

## AN INTELLIGENT CALI SYSTEM FOR GRAMMATICAL ERROR DIAGNOSIS

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**Introduction:** This paper describes an approach to computer-assisted language instruction (CALI) based on the application of artificial intelligence (AI) technology to grammatical error diagnosis. We have developed a prototype CALI system, *Scripsi*, capable of recognising a wide range of errors in the writing of language learners (1). *Scripsi* not only detects ungrammaticality (2), but hypothesises its cause and provides corrective information to the student. These diagnostic capabilities rely on the application of a model of the learner's linguistic knowledge.

*Scripsi* operates interactively, accepting the text of the student's composition and responding with diagnostic information about its grammatical structure. In contrast to the narrowly defined limits of interaction available with automated grammatical drills, the framework of interactive composition provides students with the opportunity to express themselves in the language being learned.

Although *Scripsi's* diagnostic functions are limited to purely structural aspects of written language, the way is left open for the incorporation of semantic processing. The design of *Scripsi* is intended to lay the groundwork for the creation of intelligent tutoring systems for second language instruction. The development of such expertise will remedy many of the deficiencies of existing technology by providing a basis for genuinely *communicative* instructional tools — computerised tutors capable of interacting linguistically with the student.

The research is based on the assumption that the language produced by the language learner, 'learner language', differs in systematic ways from that of the native speaker (Corder, 1967). In particular, the learner's errors can be attributed primarily to two causes: the operation of universal principles of language acquisition and the influence of the learner's native language (see below). A central concern in the design of *Scripsi* has been the incorporation of a psychologically sound model of the linguistic competence of the second language learner.

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- (1) Throughout this document, we use the term 'language learner' to denote one who undertakes to acquire a second language *after* having achieved proficiency in his or her native language. We will apply the terms 'language learner' and 'second language learner' interchangeably with this definition in mind. Of course, it is not possible to determine exactly *when* a learner can be said to have 'achieved proficiency in his or her native language'. However, this rough definition is sufficient for our purposes.
- (2) Newmeyer (1983) notes that the term 'ungrammaticality', as used here, is more properly expressed as 'unacceptability'. We prefer the less precise (but more intuitive) terminology.

The development of intelligent CALI (ICALI) draws on expertise from AI, linguistics, and language pedagogy. AI offers techniques both for the implementation of intelligent systems and for the computational processing of linguistic data. Theoretical linguistics, in turn, provides the grammatical formalisms that underlie computational representations of linguistic knowledge. Research into second language acquisition yields explanations for the grammatical errors of second language learners, while the methodologies advanced by language educators form the pedagogical basis for computer-based language instruction.

In order to justify research into the development of intelligent tools for grammatical diagnosis, a number of questions must be answered. Is the development of CALI worthwhile at all? Is the focus on grammatical error diagnosis appropriate? Finally, does the design of *Scripsi* represent a significant improvement over related systems?

**The Case for Intelligent CALI:** The potential for CALI to enhance second language learning might seem too obvious to question. Arguments offered in favour of the development of CALI abound. Barchan (1986) suggests several possible benefits.

1. The computer can save the human tutor's time by correcting 'simple' errors . . . .
2. The computer is always available and has unlimited time and patience.
3. The computer is currently able to attract a great deal of student interest which hopefully helps to increase motivation (p. 93).

Yet CALI's potential will remain untapped if the design of CALI courseware does not reflect sound pedagogical principles. Farrington (1986a), for example, has criticised systems that merely automate tedious grammatical drill. His opinions are shared by other researchers:

Much of the current CALL software is trivial and apparently untouched by the advances in communicative methodology of the seventies. Its origins can be traced to programmed learning and the behaviourist psychology which gave rise to it (Phillips, 1985, p. 3).

If current programs exemplified all that CALI were capable of, there would seem to be little point in continuing with it (Nelson, *et al.* 1976, p. 30).

What is needed, according to many language teachers, is a *communicative, interactive* approach to instructional systems:

Current CALI programs do not take full advantage of the computer's capacity to interact; much richer interactions are possible. Programs can be designed in which student errors bring forth specific responses designed to help the student understand what his mistake was and what he has to do to correct it . . . . With such programs, CALI can become a dialogue between the computer and the student (Nelson, *et al.* 1976, p. 31).

A CALL exercise should oblige, and stimulate, the learner to interact with the system in the language being learnt (Farrington, 1986a, p. 87).

The creation of communicative language instruction systems will involve the development of 'intelligent' software, computational systems that 'understand' language. Weischedel *et al.*, (1976) have taken tentative steps along these lines. Noting successes in the application of AI to other areas of CAI, they remark on the possibilities for ICALI:

A natural next step is an intelligent tutor for foreign language instruction. The potential is great, for such computer-assisted instruction would permit students to express themselves in the foreign language. Furthermore, the tutor, by its attempts to understand the student's expressions, could point out mistakes and hypothesise their cause (p. 226).

As CALI software becomes more intelligent and complex, the need for a theoretically sound approach becomes correspondingly more important. An examination of the theoretical underpinnings of ICALI is a central concern of our work: a computational characterisation of the language learner's errors, based on the results of research in linguistics and second language acquisition, underlies *Scripsi's* diagnostic capabilities.

It is clear, then, that while CALI holds out great promise for the enhancement of second language teaching, its successful implementation is dependent on a theoretically motivated approach to the development of intelligent software.

**Grammatical Diagnosis in CALI:** The foregoing discussion presented criticisms of the emphasis on grammatical drills characteristic of the bulk of CALI systems. It may seem inconsistent to suggest, as we do here, that the reorientation of CALI toward communicative interaction can be achieved through the application of AI to grammatical diagnosis. If the intent is to 'shift the focus of attention from the grammatical to the communicative properties of language' (Allen & Widdowson, 1979, p. 122), why not address semantic and pragmatic issues rather than (or in addition to) syntactic ones?

The answer is that the development of systems with genuinely communicative capabilities is contingent on the satisfactory treatment of syntactic phenomena. A characterisation of the grammatical (i.e. syntactic) properties of language is a necessary prerequisite for the construction of a complete model of the human language faculty (Chomsky, 1965).

Furthermore, language instructors have not entirely abandoned the teaching of grammar. Although it is widely recognised that communicative skills are paramount, many teachers see a need for the development of grammatical skills:

There is now general agreement that learning grammatical paradigms will not guarantee a facility in communicative skills. However, the place of grammar in the language-teaching curriculum is still disputed between the not necessarily exclusive camps of 'accuracy' and 'communicative competence' (Ahmad *et al.*, 1985, p. 102).

A CALI system for grammatical diagnosis is ideally suited for the 'accuracy' -oriented classroom.

Our approach to grammatical modelling is based on the premise that learner language, while often ungrammatical, does not deviate from 'correct' structure merely in random ways. Rather, the errors characteristic of learner language reflect identifiable learning strategies (Corder, 1967; Selinker, 1972). One goal of research in second language acquisition is to characterise these strategies, to produce a model of the linguistic competence of language learners that accounts for their errors.

One of the strategies identified, the transfer of knowledge of the native language to the target language (language transfer), is most apparent in the pronunciation of language learners. Stereotypical foreign language accents provide clear evidence of the systematic nature of the influence of the learner's native language on the language being learned (Weinreich, 1953). Similar influence takes place at the syntactic level. It is precisely because this influence and other manifestations of language learning strategies follow systematic patterns that the understanding of learner language is possible at all. Thus, only if the learner's competence can be modelled computationally is there hope of developing CALI systems capable of dealing intelligently with learner language.

If computers are ever to understand the language learner, we must build systems that can cope with learner language. In order to converse with the student, then, the computer must be able to determine the *intended* form of the learner's linguistic output, a capability we believe can only be achieved by modelling the learner's linguistic competence. Thus, while a CALI system for grammatical diagnosis is not directly compatible with communicative methodology, the intelligent grammatical core on which such a system depends will ultimately provide the foundation for communicative CALI systems as well. It is this rationale that underlies our claim that the development of technology for intelligent grammatical diagnosis will serve as a basis for communicative CALI systems.

**The Inadequacy of Current CALI Systems:** Recent developments in CALI technology give cause for hope that the goal of communicative language instruction software may not be too far off. Weischedel's *et al.* (1976) German tutor supports a dialogue between machine and student that allows for diagnosis of both grammatical and comprehension errors. Schuster's (1986) VP<sup>2</sup> system incorporates a rudimentary model of the student's native grammar that provides a basis for the diagnosis of syntactic errors arising from linguistic interference. Barchan *et al.* (1985) have constructed a parser for French capable of detecting many of the grammatical errors typical of anglophone learners.

Nevertheless, these and other CALI systems are inadequate on a number of grounds. A detailed exposition of the flaws of current technology is given in a later section. It is sufficient to note here that a deficiency common to all existing systems is the incompleteness or non-existence of a credible model of the linguistic competence of language learners, one that takes into account the strategies that give rise to ungrammaticality in learner language.

The inadequacy of traditional approaches to CALI is clear, as is its remedy: the development of communicative software. The creation of intelligent language instruction software in turn depends on the incorporation of psychologically sound theoretical principles — we must follow the advice of Leech & Candlin (1986) in developing 'software which matches what we already know about second language acquisition' (p. xiv).

**Towards Intelligent CALI:** Communicative software for language instruction must exhibit 'intelligent' properties. Indeed, fully developed ICALI systems will embody expertise from two distinct fields of AI: intelligent tutoring systems (ITS) and natural language processing (NLP).

A central concern of ITS technology is the diagnosis of students' errors and misconceptions (Sleeman & Brown, 1982; Wenger, 1987). A basic component of computational systems for educational diagnosis is the 'student model', which represents the current state of the student's knowledge, incorporating 'all the aspects of the student's behaviour and knowledge that have repercussions for his performance and learning' (Wenger, 1987 p. 16).

In CALI, a representation of the student's knowledge takes the form of a grammatical model (Schuster, 1986). A reasonable model of the language learner will include native and second language grammars as well as rules specifying the learner's error-inducing acquisition strategies.

Although the construction of student models for educational diagnosis is in general difficult, the nature of linguistic knowledge lends itself more readily to the task. Linguistic theory has developed explicit formal characterisations of grammatical knowledge that are easily represented and interpreted computationally.

Of course, there is more to a student's knowledge of language than a grasp of syntactic structure. All of the factors relevant to the student's 'communicative competence' (Hymes, 1971) must be brought to bear in the construction of a complete model of his linguistic abilities. Nevertheless, the scope of the present research is limited to syntactic and morphological aspects of linguistic knowledge. The design of *Scripsi*, however, does not preclude the possibility of future extensions which will incorporate semantic processing and other refinements.

**Transfer and Overgeneralisation in Second Language Learning:** Modern linguistic theory concerns itself primarily with the issue of first language (L1) acquisition, aiming to provide an explanation for the astonishing rapidity and uniformity of language learning in children—indeed, for the extraordinary fact that the acquisition of language is possible at all (Chomsky, 1965). The most cogent accounts of language learning rest on the assumption that language acquisition is facilitated by innate knowledge of language structure. A formal characterisation of this biological endowment, 'universal grammar' (Chomsky, 1981), remains a key goal of theoretical linguistics.

But language learning is not restricted to children. Adults often acquire a second language (L2), even to the point of gaining native-speaker proficiency. Most often, however, languages learned in adulthood are learned *imperfectly*. The seeming asymmetry between L1 and L2 acqui-

sition has given rise to a branch of linguistics concerned with explaining this difference—the study of Second Language Acquisition (SLA).

Learner language typically shows evidence of ‘interference’ from the mother tongue. As noted above, the most striking aspect of this interference manifests itself phonologically as a ‘foreign accent’. Influence of the L1 on the L2 appears to operate on the syntactic level as well. It might seem that L2 acquisition is achieved simply by ‘transferring’ rules of the L1 to the L2.

Yet if the arguments of theoretical linguistics are carried to an extreme, it might be suggested that language acquisition, guided as it is by innate knowledge, should not vary dramatically between adults and children (3). On this view, the language learner’s errors arise not through interference from the L1, but through the operation of the learner’s own innate language acquisition mechanism. In its strongest form, this ‘nativist’ account denies that language transfer plays a significant role in SLA.

Linguists studying L1 and L2 acquisition have identified *rule overgeneralisation* as a key source of errors in learner language. Rule overgeneralisation occurs when the learner, in analysing linguistic input, hypothesises a grammatical rule which, while accounting for the data at hand, nevertheless fails to predict correct structure in all cases. (For example, a learner who deduces that the English past tense is formed by suffixing *-ed* to the main verb will incorrectly produce the forms *writed*, *speaked*, and so on.) As the learner encounters more grammatical structures, he or she refines the earlier rule hypothesis, and by a process of successive approximation gradually constructs a grammatical system that conforms to the target language (Dulay & Burt, 1977).

Over the past several decades, scholars have debated the relative merits of nativist and transfer-based theories of SLA. Cognitive psychologists in the behaviourist tradition were the first to undertake serious efforts at developing a theory of SLA. They posited language transfer as the chief source of errors in learner language, a view adopted by Lado (1957) in his theory of *contrastive analysis*. As behaviourism gave way to Chomskyan linguistics (Chomsky, 1957, 1965), and the empirical inadequacies of contrastive analysis became apparent (Dusková, 1967), investigators appealed increasingly to nativist arguments in explaining learners’ errors. The school of *error analysis* (Corder, 1967; Selinker, 1972) accorded equal theoretical weight to transfer and overgeneralisation. According to error analysis, the internalised grammatical knowledge of the language learner, or ‘interlanguage’, is a linguistic system in its own right. An analysis of errors, it was believed, could reveal the structure of the learner’s interlanguage, and thus give insights into the nature of SLA. Before long, though, error analysis was challenged by a new conception of SLA. Some researchers, encouraged by the successes of nativist approaches to SLA, advanced the view that language transfer does not figure significantly in SLA at all (Dulay & Burt, 1977). Their theory of *creative construction* rested on the reinterpretation

- (3) Such an argument would assume, contrary to substantial evidence, that (a) the innate language acquisition mechanism maintains its effectiveness over time, and (b) the adult learner’s more advanced cognitive development does not affect the acquisition process.

of data that had previously been adduced in favour of contrastive analysis. Many errors that had been considered instances of transfer were shown to be compatible with creative construction theory. But their conclusions were widely regarded as overstated, and creative construction attracted few serious adherents. Prevailing accounts of SLA (e.g. Flynn, 1987) acknowledge their debt to early SLA researchers in recognising both transfer and overgeneralisation as key factors in explaining learners' errors.

Despite widespread agreement that transfer and overgeneralisation are the central causes of ungrammaticality in learner language, there is no consensus on the nature of the mechanisms that underlie their operation. How is linguistic knowledge represented and manipulated in the human mind? What distinguishes knowledge of the L2 from that of the L1? These questions, indeed, are fundamental to linguistic theory. Although a detailed examination of these issues lies outside the scope of the present work, the project of constructing a computational model of the learner's linguistic competence (the cornerstone of *Scripsi's* design) nevertheless rests on explicit assumptions about the properties of linguistic knowledge.

Virtually all theories of language assume, explicitly or implicitly, that linguistic behaviour is *rule-governed*; that is, that we produce and understand language by applying internalised grammatical rules. This assumption accords well with our intuitions, of course, and there is a long pedagogical tradition in which language instruction is equated with the rote learning of grammatical rules. *Scripsi's* computational model is firmly rooted in the rule-oriented tradition of linguistic theory and exploits a grammatical formalism based on Chomsky's (1965) transformational grammar. It is not our purpose here to elaborate the formal basis of *Scripsi's* design, nor to provide a rigorous classification of learners' errors within this framework: we refer the interested reader to Catt (1988) and Catt & Hirst (1990a, 1990b) for such discussions. In the sections that follow we present examples of transfer and overgeneralisation informally. The data (4) is intended to illustrate the complex and varied manifestations of ungrammaticality in learner language, and to point up the broad range of errors that any reasonable model of interlanguage must account for in providing a basis for intelligent grammatical diagnosis.

**Examples of Language Transfer:** Language transfer occurs when the learner applies grammatical rules of the L1 in producing the L2.

The following examples illustrate the transfer of word order rules:

I like very much your dress. (I)  
(Cf. *J'aime beaucoup ta robe.*)

- (4) The data presented in the following sections is taken from a number of sources, identified alphabetically as follows:

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|---------------------------|---------------------|------------------|
| (a) Adjémian, 1984        | (d) Richards, 1971a | (g) Swan, 1987   |
| (b) Burt & Kiparsky, 1972 | (e) Richards, 1971b | (h) Taylor, 1975 |
| (c) Dusková, 1967         | (f) Schuster, 1986  | (i) Walter, 1987 |

He became finally President. (G)  
 (Cf. *Er wurde endlich Präsident.*)  
 I saw go out a short man. (I)  
 (Cf. *J'ai vu sortir un petit homme.*)  
 This car have I very cheap bought. (G)  
 (Cf. *Dieses Auto habe ich sehr billig gekauft.*)

Very often, words, idioms, or expressions are translated directly:

They want to fight themselves against this. (A)  
 (Eng. *fight* = Fr. *se battre contre*)  
 I dreamed with the angels. (F)  
 (Eng. *dream of* = Sp. *soñar con*)  
 I have hunger. (I)  
 (Eng. *hungry* = Fr. *avoir faim*)  
 James ... gave it his actual form. (D)  
 (Eng. *his/her/its present form* = Fr. *sa forme actuelle*)

**Examples of Overgeneralisation:** Errors of rule overgeneralisation reflect the learner's error-prone rule hypothesis strategies. Overgeneralisation often involves oversimplification or overapplication of grammatical rules.

For example, errors in verbal inflections are common. The high degree of irregularity in common English verbs leads to frequent overgeneralisation:

I writed .... (C)  
 I spoked .... (C)

Learners of English often have difficulty with the rule of subject-verb agreement:

He come from India. (D)  
 This solution correspond .... (C)  
 Doesn't the girls walk every day? (H)  
 Don't she speak with her teacher? (H)

The rules for question formation in English are subtle and difficult for the learner to acquire. The learner must know when subject-verb inversion is required, and when the 'do' auxiliary is called for. Also, subject-verb inversion occurs in direct questions, but not in indirect questions. Learners typically have difficulty with these constructions.

I wonder which department does she work for. (I)  
 I don't know how many are there in the box. (E)  
 When began the game? (B)  
 What was called the film? (E)

Verbs requiring infinitive or gerund complements are problematic for learners. Some verbs, such as *like*, allow both types of complement. Others allow only one or the other, resulting in overgeneralised structures.



Nobody wants doing that. (B)  
 (Cf. *Nobody wants to do that.*)  
 I will enjoy to swim. (B)  
 (Cf. *I will enjoy swimming.*)

**Related Research:** We now present a critical review of current approaches to grammatical diagnosis in CALI, evaluating a number of intelligent language instruction systems. In our examination of current approaches to intelligent grammatical diagnosis, we will equate 'intelligent grammatical diagnosis' with 'rule-based parsing of language for the purpose of determining the presence and nature of structural ill-formedness'.

The restriction to rule-based parsing systems eliminates the bulk of current CALI technology from consideration. Most CALI systems do not parse input at all, merely comparing students' answers with a stored list of anticipated responses (Pusack, 1983). Although some rather sophisticated software has been developed within this framework of input matching, such systems invariably require the user (instructor or course designer) to specify the set of correct (anticipated) responses (5). Farrington's (1986b) LITTRE system is an especially impressive such 'authoring system'. LITTRE is capable of processing students' translations, allowing considerable variation in diction and word order. Nevertheless, the instructor must supply the program with parsed responses, making LITTRE's 'intelligence' external.

Menzel's (1988) system is more sophisticated. His program does not rely on matching input against a stored list of expected responses, and its diagnostic procedure is rule-based and 'intelligent'. However, the system does not parse its input; rather, it accepts only isolated words and phrases of fixed structure. Although Menzel suggests that his system could be integrated 'as a specialised subroutine into an error sensitive parser' (p. 419), the program in its present form is not a 'rule-based parser'.

The limitation to CALI technology also disqualifies many systems from consideration. Systems that have been developed for parsing ill-formed input in natural language interfaces to computer systems (e.g. Carbonell & Hayes, 1983; Kwasny & Sondheimer, 1981) are therefore not evaluated. While the techniques used in such systems may eventually serve as valuable tools for grammatical diagnosis, the systems lack the means to model the learner and hence are not viable as bases for intelligent CALI.

Software tools for computer-assisted composition have become increasingly popular in recent years. Although most of these are not strictly CALI systems, Wallraff (1988) reports that some universities have adapted commercial packages such as *Writer's Workbench* for just this purpose. There exists a great variety of computer-assisted composition software, including simple spelling checkers (Durham *et al.*, 1983), unintelligent diction and grammar analysers (Raskin, 1986), a rudimentary syntactic pattern-

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- (5) But it is impossible to anticipate and specify all of the student's potentially erroneous inputs, even where the range of student responses is highly constrained. Thus, if a system is to deal with free-form input, it must have some kind of error-sensitive parsing capability.

matcher (Hull *et al.*, 1987), and a fully developed parser, CRITIQUE, designed for diagnosing errors of spelling, diction, grammar, and style (Jensen *et al.*, 1983). Of these, only CRITIQUE contains a 'rule-based parser'. Although CRITIQUE's primary application is in business and office environments, Richardson & Braden-Harder (1988) have suggested that it might profitably be applied to language instruction. For this reason, CRITIQUE warrants investigation as a potential CALI system.

Besides CRITIQUE, we will review four intelligent parsing systems designed specifically for CALI applications: Weischedel's *et al.* (1976) automated German tutor, Schuster's (1986) VP<sup>2</sup> system, the French Grammar Analyser of Barchan *et al.* (1986), and Schwind's (1988a, 1988b) intelligent language tutoring system.

In judging these systems, we will pose a number of questions in assessing both their performance and their design. What range of errors does the system diagnose? Does the system recognise the errors of transfer and overgeneralisation identified above? Does it incorporate a credible model of the learner's linguistic competence? In particular, does the system's representation of linguistic knowledge reflect a psychologically realistic design, or are its rules *ad hoc*?

**An Automated German Tutor:** The automated German tutor (AGT) of Weischedel *et al.* (WVJ) (1976) is an interactive system aimed at diagnosing both grammatical and comprehension errors. The system's parser is an augmented transition network (6) (ATN) (Woods, 1970). WVJ describe the operation of their system as follows.

This tool is designed to assist students in developing reading comprehension skills and their ability to compose well-formed answers to questions about reading passages. A short text is presented to a student in advance, followed by a set of questions about the content of the text. As the student practises the language by typing sentences as answers, the intelligent tutor searches for possible problems in the student's response, including errors in syntax, semantics, comprehension, and spelling. If possible, the tutor hypothesises the cause of the student's errors to pinpoint his or her problem (p. 226).

The AGT handles a very limited dialogue, having been implemented with only one sample text.

As the quotation indicates, the AGT recognises errors of meaning and comprehension as well as grammatical errors; however, we will restrict our attention to its syntactic capabilities.

The AGT diagnoses errors of two broad (and ill-defined) categories: those recognised through violations of 'predicates on ATN arcs' (see below) and those 'anticipated' as arising from negative transfer from the student's L1 (assumed to be English).

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- (6) Readers unfamiliar with computational approaches to grammatical analysis will find King (1983) an excellent overview of parsing techniques. Her survey covers augmented transition networks, phrase-structure grammars, and other formalisms.

An example of an error of the first sort is the following sentence, containing what might be considered a violation of gender agreement (the masculine noun *Student* occurs where the feminine *Studentin* is appropriate).

Fräulein Moreau ist Student.

(Cf. *Fräulein Moreau ist Studentin* = Miss Moreau is a (female) student.)

WVJ suggest that such errors can be viewed as violations of co-occurrence constraints on constituents of a phrase. These are detected through the use of 'predicates on ATN arcs'.

A way of designing parsers is to search for groups of constituents as if they were combined by context-free rules, but to add predicates on the constituents which must hold if the group of constituents is to combine to form another constituent (p. 231).

WVJ recognise that language transfer is responsible for many learner errors.

When composing sentences, English-speaking students make many errors in German word-order due to interference from their first language (p. 230).

However, they do not propose a systematic framework within which to diagnose errors of transfer. Rather, they suggest that such errors as arise from interference must be anticipated by the designer of the parser and recognised through *ad hoc* ATN rules.

Where particular incorrect syntactic forms can be anticipated, we may add these incorrect forms to the grammar (p. 231).

The following sentence, for example, which the AGT recognises as ill-formed, illustrates the student's tendency to use English-like syntax.

Sie hat es gelernt in der Schule.

(Cf. *Sie hat es in der Schule gelernt* = She learned it in school.)

The AGT has been designed to anticipate this kind of error.

The types of ungrammaticality detected by the AGT are few when compared against the range of errors described above. WVJ have evidently provided no mechanism for recognising instances of over-generalisation other than those involving violations of grammatical agreement, and treat errors of transfer in an *ad hoc* fashion.

The design of the AGT is less than ideal. Since all syntactic information is encoded in the ATN, L1 and L2 knowledge are not separately represented, making a systematic account of transfer errors all but impossible. The result is an *ad hoc* approach to the diagnosis of errors, with no indication as to how errors are to be 'anticipated'.

**CRITIQUE:** CRITIQUE is a text-critiquing system that provides error diagnosis for diction, spelling, grammar, and style (Heidorn *et al.*, 1982; Jensen *et al.*, 1983; Richardson & Braden-Harder, 1988). CRITIQUE was originally intended for use in an office environment:

The long-term objectives of the EPISTLE (7) project are to provide office workers, particularly middle-level managers, with a variety of application packages to help them interact with natural language text (Heidorn *et al.*, 1982, p. 305).

Recently, however, Richardson & Braden-Harder (1988) have proposed that CRITIQUE could be used as a CALI tool in teaching English as a second language. We will now consider CRITIQUE's potential for this application, restricting our attention to its syntactic capabilities.

CRITIQUE is an immense system comprising a 100,000 word dictionary and hundreds of syntactic rules in the form of feature-augmented phrase-structure rules (Chomsky, 1965). CRITIQUE recognises a wide range of the grammatical errors that are common in the writing of native speakers of English. However, many of the errors described above as being characteristic of second language learners are not diagnosed. Errors of transfer, of course, are not detected, but neither are many errors of overgeneralisation. CRITIQUE's error detection is geared toward the complex syntactic forms of English that give native speakers trouble: verbal agreement with complex subjects, parallel structures, co-ordination, and the like.

CRITIQUE's error detection mechanisms parallel those of the AGT. Commonly occurring (anticipated) errors are encoded directly as phrase-structure rules. Another class of errors, including violations of grammatical agreement rules, is recognised through 'constraint relaxation', whereby co-occurrence restrictions on constituents of a phrase are relaxed so as to permit the recognition of ill-formed structures. This latter technique corresponds closely to WVJ's use of predicates on ATN arcs.

CRITIQUE does not treat errors of transfer, owing to its original intent as a tool for native speakers. However, if such errors were to be diagnosed in CRITIQUE, it is clear that the errors would have to be specified in advance and rules incorporated to recognise them, as in the AGT.

CRITIQUE shares with the AGT a fundamental design limitation, in that all linguistic knowledge is encoded in a single rule format (in CRITIQUE's case, as phrase-structure rules). As a consequence, errors other than those directly recognisable by phrase-structure rules cannot readily be diagnosed. While this may be satisfactory for CRITIQUE's primary application, the diagnosis of learners' errors requires a more principled approach.

**VP<sup>2</sup>: A Prolog-based CALI System:** Schuster's (1986) VP<sup>2</sup> system is designed to diagnose errors of transfer in the translations of Spanish-speaking learners of English. VP<sup>2</sup> operates by prompting the student with a Spanish sentence for translation into English, parsing the response, and reporting any detected errors to the student. VP<sup>2</sup>'s parsing mechanism is implemented as a definite clause grammar (Warren & Pereira, 1980).

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(7) EPISTLE was CRITIQUE's original name.

Schuster's system represents a significant advance over previous work, inasmuch as she recognises the need to model the native grammar of the learner.

In VP<sup>2</sup> we demonstrate how a tutoring system can rely on the principles of contrastive analysis to assist a non-native speaker of English in his/her learning of the usage of verbs and prepositions and (or) particles (p. 94).

Nevertheless, the range of errors detected by VP<sup>2</sup> is highly restricted, being limited to transfer errors in a class of verbal constructions.

Certain verb-particle and verb-preposition expressions in English are a source of difficulty for Spanish speakers because they do not translate directly into Spanish. For example, the Spanish expression *pensar en* (lit. *to think in*) is correctly rendered into English as *to think of or about*. This leads to transfer errors, as in the following ungrammatical translation:

Pensaba en estudiar Español.  
*I thought in studying English.*

VP<sup>2</sup> is able to diagnose errors of this sort by modelling aspects of the student's L1 (Spanish) grammar.

Despite VP<sup>2</sup>'s success in treating such transfer errors, however, the system is inadequate, since large classes of learner errors, such as errors of overgeneralisation, are left undiagnosed. Clearly, a more comprehensive model of the learner is called for.

**The French Grammar Analyser:** The French Grammar Analyser (FGA) of Barchan *et al.* (1985) (BWY) is a Prolog-based parser for French. FGA is a refinement of an earlier system called FROG (Imlah & du Boulay, 1985). An important motivation for the development of FGA and FROG was the desire to replace the drill-and-practice approach with free-form input analysis.

FGA operates by accepting the student's input French sentence and responding with diagnostic information about grammatical errors. Its parsing mechanism, inherited from FROG, combines 'deterministic island-driven bottom-up' analysis with 'context-free phrase-structured top-down' parsing (Imlah & du Boulay, 1985, p. 144). The authors claim that this combination of strategies provides more robust capabilities than is possible with definite clause grammars.

Despite the sophistication of the syntactic analysis procedure, however, the underlying approach to grammatical diagnosis is *ad hoc*. This is clear from the authors' own description of FGA's error detection capabilities, which require the systems' designers to 'anticipate' many of the learner's errors.

An added bonus is the ease with which expected incorrect structures can be anticipated and built into the grammar with an appropriate error message tag. For example, a fair number of students may produce *je les n'aime pas* instead of the correct *je ne les aime pas*: an error message

to the effect that the pronoun list should be within the negation rather than outside it is incorporated into FGA (p. 32).

Like the AGT, BWY's system suffers from two major flaws. First, there is no clear separation of L1 and L2 information. Second, the error diagnosis facility is *ad hoc*, requiring FGA's designers to anticipate learner errors. The result, again, is an unprincipled approach to the diagnosis of ungrammaticality.

**Schwind's Intelligent Language Tutor:** Schwind's (1988a, 1988b) intelligent language tutoring system (ILTS) is an ambitious and impressive work of software engineering, and shares with the present research a common goal.

To define in a clear and transparent way what an error is and ... to analyse errors as arising from a misunderstanding or ignorance of grammatical rules on the part of the students (1988a, p. 608).

The similarity between Schwind's system and *Scripsi* extends to several details of implementation. Most notably, both rely on feature-based grammatical formalisms realised in Prolog (in Schwind's case, the metamorphosis grammar of Colmérauer (1978)). This in itself is remarkable, given that these systems were developed quite independently, and their respective authors considered feature-based error diagnosis an innovation.

To our knowledge, until now feature grammars have never been applied to the problem of analysing ill-formed sentences, nor within the context of language teaching (1988a, p. 609).

Despite its superficial similarity to the present work, however, Schwind's research diverges from ours in two important respects. The first might be termed a difference of *focus*, for Schwind's ILTS is more general than *Scripsi*:

The aim of our research was to construct a very fundamental and 'objective' knowledge base about the language taught (in our application, German). This knowledge base should represent structural and semantic knowledge of German in such a way that very different access modes can be used in very different ways (1988b, pp. 1-2).

The 'access modes' Schwind has in mind encompass both analysis and synthesis of language. Her system is flexible enough to allow a variety of tutorial exercises, including sentence construction, translation, composition, text understanding, and conversation. These capabilities compare favourably with *Scripsi*'s more narrow focus on composition.

The second major difference between Schwind's system and ours involves grammatical error diagnosis. On this score, the ILTS is clearly inferior. In the ILTS, an inadequate model of the learner's linguistic competence results in *ad hoc* treatment of an important class of syntactic errors.

This is not to say that the ILTS lacks broad grammatical coverage — on the contrary, excepting inflectional errors, and despite the lack of distinction between errors of transfer and overgeneralisation, Schwind's system recognises all of the error types outlined above in our earlier sections.

Rather, her treatment of syntactic errors is not at all general, since many of these must be explicitly 'anticipated'.

Schwind defines syntactic errors as those involving the omission, addition, or permutation of words or syntactic groups.

Low level syntactic errors involve the omission or addition of functional words such as articles or prepositions, and the permutation of words on the lexical level (8). High level syntactic errors involve the permutation of groups of words (1988a, p. 611).

Schwind handles the diagnosis of high-level syntactic errors through error-specific (*ad hoc*) rules, as she admits.

High level syntactic errors have to be anticipated, so that their treatment is not very general (p. 612).

Her justification for this deficiency is weak, however, as she goes on to suggest that it might be considered desirable.

Consequently, totally disordered sentences cannot be analysed (but should they be?).

This reasoning is clearly misguided, for there is undoubtedly a class of ungrammaticality between the extremes of correctness and 'total disorder' that reflects the learner's interlanguage. But without a model of the learner's competence, we cannot hope to develop a principled method for analysing this ill-formedness. Thus, Schwind's ILTS suffers from the same deficiency that plagues CALI software generally, namely, an inadequate student model.

**The Inadequacy of Current Technology:** All of the systems considered above have been shown to be seriously deficient. VP<sup>2</sup>, while incorporating a (rudimentary) model of the learner's native grammar, nevertheless requires a more comprehensive account of the learner's linguistic knowledge if it is to diagnose errors of overgeneralisation. The remaining systems (FGA, CRITIQUE, AGT, and ILTS) lack a credible student model entirely, relying on *ad hoc* techniques for the detection of ungrammaticality. Only a theoretically motivated approach, it seems, will provide the broad diagnostic coverage called for in intelligent CALI.

**Scripsi: An Intelligent CALI System for Second Language Learning : Grammatical Error Diagnosis:** We now turn to a description of the design and operation of *Scripsi*, a prototype CALI system for grammatical error diagnosis. A principled account of the processes of transfer and overgeneralisation gives *Scripsi* diagnostic capabilities superior to those of other CALI systems.

Since our primary goal here is to describe the system's behaviour (rather than its internal structure), we will merely outline the salient features of *Scripsi*'s design. Readers wishing a more thorough exposition of *Scripsi*'s inner workings should see Catt (1988) & Catt and Hirst (1990a, 1990b), which the following section summarises.

(8) By 'permutation of words on the lexical level' Schwind means the misordering of verbal arguments.

**The Architecture of Scripsi:** In keeping with received practice in software engineering, *Scripsi's* intelligence (grammatical knowledge) is implemented in layers. The first layer provides low-level lexical and syntactic analysis procedures, while the second implements the learner model. Although the layers do not operate completely independently, it is helpful to analyse them as autonomous subsystems.

**Grammatical Analysis:** *Scripsi's* grammatical (syntactic) analysis module parses the student's input sentences. Using a combination of existing techniques and newly developed procedures, the syntactic component converts strings of words (sentences) into feature-annotated syntax trees (akin to the 'phrase markers' of transformational grammar). *Scripsi's* higher-level functions diagnose the learner's grammatical errors by analysing these phrase markers.

The analysis process relies on a parsing algorithm and a database of grammatical rules.

*Scripsi's* parser uses four kinds of grammatical rule: morphological, lexical, phrase-structural, and transformational. Morphological rules, encoded in the lexicon, describe how words are analysed into their component parts (morphemes). Lexical rules (here taken to mean 'verb subcategorisation rules') also appear in the lexicon. These determine the types of complements verbs may take. The verb *rely*, for instance, takes as complements the preposition *on* followed by a noun phrase. Phrase-structure rules correspond to those of a constituent structure grammar (Chomsky, 1957), such as those used in CRITIQUE. These describe basic sentence structure. Transformational rules are used to analyse syntactic phenomena involving the movement of constituents (Chomsky, 1957, 1965), such as the rule for inverting subject and verb in English.

*Scripsi's* parsing algorithm is an extension of a simple technique for parsing context-free languages (shift-reduce parsing (Shieber, 1983; Pereira, 1985)). Our 'extended shift-reduce parser' is capable of analysing context-sensitive and transformational constructions common in natural language. The parser's power, flexibility, and elegance make it a candidate for use in applications beyond CALI, a possibility that we explore further in Catt & Hirst (1990b).

**Modelling the Learner's Interlanguage:** Current AI technology is far from achieving the ideal of a perfectly fluent computer. Existing systems (e.g. Schuster, 1986; Weischedel *et al.*, 1978) treat small subsets of natural language and exploit simplifying assumptions to reduce the complexity of their underlying models.

This is true of *Scripsi* as well. *Scripsi's* syntactic analysis module handles a limited vocabulary and a restricted range of syntax (at least, compared with the vast grammatical inventory of the English language). The interlanguage model, *Scripsi's* 'intelligent' higher level, also represents a simplification, for it targets an idealised language learner whose interlanguage exhibits errors of transfer and overgeneralisation only; other potential sources of error are ignored. This approach simplifies the learner model without sacrificing an account of the central causes of ungrammaticality in learner language.



*Scripsi's* model incorporates rules of both the L1 and the L2 and uses them to analyse the student's input sentences. By modelling the processes of transfer and overgeneralisation, *Scripsi* simultaneously detects and diagnoses ungrammaticality in the student's writing.

The detection of transfer is straightforward. Whenever the input cannot be recognised by L2 rules alone, *Scripsi* applies L1 rules. Since sentence construction typically involves a multiplicity of rules, it very often happens that the student uses a mixture of L1 and L2 rules; *Scripsi* takes this into account.

Overgeneralisation is more subtle. *Scripsi* attempts to model the learner's faulty rule hypothesis processes by equating rule overgeneralisation with *constraint violations*. This approach rests on the assumption that linguistic rules can be specified, at least in part, in terms of constraints. For example, the rule for constructing a simple declarative English sentence specifies that a subject noun phrase must be followed by a verb phrase, with the constraint that the subject and verb must agree in person and number. Thus, when a learner utters 'He come from India', we say that he or she has violated a syntactic constraint. *Scripsi* detects such overgeneralisation by means of *constraint relaxation*; that is, by suspending constraints when they are not observed.

As the examples below illustrate, these techniques serve well to diagnose a broad range of learners' errors.

**Examples of Grammatical Error Diagnosis:** We now present a representative selection of error diagnoses provided by *Scripsi*.

*Scripsi* can be configured to analyse the composition of French- or Chinese-speaking learners of English. Of course, *Scripsi* detects a broad range of overgeneralisation errors that do not depend on the learner's L1.

*Scripsi's* user interface is simple. The student types sentences at the terminal and the computer responds to each sentence with a message (or messages) indicating the grammatical errors (if any) that occurred in the student's input. The student's input is preceded by the character '\*', *Scripsi's* responses by '..'.

\* My friend wroted a book.

..

.. (1) Verb WRITE has irregular past tense: WROTE.

*Scripsi* has detected an instance of overgeneralisation of inflectional rules. The word *wroted* neither appears in *Scripsi's* dictionary nor can it be correctly derived by morphological rules from a root verb, so *Scripsi* hypothesised the use of the *-ed* suffix with the non-root form *wrote*.

\* These young men sees the beautiful woman.

..

.. (1) Subject THESE YOUNG MEN and verb SEES disagree.

.. Subject is PLURAL, verb is SINGULAR.

Subject-verb disagreement is a very common error. *Scripsi* has diagnosed this instance of overgeneralisation by relaxing the constraint on person-number concord between the subject noun phrase and the main verb.

\* These people speak very well English.

..

.. (1) Adverbial VERY WELL immediately precedes object ENGLISH.

*Scripsi* has detected this instance of language transfer by applying rules of French phrase structure after English rules have failed.

\* The child disobeys to his father.

..

.. (1) French usage: complement of verb DISOBEY.

.. Expecting DIRECT OBJECT complement.

*Scripsi* has determined that the use of a prepositional phrase complement with the verb *disobey* is probably due to the fact that the corresponding French verb *désobéir* takes a complement of the form *à quelqu'un* 'to someone'.

\* He tries him to read the story.

..

.. (1) Incorrect complement to verb TRIES.

.. Expecting INFINITIVE complement.

This instance of overgeneralisation possibly results from analogy with verbs like *want* that allow clausal complements of the form used here. *Scripsi* has detected this error by noting that this variety of complement is not marked in the lexicon as one of the possible complements to the verb *try*; furthermore, this type of complement does not occur with the French equivalent *essayer* and hence cannot be an instance of transfer.

\* He has hunger.

..

.. (1) AVOIR FAIM is expressed in English as TO BE HUNGRY.

*Scripsi* detects the transfer of idioms from French into English by encoding idioms in its internal lexicon.

\* They ask what does he see.

..

- .. (1) Subject inversion not allowed in indirect questions.

This case of overgeneralisation has been detected by relaxing the constraint on the distribution of the subject-verb inversion rule.

\* Reads he the book.

..

- .. (1) French usage: subject inversion requires auxiliary verb.

*Scripsi* has diagnosed the transfer of the French rule for subject-verb inversion in which no auxiliary is used.

\* Does he may see him.

..

- .. (1) DOES incorrectly occurs with modal or auxiliary verb.

*Scripsi* has diagnosed an instance of overgeneralisation in the formation of the English interrogative. The error was detected by relaxing the constraint on the use of the auxiliary *do* in questions.

\* They wonders what will these boy enjoys to eat.

..

- .. (1) Subject THEY and verb WONDERS disagree.  
.. Subject is PLURAL, verb is SINGULAR.
- .. (2) Subject inversion not allowed in an indirect question.
- .. (3) Incorrect complement to verb ENJOYS.  
.. Expecting GERUND complement.
- .. (4) Modal WILL incorrectly followed by an inflected verb.
- .. (5) Determiner THESE and noun BOY disagree.  
.. Determiner is PLURAL, noun is SINGULAR.

*Scripsi's* design allows for the detection of multiple errors in students' input sentences.

*Scripsi* can also be configured to detect grammatical errors typical of sinophone learners of English.

\* He very happy.

..

- .. (1) Chinese usage: sentence lacks a copula verb.

*Scripsi* has recognised the transfer of Chinese clause structure.

\* He should use these equipments.

..

.. (2) Chinese usage: pluralised mass noun EQUIPMENTS.

This instance of overgeneralisation results from the lack of distinction in Chinese between mass and count nouns.

**Conclusion:** We have described in some detail the operation of *Scripsi*, a prototype CALI system for intelligent grammatical diagnosis. *Scripsi* represents a significant advance over similar systems, deriving its robust diagnostic capabilities from a model of the learner's linguistic competence.

The poor quality and limited pedagogical value of existing CALI systems, which for the most part are merely automated grammatical drills, have provided the motivation for the development of intelligent CALI software. Researchers in this area hope ultimately to create *communicative* computer systems for language tutoring, with which students will be able to interact linguistically. The first step towards the fulfilment of this goal is the development of intelligent software for grammatical error diagnosis, for only once the *intended form* of the learner's linguistic output is determined will it be possible to ascertain its meaning. We have argued that such diagnostic capabilities hinge crucially on the development of a realistic student model. In CALI, this entails the construction of a model of the language learner's linguistic competence.

Careful consideration of the diagnostic mechanisms of other intelligent CALI systems exposed a common fatal flaw—the lack of a robust, credible model of the learner's linguistic knowledge. These systems were shown to be inadequate either through lack of broad grammatical coverage (VP<sup>2</sup>) or through reliance on *ad hoc* techniques for error diagnosis (AGT, CRITIQUE, FGA, ILTS). *Scripsi* remedies their most serious deficiency by incorporating a credible model of the second language learner's linguistic competence, one that takes into account the phenomena of transfer and overgeneralisation. *Scripsi* is able to formulate reasonable hypotheses about incorrect forms in learner language, detecting instances of transfer and overgeneralisation in a wide range of constructions. In its broad coverage and principled approach to grammatical diagnosis, *Scripsi* is clearly superior to its rivals.

This is not to say that *Scripsi* surpasses other CALI technology in every respect, for much of the functionality found in related CALI systems has not been implemented in *Scripsi*. Such apparent deficiencies reflect the motivation for our research: *Scripsi* was not intended to embody all the characteristics of a fully functional CALI system, but rather to provide a syntactic core around which a more pedagogically sound system can be built. The CALI system of the future, we believe, will derive its intelligent capabilities from just such a grammatical foundation.

**Directions for Future Research:** *Scripsi* is a prototype system, as yet untested in the classroom. It would clearly be desirable to test the effectiveness of our approach in real teaching situations. This would require rather straightforward additions to *Scripsi*'s lexicon and grammatical rule inventory, which at present do not extend beyond the range of vocabulary and syntax appearing in our examples.

However, as hinted above, *Scripsi*'s full potential will not be realised

without significant extensions to its functionality. Two further objectives therefore suggest themselves as desirable goals for future research. A more immediate goal involves extending and enhancing *Scripsi's* current diagnostic capabilities. A more distant (but more enticing) goal is the development of a genuinely communicative system that exploits *Scripsi's* diagnostic capabilities in providing a basis for meaningful linguistic interaction.

A direct extension of the present research is the development of more robust error diagnosis. This can be achieved by adding the following features to *Scripsi*.

- Extended syntactic and lexical coverage
- Semantic processing
- An improved learner-model
- Diagnosis of orthographic errors

Extended grammatical coverage is clearly desirable, for *Scripsi* currently handles a relatively small range of syntax and vocabulary. Semantic processing is vital to grammatical diagnosis largely for its importance in structural disambiguation (Hirst, 1987). An improved learner-model can be constructed by taking into account learning and production strategies other than those of transfer and overgeneralisation (Selinker, 1972) and by incorporating the results of recent developments in linguistics and SLA research (e.g. Flynn, 1987). The problem of spelling errors is an important one in CALI, but has been ignored in the development of *Scripsi*. Word-level errors must be treated intelligently in a practical CALI system, owing to the large number of orthographic errors in students' writing.

These features will contribute to more accurate and extensive error diagnosis. Improvements in diagnostic capabilities, however, do nothing to enhance the communicativity of the system. What is needed for this purpose is an entirely different interface.

Perhaps the most promising avenue for the development of communicative CALI systems lies in integrating the techniques of mainstream computational linguistics with the results of our own research. By combining the *interpretive* properties of language understanding systems (Winograd, 1972) with the *diagnostic* capabilities of *Scripsi*, we can look forward to creating a system that understands the learner. Rather than respond to the student's ill-formed language with diagnostic messages, such a system would first apply diagnostic procedures to determine the intended form of the input, and then interpretive procedures to derive its meaning and formulate a response. In this way, the intelligent CALI system of the future will synthesise the results of AI research by incorporating both grammatical and semantic treatments of natural language (9).

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(9) **Acknowledgments** : Department of Computer Science, University of Toronto.

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