

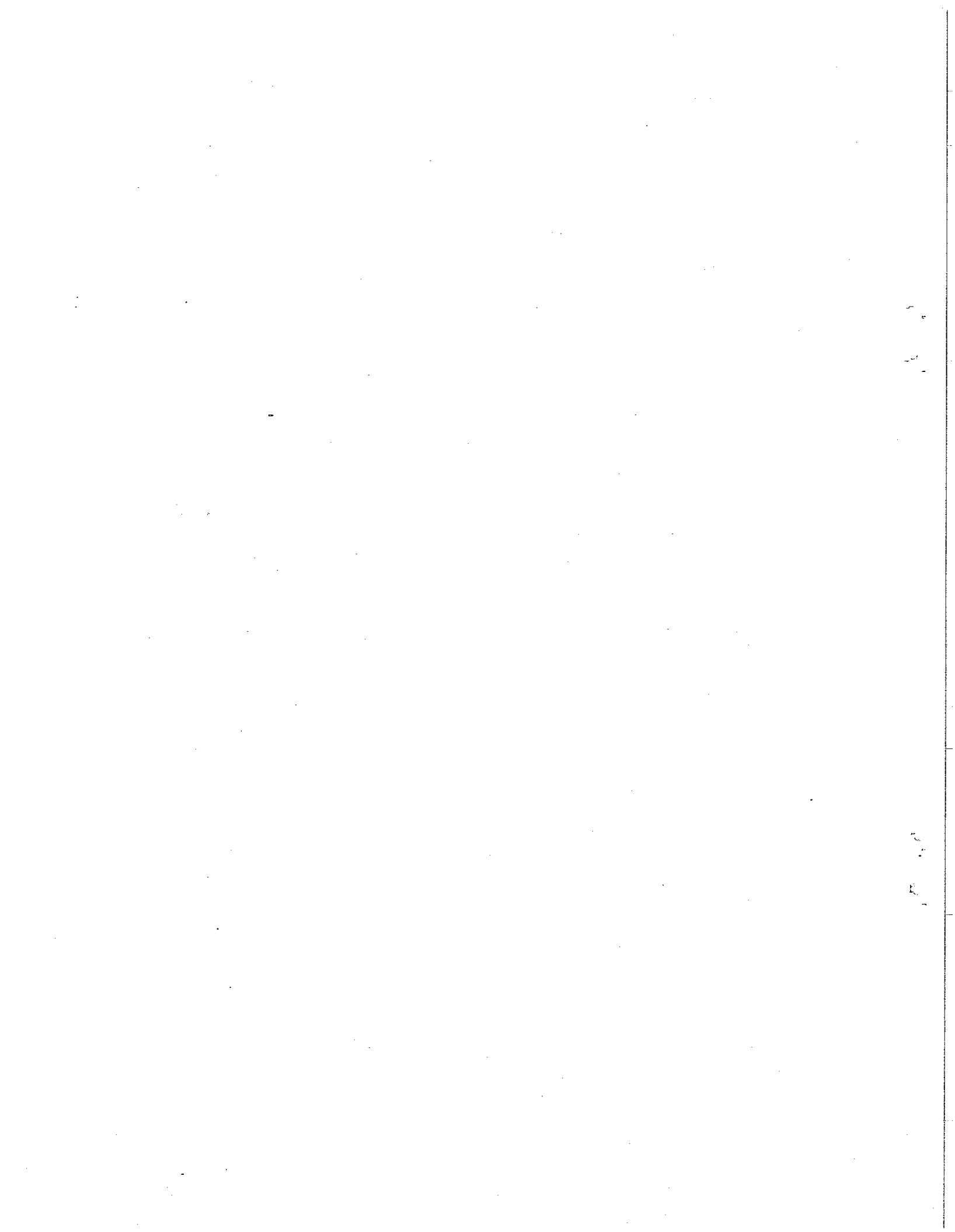
**Intelligent Diagnosis of Ungrammaticality
in
Computer-Assisted Language Instruction**

Mark Edward Catt

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Computer Systems Research Institute
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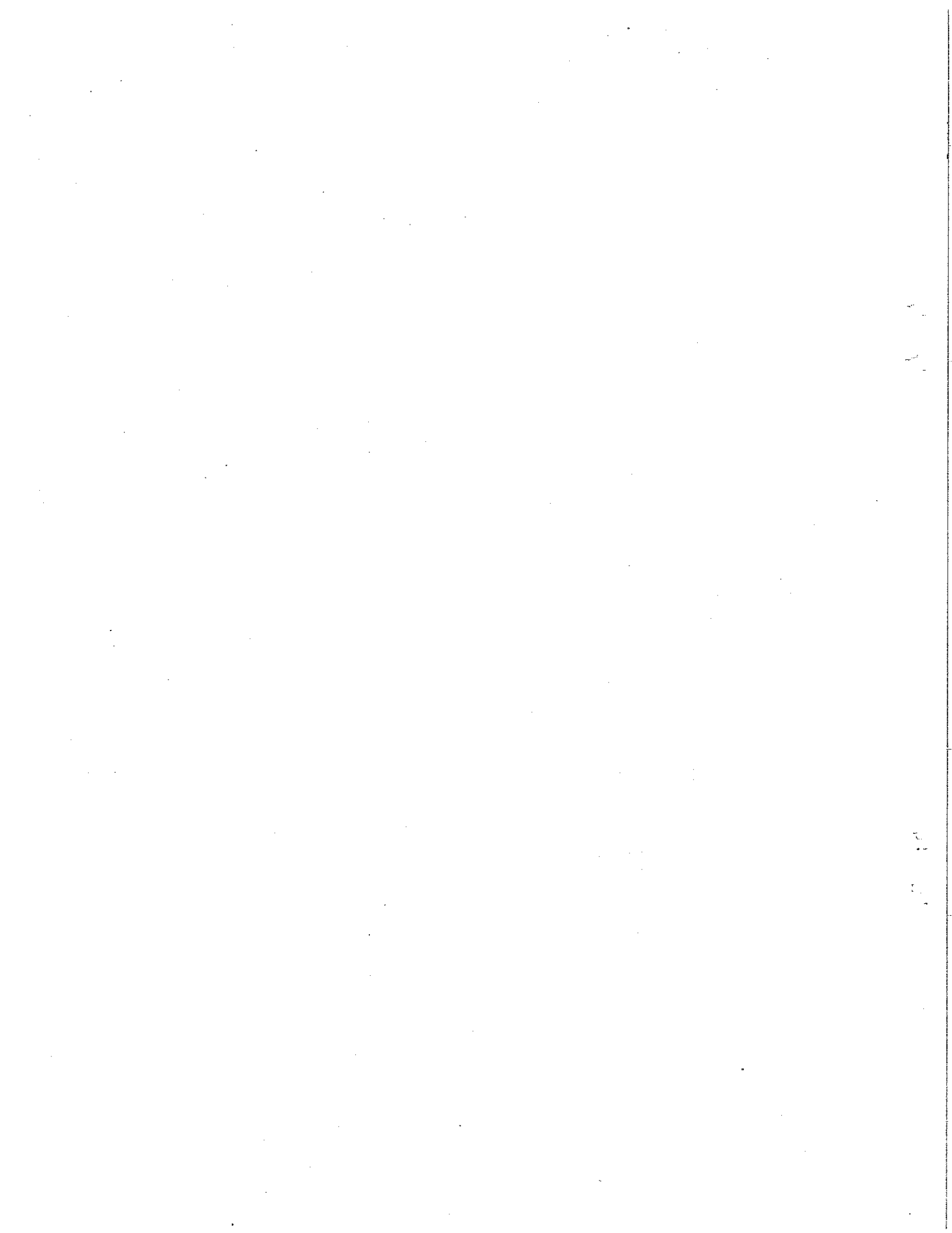
Intelligent Diagnosis of Ungrammaticality
in
Computer-Assisted Language Instruction

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Toronto, Ontario, Canada
October 1988

A Thesis submitted in conformity with the requirements
for the Degree of Master of Science in the
University of Toronto

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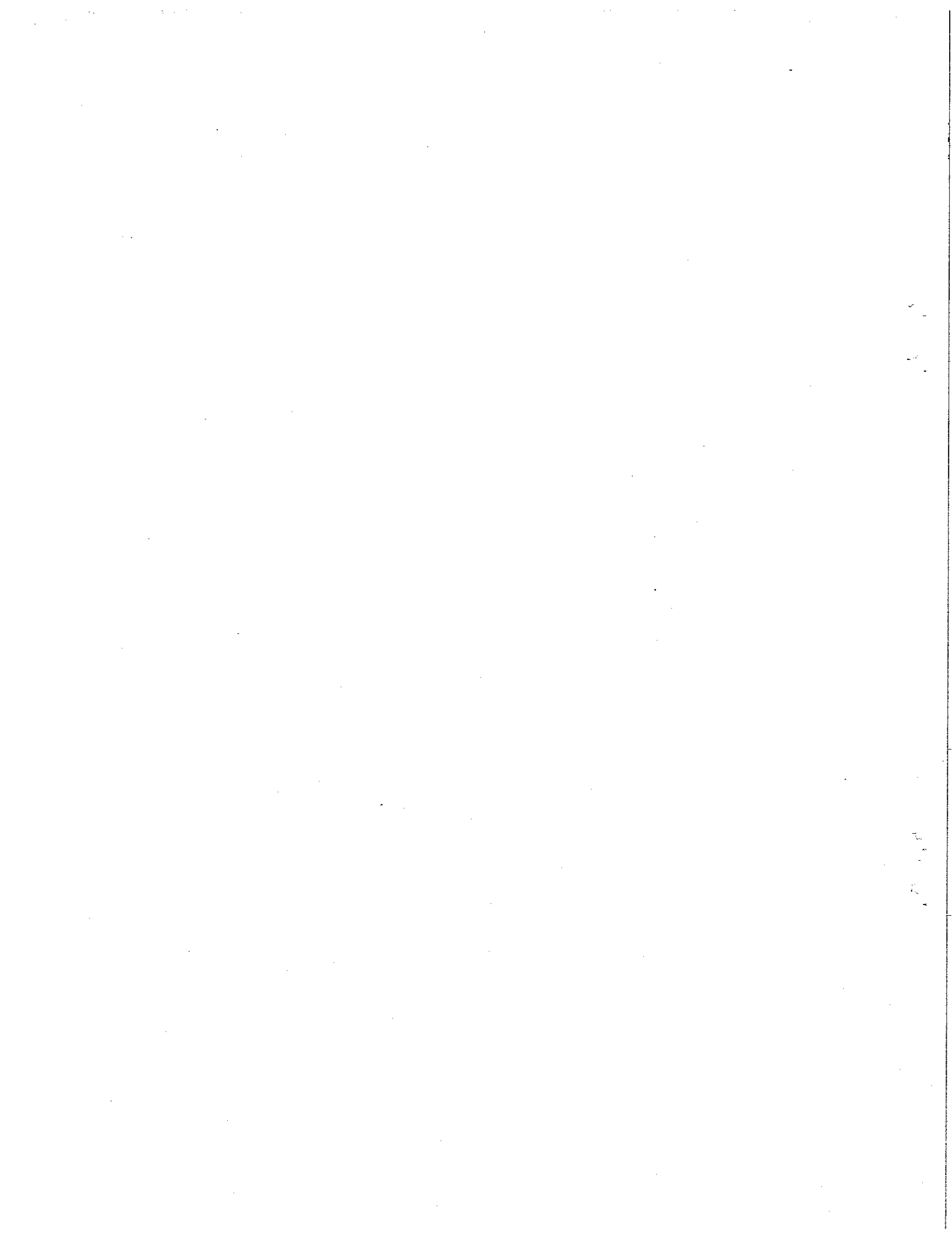
Abstract

We describe an approach to grammatical error diagnosis in computer-assisted language instruction (CALI). Our prototype system, Scripsi, employs a model of the linguistic competence of the second language learner in diagnosing ungrammaticality in learners' writing. Scripsi not only detects errors, but hypothesises their cause and provides corrective information to the student.

Scripsi's grammatical model reflects the results of research in second language acquisition, which has identified *language transfer* and *rule overgeneralisation* as the chief sources of error in learner language. Thus, in characterising the learner's "transitional competence", we model not only the grammar of the learner's native language, but also the strategies that give rise to overgeneralisation. Although the approach is language-independent, our implementation targets French-speaking and Chinese-speaking learners of English.

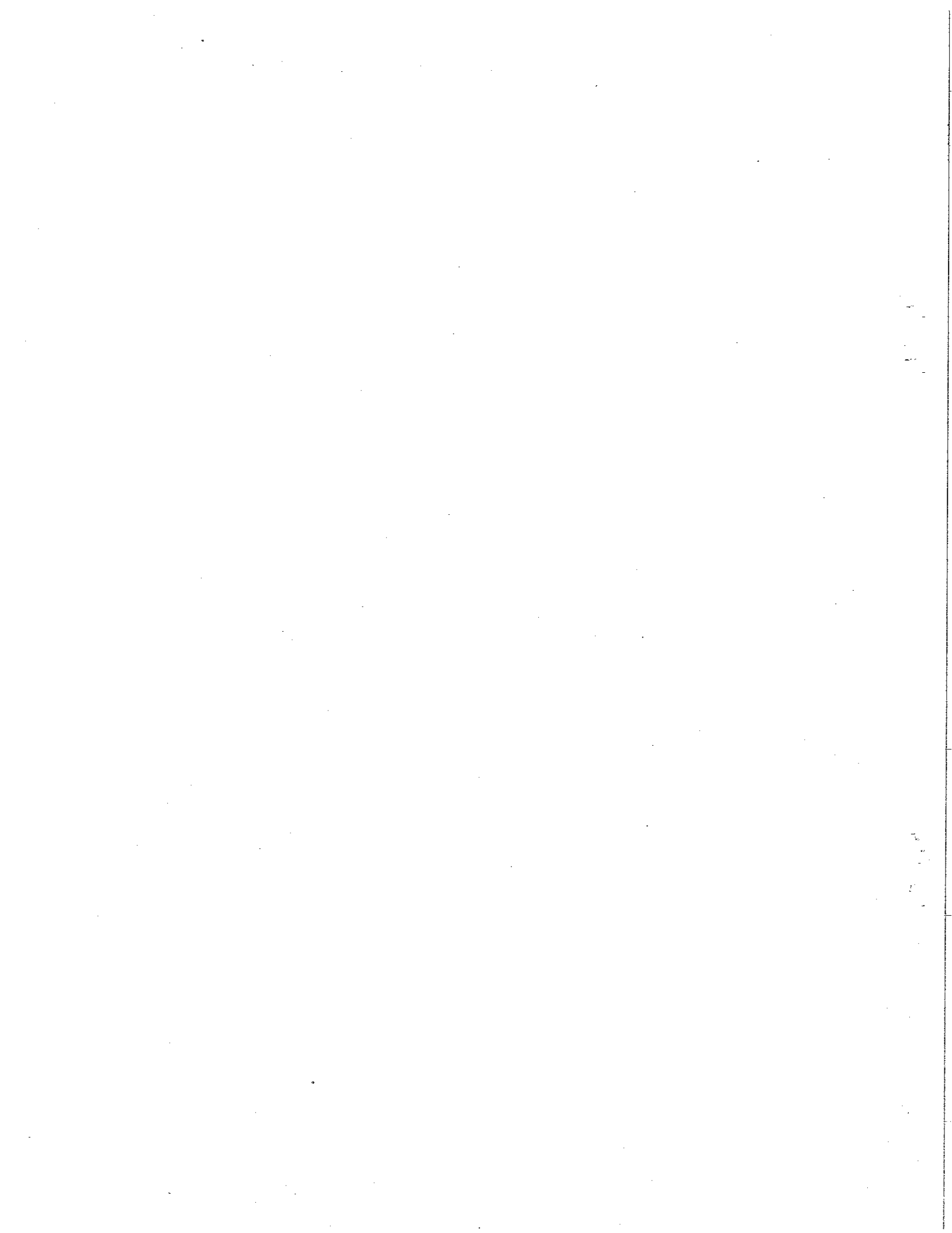
The computational realisation of the model assumes that linguistic behaviour is *rule-governed*. We have adopted a rule-oriented grammatical formalism in which the processes of transfer and overgeneralisation are readily interpreted. Linguistic rules are expressed in a feature-based grammatical framework closely related to the Standard Theory of transformational grammar. We have extended the shift-reduce parsing algorithm in order to accommodate context-sensitive and transformational aspects of the formalism.

We argue that the development of expertise in intelligent grammatical diagnosis is a prerequisite for the next generation of CALI tools—genuinely communicative systems capable of interacting linguistically with the student.



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Introduction

This thesis 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 ungrammaticality² in written texts, 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,³ the framework of interactive composition provides the student with the opportunity to express himself 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. Scripsi's design is intended to lay the groundwork for the creation of intelligent tutoring systems for foreign 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 premised on the notion 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 chapter 2). A central concern in the design of Scripsi

¹Here, and throughout this document, we use the term "language learner" to denote one who undertakes to acquire a foreign language *after* having achieved proficiency in his native language. We will apply the terms "language learner", "foreign 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 native language". However, this rough definition is sufficient for our purposes.

²Newmeyer (1983) notes that the term 'ungrammaticality', as used here, is more properly expressed as 'unacceptability'. We prefer the less precise (but more intuitive) terminology.

³Unfortunately, most current CALI programs are merely computerised drills.

has been the incorporation of a psychologically sound model of the linguistic competence of the second language learner.

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 foreign 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 remainder of this chapter presents arguments suggesting that these questions can be answered unequivocally in the affirmative. Succeeding chapters detail the theoretical underpinnings of Scripsi's design, and describe its implementation and operation.

1.1 The Case for Intelligent CALI

The potential for CALI to enhance foreign language learning might seem too obvious to question. Arguments offered in favour of the development of CALI abound in the literature. 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 good deal of student interest which hopefully [*sic*] helps to increase their motivation (p. 93).

Yet there is a danger that 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 the tedious grammatical drill. His opinions are shared by other researchers:

Much of the current CALL [computer-assisted language learning] 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. Thus we have a grave responsibility to alert ourselves to the dangers as well as to the opportunities if the computer is not simply to become a teaching machine writ large (Phillips 1986 p. 3).

The shortcomings of automated drill-and-practice exercises are so severe in the eyes of some researchers that the very use of such software is called into question:

The linguistic and pedagogical inadequacies of current CALI programs are not removed by the fact that some of them have been successful. In some cases, the apparent success of CALI may have been only a relative one in comparison with a poorly structured 'conventional' language course. Even where it has been clearly successful, one must ask if it is sufficiently better than a good programmed text to warrant the difference in cost. In fact, 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).

This unfavourable assessment of computerised drill-and-practice courseware is reflected in a study of the effectiveness of such systems:

We have found no basis for the claim that either CALI or the language laboratory result in achievement superior to that of a group whose language activity and growth are the result of classroom interaction Our study indicates that programs using drill, error correction, and grammatical analysis formats do not contribute to the overall language proficiency of students (Donato et al. 1984 p. 124).

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. As with dialogues between students and teachers, the course of each dialogue will depend on the specific needs of each student. This, rather than programmed learning and self-paced courses, is truly 'individualized' instruction (Nelson et al. 1976 p. 31).

Farrington, too, suggests that the student must play a more active role in the interaction. His prescription for change is clear:

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

The replacement of drill-and-practice software with communicative systems represents a radical reorientation of effort in the development of CALI, one that will

allow the creation of . . . 'third generation CAI [computer-assisted instruction]' programs for language learning, in which student attention will be focused not on the forms of language, but on the uses of language (Paramskas 1985 p. 619).

Yet the shift towards communicative methodology is necessary if computational tools for language instruction are to keep pace with advances in language pedagogy:

There is a need for a new approach to language teaching which will shift the focus of attention from the grammatical to the communicative properties of language (Allen and Widdowson 1979 p. 122).

The creation of communicative language instruction systems will involve the development of "intelligent" software, computational systems that "understand" language. Weischedel, Voge, and James (1976) have taken tentative steps along these lines. Noting successes in the application of AI to other areas of CALI, 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 hypothesize their cause (p. 226).

As CALI software becomes more intelligent and complex, the need for a theoretically sound approach becomes correspondingly more important:

As we face the possibility of extensive and possibly indiscriminate adoption of CALL, it is vital that we turn our thoughts to the question of a rationale. Indeed, it is particularly crucial that we begin critically to examine its theoretical foundations (Phillips 1985 pp. 1-2).

An examination of the theoretical underpinnings of ICALI is a central concern of this work. A computational characterisation of the language learner's errors, contingent as it is on the representation and processing of linguistic knowledge, can only be achieved through careful consideration of theoretical accounts of second language learning.

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

1.2 Grammatical Diagnosis in CALI

The foregoing discussion has 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", 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).

Nor should it be understood that language instructors have 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 grammar-oriented classroom.

The need for a principled approach to syntax is particularly important in language teaching, where the intelligent treatment of ungrammatical language is a *sine qua non*. The crucial point is 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 clearly evident 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.

1.3 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, Voge, and James's (1976) German tutor supports a dialogue between machine and student that allows for diagnosis of both grammatical and comprehension errors. Schuster's (1986)

VP² 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, Woodmansee, and Yazdani (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 existing technology is given in chapter 3. 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 and Candlin (1986) in developing “software which matches what we already know about second language acquisition” (p. xiv).

1.4 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 and 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 grammars of the learner's native and second languages as well as rules specifying his 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 linguistic knowledge that are readily 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, reflects current views on the modular nature of mental faculties in general (Fodor 1983), and the language faculty in particular (Chomsky 1981, 1982), in observing the “autonomy of syntax”.

Linguistic Theory and Second Language Learning

Learner language is characterised by ungrammaticality: deviation from the accepted linguistic forms¹ of the language being learned. It should be uncontroversial to suggest that the intelligent treatment of such language will be possible only with an understanding of the processes involved in second language acquisition (SLA). If such an understanding is to be realised computationally, the results of SLA research must be incorporated into explicit models of learners' linguistic competence. To this end, the present chapter provides a review of the major currents in the SLA research of recent decades, describes prevailing accounts of language learning strategies, and presents examples of learners' errors within this theoretical framework.

2.1 Theoretical Accounts of Second Language Acquisition

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 the preoccupation of the mainstream of theoretical linguistics.

But language learning is not restricted to children. Adults are known to acquire a second language (L2), sometimes to the point of developing native-speaker proficiency. Most often, however, languages learned in adulthood are learned *imperfectly*. The seeming difference between L1 and L2 acquisition has given rise to a branch of linguistic

¹Linguists are careful to distinguish between *descriptive* and *prescriptive* accounts of grammar. Descriptive linguistics concerns itself with the analysis of *observed* properties of grammar, irrespective of received standards of "correctness"; prescriptive linguistics deals with normative aspects of language use. The term "accepted linguistic form" can be applied in either of these contexts. Since the present research treats both theoretical and practical aspects of grammar, the term is left intentionally vague.

inquiry concerned with explaining this difference—the study of second language acquisition.

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 appear that the acquisition of the L2 could be 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 argued that language acquisition, guided as it is by innate knowledge, should not vary dramatically between adults and children.² In its strongest form, this “nativist” view denies that language transfer plays a significant role in SLA.

The following sections outline the course of the debate between advocates of transfer-oriented accounts of SLA, supporters of the nativist view, and those taking an intermediate position. The outcome of the dispute is a theory that recognises both language transfer and innate principles of language learning as important factors in SLA.

2.1.1 Contrastive Analysis

Transfer-based accounts of language learning arose in the intellectual climate of behaviourism that prevailed before the Chomskyan revolution in linguistics. In 1957, Lado published a landmark work in SLA research detailing the theory of *Contrastive Analysis* (CA). The fundamental tenet of CA was that the errors made in the speech of second language learners were due to the influence of the learner’s native language:

Individuals tend to transfer the forms and meanings, and the distributions of forms and meanings, of their native language and culture to the foreign language and culture (Lado 1957 p. 2).

In behaviourist terms, the learning of language was equated with the acquisition of habits. This was believed to hold of both first and second language acquisition. The apparent influence of the L1 on the L2, it was claimed, was due to the transfer of habits from the prior learning of the L1. A corollary of CA theory was the belief that the errors evident in the L2 could be *predicted* by a careful analysis and contrast of the grammars of the L1 and the L2.

The theory of CA had great intuitive appeal and provided a satisfactory explanation for many of the phenomena of SLA. The phonological data, in particular, appeared to lend strong support to the theory of transfer.

Nevertheless, CA was fraught with problems. First, it was difficult to say just *how* grammars of two languages were to be contrasted. What kind of analysis, using what theory of grammar, was appropriate for the analysis? Clearly, the theory’s predictions were dependent on the analysis of contrasts made. Second, and more seriously, it became apparent that not all of the errors of the L2 learner were due to transfer from the

²Such an argument assumes, 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.

native language. For instance, many errors common in first language learning, to which an explanation of transfer could not apply, appeared in the speech of second language learners (Dušková 1967). Finally, it was found that the predictions of CA were often false: interference did not take place in some instances where contrasts between the L1 and the L2 existed (Singleton 1981). These theoretical and empirical difficulties proved insuperable and CA fell into disfavour.

Later research attempted to resuscitate CA by modifying its claims, distinguishing the *weak* CA hypothesis from the *strong* version (Wardaugh 1970). The strong hypothesis (corresponding to the original statement of CA theory) held that errors could be *predicted* by CA, while the weak version stated only that observed errors could be accounted for in terms of grammatical contrasts. But even this distinction failed to save the theory, for the strong version was shown to be untenable, and the weak version did not constitute a *theory* of SLA at all, as it made no predictions (Singleton 1981).

Nevertheless, CA persisted even after the behaviourist account of language had been discredited. DiPietro, for example, defended CA within the framework of Fillmore's "Case Grammar" (DiPietro 1978; Fillmore 1968). Nowadays, however, CA has few serious adherents.

2.1.2 Error Analysis

The school of *Error Analysis* (EA) emerged in response to the collapse of CA. Inspired by Chomsky's theory of transformational grammar, researchers in EA sought to augment transfer-based accounts of SLA with nativist principles of language learning. By admitting both language transfer and universal principles of language learning as sources of error in SLA, EA provided a satisfying theory of learner's errors without sacrificing CA's important insights.

As its name suggests, EA considered the main problem in SLA research to be that of analysing the errors of L2 learners. A key distinction in EA, closely paralleling Chomsky's competence-performance dichotomy, was made between the "errors" and "mistakes" of the learner. Errors reflect the learner's linguistic competence—they are indications of the state of the learner's linguistic knowledge. Mistakes, however, arise from the same sources that give rise to ungrammaticality in fully competent native speakers: memory limitations, lapses of attention, and so forth. With such a distinction, it was possible to regard the learner's knowledge of the L2 as a linguistic system in its own right, referred to as his "transitional competence" (Corder 1967), or "interlanguage" (Selinker 1972). EA theorists held that the learner's transitional competence could be determined through the analysis of his errors.

Although EA and its variants are not without problems of their own, the view that both transfer and universal grammar are important sources of error in SLA has come to be widely accepted.

2.1.3 The L1 = L2 Hypothesis

Another major current in SLA research adopted a position diametrically opposed to that of Contrastive Analysis by attributing the bulk of learners' errors to the operation of innate language acquisition mechanisms. Dulay and Burt (1977) presented a theory of

SLA that considered L1 and L2 acquisition to be essentially identical processes. The theory, called *Creative Construction* (CC), alternatively known as the "L1 = L2 hypothesis", challenged the view that language transfer is a significant source of learners' errors in SLA.

Dulay and Burt (1977) claimed that learners' errors arise through a process of "creative construction":

"Creative construction" in language acquisition refers to the process by which learners gradually reconstruct rules for speech they hear, guided by innate mechanisms which cause them to formulate certain types of hypotheses about the language system being acquired, until the mismatch between what they are exposed to and what they produce is resolved (p. 67).

The error-inducing process associated with creative construction has been called "rule overgeneralisation". Rule overgeneralisation occurs when a grammatical rule hypothesised by the learner is applied incorrectly or in inappropriate contexts.

CC theorists devoted much of their effort to the reinterpretation of data that had previously been adduced in support of CA. Many errors that had been considered instances of language transfer were shown to be compatible with the CC view. What is more, many data that could not be explained in terms of language transfer were readily accounted for by CC.

Despite this success, however, CC had its inadequacies. Most serious was the fact that the evidence in favour of language transfer was simply too strong to be ignored. Although CA theory was invalid, its major insight was not: learner language is influenced by the native grammar of learners. Kohn (1986) noted this in summarising the CC episode:

The turning point in the development of the analysis of transfer was marked by the promotion of a concept of second language acquisition emphasising the learner's own active and creative contribution. The behaviouristic equation of transfer with learning and of contrasts with learning difficulties, which up to that time had shaped the predominant concept of transfer analysis, was effectively challenged. But what at first appeared to have been a fatal blow to transfer analysis in general eventually led the way toward a necessary and fruitful reinterpretation of the still obvious fact that a learner's L1 does indeed leave its traces in his interlanguage (p. 21).

2.1.4 Parametric Syntax and Language Learning

The desire to keep pace with developments in Chomskyan linguistics, combined with an appreciation for the indisputable evidence of transfer in second language acquisition, provided the motivation for a theoretical successor to Creative Construction. Chomsky's (1981, 1982) "principles and parameters" approach to syntactic theory, the so-called theory of government and binding (GB theory), suggested a new characterisation of the creative construction process. GB theory posits a set of universal (innate) principles of language structure and a group of parameters that define the range of language variation. According to GB theory, the learner constructs a grammar by determining values for

these parameters. This hypothesis-formation process is guided by the learner's innate knowledge of grammar—the “principles” of GB theory.

Flynn's (1987) theory of *Contrast and Construction* attempts to explain SLA by recasting the problem in the light of GB theory. Flynn suggests that L2 acquisition is facilitated where the values of L2 parameters match those of the L1, and is inhibited where they diverge:

Consistent with CC, L2 learners within this model use principles of UG [universal grammar] isolated in L1 acquisition in the construction of the L2 grammar; however, when values of parameters associated with these principles differ between the L1 and the L2, learners assign a new value to cohere with the values for the new target language. The L1 experience counts in determining whether such a new assignment of a parametric value is necessary. This aspect of the model is consistent with a traditional CA theory of L2 learning (p. 19).

Like EA, the parametric account of SLA recognises both transfer and innate principles of language acquisition as key factors in SLA. Unlike EA, however, it looks beyond phenomena of surface errors towards a deeper explanation of the SLA process. Flynn's theory is superior in this regard to EA since it provides an explanatory, rather than simply descriptive, theory of SLA.

2.2 Transfer and Overgeneralisation

The language learner is faced with the task of constructing a mental grammar corresponding to the linguistic data that he encounters. According to current linguistic theory, the construction of the L1 learner's grammar is guided by innate knowledge of language structure. This so-called “universal grammar” constrains the range of hypotheses that the learner may entertain in accounting for linguistic input. Despite this knowledge, however, language learners make errors in their linguistic production. This is not at all surprising, of course, since human languages do not evince the kind of regularity and simplicity that might lead (in principle) to error-free acquisition.³

A characterisation of the strategies that the L1 learner brings to bear in the creation of his mental grammar will account for many of the errors observed in learner language. These same strategies have been hypothesised to account for the errors of second language learners as well.

But what are these strategies? If the view is accepted that language behaviour is “rule-governed”, it is possible to explain some of the learner's strategies in terms of the construction of linguistic rules.

It is evident that the learner brings to bear prior linguistic knowledge in the language acquisition process. For the L1 learner, prior linguistic knowledge is limited to innate

³All natural languages admit some kind of irregularity. A case in point is the phenomenon of *suppletion*, whereby a verbal paradigm contains etymologically unrelated forms. In English, for example, the past tense verb *went* cannot be predicted from the uninflected form *go*. Learners of English (both as L1 and L2) will often produce *goed* by applying the general rule for forming the past tense.

principles of universal grammar. The L2 learner has, in addition to universal grammar, a knowledge of his L1.⁴

The L2 learner is known to transfer knowledge of his native language to the L2. In a rule-oriented analysis of language acquisition this means simply that the L2 learner uses the rules and representations of the L1 in the production or analysis of the L2. Such L1 transfer often results in correct forms of the L2. In this case, transfer is said to *facilitate* L2 acquisition and is termed "positive transfer". When transfer leads to errors in the L2, it is said to *inhibit* L2 acquisition—so-called "negative transfer".

Knowledge of universal grammar plays a key role in the hypothesis formation (creative construction) processes of both L1 and L2 learners. The main source of error in these processes is rule overgeneralisation, whereby the learner forms a more general rule than the target language permits.

Transfer and overgeneralisation account for the bulk of the errors observed in the linguistic output of second language learners. Yet these are not the only causes of errors in learner language. Selinker (1972) identified five sources of error in interlanguage.⁵

Nor is it clear that transfer and overgeneralisation are entirely separate processes. Andersen (1979) presents evidence suggesting that the two strategies interact in complex ways:

The relationship between L1 transfer and L2 overgeneralisation is still unclear. Most studies tend to treat L1 transfer and L2 overgeneralisation as mutually exclusive opposing strategies in the acquisition and use of a second language. While there are indeed clear-cut cases of L1 transfer as distinct from other clear-cut cases of L2 overgeneralisation, it is often difficult or impossible to assign an error exclusively to one of the two strategies (p. 43).

The use of the two strategies also varies with the level of proficiency attained by the L2 learner. Taylor (1975) argues that transfer predominates in the early stages of SLA, while overgeneralisation becomes more prevalent in intermediate and advanced learners.

It appears as well that the occurrence of transfer is dependent on the degree of similarity between structures of the L1 and the L2. Zobl (1980) maintains that transfer is more likely to occur when the L1 and L2 constructions involved have similar structures.

Despite these complications, the present research follows widespread current practice in maintaining a sharp distinction between transfer and overgeneralisation in the classification of linguistic errors. Furthermore, sources of error other than these strategies have been ignored. This allows for a simplification of the program of constructing a model of the learner's "transitional competence" while admitting a wide range of phenomena for consideration.

⁴In its broad sense, the phrase "knowledge of language" can be construed to include, in addition to a knowledge of grammar, a command of strategies for producing and recognising language. The term is elsewhere used more narrowly to denote simply a knowledge of grammar (Chomsky 1981).

⁵Besides transfer and overgeneralisation, he posited (1) transfer of training, (2) strategies of second language learning, and (3) strategies of second language communication.

2.3 The Formal Basis of Linguistic Description

The project of constructing a psychologically sound model of the learner's linguistic competence rests on an underlying grammatical theory. Such a theory will serve as a basis for the computational realisation of linguistic rules and representations.

One candidate for this purpose is GB theory, which currently counts among the most influential theoretical paradigms in the field of linguistic inquiry. Quite apart from its distinguished status as a leading theory of grammar, GB theory provides a promising basis for an explanation of second language learning, as Flynn (1987) has shown.

Yet GB theory's formal apparatus does not lend itself readily to computational implementation. Unlike its theoretical predecessor, transformational grammar (TG), which specifies an explicit mechanism for generating syntactic structures, GB's rules (principles) are expressed for the most part as well-formedness conditions (constraints) on linguistic forms. The relation between these principles and some equivalent set of procedures for syntactic analysis is rather opaque,⁶ particularly in comparison with the relatively straightforward correspondence between TG's generative rules and their analytic counterparts.

It goes without saying, of course, that TG would not have been abandoned had it not been shown to suffer serious theoretical inadequacies.⁷ Nevertheless, we have adopted TG as our formal framework, extending or modifying the formalism to suit our purposes. In particular, we have incorporated elements of GB theory and Bresnan's lexical grammar (Bresnan 1978, 1982). Superficially, however, the computational model elaborated here resembles most closely the so-called Standard Theory of transformational grammar (Chomsky 1965).

Chapter 4 provides details of the computational implementation of the formalism. For the purposes of classifying learners' errors, a project to which we turn presently, it is sufficient to note that we will carry over into the present work the major grammatical rule components of TG: a lexicon containing morphological rules and verb subcategorisation information; phrase structure rules generating the underlying syntactic forms of sentences (deep structures); and transformational rules mapping deep structures onto sentences. In describing errors, we will assume that the learner transfers or overgeneralises rules of these grammatical components.

⁶But see Berwick and Weinberg (1984).

⁷These inadequacies were both empirical (Fodor et al. 1974) and formal (Peters and Ritchie 1973) in nature.

2.4 Errors of Second Language Learners

In this section we present examples⁸ of grammatical errors typical of second language learners. We will assume the formal framework outlined in the previous section in assigning errors to the following categories:

- Phrase structure
- Transformations
- Morphology
- Verb subcategorisation⁹
- Direct translation

We will consider only errors of learners of English as a second language, classifying errors as instances of transfer or overgeneralisation. Transfer errors will be accompanied (where possible) by well-formed sentences of the L1 on which the transfer is presumably based. Where appropriate, instances of overgeneralisation will be accompanied by the correct English form.

We must caution the reader that the classification of linguistic errors is anything but an exact science—it is virtually impossible to determine with complete certainty the cause of a learner's error. The following error classification is therefore to be regarded as reflecting *plausible* diagnoses of linguistic ill-formedness, rather than absolute judgments of cause and effect. This caveat applies to the data generally, but where significant doubt surrounds the classification of an error, we accompany the example in question with an explanatory footnote.

Transfer of Phrase Structure Rules

The following examples, in which the rules of adverb placement are violated, are possible instances of transfer of phrase structure rules.

- (I) You speak very well German.¹⁰
(Cf. *Sie sprechen sehr gut Deutsch.*)
- (I) He became finally President.
(Cf. *Er wurde endlich Präsident.*)

⁸The data are taken from a number of sources, identified alphabetically as follows:

- | | | |
|----------------------------|----------------------|-----------------|
| (A) Adjémian 1984 | (E) LeCompagnon 1984 | (I) Swan 1987 |
| (B) Burt and Kiparsky 1972 | (F) Richards 1971a | (J) Taylor 1978 |
| (C) Chang 1987 | (G) Richards 1971b | (K) Walter 1987 |
| (D) Dušková 1967 | (H) Schuster 1986 | |

⁹We will indulge in yet another mild abuse of terminology by extending the purely syntactic notion of 'verb subcategorisation' (Chomsky 1965) to cover phenomena more correctly viewed as involving properties of 'predicate argument structure' and 'functional structure' (Bresnan 1982).

¹⁰This example may reflect confusion between adverbial *well* and adjectival *good*, since both are rendered as German *gut*.

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

Many syntactic patterns of Chinese are transferred into English by sinophone learners. For example, Chinese uses no copula verb between subject and predicate adjective.

- (C) I busy.
(C) She very happy.

The use of pluralisation differs significantly between English and Chinese. Plural forms are used much less frequently in Chinese.

- (C) I've seen a lot of play lately.

Overgeneralisation of Phrase Structure Rules

It is natural to treat errors of concord (grammatical agreement) as instances of overgeneralisation in phrase structure rules: the learner fails to observe constraints on agreement between constituents of a phrase.¹¹ Such errors are very common. The following show examples of disagreement between subject and verb in English.

- (F) He always take a lot.¹²
(F) He come from India.
(D) This solution correspond
(J) Doesn't the girls walk every day?
(J) Roberto don't walk to class every day.¹³
(J) Don't she speak with her teacher?

In some cases, overgeneralisation is induced by the learner's L1, as when the L2 makes a grammatical distinction not present in the L1. For example, Chinese does not distinguish *mass* nouns from *count* nouns. In contrast to count nouns, mass nouns never take the plural, and may not be referred to as discrete (countable) units.

- (C) She's brought many luggages with her.
(C) Let me tell you an interesting news.

¹¹This will become clear in section 4.5.2.

¹²This example and the following two may reflect the learner's inability to pronounce the third-person singular clitic *-s*, which is a common difficulty for many learners of English.

¹³This example and the following may be instances of transfer, since this 'error' is common in some colloquial dialects.

Transfer of Transformational Rules

French, German, and English have rules of subject-verb inversion. The rules differ in their application (English, example, often uses the *do* auxiliary) and their distribution (French employs inversion in certain subordinate clauses where English does not, and German inversion is mandatory when the subject does not occur initially in the main clause). These differences lead to many instances of transfer.

- (K) I saw go out a short man.
(Cf. *J'ai vu sortir un petit homme.*)
- (K) I heard open the living room door.
(Cf. *J'ai entendu s'ouvrir la porte du salon.*)
- (K) I told her what wanted the others.
(Cf. *Je lui ai dit ce que voulaient les autres.*)
- (I) This car have I very cheap bought.
(Cf. *Dieses Auto habe ich sehr billig gekauft.*)

Overgeneralisation of Transformational Rules

Inversion properly occurs only in main clauses, but learners often incorrectly use inversion in indirect questions.

- (K) They asked us where were we going.¹⁴
- (K) I wonder which department does she work for.
- (G) Please write down what is his name.
- (G) I told him I do not know how old was it.
- (G) I don't know how many are there in the box.

The inversion rule is often incorrectly applied, as when a main verb other than *have* or *be* is inverted (the auxiliary *do* is called for in such cases).

- (B) Paints the boy?
- (B) Go you to school?
- (B) When began the game?
- (G) What was called the film?

Transfer of Morphological Rules

We have found no examples of transfer of morphological rules in the literature.

¹⁴These examples may arise from transfer, since some American dialects are known to allow inversion in indirect questions.

Overgeneralisation of Morphological Rules

Overgeneralisation of morphological rules is very common, as in L1 learning. Learners typically apply regular inflexional rules where irregular forms are appropriate. Often, a regular inflexion is applied to an already inflected form.

(D) I writed

(D) I spoked

Transfer of Verb Subcategorisation

Transfer of verb subcategorisation is very common. Typically, this involves the misuse of prepositions, whereby learners incorrectly transfer the subcategorisation properties of equivalent verbs in their native language. A further complication in the case of French-speaking learners of English is the presence of "pronominal" verbs in French which have reflexive form but non-reflexive English translations, for example, *se battre contre* (literally *to fight oneself against*) meaning simply *to fight (against)*.

(A) At sixty-five they must retire themselves.¹⁵

(Eng. *retire* = Fr. *se retirer*)

(A) They want to fight themselves against this.

(Eng. *fight* = Fr. *se battre contre*)

(H) . . . thinking in buying a car

(Eng. *think about* = Sp. *pensar en*)

(H) I dreamed with the angels.

(Eng. *dream of* = Sp. *soñar con*)

(G) . . . married with her.

(Eng. *marry* = Fr. *se marier avec*)

(G) . . . depends of civilisation.

(Eng. *depend on* = Fr. *dépendre de*)

Overgeneralisation of Verb Subcategorisation

Overgeneralisation of verb subcategorisation occurs when learners use the subcategorisation frames of related or similar verbs. For instance, one can say *I like to swim* but not *I enjoy to swim*, although both *I like swimming* and *I enjoy swimming* are possible.

(B) We plan on finish this today.

(Cf. *We plan on finishing this today.*)

¹⁵This example is suspect since English *retire* is normally expressed in French as *prendre la retraite*.

- (B) I was delighted at him to resign.
(Cf. *I was delighted at his resigning.*)
- (B) Nobody wants doing that.
(Cf. *Nobody wants to do that.*)
- (B) I will enjoy to swim.
(Cf. *I will enjoy swimming.*)

Many verbs in English taking both a direct and an indirect object have two possible subcategorisation frames. The verb *give*, for example, is one of these. Both *She gave the book to John* and *She gave John the book* are possible. Not all such verbs allow this construction, however, resulting in overgeneralised forms in learner English.

- (E) I can describe you the house.
- (E) You explained me the rule many times.
- (E) He said me that yesterday.

Direct Translation

Errors of direct translation occur when words are translated verbatim from the L1 to the L2. In some cases, the lexical translation process is itself faulty, as when semantically divergent cognate forms are considered synonymous.

- (F) James ... give it his actual form.
(Eng. *his/her/its present form* = Fr. *sa forme actuelle*)

In other cases, the lexical correspondences of the translation are valid, but the resulting L2 form has inappropriate diction or syntax. This situation often obtains when the learner directly translates idiomatic expressions.

- (K) I have hunger.
(Eng. *be hungry* = Fr. *avoir faim*)
- (K) She has heat.
(Eng. *be hot* = Fr. *avoir chaud*)
- (K) You have reason.
(Eng. *be right* = Fr. *avoir raison*)

Related Research

This chapter presents a critical review of current approaches to grammatical diagnosis in CALI, evaluating a number of intelligent language instruction systems.

We have argued above (section 1.2) that effective grammatical diagnosis hinges on the exploitation of a psychologically sound model of the learner's linguistic knowledge; a central claim of the present work is, in fact, that our system more closely approaches this ideal than does similar technology. It is therefore worth emphasising the argument with a detailed example.

Consider again the following ill-formed¹ sentence produced by a francophone learner of English:

- (1) They want to fight themselves against this.

Contrast this with the following well-formed sentence, which has a surface form similar to that of sentence (1):

- (2) They want to press themselves against the wall.

It is surely a property of the verb *press* (in the sense of *squeeze*) that it can be used reflexively and with a prepositional phrase complement *against (something)* as in sentence (2). Furthermore, the ill-formedness of (1) follows from the fact that the verb *fight* lacks this property—the learner has produced (1) by presumably transferring the subcategorisation properties of the equivalent French verb, *se battre contre*. Hence it is a fact about (a) the structure of the human mental lexicon and (b) the transferability of lexical properties in learner language that makes (1) ungrammatical. Any system that hopes to detect and explain the ill-formedness of (1) must take this fact into account; that is, it must model the linguistic knowledge of the language learner.

In judging CALI systems, it is also important *how* such a model is implemented. Information about the learner's L1 lexicon, for example, should be encoded separately from information about L2 phrase structure. CALI software should be modularised in correspondence with the components of a sound theory of grammatical knowledge. Thus,

¹The sentence is ill-formed in its intended reading—the learner did not use the reflexive pronoun for special emphasis, which would have made the sentence acceptable.

a CALI system that represents all linguistic information in, say, phrase structure rules must be deemed inferior (*ceteris paribus*) to one that maintains such a modularisation.

We now consider current approaches to intelligent grammatical diagnosis in CALI in the light of these observations. 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 student's answers with a stored list of anticipated responses (Pusack 1983). Although some rather sophisticated software has been developed within this framework, such systems invariably require the user (instructor or course designer) to specify the set of correct (anticipated) responses. Farrington's (1986b) LITRE system is an especially impressive such "authoring system". LITRE 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 LITRE's "intelligence" external.

Menzel's (1988) system is more sophisticated still. 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 (Carbonell and Hayes 1983; Kwasny and 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) and Paramskas (1985) report 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 (Peterson 1986; Durham et al. 1983), unintelligent diction and grammar analysers (Raskin 1986), a rudimentary syntactic pattern-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 and 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, Voge, and James's (1976) automated German tutor, Schuster's (1986) VP² system, the French Grammar Analyser of Barchan, Woodmansee, and Yazdani (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*?

3.1 An Automated German Tutor

The automated German tutor (AGT) of Weischedel, Voge, and James (WVJ) (1976) is an interactive system aimed at diagnosing both grammatical and comprehension errors. The system's parser is an augmented transition network (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).

An example of an error of the first sort is the following sentence, containing what might be considered a violation of gender agreement:

Fräulein Moreau ist Student.

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

WVJ suggest that such errors can be viewed as violations of cooccurrence 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 so designed as to anticipate this kind of error.

The types of ungrammaticality detected by the AGT are few when compared against the range of errors described in section 2.4. WVJ have evidently provided no mechanism for recognising instances of morphological overgeneralisation, and do not treat errors of verb subcategorisation at all.

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".

3.2 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 and Braden-Harder 1988). CRITIQUE was originally intended for use in an office environment:

The long-term objectives of the EPISTLE² 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 and 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.

²CRITIQUE was originally called EPISTLE.

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 (PSRs). 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, such as those of verb subcategorisation. 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, coordination, and the like.

CRITIQUE's error detection mechanisms parallel those of the AGT. Commonly occurring (anticipated) errors are encoded directly as PSRs. Another class of errors, including violations of grammatical agreement rules, is recognised through "constraint relaxation", whereby cooccurrence 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 need to be specified in advance and rules incorporated to recognise them, as in the AGT.

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

3.3 VP²: A Prolog-based CALI System

Schuster's (1986) VP² system is designed to diagnose errors of transfer in the translations of Spanish-speaking learners of English. VP² operates by prompting the student with a Spanish sentence for translation into English, parsing the response, and reporting any detected errors to the student. VP²'s parsing mechanism is implemented as a definite clause grammar (Warren and Pereira 1980).

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 VP² we demonstrate how a tutoring system can rely on the principles of contrastive analysis to assist a nonnative 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 VP² is highly restricted, being limited to transfer errors in verb subcategorisation.

Certain verb-particle and verb-preposition expressions in English are a source of difficulty for Spanish speakers because their subcategorisation properties do not match those of their Spanish equivalents. 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.

VP² is able to diagnose errors of this sort by modelling aspects of the student's L1 (Spanish) grammar.

Despite VP²'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.

3.4 The French Grammar Analyser

The French Grammar Analyser (FGA) of Barchan, Woodmansee, and Yazdani (BWY) (1985) is a Prolog-based parser for French. FGA is a refinement of an earlier system called FROG (Imlah and 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.

FGA's parsing mechanism, inherited from FROG, combines "deterministic island-driven bottom-up" analysis with "context-free phrase-structured top-down" parsing (Imlah and du Boulay 1985 p. 144). The authors claim that this combination of strategies provides more robust capabilities than is possible with the DCG formalism.

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.

3.5 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 (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 morphological 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 section 2.4. 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.³ High level syntactic errors involve the permutation of groups of words (1988a p. 611).

³By "permutation of words on the lexical level" Schwind means the misordering of verbal arguments.

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?) (p. 612).

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.

3.6 The Inadequacy of Current Technology

All of the systems considered above have been shown to be seriously deficient. VP², 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 Error Diagnosis System

In this chapter we describe the design and operation of Scripsi, a prototype CALI system for grammatical error diagnosis. Scripsi is a Prolog-based system incorporating a robust syntactic analyser. A principled account of the processes of transfer and overgeneralisation gives Scripsi diagnostic capabilities superior to those of other CALI systems.

The following sections illustrate the operation of Scripsi and provide a detailed description of its design and implementation.

4.1 Scripsi in Operation

We now present a representative selection of error diagnoses provided by Scripsi. The examples illustrate Scripsi's ability to detect errors from each of the categories identified in section 2.4.

Scripsi can be configured to analyse the composition of French-speaking 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 morphological overgeneralisation. The word *wroted* neither appears in the dictionary nor can 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 French.
- >
- > (1) Adverbial VERY WELL immediately precedes object FRENCH.

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 an indirect object complement to 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 of verb subcategorisation 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 the 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 use of the English subject-verb inversion transformation. 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' inputs.

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.

4.2 Linguistic Competence and the Design of Scripsi

Scripsi's operation is based on a model of the linguistic competence of language learners—a model inspired by Chomsky's (1965) theory of transformational-generative grammar. A crucial concept of this theory is the notion of "linguistic competence", which Chomsky defines as the linguistic knowledge of an idealised speaker-hearer:

Linguistic theory is concerned primarily with an ideal speaker-listener, in a completely homogeneous speech-community, who knows its language perfectly and is unaffected by such grammatically irrelevant conditions as memory limitations, distraction, shifts of attention and interest, and errors (random or characteristic) in applying his knowledge of the language in actual performance (p. 3).

A theoretically adequate description of linguistic competence, Chomsky argues, takes the form of a generative grammar: an explicit, formal specification of the set of sentences recognisable (or producible) by the ideal speaker-hearer.

The concept of linguistic competence can be extended to the theory of second language acquisition. An idealised second language learner produces not only correct utterances of the L2, but also sentences containing errors induced by transfer from the L1 and overgeneralisation of rules of the L2.¹ Hence a formal characterisation of this extended L2, or "learner language", represents a model of the linguistic competence of the second language learner.

We now turn to a description of the design of Scripsi, focusing on details of grammatical representation and analysis. We will ignore the more mundane aspects of the implementation (such as text processing functions, user interface, and so on).

Scripsi's computational apparatus for grammatical analysis is rather complex, so it will be introduced gradually. First, we describe the components of grammar, specifying the representation of linguistic knowledge. Next, we discuss the computational mechanisms for parsing. Then we extend the model to account for learner language by incorporating the grammars of two languages and modelling the processes of transfer and overgeneralisation. Finally, we describe how this model is used to detect and diagnose

¹It will perhaps strike the reader as bizarre to define an 'ideal language learner' as one who produces both correct and incorrect utterances of the L2. We stress that the idealisation is one of theoretical, not pedagogical, significance. We wish to characterise formally the set of sentences producible by the stereotypical L2 learner, just as linguists endeavour to construct formal grammars in describing the linguistic output of the 'ideal speaker-hearer'. The 'ideal second language learner' in our sense is simply an abstraction corresponding to the class of sentences comprising "learner language".

errors in learner language. These descriptions will be accompanied by many examples illustrating the principles involved.

4.3 Components of Grammar

A transformational-generative grammar of language L in the Standard Theory contains three major components: lexicon, phrase structure rules, and transformational rules. The lexicon contains the words of L as well as a system of morphological rules capturing inflexional regularities. The phrase structure component consists of a finite set of context-free phrase structure rules that specify the underlying constituent structure (deep structure) of sentences. Transformations map the output of the phrase structure component (deep structures) onto the sentences of L (surface structures).

The organisation of grammatical information in Scripsi corresponds to this modularisation² of syntax. Scripsi incorporates a *parser*, which determines the deep structure of sentences by applying the rules contained in these grammatical components. The following sections describe Scripsi's syntactic components in detail.

4.3.1 Lexicon

The lexicon is a repository for the words of L . Only root³ words and irregular forms are explicitly stored: morphological rules (described below) provide a mechanism for decomposing inflected words into their component parts (root and inflexion). Each lexical entry (word) is specified as a category-feature complex, indicating its syntactic category and grammatical features. For example, the entry for the pronoun *him* would appear as follows:

him : PR
 [num (sing)]
 [case (obl)]
 [person (3)]

The syntactic category symbol PR designates the class of pronouns. The entry specifies that *him* is a third-person singular oblique (non-nominative, non-genitive) pronoun.

Verbs have a feature 'frame' specifying their subcategorisation frame(s). The verb *kick*, for example, is transitive, taking a direct object (noun phrase) complement:

kick : V
 [frame (_ NP)]

²This use of the term 'modularisation' is not to be confused with Fodor's (1983) terminology. We follow widespread practice in using 'modularisation' to denote the separation of computational systems into independent components.

³We do not distinguish between *root* and *stem* (see Matthews (1974)).

4.3.2 Morphological Rules

Morphological rules⁴ provide a mechanism for determining the root and inflexion of words. Since this research deals with the analysis of *written* language, however, the distinction between morphology and orthography frequently becomes blurred, and we will use both morphological and graphical representations in the expression of morphological rules. It serves no purpose here to maintain the fine distinctions between morpheme and lexeme on the one hand, and morpheme and allomorph on the other.⁵ Thus, for example, we will refer to the English past tense morpheme uniformly as *-ed*, even though it (arguably) appears in some contexts simply as *-d*, and may be realised phonetically in one of a number of allomorphic forms. This having been said, we can express the rule for the formation of the past tense of regular verbs in English as follows:

$$\begin{array}{c} \text{V} \\ \text{[tense (null)]} \end{array} + \text{-ed} \rightarrow \begin{array}{c} \text{V} \\ \text{[tense (past)]} \end{array}$$

So, for instance, the uninflected verb *kick* may combine with the past tense marker *-ed* to form *kicked*.

4.3.3 Phrase Structure Rules

Scripsi uses a phrase structure rule (PSR) format more powerful than that of the Standard Theory. While the PSRs of the latter are strictly context-free, Scripsi enhances its PSRs with features and variables (Gazdar et al. 1985; Shieber 1986; Schwind 1988a, 1988b).

Context-free PSRs augmented by features and variables provide a mechanism for describing syntactic phenomena more succinctly than is possible with simple context-free rules. Such feature-augmented PSRs allow a concise specification of cooccurrence restrictions among constituents of a phrase (e.g., conditions of grammatical agreement). For example, number agreement is required in English between determiners (category DET) and the nouns they modify (category N). Hence the phrases *this book* and *these books* are well-formed, whereas *these book* and *this books* are not. This dependency is easily expressed in the following rule (where category NP indicates "noun phrase"):

$$\text{NP} \rightarrow \begin{array}{c} \text{DET} \\ \text{[num(X)]} \end{array} \begin{array}{c} \text{N} \\ \text{[num(X)]} \end{array}$$

Here, a noun phrase consists of a determiner followed by a noun. The feature specification 'num(X)' ensures that these constituents agree in number.

While these grammatical dependencies can be expressed with context-free rules, the analysis requires a proliferation of rules and nonterminal symbols.

⁴The present work treats only inflexional morphology, leaving phenomena of lexical (i.e., derivational and compositional) morphology for future research. For an explanation of the difference, see Matthews (1974).

⁵We direct the interested reader to Matthews (1974) for an explanation of the theoretical subtleties.

4.3.4 Transformational Rules

There are several differences between the transformational rules allowed in the Standard Theory and those used in Scripsi. First, transformations in Scripsi operate in the opposite direction, in effect “detransforming” surface structures. Second, the range of syntactic phenomena considered transformational in Scripsi is severely reduced, reflecting the trends in post-Standard Theory linguistics towards constraining the transformational component. Hence syntactic phenomena such as passivisation, raising, and *wh*-movement are not treated as transformational in Scripsi. In fact, the only transformational rules implemented in Scripsi deal with subject-auxiliary inversion. A third difference reflects the use of features in Scripsi: transformational rules may refer not only to the syntactic categories of grammatical elements, but to their features as well.

These points are best illustrated by means of an example. Transformational rules operate on strings of syntactic elements (category-feature complexes). A transformation maps a string onto a new string by adding, deleting, or permuting elements. A transformational rule is given as a “structural description” (a syntactic pattern) and a “structural change” (a specification of the operations to be performed in creating the new string). For instance, the following transformation inverts an auxiliary verb and the subject noun phrase of a sentence:

$$\begin{array}{ccccccc} V_1 & & NP_2 & & \xi_3 & \Rightarrow & NP_2 & & V_1 & & \xi_3 \\ [type(aux)] & & & & & & & & [type(aux)] & & \end{array}$$

The structural description (left-hand side) indicates that the transformational rule applies to clauses consisting of an auxiliary verb followed by a noun phrase followed by an arbitrary string of constituents (indicated by the variable ξ). The structural change indicates that the first and second elements of the string satisfying the structural description are permuted. The subscripts uniquely identify elements of the structural description.

4.3.5 Syntactic Objects in Scripsi

One of the benefits of using feature-augmented category descriptions in syntax is that category/feature-matrix pairs (CFPs) can be used in all components of the grammar, making for a unified account of grammar. Entries in the lexicon are CFPs, the output of morphological rules are CFPs, and phrase structure and transformational rules operate on strings of CFPs. The pervasiveness of the CFP as syntactic object in Scripsi makes the interface between the various components of grammar especially simple.

We will have occasion to abbreviate the representation of CFPs. For example, certain features, such as ‘case’, allow a broad range of values, while others, such as ‘number’, are binary-valued. We will adopt the notational convention of representing binary-valued features with the unary operators + and –:

DET
[–sing]

This CFP represents a determiner of non-singular (i.e., plural) number. In cases where

the value of a binary-valued feature is variable, we will use Greek letters as variables ranging over the set $\{+, -\}$, as in the following version of an earlier example:

$$\text{NP} \quad \rightarrow \quad \begin{array}{cc} \text{DET} & \text{N} \\ [\alpha \text{ sing}] & [\alpha \text{ sing}] \end{array}$$

Finally, it will often be convenient to represent features as subscripts rather than as elements of a feature matrix:

$$\text{NP} \quad \rightarrow \quad \text{DET}_{\alpha \text{ sing}} \quad \text{N}_{\alpha \text{ sing}}$$

4.4 Grammatical Analysis in Scripsi

We now consider the problem of constructing a parser for language L , assuming the representation of linguistic knowledge outlined above. We wish to develop a computational mechanism for recovering the deep structure of sentences of L . We will refer to this model of grammatical analysis as the “L-model”.

There are two stages in this grammatical process: lexical analysis and syntactic analysis. Lexical analysis converts words into CFPs by consulting the lexicon and applying morphological rules. The parser analyses strings of CFPs using phrase structure rules, transformational rules, and verb subcategorisation information. Figure 4.1 illustrates the structure of the L-model.

4.4.1 Lexical analysis

Lexical analysis (LA) converts words of L into CFPs. More specifically, for each word W of an input sentence S , LA determines the set C of all CFPs to which W corresponds. In cases where C contains more than one element, the parser will determine which (if any) represents the intended reading.

LA constructs the set C from W as follows. First, LA extracts all CFPs corresponding to W from the lexicon, yielding the set C' . Then LA determines the set C'' of all CFPs derivable from W by application of morphological (inflexional) rules. The set C is then given simply as the union of C' and C'' .

4.4.2 Syntactic Analysis

The syntactic analysis (parsing) phase operates on the output of the lexical analysis procedure to determine whether the input string is a sentence of L . The input to the parser is a list S of sets of CFPs. The parser attempts to reconstruct the derivation of S in a bottom-up fashion using a strategy based on the shift-reduce parsing technique of Shieber (1983) and Pereira (1985).

Shift-reduce parsing (SR-parsing) is a bottom-up syntactic analysis scheme for context-free languages. The method is well suited for analysing the artificial languages of mathematics and computer science, since these can be readily defined in terms of context-free grammars. However, SR-parsing is inadequate for the analysis of natural language. This is so for two important reasons. First, many syntactic properties of natural language

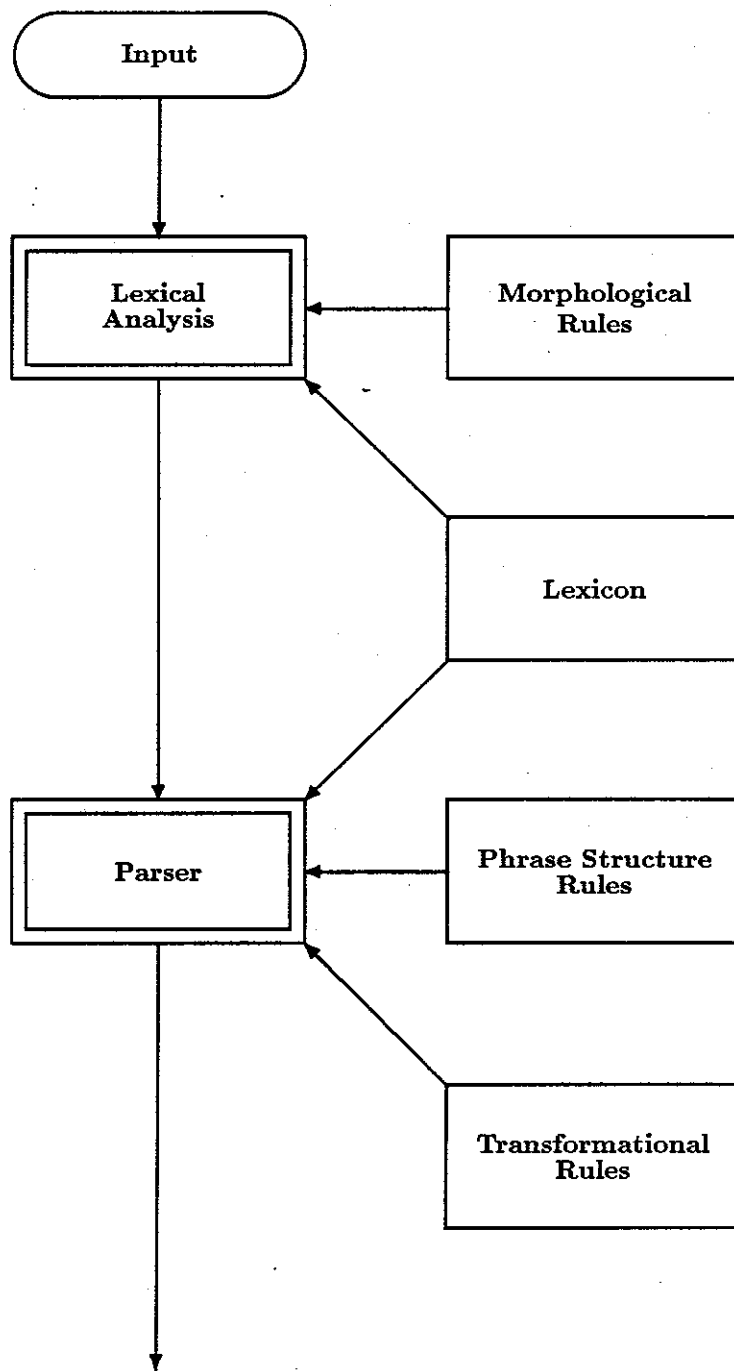


Figure 4.1. Grammatical Analysis: The L-model.

defy straightforward description with context-free grammars. For example, phenomena that have traditionally been treated as transformational are not easily characterised with context-free rules. Second, the technique demands that all syntactic information be encoded in phrase structure rules. This is inconsistent with much of modern linguistic theory, which advocates distributed representations of syntactic knowledge.

Scripsi's syntactic analysis procedure overcomes these difficulties by enhancing the shift-reduce parsing scheme. Our extended shift-reduce parser (ESRP) admits context-sensitive syntactic rules and distributed representations of grammatical knowledge. The ESRP extends the context-free grammar formalism by allowing phrase structure rules augmented by features and variables. Transformational phenomena such as subject-verb inversion are treated through the use of transformational rules, while *wh*-movement is handled by modifying the parsing mechanism itself. Scripsi also admits lexically encoded syntactic information such as verb subcategorisation rules. Finally, the ESRP mechanism uses recursion for the analysis of embedded clauses. These enhancements provide the necessary tools for treating the complex syntactic phenomena of natural language.

We now describe Scripsi's parsing scheme, detailing first the original shift-reduce parsing framework and gradually enhancing its power until the full functionality of the ESRP has been described.

Mechanics of shift-reduce parsing

An SR-parser operates on a context-free phrase structure grammar using two storage areas, a push-down stack and a buffer. The parser analyses sentences of the context-free grammar in the following way. Initially, the sentence to be parsed is placed in the buffer and the stack is cleared. The parser allows two operations: **SHIFT** and **REDUCE**. The **SHIFT** operation moves an element from the front of the buffer to the top of the stack. The **REDUCE** operation matches elements on the top of the stack against the right-hand side of a phrase structure rule, replacing these elements on the stack with the left-hand side of the rule. These operations may apply at any time during the course of a parse. If a sequence of operations yields an empty buffer with a single symbol on the top of the stack (the start symbol of the context-free grammar), the parse succeeds; otherwise, it fails. Figure 4.2 contains an example of the SR-parsing technique.

Nondeterminism

It may happen during the course of a parse that neither operation, **SHIFT** or **REDUCE**, is applicable. In this case, the parse is said to be *blocked*. On the other hand, it frequently happens that both **SHIFT** and **REDUCE** operations are applicable at the same time. Often, the choice between them is crucial, since with one alternative the parse may succeed and with the other it may fail. The solution to this problem is to make the process nondeterministic; that is, to ensure that all possible analyses are attempted before declaring failure. Such nondeterminism may be implemented in a number of ways, but the simplest (and the one most natural in a Prolog implementation) is to use *backtracking*. Backtracking is implemented as follows. Whenever more than one rule is applicable in a given state, the state is said to be a *choice point*. An arbitrary choice is made and the analysis proceeds. If the analysis later becomes blocked, the parser returns to the most recent choice

Phrase Structure Rules		
S	→	NP VP
NP	→	DET N
NP	→	PR
VP	→	V NP
DET	→	the
N	→	man
PR	→	it
V	→	saw

Rule/State	Stack	Buffer
start	.	the man saw it
shift	the	man saw it
reduce	DET	man saw it
shift	DET man	saw it
reduce	DET N	saw it
reduce	NP	saw it
shift	NP saw	it
reduce	NP V	it
shift	NP V it	.
reduce	NP V PR	.
reduce	NP V NP	.
reduce	NP VP	.
reduce	S	.
success	S	.

Analysis of *The man saw it*.

Figure 4.2. Simple shift-reduce parsing.

point and continues the analysis. Only when the parse succeeds or exhausts all the alternatives through backtracking does the process terminate. See figure 4.3 for an example of nondeterministic parsing, in which the choice point is marked with a raised '@'.

Choice points are particularly common in Scripsi due to the nature of the objects on which the parser operates. As mentioned previously, buffer elements are not words but sets of CFPs, which may contain more than one element. This forces a modification of the SHIFT operation. If the set of CFPs at the front of the buffer contains more than one element, the SHIFT operation moves only one of these to the top of the stack, and the SHIFT becomes a choice point. If the parser returns to this choice point, the next element of the set is moved to the stack, and the algorithm proceeds.

SR-parsing in a feature-based formalism

Scripsi's phrase structure rules are augmented by features and variables. This enhancement to the context-free formalism allows, for example, a concise statement of constraints on agreement among constituents of a phrase. Figure 4.4, for instance, illustrates how subject-verb agreement can be specified in a feature-enhanced grammar. The feature 'number' may be either singular (+*sg*) or plural (-*sg*). (Note that the blocked parse in the figure has not been shown in its entirety—it will backtrack and eventually fail.) The SR-parsing algorithm need be modified only slightly to handle features: the parser must ensure that feature-variables unify⁶ whenever the REDUCE operation is employed.

⁶For a rigorous definition of unification, see Shieber (1986). For our purposes, it is sufficient to say that variables unify if they have compatible values.

Phrase Structure Rules		
S	→	NP VP
VP	→	V
NP	→	it
V	→	died

Rule/State	Stack	Buffer
start	.	it died
shift	it	died
shift@	it died	.
reduce	it V	.
reduce	it VP	.
blocked	it VP	.
reduce	NP	died
shift	NP died	died
reduce	NP V	.
reduce	NP VP	.
reduce	S	.
success	S	.

Analysis of *It died*.

Figure 4.3. Nondeterminism in parsing.

Verb subcategorisation

We now consider the use of verb subcategorisation information in parsing. Observe that every natural language allows a variety of syntactic elements as complements to verbs. In English, for example, verbs may be intransitive (requiring no complements) or transitive (requiring an object noun-phrase complement) or may take clausal, infinitival, prepositional, or particle complements. Many verbs allow a variety of complements.

This has traditionally been problematic for syntactic theory. The solution given by the Standard Theory is to encode all possible verb-phrase configurations in phrase structure rules and to use lexical rules to insert verbs into phrase markers only in those environments compatible with their subcategorisation frames (these latter encoded in the lexicon).

In Scripsi, a different method is used. The phrase structure component of Scripsi contains no rules for verb-phrase structure. Instead, the subcategorisation frame information corresponding to a verb in the lexicon is treated as a phrase structure rule. In this way, the verb phrase is considered to be projected from the lexicon (Stowell 1981). The SR-parsing algorithm is extended to allow a new rule, PROJECT, which reduces the stack according to the subcategorisation of the verb closest to the top of the stack. Figure 4.5 gives an example of this operation (in which nondeterminism and feature-enhancements are ignored).

Transformational rules

The parsing algorithm is easily extended to allow for transformational rules. Scripsi constrains these rules, as in the Standard Theory, to apply *cyclically*. That is, transformations apply first in the most deeply embedded clauses of a sentence, and operate on

Feature-augmented Phrase Structure Rules		
S	→	NP _{αsg} VP _{αsg}
NP _{αsg}	→	PR _{αsg}
PR _{+sg}	→	he
PR _{-sg}	→	they
VP _{+sg}	→	sits
VP _{-sg}	→	sit

Rule/ State	Stack	Buffer
start	.	he sits
shift	he	sits
reduce@	PR _{+sg}	sits
reduce@	NP _{+sg}	sits
shift	NP _{+sg} sits	.
reduce	NP _{+sg} VP _{+sg}	.
reduce	S	.
success	S	.

Rule/ State	Stack	Buffer
start	.	they sits
shift	they	sits
reduce@	PR _{-sg}	sits
reduce@	NP _{-sg}	sits
shift	NP _{-sg} sits	.
reduce	NP _{-sg} VP _{+sg}	.
blocked	NP _{-sg} VP _{+sg}	.
⋮	⋮	⋮

Analysis of *He sits* and *They sits*.

Figure 4.4. Parsing with feature-augmented phrase structure rules.

Phrase Structure Rules	Rule/State	Stack	Buffer
S → NP VP	start	.	they give it to him
NP → they	shift	they	give it to him
NP → him	reduce	NP	give it to him
NP → it	shift	NP give	it to him
	shift	NP give it	to him
	reduce	NP give NP	to him
	shift	NP give NP to	him
	shift	NP give NP to him	.
	reduce	NP give NP to NP	.
	project	NP VP	.
	reduce	S	.
	success	S	.

Lexicon
give: V [frame (_ NP to NP)]

Analysis of *They give it to him.*

Figure 4.5. Verbal projection in parsing.

higher clauses only after they have been exhaustively applied at lower levels.⁷

Scripsi implements transformational rules via the TRANSFORM operation, which operates by (1) matching the top elements of the stack against the structural description (SD) of a transformational rule, and (2) replacing these elements with the string corresponding to the rule's structural change (SC). Figure 4.6 illustrates the application of the TRANSFORM operation with a simplified example.

In order to enforce the condition of cyclicity, Scripsi imposes the following constraints on the application of TRANSFORM:

- (1) the SD must exactly match the entire stack, and
- (2) the buffer must be empty.

These conditions together ensure that the SD of a transformation matches a complete clause. Unfortunately, these constraints allow the application of transformations only in main clauses. The use of transformations in embedded clauses will require a further refinement to the parsing procedure, recursion, to be described below.

wh-movement

Relative clauses and *wh*-questions in both English and French are subject to a process called *wh*-movement, in which the relative pronoun or question word is moved to the front of the clause from the position it occupies in deep structure. Consider the following

⁷This should not be construed as a feature with profound theoretical import. The constraint serves simply to reduce the range of applicability of transformations, and thus to improve the efficiency of Scripsi's parsing algorithm.

Phrase Structure Rules		Rule/State	Stack	Buffer
S	→ NP \overline{VP}	start	.	will the man live
NP	→ DET N	shift	will	the man live
\overline{VP}	→ AUX VP	reduce	AUX	the man live
DET	→ the	shift	AUX the	man live
N	→ man	reduce	AUX DET	man live
AUX	→ will	shift	AUX DET man	live
VP	→ live	reduce	AUX DET N	live
Transformation		reduce	AUX NP	live
		shift	AUX NP live	.
AUX ₁ NP ₂ ξ_3 ⇒ NP ₂ AUX ₁ ξ_3		transform	NP AUX live	.
		reduce	NP AUX VP	.
		reduce	NP \overline{VP}	.
		reduce	S	.
		success	S	.

Analysis of *Will the man live.*

Figure 4.6. Transformations in parsing.

examples of *wh*-movement, in which an underlying structure is converted into surface form (the final example illustrates the *qui-que* alternation of French):

- You have read *which book*.
 ⇒ *Which book* have you read?
 Tu as lu *quel livre*.
 ⇒ *Quel livre* as-tu lu?
 I saw the man [_S my brother knows *whom*].
 ⇒ I saw the man [_S *whom* my brother knows].
 J'ai vu l'homme [_S mon frère connaît *qui*].
 ⇒ J'ai vu l'homme [_S *que* mon frère connaît].

wh-movement can cross clause boundaries as well, as in the following examples:

- It seems that [_S John has read *which book*].
 ⇒ *Which book* does it seem that [_S John has read].
 Il semble que [_S Jean ait lu *quel livre*].
 ⇒ *Quel livre* semble-t-il que [_S Jean ait lu]?

It is clear that *wh*-movement is very similar in French and English. Although there are some differences in their range of application which could (in theory) be a source for transfer error, Scipio exploits the great similarity between the processes in assuming they are identical.

In the Standard Theory of transformational grammar, *wh*-movement is considered a transformational phenomenon. In Scripsi, however, *wh*-movement is not treated through the use of transformational rules. Rather, its behaviour is built directly into the parsing mechanism. This is achieved by adding a storage space for *wh*-phrases, called the WH-register, and by adding two new rules, PUSH and POP. PUSH moves a *wh*-phrase from the top of the stack to the WH-register; POP moves the contents of the WH-register to the top of the stack.

If PUSH and POP were allowed to operate at any time during the parsing procedure, there would be an unacceptable proliferation of invalid hypotheses, resulting in a large number of blocked paths and hence a degradation in performance. To avoid this, the operation of these rules has been constrained in Scripsi. PUSH may apply only if the following conditions are met:

- (1) the WH-register is empty, and
- (2) the stack contains only a single element: a *wh*-phrase.⁸

Note that PUSH, like all other parsing rules, is optional. That is, whenever the conditions for PUSH are satisfied, a choice point takes place. POP may apply only if the following two conditions are met:

- (1) the WH-register is not empty, and
- (2) the buffer is empty.

Condition (2) is clearly too strong, for it implies that non-subject *wh*-phrases can only be moved from clause-final positions. A more robust parsing algorithm would need to relax this condition.

Figure 4.7 provides an example of parsing a *wh*-interrogative. Note that the requirement of subject-verb inversion has been ignored in this case: *Who it sees* is correctly expressed as *Who does it see*. This simplification is used merely to illustrate the operation of PUSH and POP.

Long-distance *wh*-movement (that is, movement of a *wh*-phrase beyond a clause boundary) is most naturally handled by recursion in the parsing procedure, a topic to which we now turn.

Recursion

The constraints placed on the application of transformations in Scripsi make it impossible to handle transformations in embedded clauses because strings corresponding to variables in structural descriptions may not contain unmatched clause boundaries. Furthermore, the restrictions on the application of PUSH and POP make the treatment of long-distance *wh*-movement inadequate: a *wh*-phrase may occur only as the subject of the matrix clause or as the final constituent of the sentence (possibly within an embedded clause). For example, the following sentences (in which the deep structure position of the *wh*-phrase is indicated by the gap symbol '□') will be parsed:

⁸A *wh*-phrase is a constituent with the feature +*wh*.

Phrase Structure Rules	
S	→ NP VP
NP _{-wh}	→ it
NP _{+wh}	→ who
VP	→ V NP
V	→ sees

Rule/State	Stack	Buffer	WH
start	.	who it sees	.
shift	who	it sees	.
reduce	NP _{+wh}	it sees	.
push	.	it sees	NP _{+wh}
shift	it	sees	NP _{+wh}
reduce	NP	sees	NP _{+wh}
shift	NP sees	.	NP _{+wh}
reduce	NP V	.	NP _{+wh}
pop	NP V NP _{+wh}	.	.
reduce	NP VP	.	.
reduce	S	.	.
success	S	.	.

Analysis of *Who it sees*.

Figure 4.7. *wh*-movement in parsing.

Who □ said Mary thought Bill ate the cake?

What did Mary say John thought Bill ate □?

But this one will not:

Who did Mary say □ ate the cake?

Both of these problems can be remedied by allowing recursion in the parsing procedure. Whenever a clause is anticipated as the next constituent, the parsing procedure is recursively invoked with the current contents of the buffer as argument and the stack temporarily cleared. Scripsi knows when a clause is expected as the next constituent—when a verb on the top of the stack has a single clause in its subcategorisation frame.⁹

Figure 4.8 gives an example of using recursion to parse a sentence in which an embedded clause has undergone subject-auxiliary inversion. Note that the example sentence *She wonders does he sleep* is not correct in standard English, but is typical of learner English. The embedded clause *does he sleep* must undergo a transformation if it is to be parsed. Yet the presence of constituents on the stack will block the application of the inversion transformation. Thus the clause *does he sleep* must be recognised independently through recursive invocation of the parsing procedure.

The rule/state identifiers in figure 4.8 are marked with a prefixed ‘*’ to indicate each level of recursion. The initial recursive call is marked by the state identifier *START. The recursive invocation may terminate either in failure (state FAIL) or success (state SUCCESS). When control returns to the invoking procedure, the state is BLOCKED if the recursive call has failed, and is denoted RETURN if the call has succeeded.

⁹Scripsi currently allows embedded sentences only as arguments of verbs; relative clauses are not recognised.

Lexicon
sleep :
V
[frame (-)]
wonder :
V
[frame (- S)]

Transformation
AUX ₁ NP ₂ ξ ₃ ⇒
NP ₂ AUX ₁ ξ ₃

Phrase Structure Rules
S → NP \overline{VP}
NP → she
NP → he
\overline{VP} → AUX VP
\overline{VP} → VP
AUX → does

Rule/State	Stack	Buffer
start	.	she wonders does he sleep
shift	she	wonders does he sleep
reduce	NP	wonders does he sleep
shift	NP wonders	does he sleep
*start	.	does he sleep
*shift	does	he sleep
*reduce	AUX	he sleep
*shift	AUX he	sleep
*reduce	AUX NP	sleep
*shift	AUX NP sleep	.
*transform	NP AUX sleep	.
*project	NP AUX VP	.
*reduce	NP \overline{VP}	.
*reduce	S	.
*success	S	.
return	NP wonders S	.
project	NP VP	.
reduce	NP \overline{VP}	.
reduce	S	.
success	S	.

Analysis of *She wonders does he sleep.*

Figure 4.8. Recursion in parsing: transformations in embedded clauses.

Recursive parsing becomes slightly more complicated when the WH-register is not empty at the time of invocation. Yet this situation must be handled if long-distance *wh*-movement is to be treated correctly. The modification to the invocation procedure required to handle this condition is minor, however: whatever appears in the WH-register is placed on the stack at the time of the recursive call.¹⁰ If the *wh*-phrase is to function as the subject of the embedded clause, no further use of the WH-register will be required. Otherwise, the *wh*-phrase may be immediately PUSHED for later use. Figure 4.9 gives an example of parsing a sentence with *wh*-movement out of the subject position of an embedded clause.

4.5 Grammatical Analysis of Learner Language

The L-model of grammar (section 4.4) can be extended to account for learner language. The L2-model (figure 4.10) analyses sentences of the second language learner. Solid boxes correspond to components of the L2; dashed boxes to those of the L1. The dashed line connecting the lexicons of the L1 and the L2 represents the lexical translation process. Arrows emanating from the L1 components indicate the transfer of L1 rules, while those from the L2 components represent the application of correct or overgeneralised rules of the L2.

4.5.1 Transfer

In section 2.4 we identified four areas of language transfer: phrase structure rules, transformational rules, subcategorisation rules, and direct translation. Our computational interpretation of these processes assumes that the transfer of linguistic knowledge follows well-defined procedures. The transfer of phrase structure rules and transformational rules is especially straightforward in the L2-model—syntactic rules of the L1 are applied as if they were rules of the L2. Transfer of verb subcategorisation is only slightly more involved. In this case, a verb subcategorisation rule of L1 verb *V* may be applied with *V'*, *V*'s translation in the L2. For example, the L2 (English) verb *disobey* might be used with the subcategorisation frame of *désobéir*, the corresponding L1 (French) verb. The modelling of direct translation is not problematic (insofar as direct lexical translation is possible): words are translated from the L2 to the L1 and processed by L1 rules.

4.5.2 Overgeneralisation

Section 2.3 describes overgeneralisation of morphological rules, phrase structure rules, transformational rules, and subcategorisation rules. Overgeneralisation of morphological rules manifests itself primarily as overregularisation, whereby the learner uses regular inflexional forms where irregular forms are required (using, for instance, *writed* instead of *wrote*). We treat all other cases of overgeneralisation as constraint violations, expressed in terms of syntactic features. A widely used approach to the recognition of such violations

¹⁰This corresponds to the so-called COMP-to-COMP analysis of *wh*-movement. See Newmeyer (1986) for discussion and references.

Lexicon
like :
V
[frame (- NP)]
say :
V
[frame (- S)]

Transformation
$AUX_1 NP_2 \xi_3 \Rightarrow$
$NP_2 AUX_1 \xi_3$

Phrase Structure Rules
S → NP \overline{VP}
NP _{-wh} → she
NP _{-wh} → Bill
NP _{+wh} → who
\overline{VP} → AUX VP
\overline{VP} → VP
AUX → did

Rule State	Stack	Buffer	WH
start	.	who did she say likes Bill	.
shift	who	did she say likes Bill	.
reduce	NP _{+wh}	did she say likes Bill	.
push	.	did she say likes Bill	NP _{+wh}
shift	did	she say likes Bill	NP _{+wh}
reduce	AUX	she say likes Bill	NP _{+wh}
shift	AUX she	say likes Bill	NP _{+wh}
reduce	AUX NP	say likes Bill	NP _{+wh}
shift	AUX NP say	likes Bill	NP _{+wh}
*start	NP _{+wh}	likes Bill	.
*shift	NP _{+wh} likes	Bill	.
*shift	NP _{+wh} likes Bill	.	.
*reduce	NP _{+wh} likes NP	.	.
*project	NP _{+wh} \overline{VP}	.	.
*reduce	NP _{+wh} \overline{VP}	.	.
*reduce	S	.	.
*success	S	.	.
return	AUX NP say S	.	.
transform	NP AUX say S	.	.
project	NP AUX VP	.	.
reduce	NP \overline{VP}	.	.
reduce	S	.	.
success	S	.	.

Analysis of *Who did she say likes Bill*.

Figure 4.9. Recursion in parsing: long-distance *wh*-movement.

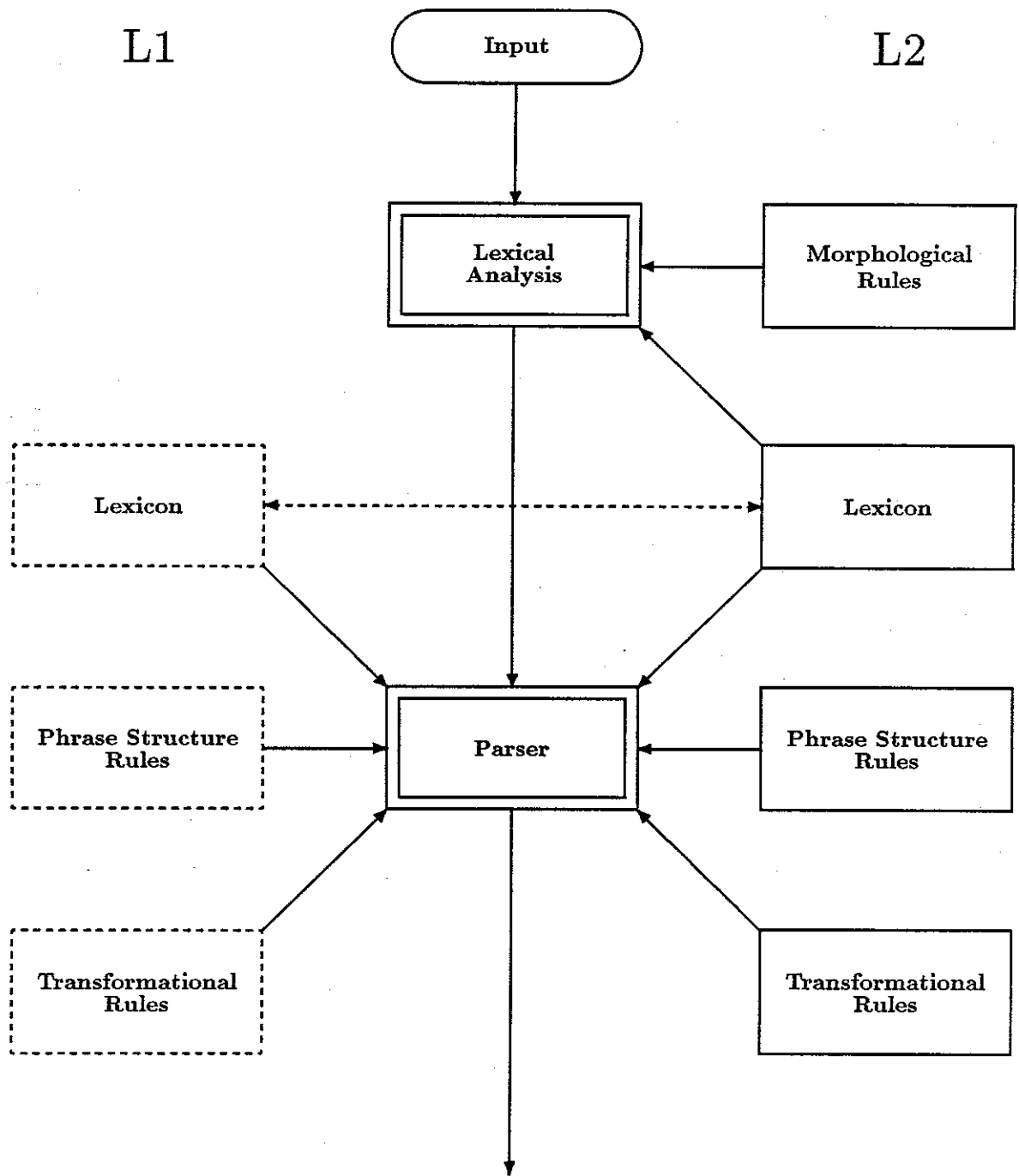


Figure 4.10. Grammatical Analysis: The L2-model.

is the technique of “constraint relaxation” (Kwasny and Sondheimer 1981; Jensen et al. 1983).

Constraint relaxation extends the applicability of rules by loosening restrictions on their application. The technique has a natural implementation in the rule format we have adopted here, since constraints on rules are expressed as feature specifications in CFPs. For example, recall the simplified phrase structure rule enforcing number agreement between determiner and noun:

$$\text{NP} \quad \rightarrow \quad \text{DET}_{\alpha \text{sing}} \quad \text{N}_{\alpha \text{sing}}$$

The constraint on number agreement can be relaxed by allowing distinct values of the feature ‘sing’:

$$\text{NP} \quad \rightarrow \quad \text{DET}_{\alpha \text{sing}} \quad \text{N}_{\beta \text{sing}}$$

This “relaxed” rule will admit phrases such as *these book* and *this books*, which may result from rule overgeneralisation.

Constraint relaxation is easily extended to transformational and subcategorisation rules, since these are also specified in terms of CFPs.

4.6 Error Analysis and Diagnosis in Scripsi

We now describe error diagnosis in Scripsi, extending the L-model parsing scheme (section 4.4) to incorporate the computational techniques identified above (section 4.5) for the recognition of learners’ errors.

4.6.1 A Diagnostic Parser

A diagnostic grammatical analyser must not only detect errors but hypothesise their cause. In this way, the analyser can hypothesise the correct (intended) structure of ungrammatical language. A synthetic (bottom-up) parsing procedure is ideal for this purpose. Scripsi’s extended shift-reduce parser builds successively more complex syntactic structures from smaller ones, applying lexical and syntactic rules as discrete analytical units (viz., the operations REDUCE, PROJECT and TRANSFORM). Instances of transfer and overgeneralisation (other than those of morphological rules) are detected and diagnosed by modifying the operation of these rules (see below). When the parser detects an error, the nature of the ungrammaticality is recorded, the ill-formed structure is reanalysed as if it were correct, and the parser proceeds. At the end of the analysis procedure, Scripsi reports all errors to the user. The diagnostic treatment of learner language is thus achieved through straightforward extensions of the procedure for parsing well-formed language.

4.6.2 Detection of Transfer

Scripsi recognises instances of transfer by allowing the application of L1 rules in the parsing process. The standard parsing rules REDUCE, PROJECT, and TRANSFORM have corresponding "transfer" versions: !REDUCE, !PROJECT, and !TRANSFORM. These indicate when an L1 rather than an L2 rule has been applied.

The recognition of errors of "direct translation" is problematic for Scripsi, since such transfer frequently results in structurally valid forms. The phrase *its actual form* is syntactically correct, for example, even though it may have been incorrectly rendered from the French *sa forme actuelle* 'its present form'. Scripsi is unable to detect such instances of transfer. There is a class of direct translation errors, however, that Scripsi can recognise. Certain idiomatic expressions (e.g., French *avoir faim* 'to be hungry') are often translated verbatim into English. By treating these as special cases of subcategorisation transfer, Scripsi detects such idiomatic transfer via the !PROJECT operation.

4.6.3 Detection of Overgeneralisation

Morphological overgeneralisation (overregularisation) is detected at the lexical analysis phase. Other instances of overgeneralisation are recognised by the parser through the relaxation of constraints on feature values in the application of L2 rules. Occurrences of overgeneralisation are denoted by the operators ?REDUCE, ?PROJECT, and ?TRANSFORM.

4.6.4 Ambiguity in Grammatical Analysis

The addition of rules for the detection of transfer and overgeneralisation increases the chances for multiple parses of sentences. Scripsi must therefore have the capability of selecting from among a set of alternative analyses the one most plausible as the intended form. A more robust parser would undoubtedly bring to bear semantic as well as syntactic information in this process. Semantic information not being available, however, Scripsi must make do with a more simplistic approach: given a set of alternative parses, Scripsi chooses the one containing the fewest errors. In the event of a tie, Scripsi selects the analysis first reached. This is admittedly an unintelligent approach to disambiguation, one that could lead to inappropriate diagnoses.¹¹

4.6.5 Examples of Error Analysis

We now present examples of Scripsi's error diagnosis procedure. Figure 4.11 represents the components of an L2-model that assumes a French L1 and an English L2. For brevity, we have included only enough information to explain the examples. The morphological component of English is not represented, nor are lexical entries in either language other than those of verbs. For some verbs, only a subset of the possible verb frames are represented. The example parses of succeeding figures assumes these grammar fragments. Note that the error messages indicated at the bottom of the figures are not the full

¹¹Consider the sentence *She died the shirt*, in which the student has misspelt the verb 'dyed'. Since Scripsi does not have available semantic information, a diagnosis of "Unexpected DIRECT OBJECT complement of verb DIED" is equally likely!

diagnostic messages given the student. They serve only to identify the error to the reader tracing through the analyses.

For expository reasons, we have conflated the lexical and syntactic phases in the examples. A new rule, MORPH, has been added for this purpose. MORPH operates by simultaneously converting a word into a CFP and shifting it onto the stack. This is not exactly how Scripsi operates, but the simplification should cause no confusion.

Lexicon (L1)
désobéir :
V
[frame (- à NP)]

Transformation (L1)
$V_1 \quad NP_2 \quad \xi_3 \Rightarrow$
[-aux]
$NP_2 \quad V_1 \quad \xi_3$
[+inv] [-aux]

Phrase Structure
Rules (L1)
$\bar{N}_{\alpha sg} \rightarrow N_{\alpha sg} \text{ ADJ}$

Lexicon (L2)
disobey :
V
[frame (- NP)]
try :
V
[frame (- to VP)]
ask :
V
[frame (- S)]
smile :
V
[frame (- at NP)]

Transformation (L2)
$V_1 \quad NP_2 \quad \xi_3 \Rightarrow$
[+aux]
$NP_2 \quad V_1 \quad \xi_3$
[+inv] [+aux]

Phrase Structure
Rules (L2)
$S_{\beta inv} \rightarrow NP_{\alpha sg} \bar{VP}_{\alpha sg}$
$NP_{\alpha sg} \rightarrow DET_{\alpha sg} \bar{N}_{\alpha sg}$
$\bar{N}_{\alpha sg} \rightarrow \text{ADJ } \bar{N}_{\alpha sg}$
$\bar{N}_{\alpha sg} \rightarrow N_{\alpha sg}$
$\bar{VP}_{\alpha sg} \rightarrow V_{+aux} VP_{\alpha sg}$
$\bar{VP}_{\alpha sg} \rightarrow VP_{\alpha sg}$
$PR_{+sg} \rightarrow \text{he}$
$PR_{-sg} \rightarrow \text{they}$
$VP_{+sg} \rightarrow \text{sits}$
$VP_{-sg} \rightarrow \text{sit}$

Figure 4.11. L2-model components.

Rule/ State	Stack	Buffer
start	.	he disobey to his father
morph	NP _{+sg}	disobey to his father.
shift	NP _{+sg} disobey	to his father
shift	NP _{+sg} disobey to	his father
morph	NP _{+sg} disobey to DET	father
morph	NP _{+sg} disobey to DET N	.
reduce	NP _{+sg} disobey to DET \bar{N}	.
reduce	NP _{+sg} disobey to NP	.
!project ¹	NP _{+sg} VP _{-sg}	.
reduce	NP _{+sg} $\bar{V}P$ _{-sg}	.
? reduce ²	S	.
success	S	.

Errors	
1	Transfer: subcategorisation of verb DISOBEY
2	Overgeneralisation: subject-verb agreement error

Analysis of *He disobey to his father.*

Figure 4.12. Diagnosis of Errors.

Rule/ State	Stack	Buffer
start	.	he ask who does she smile to
morph	NP _{+sg}	ask who does she smile to
shift	NP _{+sg} ask	who does she smile to
*start	.	who does she smile to
*morph	NP _{+wh}	does she smile to
*push	.	does she smile to
*morph	V _{+aux}	she smile to
*morph	V _{+aux} NP	smile to
*shift	V _{+aux} NP smile	to
*shift	V _{+aux} NP smile to	.
*transform	NP _{+inv} V _{+aux} smile to	.
*pop	NP _{+inv} V _{+aux} smile to NP _{+wh}	.
*?project ¹	NP _{+inv} V _{+aux} VP	.
*reduce	NP _{+inv} \overline{VP}	.
*reduce	S _{+inv}	.
*success	S _{+inv}	.
return	NP _{+sg} ask S _{+inv}	.
?project ²	NP _{+sg} \overline{VP} -sg	.
reduce	NP _{+sg} \overline{VP} -sg	.
?reduce ³	S	.
success	S	.

Errors	
1	Overgeneralisation: incorrect complement to verb SMILE
2	Overgeneralisation: inversion not allowed in indirect questions
3	Overgeneralisation: subject-verb agreement error

Analysis of *He ask who does she smile to.*

Figure 4.13. Diagnosis of Errors.

Examples of Error Diagnosis in Scripsi

We now present examples of Scripsi's error diagnosis capabilities. The sample parses show the analysis of well-formed sentences followed by examples with grammatical errors.

* He reads the books.

>

> No errors.

* Him reads the books.

>

> (1) Subject HIM is not in nominative case.

* This young man sees the beautiful woman.

>

> No errors.

* These young men sees the beautiful woman.

>

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

> Subject is PLURAL, verb is SINGULAR.

* She wants to read this book.

>

> No errors.

* She wants to read this books.

>

> (1) Determiner THIS and noun BOOKS disagree.

> Determiner is SINGULAR, noun is PLURAL.

* The happy child saw his father.
>
> No errors.

* The happy child seen his father.
>
> (1) Main verb SEEN lacks tense inflexion.

* They have written a book.
>
> No errors.

* They have wrote a book.
>
> (1) Auxiliary HAVE is not followed by a past participle.

* They are writing a book.
>
> No errors.

* They are write a book.
>
> (1) Auxiliary ARE is not followed by a present participle.

* He does write a book.
>
> No errors.

* He does writes a book.
>
> (1) DOES incorrectly followed by an inflected verb.

* She wants to write a book.
>
> No errors.

* She wants to writes a book.
>
> (1) Infinitive TO incorrectly followed by an inflected verb.

* She wants to writing a book.
>
> (1) Infinitive TO incorrectly followed by an inflected verb.

* She is in the house.
>
> No errors.

* Is she in the house?
>
> No errors.

* Does she be in the house?
>
> (1) Auxiliary DOES occurs with main verb BE.

* My father wrote a book.
>
> No errors.

* My father writed a book.
>
> (1) Verb WRITE has irregular past tense: WROTE.

* My father wroted a book.
>
> (1) Verb WRITE has irregular past tense: WROTE.

* My friend is very hungry.
>
> No errors.

* My friend has hunger.
>
> (1) AVOIR FAIM is expressed in English as TO BE HUNGRY.

* These people speak German very well.
>
> No errors.

* These people speak very well German.
>
> (1) Adverbial VERY WELL immediately precedes object GERMAN.

* She wants to read the book.
>
> No errors.

* She wants reading the book.
 >
 > (1) Incorrect complement to verb WANTS.
 > Expecting INFINITIVE complement.

* This child disobeys his father.
 >
 > No errors.

* This child disobeys to his father.
 >
 > (1) French usage: complement of verb DISOBEY.
 > Expecting DIRECT OBJECT complement.

* Who does this child disobey to?
 >
 > (1) French usage: complement of verb DISOBEY.
 > Expecting DIRECT OBJECT complement.

* To who does this child disobey?
 >
 > (1) French usage: complement of verb DISOBEY.
 > Expecting DIRECT OBJECT complement.

* He reads the book.
 >
 > No errors.

* Does he read the book?
 >
 > No errors.

* Reads he the book?
 >
 > (1) French usage: subject inversion requires auxiliary verb.

* What do they want to see?
 >
 > No errors.

* What they want to see?
 >
 > (1) Wh-question subject and verb are not inverted.

* What does she read?

>

> No errors.

* What reads she?

>

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

* They ask what the women see.

>

> No errors.

* They ask what do the women see.

>

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

* She wonders what he writes.

>

> No errors.

* She wonders what writes he.

>

> (1) French usage: invalid inversion in indirect question.

* He looks very happy.

>

> No errors.

* He very happy.

>

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

* He sees many children.

>

> No errors.

* He sees many child.

>

> (1) Chinese usage: noun CHILD lacks a plural inflexion.

* He can read the book.

>

> No errors.

* He can read book.

>

> (1) Chinese usage: singular count noun BOOK lacks an article.

* He should use this equipment.

>

> No errors.

* He should use these equipments.

>

> (1) Chinese usage: pluralised mass noun EQUIPMENTS.

Conclusion

We have described in some detail the design and 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. We devote this chapter to a summary of our work and an outline of directions for future research in the field.

6.1 Summary

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. We turned to research in the field of second language acquisition (SLA) for a theoretical and empirical basis for this endeavour.

Our brief survey of theoretical accounts of SLA revealed sharp disagreements among researchers regarding the sources of errors in learner language. While early accounts of SLA posited language transfer as the primary cause of learners' errors, later research put more emphasis on the operation of innate language acquisition strategies. There has now emerged a consensus that both language transfer and creative construction figure prominently in the learner's acquisition and production strategies. As a result, researchers have been able to attribute many of the learner's errors to transfer and overgeneralisation, a view of SLA that is directly reflected in the design of Scripsi's linguistic model.

We next reviewed a number of intelligent CALI systems, with an eye toward comparing their diagnostic capabilities against those of Scripsi. Careful consideration of the diagnostic mechanisms of these 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 deficient either through lack of broad grammatical coverage (VP²) or through reliance on *ad hoc* techniques for error diagnosis (AGT, CRITIQUE, FGA, ILTS).

After demonstrating the need for a more principled approach to grammatical diagnosis, we turned to a description of our own system, Scripsi. Scripsi remedies the most egregious deficiency of other CALI systems 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's linguistic knowledge encompasses only structural (i.e., morphological, lexical, and syntactic) information. Phenomena of semantics, pragmatics, and world knowledge do not enter into Scripsi's linguistic model or parsing mechanism. Even with this limitation, however, Scripsi is able to formulate reasonable hypotheses about ill-formedness in learner language. Scripsi detects instances of transfer and overgeneralisation in morphology, phrase structure, and verb subcategorisation. 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.

Some of Scripsi's deficiencies stand out as being particularly serious for a CALI system. First, Scripsi lacks semantic processing. Unlike the AGT, Scripsi has no facility for determining the meaning of the student's input. This not only precludes the detection of semantic errors, but makes syntactic analysis more uncertain, since semantic properties of language are known to be vital to structural disambiguation (Hirst 1987). Second, Scripsi treats only a subset of English syntax. Although Scripsi's grammatical coverage exceeds that of other systems in simple sentence structures, the treatment of the enormous stylistic variations possible in English syntax (which CRITIQUE attempts to achieve) is well beyond Scripsi's current capabilities. Finally, Scripsi does not deal with the errors of spelling and orthography that abound in the writing of language learners. On this score Scripsi is clearly inferior to both CRITIQUE and FGA, which provide some facility for error checking at the word level.

Despite these shortcomings, however, Scripsi holds out great promise for CALI. We believe that Scripsi will provide the foundation for more sophisticated instructional systems. The following section explores the possibilities for future research in greater detail.

6.2 Directions for Future Research

Two objectives suggest themselves at once as desirable goals for further 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, as noted above. 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.

References

Adjémian, C., 1983, "The Transferability of Lexical Properties", in S. Gass and L. Selinker (eds.), *Language Transfer in Language Learning*, Newbury House Publishers, New York.

Ahmad, K., G. Corbett, M. Rogers and R. Sussex, 1985, *Computers, Language Learning and Language Teaching*, Cambridge University Press, Great Britain.

Allen, J. P. B. and H. G. Widdowson, 1979, "Teaching the Communicative Use of English", C. J. Brumfit and K. Johnson (eds.), *The Communicative Approach to Language Teaching*, Oxford University Press, Great Britain.

Andersen, R., 1979, "The Relationship between First Language Transfer and Second Language Overgeneralisation: Data from the English of Spanish Speaking Learners", in R. Andersen (ed.), *The Acquisition and Use of Spanish and English as First and Second Languages*, TESOL, Washington, D. C.

Atwell, E., 1986, "Beyond the Micro: Advanced Software for Research and Teaching from Computer Science and Artificial Intelligence", in G. Leech and C. Candlin (eds.), *Computers in English Language Teaching and Research*, Longman, USA.

Barchan, J., 1986, "New Approaches to Computer Aided Language Learning", in K. C. Cameron, W. S. Dodd and S. P. Q. Rahtz (eds.), *Computers and Modern Language Studies*, Ellis Horwood, England.

Barchan, J., B. Woodmansee and M. Yazdani, 1985, "A Prolog-based Tool for French Grammar Analysis", *Instructional Science* 15(1) 21-48.

Berwick, R. and A. Weinberg, 1984, *The Grammatical Basis of Linguistic Performance*, MIT Press, Cambridge, Mass.

Bresnan, J., 1978, "A Realistic Transformational Grammar", in M. Halle, J. Bresnan and G. Miller (eds.), *Linguistic Theory and Psychological Reality*, MIT Press, Cambridge, Mass.

Bresnan, J. (ed.), 1982, *The Mental Representation of Grammatical Relations*, MIT Press, Cambridge, Mass.

Burt, M. and C. Kiparsky, 1972, *The Gooficon*, Newbury House Publishers, USA.

Carbonell, J. G. and P. J. Hayes, 1983, "Recovery Strategies for Parsing Extragrammatical Language", *American Journal of Computational Linguistics* 9 (3-4) 123-146.

Chang, J., 1987, "Chinese Speakers", in M. Swan and B. Smith (eds.), *Learner English: A Teacher's Guide to Interference and other Problems*, Cambridge University Press, Great Britain.

Chomsky, N., 1965, *Aspects of the Theory of Syntax*, MIT Press, Cambridge, Mass.

Chomsky, N., 1981, *Lectures on Government and Binding*, Foris Publications, Dordrecht, Holland.

Chomsky, N., 1982, *Some Concepts and Consequences of the Theory of Government and Binding*, MIT Press, Cambridge, Mass.

Colmérauer, A., 1978, "Metamorphosis Grammar", reprinted in L. Bolc (ed.) *Natural Language Communication with Computers*, Springer-Verlag, Berlin.

Corder, S. P., 1967, "The Significance of Learners' Errors", reprinted in S. P. Corder, 1981, *Error Analysis and Interlanguage*, Oxford University Press, Great Britain.

DiPietro, R., 1978, *Language Structures in Contrast*, Newbury House Publishers, USA.

Donato, R. and D. Coen, 1984, "A Study on the Effectiveness of CALI and the Language Laboratory", in J. P. Lantolf and A. Labarca (eds.), *Research in Second Language Learning: Focus on the Classroom*, Ablex Publishing, New Jersey.

Dulay, H. C. and M. K. Burt, 1977, "Remarks on Creativity in Language Acquisition", reprinted in W. C. Ritchie (ed.), 1978, *Second Language Acquisition: Issues and Implications*, Academic Press, New York.

Durham, I., D. Lamb and J. Saxe, 1983, "Spelling Correction in User Interfaces", *Communications of the ACM* 26 (10) 764-773.

Dušková, L., 1967, "On Sources of Errors in Language Learning", reprinted in B. W. Robinett and J. Schachter (eds.), 1983, *Second Language Learning: Contrastive Analysis, Error Analysis and Related Aspects*, University of Michigan Press, Ann Arbor.

Farrington, B., 1986a, "Computer Assisted Learning or Computer Inhibited Acquisition?", in K. C. Cameron, W. S. Dodd and S. P. Q. Rahtz (eds.), *Computers and Modern Language Studies*, Ellis Horwood, England.

- Farrington, B., 1986b, "LITRE: An Expert System for Checking Translation at Sentence Level", *University of East Anglia Papers in Linguistics* Nos. 25-26 pp. 57-74.
- Fillmore, C. J., 1968, "The Case for Case", in E. Bach and R. T. Harms (eds.), *Universals in Linguistic Theory*, Holt, Reinhart and Winston, New York.
- Flynn, S., 1987, "Contrast and Construction in a Parameter-Setting Model of L2 Acquisition", *Language Learning* 37 (1) 19-62.
- Fodor, J., 1983, *The Modularity of Mind*, MIT Press, Cambridge, Mass.
- Fodor, J., T. Bever and M. Garrett, 1974, *The Psychology of Language*, McGraw-Hill, New York.
- Gazdar, G., E. Klein, G. Pullum and I. Sag, 1985, *Generalized Phrase Structure Grammar*, Harvard University Press, Cambridge, Massachusetts.
- Heidorn, G. E., K. Jensen, L. A. Miller, R. J. Byrd and M. S. Chodorow, 1982, "The EPISTLE Text-critiquing System", *IBM Systems Journal* 21 (3) 305-326.
- Hirst, G., 1987, *Semantic Interpretation and the Resolution of Ambiguity*, Cambridge University Press, Great Britain.
- Hull, G., C. Ball, J. L. Fox, L. Levin, and D. McCutchen, 1987, "Computer Detection of Errors in Natural Language Texts: Some Research on Pattern-Matching", *Computers and the Humanities* 21 (2) 103-118.
- Hymes, D., 1971, "On Communicative Competence", reprinted in C. J. Brumfit and K. Johnson (eds.), *The Communicative Approach to Language Teaching*, Oxford University Press, Great Britain.
- Imlah, W. and B. du Boulay, 1985, "Robust Natural Language Parsing in Computer-Assisted Language Instruction", *System* 13 (2) 137-147.
- Jensen, K., G. E. Heidorn, L. A. Miller, and Y. Ravin, 1983, "Parse Fitting and Prose-Fixing: Getting a Hold on Ill-Formedness", *American Journal of Computational Linguistics* 9 (3-4) 147-160.
- Kohn, K., 1986, "The Analysis of Transfer", in E. Kellerman and M. Sharwood-Smith (eds.), *Crosslinguistic Influence and Second Language Acquisition*, Pergamon Press, Great Britain.
- Kwasny, S. C. and N. K. Sondheimer, 1981, "Relaxation Techniques for Parsing Grammatically Ill-formed Input in Natural Language Understanding Systems", *American Journal of Computational Linguistics* 7 (2) 99-108.
- Lado, R., 1957, *Linguistics Across Cultures*, University of Michigan Press, Ann Arbor.

LeCompagnon, B., 1984, "Interference and Overgeneralisation in Second Language Learning: The Acquisition of English Dative Verbs by Native Speakers of French", *Language Learning* 34(1) 39-67.

Leech, G. and C. Candlin (eds.), 1986, *Computers in English Language Teaching and Research*, Longman, USA.

Matthews, P. H., 1974, *Morphology*, Cambridge University Press, Great Britain.

Menzel, W., 1988, "Error Diagnosing and Selection in a Training System for Second Language Learning", *Proceedings of Coling 1988*, 414-419.

Nelson, G. E., J. R. Ward, S. H. Desch and R. Kaplow, 1976, "Two New Strategies for CALI", *Foreign Language Annals* 9(1) 28-37.

Newmeyer, F., 1983, *Grammatical Theory: Its Limits and Its Possibilities*, University of Chicago Press, Chicago.

Newmeyer, F., 1986, *Linguistic Theory in America* (second edition), Academic Press, USA.

Paramskas, D. M., 1985, "Artificial Intelligence in Computer-Assisted Language Instruction", *Canadian Modern Language Review* 42(3) 619-628.

Pereira, F. C. N., 1985, "A New Characterisation of Attachment Preferences", in D. R. Dowty, L. Karttunen and A. M. Zwicky (eds.), *Natural Language Parsing*, Cambridge University Press, USA.

Peterson, J. L., 1986, "A Note on Undetected Spelling Errors", *Communications of the ACM* 29(7) 633-637.

Phillips, M., 1985, "Intelligent CALI and the QWERTY Phenomenon: A Rationale", *System* 13(1) 1-8.

Pusack, J. P., 1983, "Answer-processing and Error Correction in Foreign Language CAI", *System* 11(1) 53-64.

Raskin, R., 1986, "The Quest for Style", *IEEE Transactions on Professional Communications* 29(3) 10-18.

Richards, J. C., 1971a, *Error Analysis and Second Language Strategies*, International Center for Research on Bilingualism, Les Presses de l'Université Laval, Québec.

Richards, J. C., 1971b, "A Noncontrastive Approach to Error Analysis", reprinted in B. W. Robinett and J. Schachter (eds.), *Second Language Learning: Contrastive Analysis, Error Analysis and Related Aspects*, University of Michigan Press, Ann Arbor.

- Richardson, S. D. and L. C. Braden-Harder, 1988, "The Experience of Developing a Large-scale Natural Language Text Processing System: CRITIQUE", *Proceedings of the Second Annual Conference on Applied Natural Language Processing* 195-202.
- Schuster, E., 1986, "The Role of Native Grammars in Correcting Errors in Second Language Learning", *Computational Intelligence* 2(2) 93-98.
- Schwind, C., 1988a, "Sensitive Parsing: Error Analysis and Explanation in an Intelligent Language Tutoring System", *Proceedings of Coling 1988*, 608-613.
- Schwind, C., 1988b, "An Intelligent Language Tutoring System", Centre National de la Recherche Scientifique, Marseille.
- Selinker, L., 1972, "Interlanguage", in B. W. Robinett and J. Schachter (eds.), *Second Language Learning: Contrastive Analysis, Error Analysis and Related Aspects*, University of Michigan Press, Ann Arbor.
- Shieber, S., 1983, "Sentence Disambiguation by a Shift-Reduce Parsing Technique", *Proceedings of the 21st Annual Meeting of the ACL*, 113-118.
- Shieber, S., 1986, *An Introduction to Unification-based Approaches to Grammar*, Center for the Study of Language and Information, Stanford, California.
- Singleton, M., 1981, *Language Transfer: A Review of some Recent Research*, Center for Language and Communication Studies, Trinity College, Dublin.
- Sleeman, D. and J. S. Brown (eds.), 1982, *Intelligent Tutoring Systems*, Academic Press, USA.
- Stowell, T., 1981, *The Origins of Phrase Structure*, Ph.D. dissertation, MIT.
- Swan, M., 1987, "German Speakers", in M. Swan and B. Smith (eds.), *Learner English: A Teacher's Guide to Interference and other Problems*, Cambridge University Press, Great Britain.
- Taylor, B., 1975, "The Use of Overgeneralisation and Transfer Learning Strategies by Elementary and Intermediate Students of ESL", *Language Learning* 25(1) 73-107.
- Wallraff, B., 1988, "The Literate Computer", *The Atlantic Monthly*, January 1988.
- Walter, C., 1987, "French Speakers", in M. Swan and B. Smith (eds.), *Learner English: A Teacher's Guide to Interference and other Problems*, Cambridge University Press, Great Britain.
- Wardaugh, R., 1970, "The Contrastive Analysis Hypothesis", *TESOL Quarterly* 4(2) 123-130.

Warren, D. H. and F. C. N. Pereira, 1980, "Definite Clause Grammars for Language Analysis—A Survey of the Formalism and a Comparison with Augmented Transition Networks", *Artificial Intelligence* 13 (3) 231–278.

Weinreich, U., 1953, *Languages in Contact: Findings and Problems*, Mouton, The Hague.

Weischedel, R. M., W. M. Voge and M. James, 1978, "An Artificial Intelligence Approach to Language Instruction", *Artificial Intelligence* 10 (3) 225–240.

Wenger, E., 1987, *AI and Tutoring Systems: Computational and Cognitive Approaches to the Communication of Knowledge*, Morgan Kaufmann, USA.

Winograd, T. 1972, *Understanding Natural Language*, Academic Press, New York.

Zobl, H., 1980, "The Formal and Developmental Selectivity of L1 Influence on L2 Acquisition", *Language Learning* 30 (1) 43–57.