regarding the nature of SLA (Huebner, 1979; Larsen-Freeman & Long, 1991, pp. 40-41). The first perspective is a *beginning-point* or *emergence* perspective. Within this approach, acquisition is determined according to the order in which specific language elements first emerge in production (e.g., the first systematic use of a syntactic structure: Meisel, Clahsen, & Pienemann, 1981; Pienemann & Johnston, 1987). The second perspective is a *middle*, *multi-staged*, or *evolutionary* perspective (N. Ellis & Schmidt, 1997, 1998; Long & Sato, 1984; Mellow, Reeder, & Forster, 1996). Within this perspective, the intermediate developmental stages of specific linguistic subsystems are considered,

including overgeneralizations and developmental shifts. The third perspective is an *end-point* or *mastery* perspective. Within this approach, acquisition is determined according to the order in which the production of specific language elements (e.g., morphemes) achieve a mastery level, such as the achievement of a criterion level (e.g., 90%) of SOC or of Target-like Use (e.g., Cazden, 1968; Hakuta, 1976; Master, 1987; Pica, 1983; Schumann, 1976).

Although these three different perspectives have been motivated by different purposes and have involved different definitions of what it means to acquire a language element, we believe the integration of these perspectives into the Framework is important because it can significantly contribute to a theory of longitudinal SLA. As illustrated later in the instantiation of the past time findings, the first perspective corresponds to Stage 1 (Emergence) in the development of a sign network, the second perspective corresponds to Stages 2 and 3, and the third perspective corresponds to Stage 4 (Near native-like).

The distinction between Stages 2 and 3 is motivated by three co-occurring patterns in the past time data: (i) high levels of suppliance of simple past; (ii) the appearance of the more complex past time sign networks, and (iii) a significant increase in overgeneralizations of simple past (the first and third findings reported above). In other words, at about 70% SOC there was a developmental shift involving multiple co-occurring changes in the sign networks. Because this shift occurs only after high SOC scores are achieved, the SCEC Framework includes the construct of a threshold level of cognitive representation (i.e., strength or consistency of network connectivity; cf. Plunkett et al., 1992, esp. p. 307; Elman et al., 1998, pp. 128-129).

Prior to the threshold, Stage 2 involves gradual development: incremental increases in SOC. Connectionist learning processes (i.e., the strengthening of patterns of connectivity) have been shown to provide a very plausible account of slow, gradual, and cumulative development (e.g., N. Ellis, 1998, 1999; N. Ellis and Schmidt 1997, 1998; Elman et al. 1998; MacWhinney, 1997, esp. p. 129; Rumelhart & McClelland, 1986a; Schmidt, 1994). After the achievement of the threshold, Stage 3 involves the expansion of a sign network so that it becomes linked to related and more complex forms and functions. Connectionist models are able to account for these patterns because associative learning exhibits both shifts and network expansions (e.g., N. Ellis, 1998; N. Ellis & Schmidt, 1997, 1998; Elman et al., 1998, esp. pp. 124-129, 173-238; Plunkett et al., 1992). Because not all sign networks will be in a cumulative complexity relationship with each other, a precise framework for understanding development will need to specify a set of developmental relationships. These relationships are addressed by the constructs of phases and subphases, illustrated in Figure 2, as well as by the notion of cumulative ordering, which is explained in the previous section. As a result of the past time findings, the threshold level that defines the boundary between Stages 2 and 3 has been tentatively set at 70% SOC. However, further investigation is required to assess and validate the nature of a threshold, including the influence of

the different task conditions in which language is used (see the Principle of Task Variation above).

Interrelationships Between Sign Networks: Overgeneralizations

Building from the Competition Model's notion of the competition of native-like and non-native-like forms for expressing meaning in production tasks, the SCEC Framework provides an account of the nature of the past time overgeneralizations. The Framework specifies different types and subparts of overgeneralizations as interrelationships between established and emerging sign networks, and accounts for them with changes in network connectivity. The nature of overgeneralization is included in the SCEC Framework because the past time findings indicated: (i) that the early uses of a sign network may be characterized by certain types of overgeneralizations, whereas later development may exhibit different types of overgeneralizations (the fourth finding reported above); (ii) that overgeneralizations of simple past forms increased significantly after the simple past exhibited a high level of suppliance (the third finding reported above); and (iii) that overgeneralizations can be changes in the production of one sign network that are associated with changes in and the appearance of another sign network.

Whereas Cazden (1968) subsumed all overgeneralizations into one period (Period C) within the development of an individual language element, the past time data suggests that there are two different types of overgeneralizations that correspond to different stages within the development of a sign network. In addition, the different types of overgeneralizations can also be characterized in reference to the phase of the sign network context to which the form is overgeneralized. Specifically, in Stage 2 the predominant inter-phasal overgeneralizations are of an emerging form (one that has low SOC scores) to the functional contexts for a previously established sign network (i.e., to the preceding phase). In Stage 3, the predominant inter-phasal overgeneralizations are of an established form (with high SOC scores) to the functional contexts for an emerging sign network (i.e., to the next phase). In addition to these two types of overgeneralization, the data and the representation in Figure 2 suggest four additional types. The third type is overgeneralizations to and from sign networks within the same phase, that is, intra-phasal overgeneralizations. The fourth type is overgeneralizations to or from sign networks that are in phases that are more than one phase apart in the acquisition order. The fifth type is overgeneralizations not involved in the order of interrelated sign networks (e.g., past time marking on an infinitival verb, as in *to came*). The sixth type is overgeneralizations within an individual sign network (e.g., suffixation used in place of internal change).

In addition to distinctions between these six types of overgeneralizations, previous studies have indicated that overgeneralization may be comprised of two developmental subparts: increases in overgeneralizations, followed by reductions in overgeneralizations. In a seminal longitudinal case study of one learner's ESL acquisition of the form-function mapping for *the* article the (phonetically realized as [da]), Huebner (1983a; see also 1979, 1983b) described these two subparts

of overgeneralization as *flooding* and *trickling*. Importantly, Huebner (1983b, p. 146) found that flooding and trickling were not random, but developed through a series of short periods in which the form was flooded to and trickled from specific functional contexts that could be defined in terms of semantic features. In addition, the linguistic contexts involved in flooding were not necessarily the same (in the reverse order) of those involved in trickling, further indicating the importance of a distinction between these two subparts of overgeneralization. Similarly, Barrett (1986), in a longitudinal case-study of one learner's L1 acquisition of early-acquired word meanings, found that word meaning developed through specific periods of overextension and rescission of overextension.[8] The SCEC Framework incorporates these two subparts of overgeneralization, labeling them as increases in overgeneralization and retreat of overgeneralization. These two subparts of overgeneralization correspond to two substages in the development of a sign network, resulting in subdivisions within Stages 2, 3, and 4.[9]

In three ways, these overgeneralizations are effectively accounted for by using the Competition Model and connectionism. First, the use of associative learning processes is effective because connectionist simulations since Rumelhart and McClelland (1986a) have consistently demonstrated that overgeneralizations and U-shaped learning curves are a natural consequence of associative learning processes (N. Ellis, 1998; N. Ellis & Schmidt, 1997; Elman et al., 1998; Gasser, 1990; Plunkett et al., 1992).

Second, using sign-based and connectionist perspectives, overgeneralizations are interpreted as changes in the interconnections within a learner's interlanguage network. As a result of 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 or expand in such a way that the forms and functions of one sign network become connected to the forms and functions of another sign network(s). Overgeneralizations then result when these "overlapping" sign networks are activated (or when a non-native-like form prevails in the competition for expressing a function). 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.

Third, this connectionist account is consistent with an environmentalist explanation of overgeneralizations and their retreat. While using language within many diverse and demanding contexts, learners are constantly attempting to comprehend complex input and to express complex meanings (see also the functionalist explanation of development: Mitchell & Myles, 1998, pp. 100, 119). During the beginning stages of development, learners are only able to process relatively simple forms and functions. However, as the patterns of connection for these simple sign networks 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 oc-

cur and increase as learners' interlanguage networks expand and begin to regularly include related, more complex forms and functions.

In addition, continued associative learning can account for retreat of overgeneralization patterns. If new forms and functions are connected to and built upon the more established sign networks, then the initial patterns of connectivity will be characterized by variability that is manifested in competition and overlapping sign networks. However, as the processing of large numbers of diverse target exemplars continues (Barlow, 1996), the connection strengths between these elements will be modified so that there will be very little or no connectivity between non-native-like forms and functions. In other words, the change in connection strength will appear as a reduction in the overlapping sign networks and therefore as a retreat of overgeneralization patterns.

Although the SCEC Framework provides a description of these developmental patterns in relation to sign networks, it does not specify the mechanism underlying these shifts. In addition, the Framework does not address technical problems in the neural network modeling of these patterns. A number of these issues and difficulties are discussed by MacWhinney (2000, in press).

AN INSTANTIATION OF THE SCEC FRAMEWORK

To improve definitional adequacy, the new constructs of the SCEC Framework have been presented in a specific, falsifiable manner. This specificity permits a precise instantiation of the constructs in relation to the five SLA past time findings presented earlier. The instantiation involves the following constructs:

(1) phases that characterize a subset of acquisition orders across sign net works;
(2) subphases that characterize an additional subset of acquisition orders across sign networks;
(3) a Compositionist Principle of Acquisition Orders that accounts for the placement of sign networks in phases (or subphases);
(4) four stages that characterize the developmental sequence within a specific sign network: Emergence, Pre-threshold, Post-threshold, and Near native-like;
(5) two substages that allow for the two subparts of overgeneralization (increases in overgeneralization and retreat of overgeneralization) within the Pre-threshold, Post-threshold, and Near native-like stages;
(6) a Principle of Task Variation that accounts for certain aspects of varibility in the suppliance of a form in its obligatory contexts;
(7) an important threshold boundary between the second and third stages of development of a sign network, with the actual threshold SOC value varying according to the attentional requirements of a task, among other possible factors;
(8) a post-threshold stage that occurs after a developmental shift and is

characterized by a significant increase in overgeneralizations (especially) the second and fifth types specified in the section above on interrelationships between sign networks);

(9) a post-threshold stage that occurs after a developmental shift and is characterized by its co-occurrence with the appearance of sign networks in the subsequent phase; and

(10) a specification of the domains of overgeneralization at each stage, with several important domains of overgeneralization linked to the Compositionist Principle of Acquisition Orders.

These precise developmental relations are illustrated in Figure 3 with respect to the development of two sign networks, simple past and present perfect.In Figure 3, 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 sign network in phase p to the context for a sign network in phase p+1.

The horizontal dimension in Figure 3 indicates increases in interlanguage complexity. More specifically, the horizontal axis indicates an acquisition order of phases across sign networks, with a subset of possible past time sign networks indicated as phase p, which includes simple past, and phase p+1, which includes present perfect. Due to space limitations, Figure 3 represents only a subset of the English sign networks that express past time. The figure includes only two past time sign networks and does not indicate subphases. In addition, Figure 3 illustrates only a subset of the possible types of overgeneralization.

Stages Within the Developmental Sequence of an Individual Sign Network

Vertically, Figure 3 represents development within each sign network, with each going through four stages and with important substages within three of those stages. Stage 1, Emergence, exhibits the beginnings of the regular, systematic use of the sign network, in contrast to very occasional use. Because of the difficulties involved in distinguishing between systematic and formulaic use, our use of the term *emergence* does not involve specify non-formulaic use (cf. Meisel, Clahsen, & Pienemann, 1981). As indicated in Figure 3, the appearance of present perfect in phase p+1 begins only after the simple past sign network in the previous phase has achieved a threshold.

Stage 2, Pre-threshold, may be a relatively long stage in real time and is characterized by the dominance of an interlanguage pattern that Stanley (1998) described as *underapplication*, the absence of inflectional forms (suffixation, internal change, or suppletion) or non-native-like forms in obligatory contexts.

Figure 3

<table>
<tr><td colspan="3">Phase p</td><td colspan="3">Phase p + 1</td></tr>
<tr><td colspan="3">simple past</td><td colspan="3">present perfect</td></tr>
<tr><td colspan="3">Stage 1 - Emergence</td><td colspan="3" rowspan="2"></td></tr>
<tr><td colspan="3">Stage 2 - Pre-threshold (<70% SOC). Underapplication
(substages not indicated)
Increases in SOC
↓</td></tr>
<tr><td colspan="3">Stage 3 - Post-threshold (>70% SOC)</td><td colspan="3">Stage 1 - Emergence</td></tr>
<tr><td colspan="3"></td><td colspan="3">Stage 2 - Pre-threshold (<70% SOC). Underapplication</td></tr>
<tr><td rowspan="2">Increases in SOC
↓</td><td>Substage 3.1 - Increases in OvG to a SN in the next phase,
↑ OvG (p → p₊₁)</td><td>Substage 3.1 - Increases in OvG from a SN in the next phase,
↑ OvG (p₊₁ → p)</td><td rowspan="2">Increases in SOC
↓</td><td>Substage 2.1 - Increases in OvG from a SN in the previous phase;
↑ OvG (p → p₊₁)</td><td>Substage 2.1 - Increases in OvG to a SN in the previous phase;
↑ OvG (p₊₁ → p)</td></tr>
<tr><td>Substage 3.2 - Retreat of OvG to a SN in the next phase,
↓OvG (p → p₊₁)</td><td>Substage 3.2 - Retreat of OvG from a SN in the next phase,
↓OvG (p₊₁ → p)</td><td>Substage 2.2 - Retreat of OvG from a SN in the previous phase;
↓OvG (p → p₊₁)</td><td>Substage 2.2 - Retreat of OvG to a SN in the previous phase;
↓OvG (p₊₁ → p)</td></tr>
<tr><td colspan="3">Stage 4 - Near native-like (>90% SOC) (substages not indicated)</td><td colspan="3">Stage 3 - Post-threshold (>70% SOC) (substages not indicated)
Increases in SOC
↓</td></tr>
<tr><td colspan="3"></td><td colspan="3">Stage 4 - Near native-like (>90% SOC) (substages not indicated)</td></tr>
</table>

Figure 3. An instantiation of the SCEC Framework, specifying stages, substages, and phases of the second language acquisition of past time sign networks (SN), including increases (↑) and decreases (↓) in overgeneralizations (OvGs) between SNs in adjacent phases. Abbreviations: SOC - suppliance in obligatory contexts; the symbols in parentheses preceding and following an arrow indicate, respectively, the phase of the form that is overgeneralized and the phase of the context to which the form is generalized.

This stage begins at just above 0% SOC and continues, with gradual increases due to associative learning, until a learner reaches the threshold, which has been operationalized at 70% SOC. During this stage, learners presumably develop and expand upon the prototypical meanings of the sign networks (e.g., Andersen & Shirai, 1994; Barlow, 1996; Barrett, 1986; Plunkett et al., 1992). In addition, the sign networks also expand to consistently include allomorphs (e.g., [t], [d], and [d]) and other morphological means of expressing these functions (e.g., internal change and suppletion).

During Stage 2, as associative learning continues, additional interlanguage patterns appear. To characterize these developmental patterns, Stage 2 has been divided into two substages, with Substage 2.1 including increases in overgeneralization and Substage 2.2 including retreat of overgeneralization (because of space limitations and in order to represent the five patterns of past time findings reported above, these substages are specified in Figure 3 only for the present perfect). The domains of overgeneralization have been specified, emphasizing those domains of overgeneralization that are linked to phases *p* and *p*+1 and to the Compositionist Principle of Acquisition Orders. Substage 2.1 includes two concurrent patterns of increases in overgeneralization (or flooding): overgeneralizations of forms from the previous phase (e.g., simple past *-ed* overgeneralized to present perfect contexts; ↑OvG (*p*→*p*+1)), and overgeneralization of the new form to the sign network in the previous phase (e.g., present perfect *have Verb+ed* overgeneralized to simple past contexts; ↑OvG (*p*+1→*p*)). Although these overgeneralization patterns have been ordered concurrently, it may be that the overgeneralization of old forms to new contexts may slightly precede, and then overlap with, the overgeneralization of new forms to old contexts (Klein, 1995).

In Substage 2.2, the later part of Stage 2 when SOC values are relatively higher, the figure indicates that the previous overgeneralizations diminish. This substage includes two concurrent patterns of the retreat of overgeneralization (or trickling): The retreat of overgeneralizations of forms from the previous phase (↓ OvG (*p*→ *p*+1)), and the retreat of overgeneralizations of the new form to the sign network at the previous phase (↓OvG (*p*+1→*p*)).

Stage 3, Post-threshold, is the stage immediately after learners exhibit a developmental shift in their interlanguage production. The threshold level of strength of cognitive representation is manifested in a high level of suppliance in obligatory contexts, with underapplication no longer being a dominant production pattern. This strength of representation is also manifested in two other production patterns: (i) a significant increase in overgeneralizations, and (ii) the appearance of sign network(s) in the subsequent phase, exhibiting the beginnings of regular, systematic use. This stage begins at 70% SOC and continues until a learner reaches a near-native-like level, which is tentatively operationalized at 95% SOC.

Because of the significance of overgeneralizations during this stage, Stage 3 has been divided into two substages, with Substage 3.1 including increases in overgeneralization and with Substage 3.2 including retreat of overgeneralization (these substages are specified in Figure 3 only for the simple past). The domains

of overgeneralization have also been specified, emphasizing those domains of overgeneralization that are linked to phases *p* and *p*+1, and to the Compositionist Principle of Acquisition Orders. Substage 3.1 includes two concurrent patterns of increases in overgeneralization: overgeneralizations of forms to the next phase (e.g., simple past *-ed* overgeneralized to present perfect contexts; ↓OvG (*p*→*p*+1)), and overgeneralizations of a form from the next phase (e.g., present perfect *have V+ed* overgeneralized to simple past contexts; ↑OvG (*p*+1→*p*)). Because these overgeneralizations are exactly the same as those specified above for Stage 2 of the present perfect, the Framework captures the fact that the two sign networks are interrelated or overlapping, sharing this developmental substage.

Stage 4, Near Native-like, exhibits very high SOC (approaching 100%). This maximal value will vary according to a number of factors, including the possibilities (i) that some learners may stabilize or fossilize at a lower level (e.g., Selinker, 1972), and (ii) that a ceiling level of SOC might be somewhat lower, due to factors such as phonotactic constraints on suffix production in speech.[10] During this stage, there will be relatively few overgeneralizations, resulting in Target-like Use values very close to 100%. Other than the overgeneralization and retreat of overgeneralization of these forms to sign networks that appear and develop later or overgeneralizations from these later sign networks (↑OvG (*p*→*p*+2); ↑OvG (*p*+2→*p*); ↓OvG (*p*→*p*+2); ↓OvG (*p*+2→*p*)), in this stage learners have generally stabilized in their use of this sign network.

EVALUATION OF THE SCEC FRAMEWORK

The SCEC Framework can be evaluated in relation to the criteria outlined in the introduction: source of theoretical constructs, definitional adequacy, empirical support, and scope. While considering data that are beyond the previous scope of the Competition Model, the SCEC Framework has maintained theoretical coherence by retaining the four original theoretical commitments. The SCEC Framework has utilized clear and specific constructs and principles in order to provide an analysis of empirical findings regarding the development of past time expression. The SCEC Framework has achieved an important goal in theory development (Fantuzzi, 1993, p. 302; Seidenberg, 1993, p. 233) because it is able to integrate and account for a diverse set of previously unrelated empirical findings. The SCEC Framework involves the unification of aspects of three dominant issues in SLA research: (i) developmental sequences, including types of overgeneralization; (ii) acquisition orders; and (iii) task variation.

Further empirical support, in the form of replications, is necessary for these past time constructs. In addition, in order to more precisely describe developmental patterns, large sample sizes and relatively long longitudinal studies are required. To insure the reliability and comparability of these data, it will be valuable to develop data elicitation procedures that vary task conditions and yet consistently elicit reasonable numbers of contexts of the specific sign networks being studied. The

techniques of corpus linguistics (e.g., Barlow, 1996; Biber, 1988; Biber et al., 1998) and time-series analysis (e.g., Mellow, Reeder & Forester, 1996; Morgan, Bonamn & Travis, 1995) would be especially useful for analyzing these data sets.

The SCEC Framework would increase its definitional adequacy if its constructs were fully falsifiable. However, to a certain extent, a number of the axiomatic assumptions and interactions of the SCEC Framework may be difficult to test and falsify. For example, it would be difficult to falsify the assumptions that sign networks are optimal units of analysis and that the actual value of a threshold SOC is due to many possible task properties, including but not limited to the availability of attentional capacities. In addition, falsification of any single construct in the SCEC Framework may be difficult because unexpected empirical results may not be attributable to the unique contribution of just one construct, but rather may be related to the entire framework of assumptions. These limitations hold equally for aspects of many complex theories, including theories such as the Competition Model and Universal Grammar. Because of problems such as these, both Long (1993) and Schumann (1993) have critically discussed the limitations of falsifiability as a requirement on theories.

In spite of these limitations, many aspects of the SCEC Framework have been expressed using precise constructs that can be tested and, potentially, falsified. For example, empirical studies could reveal that present perfect is used consistently almost as early as simple past (see Klein, 1995, as discussed in endnote 3), raising a question about the value of the constructs of phase and threshold for these sign networks. In addition, studies could reveal that the threshold level for the initial appearance of the more complex sign networks is highly variable from learner to learner, perhaps occurring only around 25% SOC rather than around 70% SOC. This result would raise a question about the value of the construct of threshold and of the distinction between phases and subphases. As a final example, it might be found that overgeneralizations of simple past to unrelated sign networks (such as infinitives) increase significantly at a time that is different than the initial appearance of the more complex, related sign networks, raising a question about the value and coherence of a developmental shift due to network expansion.

The SCEC Framework also currently has a number of limitations with respect to the scope of its theoretical components, the scope of the linguistic elements that are considered, and the scope of the empirical support. With respect to the scope of the current theoretical components, the Framework, especially the Compositionist Principle of Acquisition Orders, does not explain why some orderings of sign networks are inter-phasal and others are intra-phasal. This reflects the general difficulty that compositionist explanations have had in accounting for acquisition orders (e.g., Fantuzzi, 1992, p. 335; O'Grady, 1987, pp. 198-199; Radford, 1990, pp. 263-268). In addition, it is very difficult to determine, predict, or explain the impact of each potentially contributing factor (i.e., the relative contribution of frequency in input and of specific properties with respect to low perceptual salience, complex structural properties, low functional load, and complex functional load).

In addition, the SCEC Framework does not currently specify the interaction between first language influence and acquisition orders. At present, the Framework draws from many first language acquisition studies and could as easily be applied to the interpretation of L1 acquisition studies. However, a number of researchers have argued that connectionist models and the Competition Model can provide effective accounts of language transfer (Gasser, 1990, p. 189; MacWhinney, 1997; Shirai, 1992; Sokolik & Smith, 1992). In addition, researchers such as Zobl (1982), Rutherford (1989), Andersen (1990), Gass (1996), and Kroll and de Groot (1997) have provided important analyses that could be utilized in modeling the interaction of transfer, acquisition orders, and developmental sequences.

With respect to the scope of the linguistic elements that are considered, one limitation is that the sign networks proposed within the Framework are over-simplified because they do not include the full range of forms, functions, and linguistic features that are involved in these past time sign networks. In addition, the Framework does not currently consider other past time sign networks that may be involved in these developmental patterns. Furthermore, the number of English language elements that enter into a cumulative ordering relationship may not be extensive, potentially limiting the scope of these analyses (O'Grady, 1997, p. 350). With respect to morphological components of sign networks, it may be that agglutinating and polysynthetic languages exhibit relatively more examples of morphemes that enter into a cumulative ordering relationship. For additional sign networks that are inter-related, empirical evidence will be required to determine whether networks that are more cumulatively complex appear after less complex networks achieve a threshold level of cognitive representation.

The type of data used to support the Framework could also be expanded. The data upon which the SCEC Framework is based are primarily written monologues. Consequently, the empirical scope of the Framework could be increased by analyzing spoken data, interactional data, and data produced when learners are attending more to meaning than form. A final concern regarding scope is that the Framework has not yet been specified as a connectionist model and tested in a connectionist simulation. The Framework needs to be converted into the components of a simulation, specifying inputs, outputs, network architecture, and learning rules. If the performance of the network were to match the past time findings (or certain subsets of the complex patterns), that result would provide important support for the SCEC Framework. These simulations may be especially useful for investigating the impact of each potentially contributing factor.

CONCLUSION

This paper has proposed a detailed framework that incorporates a connectionist, incrementalist view of learning into SLA research. To achieve this, the SCEC Framework incorporates parallel empirical findings from acquisition studies and from connectionist simulations of language development. The SCEC Framework

includes a number of theoretical principles and constructs, building from the Competition Model and from accounts of longitudinal acquisition. The SCEC Framework has the following important characteristics. First, the SCEC Framework accounts for these past time findings by integrating three important patterns that have been found in connectionist simulations of language development: (i) as a result of processing a large number of exemplars of the target elements, associative learning continually adjusts the network so that native-like behaviors are gradually achieved; (ii) associative learning can result in networks that produce overgeneralizations, with many of those patterns of overgeneralization occurring relatively late in development; and (iii) although changes are usually gradual, associative learning can result in shifts or spurts of development that also typically occur relatively late in development (e.g., Elman et al., 1998; Plunkett et al., 1992).

Second, associative learning provides an account of a number of attested developmental patterns. A strengthening of network connections as a result of associative learning accounts for gradual increases in the suppliance of forms in obligatory contexts (Stage 2). A subsequent expansion of network connections, also due to associative learning, accounts for a developmental shift in the production of the sign network (Substage 3.1). The developmental shift is characterized by the co-occurrence of increases in overgeneralizations, the appearance of sign networks in a subsequent phase, and high SOC scores. The first two co-occurring phenomena are attributed to the expansion of network connections to new forms and functions, resulting in "overlapping" sign networks. As indicated by the high SOC scores, the expansion appears to occur only after the sign network has achieved a threshold strength of connectivity. Subsequent modifications of connections between the overlapping sign networks, as a result of the continued processing of native-like input and output, account for decreases in overgeneralizations (Substage 3.2). In these ways, overgeneralization and its retreat, as well as increases in SOC, can be interpreted as manifestations of incremental changes in the connections between forms and functions.

Third, the account of acquisition orders utilizes relatively concrete linguistic properties, organized into hierarchical sign structures, in conjunction with connectionist, environmentalist, and compositionist explanations. Building from Brown (1973), the orders are partially attributed to cumulative increases in the capacity to process the formal and functional properties of language elements. By specifying this Compositionist Principle of Acquisition Orders, we have also been able to precisely conceptualize the nature of overgeneralization and its retreat, specifying the domains of overgeneralization in relation to an acquisition order of phases. Fourth, the Principle of Task Variation has indicated how a connectionist approach to understanding linguistic variation may contribute to a theory of acquisition orders, especially by aiding in the operationalization of a threshold level for developmental shifts. Fifth, these assumptions and constructs have allowed a greater specification of the construct that Mellow, Reeder & Forester (1996) have described as the developmental course of SLA. Central to this account of longitudinal development

are stages, substages, phases, and subphases of the development of specific sign networks. Overall, we believe that the SCEC Framework provides a promising direction for understanding many aspects of interlanguage development.

NOTES

1. Although most proponents of connectionism argue that one of its strengths is that the networks are neurally plausible or neurally inspired (e.g., Broeder & Plunkett, 1994; N. Ellis, 1998, 1999; Rumelhart & McClelland, 1986b, pp. 136-138), Fantuzzi (1992) and Segalowitz and Lightbown (1999) have questioned this claim.
2. 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, p. 244): *John entered college in 1980. He had graduated from high school five years earlier.*
3. Klein (1995, pp. 43, 48) appears to report results that oppose this trend: Present perfect forms appeared early in relation to the development of simple past. However, the use of present perfect is described as being "much less frequent." Without descriptive or inferential statistical reports of the verb form suppliance of the two learners that Klein describes, it is difficult to interpret the meaningfulness of the perfect forms that were supplied.
4. Bardovi-Harlig (1997, p. 380) indicated that "the present perfect progressive combines the meaning of the present perfect with the notion of a continuous event or process" and provided the following example: *She has been practicing law for 5 years*.
5. Bardovi-Harlig (1997) also noted a similar, but weaker, relationship between present perfect and simple present.
6. Although different formulae are possible, a basic formula for SOC is the number of native-like suppliances of an element in obligatory contexts divided by the total number of obligatory contexts. In contrast, a Target-like Use analysis includes overgeneralization of a form and therefore a basic formula for Target-like Use is the number of native-like suppliances of an element in obligatory contexts divided by the total of the number of obligatory contexts added to the number of overgeneralizations of the form to incorrect contexts.
7. For unrelated items, a general prediction of the Competition Model is that the first forms that appear in production should be those that express the widest range of highly frequent functions.
8. Barrett (1986) also found that these two periods were preceded by a period of underextension.
9. Stage 1, Emergence, is considered to be too brief to be comprised of substages.
10. For example, in the sentence, Hillerman unearthed an ancient pot, the CCC# cluster at the end of the verb is very difficult to pronounce. This may result in the absence of the suffix, especially in speech, but also in writing due to pronunciation spellings.

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