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Automated Identification of Relative Clauses in Child Language Samples

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AUTOMATED IDENTIFICATION OF RELATIVE CLAUSES

IN CHILD LANGUAGE SAMPLES

by

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ABSTRACT

AUTOMATED IDENTIFICATION OF RELATIVE CLAUSES IN CHILD LANGUAGE SAMPLES

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Master of Science

Previously existing computer analysis programs have been unable to correctly identify many complex syntactic structures thus requiring further manual analysis by the clinician. Complex structures, including the relative clause, are of interest in child language samples due to the difference in development between children with and without language impairment. The purpose of this study was to assess the comparability of results from a new automated program, Cx, to results from manual identification of relative clauses. On language samples from 10 children with language impairment (LI), 10 language matched peers (LA), and 10 chronologically age matched peers (CA), a computerized analysis based on probabilities of sequences of grammatical markers agreed with a manual analysis with a Kappa of 0.88.

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Introduction

The ability to quantify and describe syntactic development is useful in the diagnosis of language impairment and in the assessment of progress toward language goals. As children's language becomes more complex, their utterances change from using a single verb to multiple verbs thus creating complex grammatical structures. One complex structure of note is the relative clause. Research suggests that children with language impairment develop relative clauses later, produce fewer relative clauses, and omit relative pronouns more often (Schuele & Dykes, 2005; Schuele & Tolbert, 2001). Relative clauses are somewhat rare even in longer language samples from typically developing children. Clinicians may lack the necessary time or the grammatical training to perform accurate analyses of complex grammatical constructions (Hux, Morris-Friehe, & Sanger, 1993; Kemp & Klee, 1997; Long, 1996).

Although computer software can make grammatical analysis faster (Long, 1991; Long & Fey, 1995), it can not identify complex grammatical structures or identify these structures accurately (Long & Channell, 2001). Computer programs do, however, work well for tagging individual words of an utterance such as nouns, verbs, and pronouns. Relative clauses are a grammatical structure of developmental interest, and a computerized program for accurately identifying relative clauses would be clinically preferable to manual isolation. Recently Channell (2008) created new software, called Cx, which uses combinations of word tags and parsed phrases taken from a bank of relative clauses to predict utterances that are likely to contain a relative clause. Cx may make it possible to isolate these complex structures automatically, but the software needs to be tested on a corpus of child language samples to determine whether the combinations of word tags and parsed phrases are general enough to detect relative clauses in samples from other children.

Review of Literature

The nature and development of relative clauses is discussed, as is software for the clinical analysis of syntax.

Relative Clauses

A relative clause is a complex grammatical structure formed when a finite clause post modifies a noun phrase (NP; Crystal 2004). For example, in the utterance *the cookie that you ate was chocolate* the relative clause is *that you ate.* Relative clauses begin with a relative pronoun such as *who, whose, or whom.* These relative pronouns refer to people, objects, or personified animals. *Which* is used in reference to objects, and *that* refers to objects or people. Relative clauses are used to restrict the antecedent NP or add information about the antecedent NP (Greenbaum, Quirk, Leech, & Svartvik, 1990). In the above sentence the relative clause restricts the antecedent NP by specifying that *the cookie* in the utterance is the cookie *that you ate*. Alternatively, in the utterance *Michael, who never liked ice cream, got an ice cream machine* the relative clause *who never liked ice cream* does not clarify which *Michael* but gives information about *Michael.*

Relative clauses can be categorized first by the position of the post modified noun in the sentence (subject or object) and second by whether the relativized noun phrase functions as the subject or object in the relative clause (Schuele & Nichols, 2000). Using these two classifications, relative clauses can be divided into four types as seen in Table 1. When the relativized noun phrase functions as an object (objective relative clauses), the relative pronoun is not needed in the surface structure of the utterance. Conversely, when the relativized noun phrase functions as the subject of the relative clause (subjective relative clauses), the relative pronoun is obligatory. Literature on the development of relative clauses in children with language impairment has been particularly interested in subjective relative clauses due to the obligatory relative pronoun.

Table 1

Categorization of Relative Clauses

Category	Example
SO	The cookie *(that) you ate*___ was chocolate.
OO	You ate the cookie *(that) I saw*___.
OS	You ate the cookie *that*___ *was chocolate*.
SS	The cookie *that*___ *was chocolate* broke.

Note. Relative clauses are categorized by (1) the position of the relative clause in the sentence, and (2) by function of the relativized noun phrase in the relative clause. O = object position; S = subject position. The italicized portion is the relative clause. ___ shows the subject or object position held by the relativized noun phrase.

The definition of a relative clause may differ slightly from author to author. Some use a similar definition as outlined in this paper, a finite clause post modifying a noun phrase, while others' definition may be more wide or narrow in scope. For example Hesketh (2006) included non-finite clauses, while Schuele and Dykes (2005) included nominal relative clauses. Because this difference in definition may influence outcomes, specific definitions used will be included throughout the review of literature.

The method used to elicit relative clause production may also affect the results of some sources. Methods used include conversation, narrative, and expository tasks. A recent study by Nippold, Mansfield, Billow, and Tomblin (2008) showed that expository discourse tasks may promote the use of a greater number of relative clauses even in those with language impairment. These authors explain that because expository discourse is used to convey information on numerous complex topics, the successful explanation requires more sophisticated language use. Due to these greater language demands, expository discourse tasks may necessitate the production of more complex language forms. Nippold et al. also found that expository tasks better differentiated between subjects with typical language and those with language impairment based on their use of relative clauses. Nippold et al. concluded that although expository tasks may be more useful in some areas, all three genres; conversational, narrative, and expository, are important to include in a thorough examination of syntactic development using language samples. The following sources use a combination of these three genres to examine the production of relative clauses.

Typical Development of Relative Clauses

Early research explored at what age children begin to spontaneously produce relative clauses (Limber, 1973; Hamburger & Crain, 1982), and what types of relative clauses develop first (Tyack & Gottsleben, 1986). Limber (1973) described relative clauses as being one of many complex structures that develop during the third year of life, but as his definition of a relative clause was not included, one does not know specifically what he would expect a three-year-old to produce. Tyack and Gottsleben (1986) explored at what mean length of utterance (MLU) complex structures begin to occur. Tyack and Gottsleben collected language samples from 110 children with typical language. Children with an MLU of 3.00-3.99 occasionally produced relative clauses (3% of all complex structures in the language sample; relative clauses defined according to the four classifications discussed previously), and children with an MLU between 4.00 and 5.99 produced relatives more often (4.1-5% of complex structures). Relative clauses modifying object NPs were more common than relative clauses modifying subject NPs. Ingram (1975) also found a higher frequency of relative clauses modifying an object NP.

Children can imitate relative clauses at about 3 years 5 months (Flynn & Lust, 1980). In a study of production and comprehension of relative clauses, three types of relative clauses were included: lexically headed relatives such as determinate head relatives (*Sally rolls the ball which bumps Tommy*), non-determinate head relatives (*Sally rolls the thing which hits Tommy*), and nonlexically headed relative clauses known as free relatives (*Sally rolled what pushes Tommy*). Flynn and Lust found free relatives to be more frequent during early periods of language development. In another study of young children, McKee, McDaniel, and Snedeker (1998) observed the production of relative clauses by 28 children age 2;2 (years; months) to 3;10. Using a broad definition of relative clauses which included reduced relatives, McKee et al. found that many children produced mainly what the researchers considered to be adult like relative clauses. Reduced relatives and free relatives were typically not included by most authors as a type of relative clause which may explain why other sources do not show consistent production of relative clauses in an elicitation task until about four years of age. In a study comparing the elicited use of relative clauses in children with and without language impairment, Schuele and Tolbert defined relative clauses as post modifying a noun phrase and as being classified according to sentinel position and focus (2001). Three-year-old children with typical language produced some relative clauses during an elicitation task, but four-year-old children produced relative clauses consistently.

The use of elicitation tasks has also been helpful in studying how children combine multiple clauses before the development of relative clauses (Ingram, 1975; Tager-Flusberg, 1982). Early strategies include combining information with a prepositional phrase and juxtaposition (*Michael never liked ice cream. Michael got an ice cream machine.*) Later coordination (*Michael never liked ice cream and Michael got an ice cream machine.*) is used more frequently. Children may also produce a construction referred to as a reduced relative. Reduced relatives contain a non-finite verb and do not contain a relative pronoun (*the man walking up the street has a dog,* instead of *the man that/who walked up the street has a dog*). Some do not consider reduced relatives to be a true example of embedding (Ingram 1975). Accordingly, reduced relatives were not included in the definition of a relative clause used for this study.

Children with typical language occasionally omit obligatory relative pronouns after the acquisition of relative clauses. In a study of 36 children, Tager-Flusberg attempted to get young children to produce restrictive relative clauses in order to examine their production of subject, and object relative clauses (1982). Four-year-old children omitted relative pronouns in 20% of obligatory contexts, and five-year-old subjects in 17% of obligatory contexts. As a whole, children did not produce many relative clauses in this study. Using a similar definition of a relative clause as used in this paper, Romaine (1984) reported similar results in children ages 6-10 from Scotland with 10% of obligatory relative markers omitted. Omissions were attributed to dialectical differences rather than a distinct developmental period in which relative markers are routinely omitted. Potts, Carlson, Cocking, and Copple (1979) found differences in the rate of relative pronoun omission due to dialect differences as well as socio-economic status. Out of three groups studied, middle-class white children were least likely to omit relative markers followed by lower-class white children. Lower-class black children omitted relative markers the most frequently.

McKee et al. (1998) analyzed the kinds of errors children age 2;2-3;10 made when producing relative clauses. Rather than omitting relative pronouns, the single error pattern found was the use of inappropriate relative pronouns (e.g. *pick those two up what the dinosaur is eating*). More recently, Schuele and Nichols (2000) studied the family of a child with language impairment. Children with typical language, ages three to five years, included the relative marker in all obligatory contexts. Similarly, 15 children with typical language included relative markers in Schuele and Tolbert's study in 2001. Children with typical language may occasionally omit relative pronouns, but existing research shows it does not represent a distinct period in the development of relative clauses.

Although the software used in this study was designed for use on child language samples, a brief overview of relative clause use by adolescents and adults may be helpful in understanding the development of relative clauses. Nippold, Hesketh, Duthie, and Mansfield (2005) used conversation and expository tasks to elicit the production of relative clauses in subjects age 7 to 49 with typically developing language. Relative clauses were defined as an embedded clause which acts like an adjective and modifies the noun that precedes it. The expository task yielded a greater number of relative clauses for every age group, and the use of relative clauses continued to increase through childhood to early adulthood (20 to 29) and remained stable into middle age (40 to 49). Additionally, Nippold et al. (2007) examined the use of complex language by subjects of ages 11, 17, and 25. During a peer conflict expository discourse task, 11-year-old subjects used an average of 5.11 relative clauses, 17-year-olds used 6.46 relative clauses, and 25-year-old subjects used 13.78 relative clauses on average showing, similarly to Nippold et al. (2005), that relative clause production continues to develop into early adulthood.

Development of Relative Clauses in Children with Language Impairment

The use of relative clauses in children with language impairment (LI) has been well documented. Schuele and Dykes (2005) examined the syntactic development of a child with specific language impairment (SLI) from age 3;3 to 7;10. The researchers documented the types, proportion, and errors in complex syntax across 12 language samples. The child with SLI produced relative clauses but omitted obligatory relative markers in all subjective relative clauses and less frequently in nominal relative clauses.

In a longitudinal familial case study, Schuele and Nicholls (2000) also observed the omission of relative markers in obligatory contexts by children with SLI. During a language sample and elicitation tasks, three children in the family identified with SLI omitted relative markers in subjective relative clauses. Only one of five children with a negative clinical history of language impairment omitted relative markers. Similarly, Schuele and Tolbert (2001) found that five to seven year old children with SLI omitted the relative marker from subjective relative clauses in 63% of attempts. Children with typical language, ages three to five years, included the relative marker in all obligatory contexts.

In contrast, the omission of relative markers was rare in a study by Hesketh (2006) of 66 children (age 6;0-11;11) from the United Kingdom with language impairment. Children more commonly produced reduced relative clauses. Although the study did not demonstrate a distinct pattern of omission of relative markers as previously shown, omissions were not uncommon. Differences found may have been due to differences in age, elicitation method, sampled population, or dialect.

Not all children with language impairment omit relative markers, and relative markers are not omitted solely by children with language impairment (Romaine, 1984; Tager-Flusberg, 1982). Relative pronouns are however omitted more often and at a later age than in children with typical language. Some children with language impairment may also produce a greater proportion of reduced relatives (Hesketh 2006).

Children with language impairment may also develop relative clauses later than children with typically developing language (Schuele & Nicholls, 2000). One study followed the development of a child with language impairment from age three to age seven. Relative clauses were not produced consistently until age 5;9 (Schuele & Dykes, 2005) unlike children with typical language, who use relative clauses at about three years of age and consistently by four years of age (Schuele & Tolbert, 2001; Tyack & Gottsleben, 1986).

Once the production of relative clauses is established in children with language impairment, these productions may not be as frequent as in children with typical language. Marrionellie (2004) studied the syntactic development of 10-year-old children in a conversation task. Out of 30 subjects 15 had language impairment and 15 had typical language. In a count of both restrictive and non restrictive relative clauses, children with language impairment produced an average of 2.86 relative clauses while children with typical language produced an average of 5.2 relative clauses. The researchers also wanted to examine the density of complex syntactic elements. These included relative clauses as well as many other complex structures. The group with language impairment produced fewer complex sentences and had lower levels of clausal density than the group with typical language. Bishop and Donlan (2005) found similar results in a narrative task with 7 to 9 year old children, but the results were presented in terms of dependent clauses without data on relative clauses reported separately.

For those with language impairment, difficulty producing relative clauses may continue into adolescence. Nippold et al. (2008) examined the use of relative clauses by adolescents age 12;10 to 15;5 years of age. The authors defined a relative clause simply as describing a noun. On a conversation task, no group differences were noted, but in an expository task the group with typical language development produced more relative clauses than the group with nonspecific language impairment.

Analysis of Relative Clauses

Clinical analyses of child language samples have long noted the presence of relative clauses. Relative clauses are awarded 6 points under the *Personal Pronouns* category of Developmental Sentence Scoring (DSS; Lee, 1974). Bloom and Lahey (1978), in their *Content/Form* analysis, assigned relative clauses to phase 8 under the *Specifier* category. Paul (1981) also included relative clauses in her analysis of complex grammatical structures, and the Language Assessment Remediation and Screening Procedure (LARSP; Crystal, Garman, & Fletcher, 1989) indicates relative clauses in stage V under the category *Postmodifying Clauses*. Lastly, the Index of Productive

Syntax procedure (IPSyn) by Scarborough (1990) included relative clauses among the 56 grammatical items noted.

All of the above-mentioned procedures require a skilled clinician to examine language samples and isolate relative clauses. Previously existing automated analyses such as MLU have not been able to predict the emergence of relative clause production because they merely calculate the probability of occurrence for a specific syntactic structure in an utterance. Information such as prosody, context, and meaning facilitates the human analysis of complex structures. However, such information is unavailable to software.

Automated analysis of syntactic structures has been limited beyond the analysis of word classes and morphemes. *Systematic Analysis of Language Transcripts* software (SALT; Miller & Chapman, 2004) extracts many measures from language transcripts such as MLU, type-token ratio, frequency of morphemes, use of morphemes, mazes and others. For these measures to be calculated, transcripts must contain slash characters used to code specific morphemes and brackets used for time and error information. SALT includes norms and even a Spanish version, but does not perform phrase- or clause-level analysis.

Another computerized program, *Child Language Analysis* software (CLAN; MacWhinney, 2000), includes many different tools for language transcript analysis. Although it still performs MLU, CLAN also calculates frequency counts of many items and *Measure D* (Malvern & Richards, 1997). It grammatically codes words using the *MOR* and *POST* tools, and even computes a DSS analysis. No data are available on the accuracy of this automated DSS analysis, but the authors stated it is necessary to edit the analysis manually. Sagae, Lavie, and MacWhinney (2005) created a program to calculate an overall IPSyn score that closely agrees with manual coding. Relative clauses are included in the IPSyn score, but accuracy on the identification of individual grammatical structures was not specified.

Computerized Profiling software (CP; Long, Fey, & Channell, 2003) combines many of the previously mentioned analysis. CP calculates LARSP, DSS, and IPSyn. Data are not available for CP's accuracy in coding relative clauses and other specific structures found in LARSP, but coding of the Subclause level in LARSP was found to be poor (15%; Long & Channell, 2001). Channell (2003) also found CP's analyses of the personal pronoun category in DSS which includes relative pronouns to be poor (32%).

Thus, relative clauses are a grammatical structure of clinical importance due to the difference in development and use in children with typical language as opposed to those with language impairment. Manual isolation of relative clauses is possible but time consuming. Existing computer analyses cannot identify complex syntactic structures with sufficient accuracy to be an acceptable alternative to manual isolation because they do not have access to the world knowledge and prosody humans use in the identification of complex structures. Analyses which computers are capable of performing such as word tagging and partial parsing may be combined to form a new computer program. Such a program would be able to predict the occurrence of relative clauses. Therefore, the present study is concerned with whether Cx, which incorporates combinations of grammatical markers and parsed phrases, can suggest the presence of relative clauses with accuracy approaching manual identification, making computerized identification of relative clauses a feasible alternative.

Method

Participants

Thirty child language samples collected in Reno, Nevada by Fujiki, Brinton, and Sonnenberg (1990) were used in this study. Participants included 10 children with language impairment (LI), 10 children matched for chronological age (CA), and 10 children matched for language (LA). Children in the group with LI were between the ages of 7;6 and 11;1. Children with language impairment were receiving language services from a speech-language pathologist at their school. To be included in the language impaired group, children scored one standard deviation or more below the mean on two standardized tests, showing deficits in comprehension and production. Tests included the Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981) the Test for Auditory Comprehension of Language-Revised (TACL-R; Carrow-Woolforlk, 1985), and subtests taken from the Test of Language Development-Primary (TOLD-P; Newcomer & Hammill, 1982) as well as the Clinical Evaluation of Language Functions Screening Test (Semel & Wiig, 1980). LA children ranged from 5;6 to 8;4 years. They were given the Utah Test of Language Development (Mecham, Jex, & Jones, 1967), and matched by a language age score within 6 months of the impaired child's language performance. CA children (7;6-11;2) were recruited from the same elementary school as their match with LI and were within 4 months of age. None of the children had a history of cognitive, hearing, neurological, or severe articulation impairment. Language samples lasted approximately 30 minutes. Samples were elicited using a variety of toys (View Master, the Guess Who game, Transformers, and a magic kit), and by introducing familiar conversation topics (favorite movies, favorite television programs, and Christmas vacation). Samples consisted of primarily conversation, but also included some elements of narrative and discourse tasks. Descriptive data are presented in Table 2. Language samples contained between 178 and 611 utterances. Results in Table 2 show that MLU ranged from 4.03 to 8.04 with an average of 5.91 (*SD* = 0.97). DSS scores computed by the CP software ranged from 4.27 to 10.85 with an average of 7.94 (*SD* = 1.63).

Software

Language samples were first formatted according to SALT specifications (Miller & Chapman, 2004). Once entered in to a SALT file, Cx uses combinations of word tags and partial parsing taken from existing language samples to identify c-units likely to contain a relative clause. This software requires a Windows XP or Macintosh System 10.4 operating system and may be obtained from its author at no cost.

Procedure

For this study, transcripts were formatted according to SALT specifications and utterances were divided into c-units. The researchers then scanned all c-units for relative clauses. Language samples were also scanned for noun clauses and adverb clauses, two complex structures often confused with relative clauses during manual analysis, to see whether the software would falsely identify these similar structures as relative clauses.

Manual relative clause identification data were collected in two ways: first, the total number of relative clauses manually identified, and second, the number of utterances found to contain one or more relative clauses. Child language samples yielded 385 total relative clauses or 357 c-units containing a relative clause when manually scanned. Since Cx identifies c-units which probably contain a relative clause, the second method of counting was chosen for all further analyses because it more closely resembles how Cx functions.

Table 2

Descriptive Statistics for the Reno Samples

Child	Gender	Age	N Utterances	MLU	DSS
LI 1	F	9;3	244	5.18	6.30
LI 2	F	7;6	459	5.67	8.46
LI 3	M	9;3	178	4.36	4.27
LI 4	F	8;8	300	5.23	7.30
LI 5	F	8;8	453	5.64	8.50
LI 6	F	9;5	365	5.66	8.22
LI 7	M	9;11	611	5.94	8.41
LI 8	M	11;1	475	5.39	6.88
LI 9	M	8;8	253	4.73	5.64
LI 10	M	9;1	253	4.03	4.59
LA 1	F	7;7	336	5.61	9.07
LA 2	F	7;4	231	5.62	6.08
LA 3	M	7;11	300	7.18	10.85
LA 4	F	5;6	320	5.38	7.05
LA 5	M	6;10	273	5.70	7.01
LA 6	F	8;4	497	6.20	9.40
LA 7	M	5;9	356	4.76	7.67
LA 8	M	6;5	312	5.00	6.51
LA 9	M	6;11	491	5.00	7.59
LA 10	F	7;0	363	6.43	7.12
CA 1	F	7;6	442	6.32	8.15
CA 2	M	9;0	356	7.28	9.48
CA 3	F	8;10	460	5.63	7.85
CA 4	M	8;4	468	6.79	8.32
CA 5	M	10;2	337	6.34	8.86
CA 6	F	9;2	481	8.04	10.61
CA 7	F	8;10	349	7.26	9.31
CA 8	M	8;8	398	7.01	8.84
CA 9	M	11;2	309	6.64	9.11
CA 10	F	9;2	346	7.34	10.66

Reliability

In order to obtain a measure of reliability for manually identifying relative clauses, a second observer independently coded 13% of the samples yielding a point-to-point agreement of 98.45%. To control for chance agreement between judges, Kappa was tabulated for the data and found to be .892.

Results

The number of relative clauses identified in the language samples by group is shown in Table 3. Kappa values for each subgroup are also found in Table 3. These values were 0.7658 for the group with language impairment, 0.8899 for the children matched by language, 0.911 for children matched by chronological age, and 0.8843 overall.

Table 3

Manual and Computer Identified Relative Clauses

	Number of Relative Clauses		
Group	Manual[a]	Cx[a]	Kappa[b]
LI	51	53	0.77
LA	92	85	0.89
CA	214	201	0.91
Total	357	339	0.88

[a] the number of utterances identified as containing one or more relative clauses. [b]calculated between Manual and Cx identified relative clauses.

In a one way ANOVA, groups differed in terms of the number of utterances manually identified containing one or more relative clauses $F(2, 27) = 8.62$, $\eta^2 = .390$, $p = .001$ and the identification of relative clauses by Cx $F(2, 27) = 8.05$, $\eta^2 = .374$, $p = .002$. Subsequent Newman-Keuls analyses on computer and manual counts of relative clauses showed the CA group differed from the other two groups. The group with LI and the LA matched group did not differ. Thus, the CA matched children produced consistently more relative clauses.

Table 4 shows the levels of point to point agreement between manual analysis and Cx analysis for each subject. The categories used to calculate point to point agreement are included: agreements of the presence and absence of a relative clause in a c-unit, manually identified relative clauses not identified by Cx, and relative clauses identified by Cx and not by manual analysis. Notice that several children in the group with LI produced few or no relative clauses. Kappa is also presented in Table 4 when the data met the required assumptions. Finally, when the number of relative clauses identified by automated computer analysis was compared with the number obtained by manual analysis, a Pearsons' correlation of $r = .990$ was obtained.

Discussion

In this study the Cx software was used to identify relative clauses in child language samples achieving accuracy similar to manual coding. Although imperfect, it offers the only accuracy data on automated relative clause identification. To date, published data have shown poor accuracy in the identification of sub-clausal elements. Long and Channell (2001) found accuracy on the sub-clause line of LARSP to be about 15%. Channell (2003) achieved 32% accuracy in the category of DSS which includes relative pronouns.

Table 4

Point to Point and Kappa by Subject

Child	a	b	c	d	Point to Point	Kappa
LI 1	0	0	0	244	1.00	NC
LI 2	14	1	2	442	0.99	0.90
LI 3	0	0	0	178	1.00	NC
LI 4	0	0	0	300	1.00	NC
LI 5	8	4	1	440	0.99	0.76
LI 6	6	3	0	356	0.99	0.80
LI 7	10	4	7	590	0.98	0.64
LI 8	0	1	1	473	1.00	NC
LI 9	2	0	0	251	1.00	1.00
LI 10	0	0	0	253	1.00	NC
LA 1	9	2	1	324	0.99	0.85
LA 2	7	0	0	224	1.00	1.00
LA 3	14	0	3	283	0.99	0.90
LA 4	15	0	0	305	1.00	1.00
LA 5	4	0	1	268	1.00	0.89
LA 6	7	1	2	487	0.99	0.82
LA 7	9	2	2	343	0.99	0.81
LA 8	0	0	2	310	0.99	NC
LA 9	11	1	1	478	1.00	0.91
LA 10	3	0	1	359	1.00	0.86
CA 1	14	0	1	427	1.00	0.96
CA 2	25	2	1	328	0.99	0.94
CA 3	5	1	1	453	1.00	0.83
CA 4	32	2	5	429	0.99	0.89
CA 5	11	0	1	325	1.00	0.96
CA 6	43	2	4	432	0.99	0.93
CA 7	6	3	1	339	0.99	0.74
CA 8	26	0	4	368	0.99	0.92
CA 9	9	1	4	295	0.98	0.77
CA 10	19	0	2	325	0.99	0.95

Note. NC indicates Kappa could not be calculated because data did not meet the required assumptions.
a = agreement on the presence of a relative clause in a c-unit. b = relative clauses identified by Cx and not by manual analysis. c = manually identified relative clauses not identified by Cx.
d = agreement on the absence of a relative clause in a c-unit.

Limitations

Examination of utterances where Cx either falsely identified, or missed a relative clause, reveals several patterns. Cx did not perform as well on relative clauses without a relative pronoun whether it was obligatory (*We have one person could be the bad guy*) or not (*That is the only ones I could remember*). Since children with language impairment are more likely than typically developing children to omit relative markers even when they are obligatory (Schuele & Dykes, 2005; Schuele & Nicholls, 2000; Schuele & Tolbert, 2001), the software was not as accurate for the group of children with LI.

The initial manual coding did not count relative clauses found in incomplete utterances but Cx did, creating one source of differences. Furthermore, some utterances require either world knowledge or knowledge of utterance context to decide whether a relative clause is present. Because computers do not have access to this information, it is likely impossible that computer software could be 100% accurate in identifying subclausal elements. Current accuracy of word and phrase coding may also have affected the accuracy of identifying relative clauses. Even when a rule used by Cx is correct, if the individual words or phrases are coded incorrectly by the software, a relative clause may be wrongly identified or missed. Long and Channell (2001) explained that many errors in CP's higher level analysis could have been due to errors in the word level analysis done by *GramCats.* According to Channell and Johnson (1999) *GramCats* analyzes individual words with 95.1% accuracy. Because Cx uses similar software to code individual words and phrases, some errors in relative clause identification could be attributed to mistakes in word and phrase coding.

Advantages

The researchers also questioned whether software based on the probability of combinations of word tags and partial parsing, which signal the presence of a relative clause, would break down when confronted with large amounts of complexity. Cx did not break down because of complexity, but performed the most accurately on samples from the chronologically age matched group which had the greatest levels of complexity and embedding.

Researchers hypothesized that because relative clauses are often confused with noun clauses or adverb clauses during manual coding, Cx might also have difficulty distinguishing between these forms. Confusion between relative clauses and noun or adverb clauses was not found to be an error pattern exhibited by Cx.

Although computer identification missed and wrongly identified some relative clauses, it produced a similar number of utterances containing a relative clause even for children with language impairement as seen in the high point-by-point agreement values. Another benefit to this automated software is that unlike manual raters, it does not feel the effects of fatigue and therefore identified many relative clauses overlooked during manual analyses. Furthermore, Cx does not require the large time investment of learning how to identify relative clauses and manually scanning each language sample.

Future Research

Cx has not been tested on culturally or linguistically diverse populations. The effects of differing dialects on the accuracy of computerized identification of relative clauses is unknown, thus Cx may not be appropriate for, or accurate in, identifying relative clauses in language samples from culturally or linguistically diverse children. Future research should use Cx on language samples from culturally and linguistically diverse populations and find ways to adapt the software to these populations. Additionally, Cx successfully handled the complexity of children's language in the chronologically age matched group of this study (age 7;6-11;2), but it is unknown if the additional complexity of adolescent and adult language would affect the accuracy of Cx's identification of relative clauses. Future research needs to include an older age range of participants. Lastly, in order to make the Cx software clinically useful it needs include not only an analysis of relative clauses but other complex grammatical structures as well. For example, Nippold et al. (2008) included adverb and nominal clauses in their examination of syntactic development. Perhaps the approach used by Cx in identifying relative clauses could be extended to these additional complex structures.

Conclusion

The analysis of complex grammatical structures has been recognized as a tool in the assessment of child language. Many accept the value of language sampling, but actual implementation of complex grammatical analysis is less prevalent (Hux, Morris-Friehe, & Sanger, 1993; Kemp & Klee, 1997). Factors such as time, resources, and clinical training may limit the practical value of manual analysis. The use of computer technology can reduce or eliminate some of the difficulties associated with manual language sampling. Current findings show that while Cx missed some relative clauses because of a lack of world knowledge, it also found several relative clauses that human coders had initially missed due to fatigue or a slip in attention. While analyzing each sample manually was time consuming, Cx's analyses were nearly instantaneous and identified a similar number of relative clauses, allowing a similar differentiation among groups. Thus, Cx offers potential to be a useful part of the automated analysis of language samples.

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