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Automated Identification of Relative Clauses in Child Language Samples

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ABSTRACT

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Relative clauses are grammatical constructions that are of relevance in both typical and impaired language development. Thus, the accurate identification of these structures in child language samples is clinically important. In recent years, computer software has been used to assist in the automated analysis of clinical language samples. However, this software has had only limited success when attempting to identify relative clauses. The present study explores the development and clinical importance of relative clauses and investigates the accuracy of the software used for automated identification of these structures.

Two separate collections of language samples were used. The first collection included 10 children with language impairment, ranging in age from 7;6 to 11;1 (years;months), 10 age-matched peers, and 10 language-matched peers. A second collection contained 30 children considered to have typical speech and language skills and who ranged in age from 2;6 to 7;11.

Language samples were manually coded for the presence of relative clauses (including those containing a relative pronoun, those without a relative pronoun and reduced relative clauses). These samples were then tagged using computer software and finally tabulated and compared for accuracy. ANACOVA revealed a significant difference in the frequency of relative clauses containing a relative pronoun but not for those without a relative pronoun nor for reduce relative clauses. None of the structures were significantly correlated with age; however, frequencies of both relative clauses with and without relative pronouns were correlated with mean length of utterance. Kappa levels revealed that agreement between manual and automated coding was relatively high for each relative clause type and highest for relative clauses containing relative pronouns.

Keywords: relative clause, automated analysis, language samples

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Description of Structure and Content

The body of this thesis is written as a manuscript suitable for submission to a peer-reviewed journal in speech-language pathology. An annotated bibliography is presented in the Appendix.

Introduction

One important aspect of language analysis is the identification and quantification of complex grammatical structures. The appearance of such structures can be an indication of the speaker's expressive language ability as a whole, and can be an important component of clinical diagnostic and therapeutic methods (Paul, 1981). The rate of development and production patterns of one complex grammatical structure, the relative clause, is quite different for individuals with typical language development as compared to those with language impairment (LI; Schuele & Tolbert, 2001). These unique patterns make the identification of the relative clause clinically relevant. Of course, the identification of relative clauses and other complex grammatical structures is dependent on the accurate analysis of the language sample to which they belong. Unfortunately, this analysis is often time consuming and yields variable accuracy levels depending on the clinician's proficiency in such analysis (Long, 2001). In recent years, automated analysis has been used to identify grammatical structures found within collected language samples. Motivation behind the development of computerized analysis includes the achievement of fewer tabulation errors and reduced clinician time spent. While past studies have found these automated systems to be much faster than analyses done by hand, they do not consistently label complex grammatical structures (Long & Channell, 2001). Thus, further research regarding the automated identification of complex grammatical structures, such as the relative clause, is warranted.

To better understand the importance of this grammatical structure, a relative clause will be appropriately defined and broken up into categorical subparts. Relative clauses are formed when a subordinate clause post modifies a noun or a noun phrase (NP; Diessel & Tomasello, 2000). Their purpose is to either restrict or add information to the NP they follow (Greenbaum, Quirk, Leech, & Svartvik, 1990). For example, in the sentence *The jacket that you wore was purple* the relative clause is *that you wore.* This sentence is an example of a relative clause restricting the preceding NP as it specifies that *the jacket* in the sentence is the jacket *that you wore*. In the sentence *Craig, who is afraid of heights, walked past the diving board* the relative clause *who is afraid of heights* does not clarify which *Craig* but rather gives information about him (Michaelis, 2009).

When the relativized NP functions as the subject of the relative clause, a relative pronoun is required. Commonly used relative pronouns include *which, who, whose, whom*, and *that*. Those beginning with w*hich* refer to objects while those beginning with *who, whose, whom,* or *that* refer to people or objects. Because subject relative clauses require the use of an obligatory relative pronoun, it is relatively easy to note when that marker is omitted. For this reason, subject relative clauses have been the focus of several investigations pertaining to the acquisition and production of relative clauses.

Children with typical language development generally begin using relative clauses in spontaneous language around three years of age (Limber, 1973; Tyack & Gottsleben, 1986) and show consistent use in elicitation tasks by the age of four (Hamburger & Crain, 1982). Research shows that the production of relative clauses begins when the child has obtained a mean length of utterance (MLU) of approximately 4.0 (Paul, 1981; Tyack & Gottsleben, 1986). In the early stages of acquisition, children with typical language development most commonly use relative clauses to modify object NPs as opposed to those modifying subject NPs (Ingram, 1975; Tyack & Gottsleben, 1986). While the omission of obligatory markers for those with typical language development is found to be relatively low, one error pattern found during the early stages of acquisition is the use of inappropriate relative pronouns (e.g., *the spider what was crawling up the tree*; McKee, 1998).

Children with LI begin using relative clauses somewhat later than those with typical language development. Schuele and Nichols (2000) found that children with specific language impairment (SLI) first attempted relative clauses as late as 5 or 6 years of age and with an MLU of approximately 3.5. This is roughly two years later than children with typical language development. In addition to later acquisition, children with SLI display unique error patterns in the production of relative clauses. Past research indicates that the omission of obligatory relative markers is a recognizable stage in the development of SLI but not in typical language development (Schuele & Dykes, 2005). These children typically experienced a stage of omission, followed by inconsistent use, and finally consistent use of obligatory markers. The process from omission to consistent use is estimated to take approximately two years in total (Schuele and Nichols, 2000). Further evidence that the omission of obligatory markers is characteristic of children with SLI was found in a study by Schuele and Tolbert (2001). This study indicated that only 9% of 5-year-old children with SLI included the obligatory relative marker, while those in the 6-year-old group included the markers 38% of the time, and those in the 7-year-old group included them 49% of the time. Comparatively, age-matched peers with typical language development included a relative marker in every attempt. While this experiment suggests that like those with typical language development an increase of complex syntax types emerges when the speaker matures, it also demonstrates that this syntactic maturity is achieved much later for individuals with SLI and errors within embedded grammatical features persist. Other errors include the omission of complementizers, the infinitive *to*, and WH pronouns (Schuele & Dykes, 2005). In addition, an experiment conducted by Marinellie (2004) found that children with SLI used fewer complex sentence structures, fewer combined sentence structures, and exhibited fewer clauses per utterance in child-adult conversation than those children with typical language development.

Other researchers have also examined relative clause development. Hesketh (2006) examined the ways in which children with LI in the United Kingdom (UK) acquire and produce relative clauses. Her findings indicated that rather than omitting obligatory relative markers, the participants with LI in her study commonly used the 'reduced relative' construction in which the relative clause contains a non-finite verb and no relative pronoun (e.g., *the woman living next door has a Dachshund*). However, Hesketh notes that the occurrence of reduced relatives is generally much higher in UK English versus US English and suspects dialectal variation might be one reason for the large discrepancy between her study and those conducted in the US. Nippold et al. (2005) were also interested in complex grammatical structures such as the relative clause and queried whether the method of collection influenced the amount of syntactic complexities found within a language sample. Their results indicated that for every age tested, expository tasks yielded more complex syntactical output (including relative clauses) as compared to conversational tasks.

Thorough analysis of clinical language samples is necessary in order to accurately label complex grammatical structures. However, such analyses are often painstakingly time consuming for clinicians who may or may not be well-versed in grammatical analysis protocol (Long, 2001). The need for quicker, more accurate output has prompted the use of automated analysis in recent research. Unfortunately, the results of such studies have shown low accuracy ratings in the identification of complex grammatical structures. For example, in a study conducted by Long and Channell (2001), only a 12% accuracy rating was achieved in the identification of subordinate clauses when using Computerized Profiling (CP) software. Furthermore, Channell's (2003) study of automated DSS analysis yielded an agreement average of only 40% when comparing automated to manual analysis on the categories including relative clauses. A study conducted by Michaelis (2009) investigated the accuracy of identifying relative clauses via an automated system and compared these to manually coded samples. Results indicated comparable accuracy ratings to that of manually coded samples and at a much quicker pace. However, the automated program commonly missed relative clauses that did not include a relative pronoun.

The implementation of a newly available automated parsing program, the Stanford parser (Klein & Manning, 2003) might improve the accuracy of computerized language sample analysis. The Stanford parser uses a probabilistic context-free grammar model to analyze syntactic structures. Because this parser does not directly label constructions such as the relative clauses, the output of the Stanford parser requires interpretation by another program which would then identify specific, complex grammatical structures.

Thus, the identification of relative clauses in clinical language samples is important diagnostically and for the development and management of language goals. Due to the time demand this analysis puts on clinicians, exploration for faster and more accurate methods of analysis is warranted. While earlier systems of automated analysis have had limited success identifying complex grammatical structures, the development of new software coupled with an improved parsing program may yield promising results. That aim is the focus of the present study.

Method

Language Samples

The language samples used in this study were collected by previous researchers for work unrelated to this study.

Reno samples. This collection of language samples was obtained by Fujiki, Brinton, and Sonnenberg in 1990 for a study investigating conversational repair in children with LI. These samples include those of 30 children and will hereafter be referred to as the Reno samples.

The Reno Samples were collected from 10 children with LI, 10 children matched for language age (LA), and 10 children matched for chronological age (CA). Each group included five males and five females. Children with LI ranged in age from 7;6 to 11;1, CA-matched children ranged in age from 7;6 to 11;2, and LA-matched children ranged in age from 5;6 to 8;4.

The children with LI were receiving speech and language services at the time of collection and had been since the first grade. In addition, a disabilities specialist worked with each child for issues pertaining to their communication disorder. None of the participants showed signs of intellectual impairment and scored within normal limits on nonverbal intelligence assessments. The diagnosis of LI was based on significant expressive and receptive language delays. Receptively, each participant scored below one standard deviation of the mean on two or more of the following tests: Peabody Picture Vocabulary Test-Revised (Dunn & Dunn, 1981), the Test for Auditory Comprehension of Language-Revised (Carrow-Woolfolk, 1985), select subtests from the Test of Language Development-Primary (TOLD-P; Newcomer & Hammill, 1982), and the Clinical Evaluation of Language Functions Screening Test (CELF-S; Semel & Wiig, 1980). Expressive delays were determined using subtests from the TOLD-P and CELF-S and the Clinical Evaluation of Language Functions-Diagnostic Battery (Semel-Mintz &

Wiig, 1982). LA-matched children were selected based on scores obtained from the Utah Test of Language Development (Mecham, Jex, & Jones, 1967). CA-matched children were selected to be within four months of age to a child with LI.

Language samples were collected via a 30 minute conversation with an adult examiner who introduced topics the child might find interesting (e.g., movies, vacation). In addition, several games and toys were used to elicit conversation, including Viewmasters, the *Guess Who* game, Transformer toys, and a magic kit. Two hundred to 600 utterances were collected from each child.

Provo samples. The Provo samples were collected by Barber (1989), Chamberlain (1989), and Taylor (1989) as part of three separate theses. The participants ranged in age from 2;6 to 7;11 years and were all judged to be of typical development. Each participant lived in a student family housing complex at Brigham Young University in Provo, Utah and was randomly selected from a pool of volunteers. Three children from each six-month age interval participated in a child-adult conversation where a language sample of at least 200 child utterances was collected. In order to obtain a sample most representative of the child's language capabilities, the first ten minutes of each sample was omitted.

Procedure

All relative clauses found within the language samples were manually coded and divided into subcategories for tabulation: relative clauses with a relative pronoun (RC), relative clauses with no overt relative pronoun (sometimes referred to as zero relative clauses; ZRC), and reduced relative clauses (RRC). To ensure interrater reliability, a second clinician independently coded relative clauses in 20% of the samples. The number of classification agreements was divided by total classification judgments and yielded an interrater reliability of 90%.

Next, in preparation for automated analysis, each sample was entered into a utility program which removed extraneous details including speaker codes, manual codes, utterances not produced by the participant, and parenthetical material. These files were then analyzed by the Stanford parser (Klein & Manning, 2003), a probabilistic context-free grammatical parser. This program isolates grammatical components using data extracted from training corpora. The output from the Stanford parser was then examined for utterances containing relative clauses using software called *cxs* (Channell, 2008). The cxs software was written as part of the current study and for the purposes of this study was used to locate patterns found within the Stanford parser's output. The cxs program's analysis was then compared to the manually coded samples in terms of the number and type of relative clauses found in each.

The data from both the manual and automated analysis were assigned to four categories: (a) utterances identified as containing a relative clause by manual analysis only, (b) utterances identified as containing a relative clause by software analysis only, (c) utterances identified as containing a relative clause by both manual and software analysis, and (d) utterances identified as containing no relative clauses by both manual and software analysis.

Cohen's Kappa levels were calculated for each group of participants to quantify manual to computer agreement while controlling for the possibility of chance agreement. An alpha level of $p < .05$ was used for all statistical comparisons.

Results

Findings regarding the use of relative clauses by children with language impairment and by typically developing children as well as findings regarding the accuracy of automated recognition of relative clauses are presented below.

Children's Use of Relative Clauses

Reno Samples. Table 1 shows the frequency of occurrence for each type of relative clause found within the Reno language samples. This table shows how sample length and the number of relative clauses used varied greatly across participants. The type of clause most commonly used across groups was the relative clause containing a relative pronoun. The children matched for chronological age (CA) produced far more of these structures over all when compared to those in the language impairment (LI) and language age (LA) matched groups. In fact, children in the CA matched group produced a greater number of each type of relative clause, but only significantly so for relative clauses containing a relative pronoun.

Table 2 shows a summary of the descriptive statistics for the Reno samples, organized by the relative clause type. This table shows that the standard deviations were sometimes higher or equal to the mean in many of the groups. This suggests that the mean was not a highly reliable indicator of group performance. A one-way ANOVA was used to compare the frequency of relative clause types among the three groups. This ANOVA indicates that the groups differed significantly on only one type of relative clause: the relative clause containing a relative pronoun, $F\ (2, 27) = 12.05$; $p < .0001$. Because of this significant difference, a posthoc Student-Newman-Keuls analysis was performed. This analysis showed that the RCA group differed from the RLI and RLA groups, which did not differ from each other.

The samples in the RCA group contained longer utterances and a greater number of relative clauses when compared to the two other groups. Because this could be a side effect of having longer utterances, an ANACOVA was performed to compare the three groups while controlling for the number of utterances. With this analysis, the difference of relative clauses containing a relative pronoun was significant between groups, $F\ (2, 26) = 10.61$; $p = .0001$.

Table 1

Descriptive statistics for the Reno Samples, including age in months, number of utterances and number of relative clauses with a relative pronoun (RC), relative clauses with no relative pronoun (ZRC), and reduced relative clauses (RRC)

Child	Age	N Utt.	RCP	ZRC	RRC
RLI 1	111	188	0	0	4
RLI 2	90	376	16	1	4
RLI 3	111	123	0	0	1
RLI 4	104	251	0	0	1
RLI 5	104	392	1	8	5
RLI 6	113	301	5	1	1
RLI 7	119	533	7	11	5
RLI 8	133	401	1	0	6
RLI 9	104	198	2	0	0
RLI 10	109	190	0	0	0
RLA 1	91	269	5	6	1
RLA 2	88	180	7	0	1
RLA 3	95	261	2	1	0
RLA 4	66	261	8	3	7
RLA 5	82	219	4	1	0
RLA 6	100	425	7	2	5
RLA 7	69	274	6	5	3
RLA 8	77	259	1	1	0
RLA 9	83	446	5	7	3
RLA 10	84	318	3	0	3
RCA 1	90	375	14	1	4
RCA 2	108	321	24	3	2
RCA 3	106	360	5	1	1
RCA 4	100	404	26	12	11
RCA 5	122	264	13	1	7
RCA 6	110	423	44	4	1
RCA 7	106	307	6	1	1
RCA 8	104	370	25	4	2
RCA 9	132	262	9	3	3
RCA 10	110	288	17	3	4

Table 2

Summary Statistics for the Reno Samples, including Means and Standard deviations of each group for relative clauses with a relative pronoun (RC), relative clauses with no relative pronoun (ZRC) , and reduced relative clauses (RRC)

Group		RC	ZRC	RRC
RLI				
	M	3.2	2.1	2.7
	SD	5.1	3.9	2.3
RLA				
	M	4.8	2.6	2.3
	SD	2.3	2.5	2.4
RCA				
	M	18.3	3.3	3.6
	SD	11.8	3.3	3.2

However, the groups did not differ on the frequency of relative clauses without relative pronouns nor on the frequency of reduced relative clauses.

Provo Samples. Table 3 shows the frequency of occurrence for each relative clause structure for each child in the Provo group.

Children from the Provo group varied greatly in numbers of utterances and occurrences of each relative clause type. Although the table is arranged according to age, no general pattern between age and frequency of relative clause structures can be observed. Because older children generally produced longer utterances, partial correlations were used to determine the relationship between age and frequency of relative clause structures while controlling for the number of utterances. These correlations are presented in Table 4 which shows that none of the relative clause structures were correlated with age.

Table 3

Descriptive Statistics for the Provo Samples, including age in months, number of utterances and number of relative clauses with a relative pronoun (RC), relative clauses with no relative pronoun (ZRC), and reduced relative clauses (RRC)

Child	Age	N Utt.	RC	ZRC	RRC
P1	30	190	0	0	0
P2	30	222	0	1	0
P3	33	193	0	0	0
P4	35	222	0	2	1
P5	37	232	1	0	0
P6	39	221	0	0	0
P7	45	238	1	0	2
P8	45	266	0	1	1
P9	46	206	0	0	0
P10	53	218	1	1	1
P11	56	214	1	0	0
P12	59	217	4	3	1
P13	59	259	0	0	1
P14	62	199	1	0	0
P15	62	216	0	0	0
P16	64	234	0	0	0
P17	65	226	0	2	0
P18	65	282	5	6	1
P19	66	230	0	1	0
P20	68	217	0	0	0
P21	69	377	8	3	2
P22	72	226	0	0	0
P23	75	249	1	9	1
P24	77	328	4	1	2
P25	79	225	1	2	0
P26	79	229	0	1	0
P27	84	258	1	1	0
P28	91	222	6	1	2
P29	94	301	5	2	2
P30	95	313	12	1	0

Table 4

Partial correlations between frequency of relative clauses with a relative pronoun (RC), relative clauses with no relative pronoun (ZRC), reduced relative clauses (RRC), and age, controlling for number of utterances (with df =27; 2-tailed)

	RC	ZRC	RRC
Correlation	.352	.135	-.050
Significance	.061	.484	.797

MLU may be a better indicator of syntactic complexity, therefore the relationship between the frequency of relative clause structures and MLU was also addressed. While still controlling for the number of utterances and using partial correlations, the values were obtained and presented in Table 5. Here it may be seen that the frequency of relative clauses containing a relative pronoun and relative clauses with no relative pronoun were significantly correlated with MLU.

Accuracy of Automated Analysis

The Kappa statistic, which relates the number of agreements between automated and manual analysis of both presence and absence of an item to the number of misses and false

Table 5

Partial correlations between frequency of relative clauses with a relative pronoun (RC), relative clauses with no relative pronoun (ZRC), reduced relative clauses (RRC), and MLU, controlling for number of utterances (with df =27; 2-tailed)

	RC	ZRC	RRC
Correlation	0.372	0.425	0.351
Significance	0.047*	0.021*	0.062

* $p < .05$

positives, was used to determine the level of accuracy for automated analyses of relative clause structures. The guidelines for Kappa interpretation published by Landis and Koch (1977) rate Kappas from .61 to .81 as *substantial* and .82 to 1.00 as *almost perfect* (Boslaugh & Watters, 2006). Kappa levels are presented in Table 6.

Table 6

Kappa levels for Reno children with language impairment (RLI), language-aged matched (RLA), chronological-aged matched (RCA), and Provo group for relative clauses with a relative pronoun (RC), relative clauses with no relative pronoun (ZRC), and reduced relative clauses (RRC)

	RC	ZRC	RRC
RLI	.841	.760	.599
RLA	.682	.786	.573
RCA	.829	.500	.624
Provo	.679	.681	.743

Examining the rates of sensitivity and specificity provide another indication of the accuracy of automated analyses of complex structures. For the current study, sensitivity refers to the likelihood that the software would identify a relative clause that had been identified through manual coding. Specificity refers to the likelihood that the computer software would identify a relative clause when manual analysis had not. The percentage rates for specificity and sensitivity of the automated analysis are presented in Table 7. Sensitivity and specificity rates averaged 83%.

Table 7

Sensitivity and Specificity percentage rates for the automated analysis of relative clauses with a relative pronoun (RC), relative clauses with no relative pronoun (ZRC), and reduced relative clauses (RRC) for Reno children with language impairment (RLI), language-aged matched (RLA), chronological-aged matched (RCA), and for the Provo group

	RC	ZRC	RRC
RLI			
Sensitivity	65	85	70
Specificity	99	99	99
RLA			
Sensitivity	68	88	34
Specificity	99	99	99
RCA			
Sensitivity	76	78	72
Specificity	99	99	99
Provo			
Sensitivity	51	68	41
Specificity	99	99	99

Discussion

The current study examined the frequency of three relative clause types found within two sets of clinical language samples. The frequencies of relative clauses in samples of children with LI were compared with those of children who were similar either in language test scores or in chronological age. In addition, the current study assessed the accuracy of an automated system of language analysis in terms of its ability to recognize these complex grammatical structures. A comparison of the frequency of relative clause types among the three Reno groups indicated that the group matched for CA produced significantly more relative clauses with relative pronouns than the LI and LA matched groups. However, the frequency of other relative clause types (those without relative pronouns and reduced relative clauses) did not differ significantly across groups. When inspecting the Provo language samples, partial correlations were used to determine the relationship between age and frequency of relative clause structures as well as MLU and frequency of clause structures. None of the relative clause structures were correlated with age, but the frequency of relative clauses containing a relative pronoun as well as the relative clauses with no relative pronoun was significantly correlated with MLU.

The accuracy of automated recognition of relative clauses was found to be variable but generally high in both sensitivity (identifying correctly when a relative clause was present in an utterance) and specificity (not falsely concluding that a relative clause was present).

The results of the present study can be compared with two similar studies recently conducted in which the frequency of noun clauses (Scoville, 2013) and adverbial clauses (Brown, 2013) was investigated using the same clinical language samples as the current study. In both studies, the frequency of key grammatical structures varied greatly across participants. Like relative clauses, a strong correlation was found between MLU levels and the production of key complex structures. In the case of particular noun clause types (zero-*that*-clauses and gerunds), the frequency of production was also correlated with age. Like the relative clause types, the production of these complex structures was sometimes quite sparse. The accuracy levels for the automated system of analysis of noun and adverbial clause types proved more variable than those of relative clause types. For instance, Kappa levels for three of the five noun clause types were considered at least *substantial* while the remaining two clause types were rated low. Likewise, only two of the adverbial clause types achieved Kappa levels in the *substantial* range or above. In all cases, a high average of sensitivity and specificity was achieved.

In addition, the current study adds to that of Michaelis (2009) who measured the accuracy of automated analysis in detecting relative clauses by using probability-based software. While the language samples used were the same as the current study, Michaelis did not differentiate between relative clause types (i.e. those containing relative pronouns, those without relative pronouns, and reduced relative clauses). In fact, reduced relative clauses were not accounted for at all in her investigation. While Michaelis found relatively high accuracy for the automated identification of relative clauses, the current study provides further information as to software's ability to detect specific varieties of this grammatical structure.

While there has been relatively little documented work on automated analysis to date, the findings of the current study can be compared to those of Long and Channell (2001) who found only a 12% accuracy rating in the identification of subordinate clauses using Computerized Profiling software, and Channell's (2003) study of automated DSS analysis which yielded an agreement average of only 40% when comparing automated to manual analysis on the categories including relative clauses. In comparison, the current study found a higher a level of performance of automated analysis for the identification of these grammatical structures.

The work of Schuele and Dykes (2005) suggests that an increase of complex syntax types emerge when the participant's MLU increases. The current study corroborates this claim as the frequency of relative clauses containing relative pronouns as well as those with no relative pronouns was found to be significantly correlated with MLU. Their study also found that children with LI produce fewer relative clauses than age-matched peers. The current study supports this notion as those matched for CA produced significantly more relative clauses containing relative pronouns than individuals with LI. One significant finding of Schuele and Tolbert (2001) is that the omission of obligatory relative markers is a characteristic of children with SLI. The current study did not address error patterns within groups; this topic could be of interest for future research involving the automated analysis of relative clauses.

Another area of interest might be the manner in which language samples are collected. The use of relative clauses was generally quite sparse across all language samples, but particularly so for those in which the child was engaged solely in conversational discourse, as in the Provo samples. The scarcity of relative clauses in some language samples might have contributed to lower levels of agreement between the automated system and manual coding, particularly in the cases of relative clauses with no relative pronoun and reduced relative clauses. Nippold et al. (2008) suggested that because expository tasks typically necessitate the use of complex grammatical structures, they may provide a better profile of a child's linguistic capabilities. Future studies might focus on using expository samples or use tasks that probe for specific complex structures. Such was the case in the study conducted by Schuele and Tolbert (2001). In this study, the authors chose tasks that would elicit the production of subject relative clauses because these elicited structures required the use of a relative pronoun and thus provided the researchers with the information sought. Perhaps the use of elicitation tasks or the use of expository discourse would yield a greater frequency of relative clauses and thus provide more information into the participant's true linguistic capabilities.

Another point of interest is whether the use of raw frequency data yields the best results when considering a child's grasp of complex grammatical structures. Bloom and Lahey (1978) looked at patterns of language development and language impairment and proposed the use of criteria of productivity and emergence, rather than frequency, to understand language development. The authors suggested that if a child used a construction two or three times in a sample, the structure was considered emerging. On the other hand, if the child used a construction four or more times, the construction was judged as productive. Once the construction was viewed as productive, additional uses were likely due to the nature of context, relevance, or stylistic choice rather than linguistic development. For this reason, future research may focus on re-analyzing the data based on a productivity criterion rather than on frequency counts.

While automated systems of language analysis are still a relatively new area of research, the present study illustrates new levels of accuracy for the automated identification of three relative clause types. Furthermore, new information regarding differences in the production of relative clauses between typically developing children and children with LI was uncovered. This study also provides information regarding age and MLU-related frequencies of relative clauses between two groups of children.

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Appendix: Annotated Bibliography

Bloom, L., & Lahey, M. (1978). *Language development and language disorders.* New York: Wiley.

This book provides an overview of child language development and impairment. In discussing clinical assessment, and particularly the evaluation of language samples, the authors question the use of frequency data in evaluating a child's expressive language abilities. They propose that other modes of criterion, such as emergence and productivity, might be a better measure of a child's grammatical repertoire. The ideas suggested in this book are of particular relevance to the current study and the use of emergence and productivity criterion are considered for future related research.

Brown, B. (2013). Automated identification of adverbial clauses in child language samples. (Master's thesis, Brigham Young University). Retrieved from http://contentdm.lib.byu.edu/cdm/singleitem/collection/ETD/id/3466

Like the current study, Brown investigated the accuracy of *cxs* in determining a particular complex grammatical structure. Using the same language samples, she explored the production of adverbial clauses across individuals varying in age and linguistic abilities. The results of her study revealed differences in frequencies of *so*-adverbial clauses as well as both types of finite adverbial clauses across groups. Like the results of the current study, none of the adverbial constructions were significantly correlated with age. However, frequencies of both types of finite adverbial clauses were correlated with mean length of utterance. Additionally, the Kappa levels in her study indicated the agreement between manual and automated coding was high on both types of finite adverbial clauses but less so for infinitive adverbial clauses. Brown's purpose, procedure and results are comparable to the current study and provide greater insight into the accuracy of automated language analysis at detecting complex grammatical structures.

Channell, R. W. (2003). Automated developmental sentence scoring using Computerized Profiling software. *American Journal of Speech-Language Pathology, 12*, 369-75.

In this study, Channell explores the accuracy of automated Developmental Sentence Scoring (DSS). In doing so, the author investigates specific parts of the automated analysis to discover the accuracy of each. Channell explains what DSS is, when it was established, how it operates, and reviews the perceived advantages and shortcomings of this scoring system to date. Computerized Profiling (CP) is the automated analysis software used in the current study and has been used by the author in past research. Based on previous use of CP, the author predicts that lower accuracy levels will be found when sampling older individuals with language impairment. In the current study, DSS analysis is performed using manual coding as well as CP software on language samples from 48 school-aged children (28 with language impairment). A comparison of these two scoring methods yields an overall agreement of 78% and per-category agreements ranging from 0% to 98%. Of note, the agreement levels on samples obtained from children with language impairment were lower by approximately 2%. This study provides a baseline for future automated DSS scoring and highlights the accuracy of specific units within these systems.

Diessel, H., & Tomasello, M. (2000). The development of relative clauses in spontaneous child speech. *Cognitive Linguistics, 11*, 131-151.

In this study, Diessel and Tomasello examine the use of relative clauses in the naturally occurring speech of four children between the ages of 1;9 and 5;2. A thorough definition of a relative clause is given and several types are outlined. The authors cite research which indicates that as children mature, their use of relative clauses increases and diversifies. Diessel and Tomasello speculate as to the role language processing plays in the acquisition of relative clauses and give five factors that may contribute to this development: ambient language, formulaic character of the main clause, information structure of the sentence, pragmatic function, and the limited processing capacity of young speakers. The results of this study indicate that the relative constructions used in spontaneous speech are simpler than those found in other trials. Most of these constructions express only single prepositions. Interestingly, some types of relative clauses decrease as others increase. For example, as the use of PN (predicate nominal)-relatives falls from 71 to 37 percent, the percentage of all other types shows an increase (specifically object-relatives). Likewise, as S-relatives decrease, O-relatives increase. Thus, some forms can be seen as precursors to later developing forms. The earliest produced relative clauses occur in presentational constructions and express single prepositions. The authors hypothesize that children under three years old typically avoid relative constructions with two prepositions because they do not have the processing capacity to handle such complexities.

Diessel, H., & Tomasello, M. (2005). A new look at the acquisition of relative clauses. *Language, 81*, 882-906.

Diessel and Tomasello investigate the manner in which children develop and use relative clauses. Using two sentence repetition tasks, the researchers evaluated first 21 English-speaking children ranging in age from 4;3 to 4;9 and later 24 German-speaking children of similar ages. Each participant was asked to repeat six different types of relative clauses after which error patterns were coded and evaluated. The results indicate that for both English and German speakers the use of intransitive subject relative clauses proved easier than transitive relatives and direct object relatives. Furthermore, the production of indirect object relatives, oblique relatives, and genitive relatives proved the most difficult. Although English and German are structurally quite different, the results were generally the same across studies. The authors conclude that the acquisition of relative clauses is determined by multiple factors affecting different types of relative clauses.

Hesketh, A. (2006). The use of relative clauses by children with language impairment. *Clinical Linguistics and Phonetics, 20*, 539-546.

Hesketh examines the use of relative clauses by 66 children with language impairment. These children, who range in age from 6 to 11 years, live in the United Kingdom and present with language impairment of varying severity levels. To acquire language samples, each child is presented with an elicitation and a narrative task. The results of each task are compared to the results from similar studies conducted on children with SLI in the United States (namely those conducted by Schuele & Tolbert, 2001). Past research indicates that the omission of obligatory relative markers is a recognizable stage in the development of SLI but not in typical development; however this omission was not widely observed in Hesketh's study. The findings of this study indicate that children with language disorder did, indeed, find the production of relative clauses difficult, but rather than omitting obligatory relative markers, the participants in the current study commonly used the 'reduced relative' construction (e.g., *the woman living up the road has a Labrador*). Past researchers have described reduced relatives as a developmental step reached just prior to the production of full relative clauses and thus may be clinically relevant. However, the author notes that the occurrence of reduced relatives is generally much higher in UK English versus US English and suspects dialectal variation might be one reason for the large discrepancy between the current study and those conducted in the US.

Limber, J. (1973). The genesis of complex sentences. In T. E. Moore (ed.) *Cognitive development and the acquisition of language*. Retrieved December 9, 2012, from http://pubpages.unh.edu/~jel/JLimber/Genesis_complex_sentences.pdf

Limber describes the details of a longitudinal study performed on children between the ages of 1;6 and 3;0. In this study, Limber collects hour-long spontaneous language samples and analyses each for precomplex and complex syntax constructions. First precomplex constructions are noted, which include names, predicates, referential pronouns and wh-questions. Next, complex constructions emerge which include complements, wh-clause constructions, and conjunctions. Limber documents that by age three, complements and relatives are typically mastered which aid in the production of syntactically complex expression. The author claims that the productions displayed during these first years reflect the basic English structure overall. He notes that during the third year, the progression of complex syntax acquisition follows first, N-V-N sequences in simple sentences, followed by complements, and finally the joining of two sentences (first by conjunction, next via wh-adverbial, and finally by relatives).

Long, S. H. (2001). About time: A comparison of computerized and manual procedures for grammatical and phonological analysis. *Clinical Linguistics and Phonetics, 15*, 399-426.

Long explains that the collection and accurate analysis of language samples can add much needed diagnostic information to standardized testing procedures. However, restraints on clinician's time often interfere with thorough collection and analysis. In his study, Long explores the efficiency of several grammatical and phonological analysis procedures including both manual and computerized forms. The study included 256 students and clinicians who were trained in their analysis procedure previous to their participation in this study and who were only asked to participate in analysis procedures they felt proficient in. Phonological and grammatical analysis was conducted on three samples of each and analyzed in terms of various components (such as phonetic inventory and word shapes for phonological samples and MLU, LARSP, DSS, and IPSyn for grammatical samples). While the exact time of analyses varied across participants and analysis type, results indicate that computerized analysis was always completed faster and with higher accuracy rates than those of manual analyses.

Long, S. H., & Channell, R. W. (2001). Accuracy of four language analysis procedures performed automatically. *American Journal of Speech-Language Pathology, 10*, 180-188.

The collection and accurate analysis of language samples is an important component of clinical diagnostics and treatment. However, due to limits on time or education, many clinicians opt for subpar language sample analysis. Advances in data analysis software have been made in recent years and in this report Long and Channell explore the accuracy of four automatic language analysis procedures: MLU, LARSP, IPSyn, and DSS. Computerized Profiling (CP) software was utilized to parse and identify grammatical structures found from input language samples. In total, 69 language samples were used. These included samples from individuals ranging in age from 2;6 to 7;10 and who possessed typical language, speech impairment, and language impairment. Results indicate that CP produced error-free coding for approximately half of all utterances analyzed in this study and much better in certain areas. MLU was found to be the most accurately calculated (99.4%) while IPSyn and DSS were somewhat less accurate (95.8% and 89.8% respectively). It was found that more developmentally advanced IPSyn categories proved more difficult for CP to correctly parse. LARSP proved to be the least accurate overall. Of note, it was found that CP rarely coded subordinate clause structures correctly when they were present. The article concludes that the automated analyses produced by CP are equivalent to that of human coders.

Lu, X. (2009). Automatic measurement of syntactic complexity in child language acquisition. *International Journal of Corpus Linguistics, 14*, 3-28.

In this study, Lu measures the syntactic complexity of written and spoken language using the revised Developmental Level (D-Level) scale. This scale assigns each sentence input into the system to a developmental level. Rating is completed in two stages: the processing stage which assigns each token in the sentence a tag indicating its grammatical category and then parses the sentence, and the syntactic complexity analysis stage which analyzes the parse tree and assigns each sentence to an appropriate developmental level. This system was found to achieve an accuracy of 94% on samples from the Penn Treebank and 93.2% on samples from the CHILDES database. To demonstrate the application of this software, the author used it to investigate the correlation of average D-Level scores to age level. The results showed that both the maximum and mean scores progressed linearly relative to age.

Marinellie, S. A. (2004). Complex syntax used by school-age children with specific language impairment (SLI) in child-adult conversation. *Journal of Communication Disorders, 37*, 517-533.

In this study, Marinellie sought to determine if a 100-utterance conversational sample is representative of an individual's syntactic abilities, and whether those with specific language impairment (SLI) exhibit significant differences in the use of complex sentence structures as compared to those with typical language (TL). To accomplish this, the author investigated the syntactical ability of 15 children with SLI and compared this to 15 children with TL. Participants were matched for grade (3-5), nonverbal intelligence scores, and race. Each child participated in a conversation with an adult partner and discussed topics the child might be interested in for approximately 15-25 minutes. One hundred consecutive utterances from each child were analyzed for complex sentence structures such as adverbial clauses, relative clauses, and full prepositional clauses to name a few. Of note, the complex sentences coded in this study are those typically developed in early childhood (some as early as 2-3 years of age). Marinellie found that while 100-utterance conversational samples did yield at least one example of some complex syntactic structures (adverbial, relative, full prepositional, coordinate, and infinitive clauses), others were seen very seldom (-ing/-ed clauses, catenative/let clauses, or wh-clauses). It was also found that children with TL used more complex sentence structures, more combined sentence structures, and exhibited more clauses per utterance in child-adult conversation than those children with SLI. Marinellie notes that clinicians should recognize the influence that discourse has on syntax (conversation versus narration) when collecting samples and when planning treatment goals as various genres yield different syntactic output.

McKee, C., McDaniel, D., & Snedeker, J. (1998). Relatives children say. *Journal of Psycholinguistic Research, 27*, 573-596.

McKee and colleagues examined the use of relative clauses in 28 children from ages 2;2 to 3;10. Relative clauses were elicited using a simple game in which the participants had to describe toys based on a previously read story. The samples were evaluated for the occurrence of relative clauses and any errors found within these productions. Patterns of use and errors made were noted. The acquisition and clause types were then compared to cross-linguistic variations. Results of this study indicate that the formulation of relative clauses occurs very early on and that most reflect adult-English forms. A common error pattern found was the use of inappropriate relative pronouns which the authors believe reflect typical language development.

Michaelis, H. (2009). Automated identification of relative clauses in child language samples. (Master's thesis, Brigham Young University). Retrieved from http://contentdm.lib.byu.edu/cdm/singleitem/collection/ETD/id/2023

Michaelis explored the accuracy of the software *cx* in identifying relative clauses in child language samples. *Cx*, which was the precursor to the current study's *cxs*, was also created by Channell for the purposes of identifying complex grammatical structures. While Michaelis did not separate types of relative clauses in her analysis, she did note that *cx* had greater difficulty identifying relative clauses without relative pronouns. Her study indicated that while the automated analysis missed and wrongly identified some relative clauses, a high point-by-point agreement value was achieved overall. This was true even for the samples of children with language impairment. Michaelis points out 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. Her research laid the ground for the current study and gives way for expansion and improvement of automated systems of analysis.

Nippold, M. A., Hesketh, L. J., Duthie, J. K., & Mansfield, T. C. (2005). Conversational versus expository discourse: A study of syntactic development in children, adolescents, and adults. *Journal of Speech, Language, and Hearing Research, 48*, 1048-1064.

In this study, Nippold and colleagues investigate syntactical output of 120 participants ranging in age from 7 to 49 years of age. One intent of this study was to discover whether the type of discourse used in the acquisition of language samples yielded different results in terms of syntactic complexities found therein. Both conversational and expository tasks were used. Additionally the authors hoped to explore the characteristics of syntactic development from childhood into adulthood. Results indicate that for every age, expository tasks yielded more complex syntactical output as the conversational tasks. In the expository tasks, participants were asked to describe a favorite sport or game. It is suspected that because these tasks require greater complexities of thought to convey meaning, a more complex form of expression is required as well. As might be expected, as the participant's age increased so did their use of complex syntactic structures. In fact, this growth was found to continue into young adulthood (ages 20-29). The production of relative clauses and the mean length of T-unit were good indicators of syntactical growth and noted to increase from childhood into young adulthood. Of note, variation of language ability was displayed across every age group indicating unique language ability regardless of age or discourse type. These individual differences should be considered when gathering collective data.

Nippold, M. A., Mansfield, T. C., Billow J. L., & Tomblin B. J. (2008). Expository discourse in adolescents with language impairments: Examining syntactic development. *American Journal of Speech-Language Pathology, 17*, 356-366.

Expository, conversational, and narrative discourse are natural and important forms of communication which should be considered when assessing and providing speech and language services to adolescents. The authors stress that further investigation into the syntactic abilities of adolescents should highlight these natural genres as academic performance relies heavily upon these communication modes in current curriculum. Past research indicates that adolescents with SLI typically produce short, simple sentences with limited subordination and that in tasks involving narrative, conversational and expository tasks they score much lower in terms of complex syntactic ability as compared to peers with typical language development. Research also suggests that expository tasks are much more revealing of syntactic ability versus conversational or narrative tasks because expository tasks require more sophisticated language skills to explain complex topics. Nippold and co-authors examine language samples from 444 adolescents ranging in language ability. Participants were divided into three groups: those having specific language impairment (SLI), those with nonspecific language impairment (NLI), and those with typical language development (TLD). Syntactic development was explored in both conversational and expository tasks and rated by mean length of T-unit (which consists of one main clause and any subordinate clauses that are attached to it), the occurrence of three types of subordinate clauses (nominal, relative and adverbial), and clause density (the average number of clauses per T-unit). Results of the current study indicate that the mean length of T-unit and the use of each clause type were greater during the expository task than the conversational task for all groups. In addition, those from the TLD group outperformed participants from the SLI and NLI groups on mean length of T-units overall. Of note, relative clauses occurred more often in the expository task than in the conversational task and those in the TLD group produced more relative clauses than those in the NLI group. One interesting finding of clinical relevance is that the mean length of T-unit was closely associated with clausal density. This unit of measurement was found to be quite accurate and relatively easy to gather. The authors predict this close association might save time when clinicians score language samples.

Schuele, C. M., & Dykes, J. C. (2005). Complex syntax acquisition: A longitudinal case study of a child with specific language impairment. *Clinical Linguistics and Phonetics, 19*, 295-318.

In this study, Schuele and Dykes attempt to gain greater insight into the development of complex syntactic productions for individuals with SLI. The authors follow one participant with SLI from age 3;3 to 7;10 and analyze 12 conversational language samples gathered across that span. The acquisition, rate of use, and errors found within these structures was evaluated. Initially and until age 4;8, the participant used few complex syntactic forms (catenatives, let's clauses and simple infinitives). Later, when assessed at 5;9, the participant expressed a greater variety of complex forms such as WH clausal complements, relative clauses and full prepositional clauses but not without error. Common errors included the omission of obligatory relative markers, complementizers, the infinitive *to*, and WH pronouns. Mastery of most complex structures was not achieved during this experiment and errors continued during the last trial at age 7;10. The experiment also suggests that like those with typical language development, an increase of complex syntax types emerge when the participant's MLU exceeded 4.0. However, unlike peers with typical language, this MLU is achieved much later for individuals with SLI, and errors within embedded grammatical features persist.

Schuele, C. M., & Nichols, L. M. (2000). Relative clauses: Evidence of continued linguistic vulnerability in children with specific language impairment. *Clinical Linguistics and Phonetics, 14*, 563-585.

In this study, Shuele and Nichols explore the syntactic abilities of three children with SLI in a longitudinal study. Specifically, the authors are interested in the participant's ability to produce relative clauses and whether certain acquisition patterns were noted within this group. For purposes of this study, data for subject relative clause and object relative clause production were investigated. This article reports on two separate studies. The first explores the syntactical output of one child with SLI while the second compares the SLI group (all three children with SLI) to a group of five children who were classified as language normal. The results show that the three children with SLI had a similar acquisition pattern of subject relative clauses and each was found to omit obligatory relative markers. Typically these children experienced a stage of omission, followed by inconsistent use, and finally consistent use of obligatory markers. The results of this study also indicate that children with SLI may first attempt relative clauses as late as 5 or 6 years of age when they demonstrate an MLU of approximately 3.5. This is approximately two years later than those children with typical language. The process from omission to consistent use is estimated to take approximately two years in total. Additionally, the children with SLI also demonstrated difficulty selecting relative markers for object relative clauses. The results of the second study (in which children with typical language are compared to those with SLI) indicated that four of the five children with typical language did not demonstrate the omission of obligatory relative markers and began accurately producing these complex clauses at much younger ages. Therefore the authors conclude that the omission of obligatory relative markers is a characteristic of children with SLI. Further research is warranted to rule out this omission as a developmental stage in typical language development as the children with typical language in this study were between the ages of 4;7-10;11 and past the acquisition age of relative clauses.

Schuele, C. M., & Tolbert, L. (2001). Omissions of obligatory relative markers in children with specific language impairment. ***Clinical Linguistics and Phonetics, 15*****, 257-274.**

As a follow-up to Schuele (1995) and Schuele and Nicholls (2000), the current researchers explore the rate of omission of obligatory relative markers in both children with specific language impairment (SLI) and children with typical language (TL). Twenty children with SLI (ranging in age from 5;0 and 7;11) and 15 children with TL (between the ages of 3;3 and 5;11) where chosen to participate in the study. The age discrepancy between groups was based on the findings of past researchers which report that children with SLI have language skills roughly 2 years behind those of children with TL. The authors explain in detail four types of relative clauses and outline the classification of each. For the purposes of this study, the authors choose to probe elicitation of only subject relative clauses because in such structures the relative marker is required. An overview of research regarding the production acquisition of relative clauses in typical children is also provided and, while not in absolute agreement, determines typical acquisition to be around 3 years of age. The main focus of this study is concerned with the omission of obligatory relative markers; whether children with SLI omit these relative markers in subject relative clauses, how frequently this might occur, if the rate of omission varies across age groups and finally whether children with typical language development omit these markers. The results of this study demonstrate that, indeed, the production of relative clauses was difficult for children with SLI and that these participants frequently omitted relative markers. In fact, only 9% of children in the SLI 5-year-old group included the obligatory relative marker, those in the 6-year-old group included the markers 38% of the time, and those in the 7-year-old group included them 49% of the time. Interestingly, those children with TL included a relative marker in every attempt. Of note, particular error patterns of children with SLI (such as using “this” or “what” as a relative marker) indicate that these children might have difficult identifying lexical items that can serve as relative markers. The question is raised as to whether the omission of these obligatory markers is developmental in nature. The authors explain that if so, the omission of such markers in typical language must occur earlier than 3-years-old and for a short period of time. Further research, perhaps including longitudinal data of a larger group of children with SLI, is warranted.

Scoville, C. (2013). Noun clauses in clinical child language samples. (Master's thesis, Brigham Young University). Retrieved from http://contentdm.lib.byu.edu/cdm/singleitem/collection/ETD/id/3608

Similar to the current study, Scoville investigated the accuracy of an automated system of analysis (*cxs*) at identifying complex grammatical structures: noun clauses. Using the same set of language samples as the current study, Scoville compared manual and automated identification of noun clauses including the sub-categories: finite *wh*-noun clauses, wh-alternative noun clauses, *that*-noun clauses, gerund clauses, and wh-infinitive noun clauses. An ANCOVA revealed that the differences in the frequencies of WH-infinitive noun clauses and gerunds were significant between the matched groups. In addition, “zero that clauses” and gerunds were significantly correlated with age. Kappa levels revealed agreement between manual and automated coding was high on WH-infinitive clauses, gerunds, and finite wh-noun clauses, but somewhat low for the remaining two clause types. The results of this study shed further light into the abilities of *cxs* in identifying complex grammatical structures.