PRODUCTION OF APPROXIMANTS AS EVIDENCE FOR PHONOLOGICAL DEFICITS IN DYSLEXIA

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Abstract

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This paper presents the results of an experiment conducted under the hypothesis that dyslexics have disordered phonology. The hypothesis was tested by investigating dyslexics' production and manipulation of the approximants /l, r, w, j/ in consonant clusters (such as [bl] and [tr]). Two tests were administered: 1) a remove-consonant (Rosner) test (subjects remove the 'l' sound from 'plan' and pronounce the result--'pan'--for example) and 2) a nonsense-word repetition test (nonsense words included, for example, 'teglape'). Twelve reading-disordered individuals with a mean age of 14 years, 5 months took part in the study. They were compared to a control group consisting of seven grade 2 normally-reading children. Results showed that poor readers had difficulty with the remove-consonant test and with the repetition of nonsense words. They made more errors than the control group on these tasks. Implications of these findings concerning the causes of dyslexia are discussed.

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1. Scope and Objectives

Dyslexia is a below-average reading ability that is accompanied by average non-verbal intelligence. It is well known that dyslexics have deficits in phonemic awareness, a metaphonological skill (Dyck and Penney 2002:1). However, dyslexics have been observed to have phonemic or phonological deficits. For example, their skills in symbol recognition and recall are weakened by poor recall of sound-symbol relationships and confusion of similar sounding phonemes (e.g. p/b, f/v); they demonstrate poor recall of letter sounds, difficulty in decoding nonsense words, difficulty pronouncing multisyllabic words, over-reliance on whole-word and contextual strategies; they exhibit addition of unnecessary sounds (e.g. lateral insertion), omission of necessary sounds, low knowledge of spelling rules and over-reliance on visual features (Roberts and Mather 1997:241). Studies have shown that many children with phonological disorders at preschool ages go on to have reading and spelling difficulties. For example, Lewis and Freebairn (1992) found that remnants of a preschool phonological disorder can be detected on literacy tests into adulthood. Dodd et al. (1995) also found that children with a history of phonological disorder performed more poorly on reading and spelling tasks than children without a history of phonological disorder. Larrivee and Catts (1999) concluded that children with poor reading abilities were those who had been identified as phonologically disordered in kindergarten.

While general phonemic deficits in dyslexics have been documented, more specific ones have not. For example, Snowling (1981:219-234) has noted that dyslexics have more difficulty repeating nonsense words containing consonant clusters than normally reading children. However, questions such as whether some clusters might cause more difficulty than others remain unanswered. This thesis, accordingly, will systematically investigate dyslexics' production of and ability to manipulate the English obstruent+approximant clusters, namely /sl, pl, bl, kl, gl, fl, pɹ, bɹ, tɹ, fɹ, kɹ, gɹ, dɹ, θɹ, sw, tw, dw, kw, gw, θw/. The speech processing abilities of a control group consisting of children without reading disabilities will be compared to the speech processing abilities of the dyslexic subject group.

The paper begins with a description of theoretical assumptions that are necessary to the analysis of the data in this study. The paper then moves on to a literature review of the acquisition of obstruent+approximant clusters. This latter section compares children with normally-developing and disordered phonologies to dyslexics, providing support for the hypothesis that dyslexics have disordered phonology. Specific questions about how dyslexics will deal with obstruent+approximant clusters will be drawn from the literature review and will form the basis of the design of this experiment.

2. Theoretical Assumptions

Non-linear phonology (Clements and Hume 1995; Goldsmith 1976; Kahn 1976) is the general approach adopted by this study. In non-linear phonology, speech is represented abstractly on three tiers: the segmental tier (where segment quality is encoded), the timing tier (which encodes segment length and provides the distinction between single consonants and consonant clusters), and the syllabic tier (which has subsyllabic constituents that govern the sequence of consonants in a cluster). An overview of each tier is given below, beginning with the segmental tier.

Segments are made up of abstract units called features, (often abbreviated as [F] in this thesis), which are organized into hierarchical structures, or trees[1]. The feature trees are dominated by a root node '•', which contains the major class features, relevant to sonority and manner; the root node itself represents the 'segment quality.' Among other things, features define classes of sounds: for example, the approximants /l, ɹ, w, j/ all share the feature [+approx], meaning that they are the only English consonants pronounced with a frictionless, non-turbulent airflow (Katamba 1989:7). Sounds within a class are similar to one another and are more likely to be substituted for one another in acquisition (Bortolini and Leonard 1991:1). This study focuses on consonant clusters containing approximants because they undergo unique processes in normal and delayed acquisition and should pose interesting problems for dyslexics.

[1] The features that distinguish the major classes of English phonemes are summarized in table A1 in Appendix A.

In the case of the approximants /l, ɹ, w, j/, both phonetic features and phonological ones involving natural class and sonority play a role in substitution processes in obstruent+approximant clusters; feature-based classes are described below. Voiced lateral approximants (l-sounds) are grouped with rhotics (r-sounds) under the class of 'liquids' (Ladefoged and Maddieson 1995:182). Laterals and rhotics are grouped together because they share certain phonetic and phonological properties. Phonetically they are among the most sonorous consonants (ibid.). Liquids also form a special class in the phonotactics of a language; for example, liquids are often those with the greatest freedom to occur as second members of consonant clusters because of their relatively high sonority (ibid.).

The substitution processes for liquids, mentioned briefly above, can also be viewed as phonological or distinctive feature substitutions. The feature chart in table 2.1 and the following discussion help explain the substitution patterns of liquids in Child Language Acquisition (CLA) and in dyslexic and disordered acquisition. (Substitution patterns are then discussed more fully in Section 3). Parentheses indicate a feature that is present phonetically, but which is not contrastive.

Table 2.1 Feature Matrix for English Approximants and Relevant Phonemes

	l	ɹ	w	j	n	s	ʊ
[sonorant]	+	+	+	+	+	-	+
[approximant]	+	+	+	+	-	-	-
[vocoid]	-	-	+	+	-	-	+
[nasal]	-	-	-	-	+	-	-
[voiced]	+	+	+	+	+	-	+
[strident]	-	-	-	-	-	+	-
[labial]		(0)	0				0
[coronal]	0	0		0	0	0	
[dorsal]	(0)		0				0
[anterior]	+	-		+	+	+	
[continuant]	+	+	+	+	-	+	+

As table 2.1 indicates, /l/ and /ɹ / are very similar, except that /ɹ/ is phonetically [labial], /l/ phonetically dorsal and the two differ in [±ant] and [±lateral]. /l, w, Y / share [dorsal]. /l, j/ share [+ son, +approx, +voi, coronal, +cont] and differ mainly in that /l/ is phonetically [dorsal]. /ɹ, w, j/ share [+son, +approx, +voi, +cont] and differ mainly in their place features, /ɹ, w/ both being [labial] and /ɹ, j/ being [coronal]. /l, s/ share the features [coronal, +ant, +cont]. /l, n/ are both [+voi, +ant, coronal, +son].

Substitution processes are more likely between sounds that share one or more distinctive features; therefore, substitutions might be expected in the classes outlined above. For example, substitution is possible between [l] and [n], given the number of features they share. The substitution of /n/ for liquids in Italian was recorded by Bortolini and Leonard (1991:9): a normally developing child pronounced "soldi" as [s□ndi].

Phonetic properties of English approximants might help explain processes displayed by dyslexics. /ɹ/ is produced with a high degree of lip-rounding in English;

i.e., phonetically it is [labial], sharing the same feature with [w]. Alveolar /l/ is pronounced with the tongue body also raised and backed (velarized) when in syllable codas; i.e., phonetically it is [+high, dorsal], sharing the same features with the vowels [u] and [ʊ].It should be noted that /l/ in English has an allophonic distribution. /l/ becomes palatalized and is transcribed as [ɫ] when it occurs after a vowel and before another consonant or at the end of a word (Ladefoged 1993: 94). [l] occurs elsewhere (and is the form that occurs in the cluster data in this thesis.) To illustrate, the words "led" and "clap" would be realized as [lɛd] and [klæp]; however, the words "bell" and "talc" would be realized as [bɛɫ] and [tæɫk] (ibid.: 170). These specific facts about English /l, ɹ/ could help explain why /ɹ/ is replaced by [w] more often than /ɹ/ is replaced by [l] in substitution processes - /ɹ/ shares many features with /w/. This may also explain why coda [ɫ] is replaced by a high back [ʊ], with which it shares many features. It is also possible that dyslexics mentally represent an undifferentiated "approximant" category whereby the approximant's realization depends on either: a) a rule (e.g., pronounce the approximant as a labial after another labial, or b) variability (e.g., use any of [l, ɹ, w, j].) It might be expected that, if dyslexics have disordered phonology, they will display problems with production and metaphonological manipulation of approximants in clusters because the approximants share so many features.

The timing tier is an intermediate level between the syllable and the segment (Gussenhoven and Jacobs 1998:171). Timing tier units encode the segmental duration of consonants and vowels. Short consonants and vowels are associated with one timing tier unit, while long vowels and geminate consonants are associated with two (ibid: 150). The timing tier also encodes the difference between one consonant and two. As shown in (1), a single consonant such as [k] is linked to one timing tier unit; a consonant cluster, such as [kl] would be linked to two timing tier units, one for each consonant.

(1)	[k]	[kl]
Timing tier	x	x x
Root node	•	• •
Segmental features	[F]	[F][F]

It will later be argued that the timing tier is underdeveloped in dyslexics and that dyslexics first analyse sounds at the syllabic level, but cannot further segment sounds at the levels of the timing tier or segmental tier; that is, they fail to analyse [kl] as two separate segments.

Above the timing tier, segments are organized into subsyllabic units (onset and rhyme) as well as syllables. Organization of segments into syllables conforms to the Sonority Sequencing Principle (SSP). According to the SSP, sonority rises towards the nucleus - that is, segments occupying the nucleus are more sonorous than segments occupying the onset, and the first segment in an onset is typically less sonorous than the second segment in an onset; sonority falls after the nucleus- that is, segments in the coda are less sonorous than those in the nucleus, and the first segment in the coda is typically more sonorous than subsequent segments (Clements 1990). The major classes of sounds, discussed earlier, can be arranged in a hierarchy of sonority, as in table 2.2 (modified from Clements 1990), which lists root node features that are relevant to sonority.

Approximants and glides are separated in the table because glides' specification for vocoid is null. That is, they are realized as + or – vocoid according to where they end up in the syllable.

Table 2.2 Sound Class Hierarchy of Sonority

Sound Classes	**Sonority**	**Features**
1. Obstruents	Least Sonorous	**[-vocoid, -son, -approx]**
2. Nasals	↕	**[-vocoid, +son, -approx]**
3. Approximants		**[-vocoid, +son, +approx]**
4. Glides/Vowels	Most Sonorous	**[+vocoid, +son, +approx]**

Note that approximants are the most sonorous consonants.

The SSP can be thought of as an organizing principle that helps determine what the best type of onset would be. The ideal onset is one in which sonority rises steeply toward the nucleus; an example would be [pl], where an obstruent such as /p, t, k/ is followed by an approximant. A universally impossible onset would be one in which sonority falls toward the nucleus; an example would be [lp], where an approximant is followed by an obstruent, which clearly violates the SSP. A syllable such as "plate" [plejt] conforms to the SSP because the sequence of sounds from left to right is a stop (least sonorous), liquid (more sonorous), vowel in the nucleus (most sonorous), and stop (least sonorous). A syllable such as "*lpat" [lpæt] does not conform to the SSP. The clusters which were studied in this paper conform to the SSP. In contrast, other clusters such as /sk, sf, st, sp/, do not conform to the SSP and are expected to pattern differently than obstruent+approximant clusters (Clements 1990). These other clusters were investigated by Susan Mugford; a joint experiment was done that focused on different clusters.

If dyslexics have phonological deficits, we would expect errors on all three levels of phonological representation. They might be expected to make feature-based errors such as substitution of approximants, for example, 'play'→[pwej]. They may make errors at the timing tier level by failing to distinguish between single segments and clusters, for example, substituting 'pay'→[pɹej]. On the syllable level, they may produce errors that simplify syllable structure by inserting vowels or deleting segments from clusters. Some errors that are made by dyslexics may be changes that create a more desirable sonority slope between onset and nucleus (Chin 1996:109). For example, deletion of /l/ from the word 'play' → [pej] results in a greater rise in sonority from onset to nucleus. Another example is metathesis which simplifies the syllable structure, typically by removing one consonant from a cluster and putting it elsewhere. For example, metathesis of /l/ in the word 'play' may result in [pejl].

3. Major Findings of Previous Research

If dyslexics have phonemic deficits, they should share characteristics with children who have disordered phonology and should be unlike children who have normally-developing phonology. This literature review will compare dyslexics to children with disordered phonology and with normally-developing phonology and will show that the errors that phonological dyslexics make are similar to the errors made by children with disordered phonology.

Many phonologically disordered children go through the same stages of acquisition as those with normal development, but at a slower rate (Bernhardt and Stemberger 1998). For example, results from a study on phonologically disordered Italian children indicated that they closely resembled younger, normally developing children. "Based on the particular phonological selections they make and do not make, these children stand out first and foremost as learners of a particular phonological system and, only secondarily, as being rather poor in the process" (Bortolini and Leonard 1991: 11).

The characteristics of dyslexia suggest an underlying phonological deficit that is very similar in nature to the deficit seen in phonologically disordered children. The difficulties that children with disordered phonology have can be attributed to a lack of knowledge or an immature knowledge of the phonological structure of the language. This is also the case for dyslexics' reading difficulties (Snowling 1981: 232). To illustrate, dyslexics display many of Crystal's (1987) list of characteristics common to phonological disability (reproduced in Appendix A). Like phonologically disordered children, dyslexics display articulation errors and misperception of similar sounding phonemes, exhibiting a restricted range of segments and segmental combinations. Phonologically disordered children also have difficulty distinguishing between voiced and voiceless segments, and dyslexics have a problem distinguishing between similar sounding phonemes (e.g. p/b, d/t) (Crystal 1987:44; Roberts and Mather 1997:241). Dyslexics, like phonologically disordered children, have a tendency to reduce consonant clusters to single consonants and to adhere to a canonical CVCV syllable structure. Furthermore, dyslexics have been documented to have problems pronouncing multisyllabic words. Dyslexic children appear to prefer open syllable CV structures and have trouble producing consonant clusters and segmental combinations (Snowling 1981:230). It has been shown that dyslexic children have more difficulty reading and producing nonsense words than younger normal readers (Snowling 1981:219-234; Roberts and Mather 1997). Dyslexic children are apparently unable to rely on word familiarity or semantics in tasks of nonsense word decoding; hence, their phonemic deficits are exacerbated on this purely phonological task.

The following sections provide more evidence for the hypothesis that phonologically disordered and dyslexic children possess a phonological deficit. In the next section, normal CLA is contrasted with delayed/disordered CLA and dyslexia in greater detail.

3.1 Processes of Approximant Acquisition

Approximants are of interest to the study of language acquisition and language disorders for two reasons: 1) there is a gap between the periods of acquisition of glides (/w, j/) and liquids (/l, ɹ/), glides being acquired early and liquids being acquired late, and 2) approximants (/l, ɹ, w, j/), particularly liquids, can be troublesome to the language learner, especially if the learner has a language disorder. Previous research has demonstrated that these findings are true for both acquisition of perception and for acquisition of production (which typically occurs sometime after perception) (Bernhardt and Stemberger 1998; Chin 1996; Crystal 1987; Strange and Broen 1980). A number of sources comment on the lateness of acquiring the ability to produce liquids in English. "The glides /w/ and /j/ are produced correctly at a relatively early age, /ɹ/ and /l/ are later in appearance" (Strange and Broen 1980:132). "Rhotics and /l/ are rare in early development, though they can occur" (Bernhardt and Stemberger 1998:332). The age of production of /w/ is approximately 3 years and for /j/ it is 4 years (Strange and Broen 1980:129). However, correct production of /ɹ/ and /l/ does not occur until about age 6. Furthermore, production of /ɹ/ is a frequent source of error in children with disordered language and is resistant to therapy (ibid.:129). As well, in CLA production, before they produce /l, ɹ/, children use simpler sounds like /w, j/ instead of more complex sounds like /l, ɹ/. /w, j/ are simpler than /l, ɹ/ because they have fewer terminal features; /l, ɹ/ are said to be more complex because they have more terminal features, for example,

[±lateral]. Similarly, there is a tendency for liquids to be deleted in production. In summary, although there is much variability between children in terms of their language acquisition, children generally begin to produce laterals (l-sounds) earlier than rhotics (r-sounds). Rhotics seem to be particularly challenging and it is difficult to pinpoint an age where they are produced correctly (Bernhardt and Stemberger 1998:332).

In the acquisition of phoneme perception, children typically perceive a phoneme correctly at the beginning of a word before they perceive it correctly at the end of a word, but the effect of the location of the target phoneme in a word is complex (Crystal 1987). A list of approximate ages for acquisition of perception of liquid contrasts in various word positions by a normally developing English speaking child is as follows (Crystal 1987:36): word-initial /l/ by age 3; word-initial /ɹ/ by age 3 years 6 months; word-final /l/ by age 3 years 6 months; and word-final /ɹ/ sometime after. In a study on the perception and production of contrasts between approximants by twenty-one normally developing children between the ages 2 years 11 months and 3 years 5 months, it was found that "normally developing 3-year-old children are capable of differentiating among initial approximant consonants [in phoneme identification tasks]" (Strange and Broen 1980:146). However, although 3-year olds can identify word-initial approximants, they do not necessarily use this knowledge to distinguish between minimal pairs or to produce speech (ibid.:146).

To summarize, it appears that children are able to perceive word-initial /l, ɹ, w, j/ and word-final /l/ roughly by the age of 3 years 6 months. This perception skill develops sometime later for word-final /ɹ/. By the age of 4 years children are able to produce the glides /w/ and /j/. However, the ability to produce the liquids /l/ and /ɹ/ does not develop until around the age of 6 years. Given that acquiring liquids is problematic for children with normal language development, it is expected that children with disordered phonology or phonological dyslexia will have difficulty in mastering these sounds.

In addition to the above trends, more specific patterns of acquisition of approximants in normal, disordered, and dyslexic language development have been identified (Bernhardt and Stemberger 1998: 320; Crystal 1987: 37-39) and are overviewed below.

Gliding occurs when the adult /l/ is replaced by [w] or [j]. For example, a child attempts to say "play" and produces [pwej]. Gliding usually occurs in onset position, whereas vowels or off-glides replace [l] in coda position. Gliding also occurs when [w] or [j] is substituted for /ɹ/. This usually occurs in the onset position, whereas vowels or off-glides replace /ɹ/ in coda position. An example is when the child attempts to say "pray" but pronounces it [pwej]. Gliding occurs in normal spoken language development, in disordered phonology and when dyslexics read aloud. For example, rather than deleting /l/ from "play" the dyslexic may read "play" as [pwej]. Gliding usually stops at around the age of 4 years in normal language development but persists much longer in disordered phonology and dyslexia (Crystal 1987). Nevertheless, older dyslexic children are more likely to avoid gliding. It could be that older children have a better grasp of semantics and will produce a meaningful word that is not the target, e.g. [pej] "pay" for the target "play" rather than a nonsense word that is close to the target, e.g. [pwej]. Such behavior may provide evidence that older dyslexics have compensatory strategies for their deficits.

Stopping occurs when a stop replaces the /l/; however, this process is infrequent and only occurs in very early development. An example is when the child attempts the word "leaf" and produces [tijf]. Stopping is more frequent in disordered phonology and is used by children of a more advanced age than in normal language development (ibid.). It is expected that the process of stopping will persist in dyslexics as well.

Fricative substitution occurs when (typically) an alveolar fricative, either voiced [z] or voiceless [s], replaces /l/. The substitution occurs when the [+continuant] feature of the liquid remains, but [+sonorant] does not (Bernhardt and Stemberger 1998:334). An example of this is when the child attempts to say "leaf" but produces [sijf]. Fricative substitution is more frequent in disordered phonology and is used by children of a more advanced age than in normal language development. It can be expected that the process will persist in dyslexics as well.

Vocalization occurs when syllabic consonants are replaced by vowels. For example, the child pronounces "apple" as [apʊ]. As mentioned above, this typically occurs in coda position (Crystal 1987). Vocalization is more frequent in disordered phonology and is used by children of a more advanced age than in normal language development (ibid.). It can be expected that the process will persist in dyslexics as well.

Cluster reduction occurs when an approximant is omitted from an adult target cluster that includes it. For example, the child pronounces "black" as [bæk]. In fact, as Crystal (1987: 38) points out, /l, ɹ, w, j/ are often deleted whenever preceded by an obstruent at a certain stage in CLA. Cluster reduction is a process that occurs in normal language development. However, it stops occurring at an earlier age in normal CLA than it does in the language development of phonologically disordered children. This process should be reduced in the frequency of child speech at around the age of 4 years; however it is frequently observed in the speech of much older phonologically disordered children (Crystal 1987:46). Two patterns of cluster reduction in phonologically disordered children have been observed (Chin 1996:111). The first occurs when a consonant cluster made up of a stop followed by a liquid or glide is reduced to a stop, so that any segment from the set of stops /p, b, t, d, g, k/ and approximants /l, ɹ, w, j/ is reduced to a single stop. For example, /pl/ would be reduced to [p]. The second pattern of cluster reduction occurs when a consonant cluster made up of a fricative followed by a liquid, glide, or nasal is reduced to a fricative. So any segment from the set of fricatives /f, v, s, z, h, ʃ, θ, ð, ʒ/ and sonorants /l, ɹ, w, j, m, n/ is reduced to a single fricative. For example, /fɹ/ would be reduced to [f]. The Sonority Sequencing Principle has been cited as an explanation for these patterns. The deletion of an approximant or sonorant from the onset cluster results in a less sonorous, hence more desirable, onset. The onset better conforms to the SSP by creating a steeper sonority rise towards the nucleus since the undeleted consonant is less sonorous than the deleted one (Chin 1996). Deletion/Cluster reduction also occurs when dyslexics read aloud. For example, I have witnessed dyslexics try to read "play" and say [pej]. This indicates that the process can persist in dyslexics.

Final consonant deletion occurs when the final consonant of a CVC syllable is /ɹ/ or /l/ in the adult form, but the child omits it. An example is the word "flower" pronounced [fawa]. This example illustrates cluster reduction (/fl/ becomes [f]) and also vowel harmony (only one vowel quality occurs per word). This process is exhibited by children with disordered phonology, but at an age much older than normally-developing children. It can be expected to occur in the speech of older dyslexics as well.

Consonant harmony occurs when a target, such as /ɹ/ is in a word or syllable and another consonant in the same word or syllable is pronounced in a similar or identical way. An example is a child's attempt to say "rabbit." Gliding occurs to replace /ɹ/ with [w] and then consonant harmony occurs so that the word medial consonant (which should be [b]) becomes [w] as well, resulting in the form [wawa]. (Vowel harmony also occurs in the example given.) It would be expected that consonant harmony will be produced in the speech of older dyslexics, as it is in the speech of older children with disordered phonology.

Metathesis occurs in normal language acquisition when the child reorders the sequence of segments in order to produce a simpler syllable structure. For example, a child may pronounce 'prescription' as [pəɹskɹɪpʃən], in order to avoid saying two consecutive obstruent+approximant clusters, namely [pɹ] and [skɹ] (O'Grady and Dobrovolsky 1992:49). Metathesis can also occur in dyslexic reading. For example, I have observed a dyslexic read "rat" as [ætəɹ] (atter).

Gliding, stopping, fricative substitution and vocalization are processes of feature substitution. Consonant harmony is a process of feature assimilation. Metathesis, cluster reduction, and final consonant deletion are syllable structure-based processes: in cluster reduction, the complex onset is reduced to a single consonant; in final consonant deletion, the coda is deleted. If dyslexics have delayed phonology, we expect processes and errors such as those outlined above, on all three phonological levels.

A number of processes that occur in children with disordered phonology are unknown to or uncommon in normal language development. If dyslexics have disordered phonology, it can be expected that they will exhibit some of the following processes that have been identified as frequent in disordered phonology during approximant acquisition (Crystal 1987; Kopkalli-Yavuz and Topbas 1998). *Lateral insertion* is a process unknown to normal language acquisition and has been observed in the speech of phonologically disordered children (Crystal 1987:46). Lateral insertion occurs when a lateral is spontaneously inserted where the target adult word has none. An example of this occurs when a phonologically disordered child pronounces "beach" as [pli]. (In this example, the coda consonant is also deleted). In dyslexia, lateral insertion occurs as it does in disordered phonology, but again, is unknown to normal language development. An example is the dyslexic child's attempt to read "cot" as [klɔt]. This process suggests that the child has acquired the onset but does not know it contains smaller units. It is possible that dyslexics, like phonologically disordered children, not only treat the /l/ as a segment but also treat each consonant cluster containing /l/ (e.g. /kl/, /pl/, etc.) as an unanalyzed whole. In other words, from a child's point of view, s/he is not inserting /l/, but substituting one segment for another (i.e., replacing /k/ or /l/ in the example above with the "segment" /kl/), or having difficulty segmenting clusters. This supports the idea of an underlying phonological deficit in dyslexia. (It is interesting to note, in the example above, that a real word "clot" is produced in place of "cot." More data would be needed to establish whether a lateral would be inserted if the result would be a nonsense word, e.g. "pox" [ploks]). The dyslexic alternation between deletion of a liquid (play → pay) and gliding of a liquid (play → pway) at the same stage of development suggests, on the one hand, that, dyslexics may not have acquired the distinctions between approximant consonants. On the other hand, pronouncing 'play' as [pej] suggests that dyslexics are unable to produce consonant clusters. The alternation between the two processes suggests a deeper phonological disorder where the child is either having difficulty articulating consonant clusters, or is not perceiving them as being composed of smaller units.

Lateralization is a process that has been documented to occur in normal language development, albeit so rarely that it may be considered unknown to normal development. It happens when [l] replaces target /ɹ/. An example of this is the pronunciation of "rain" as [lejn]. It might seem reasonable for the child to produce /l/ if she or he is having difficulty with /ɹ/. However, the process is unusual because /ɹ/ is more commonly replaced by /w/, as in [wejn] for "rain" (Smith 1973).

Nasalization is more common in disordered phonology than in normal language development. It occurs when a nasal surfaces for a liquid. An example is the pronunciation of "read" as [n:iə]. (The final consonant has also been deleted in this example.) It might be expected that dyslexics will exhibit this process.

If dyslexics have disordered phonology, then it can be expected that they will exhibit processes normally only present in much younger children, including gliding, stopping, fricative substitution, vocalization, and cluster reduction. It can also be expected that dyslexics will exhibit processes that are uncommon or unknown in normal English acquisition, including metathesis, lateral insertion, lateralization, and nasalization.

3.2 Main Hypothesis of Current Study

Dyslexia has traditionally been thought of as difficulty with reading; however, as more research is carried out it is becoming clearer that many complexities underlie this reading disorder. Much of the recent research on reading disorders has established a strong correlation between dyslexia and a metaphonological deficit in phoneme awareness, which includes the ability to analyse words into individual sounds, remove consonants from words and pronounce the result (Dyck and Penney 2002:1). Previous research has indicated that normally developing children possess a 'phonemic awareness' that phonologically disordered and dyslexic children lack, which later helps reading development, especially in learning grapheme-phoneme correspondences (Snowling 1981:232). An inability to segment nonsense words suggests that dyslexic children lack phoneme awareness; they are unable to identify individual phonological segments, instead leaving onsets and rhymes as unanalyzed wholes (Roberts and Mather

1997:240). The focus of this study is on phonological abilities – which develop prior to phonemic awareness – and whether some phonological deficit underlies dyslexia[2]. As shown in this chapter, dyslexics have many characteristics in common with children who have disordered or delayed phonology. Specifically, dyslexics exhibit delayed or incomplete acquisition of obstruent+approximant clusters and of syllable structure.

The main hypothesis of this study is that dyslexics have disordered phonology. While much of the literature reviewed earlier has outlined the characteristics of disordered phonology, dyslexia, and normal language acquisition, little research establishes more specific relationships between disordered phonology and dyslexia. This study seeks to bridge that gap and to expand the body of knowledge that exists on language acquisition and language disorders. The main hypothesis was investigated by testing dyslexics' production of approximants in clusters and dyslexics' metaphonological ability to manipulate approximants both as singletons and in clusters. Details of my experiment will be discussed in the next chapter, but an overview is provided here: a nonsense-word repetition test was administered to test obstruent+approximant cluster production. This task taxed the phonological component, where a deficit was suspected. It was expected that the dyslexic subject group would display difficulties in this production task similar to those that would be expected from a phonologically disordered group. For example, cluster reduction or omission was expected. A consonant removal task was also administered to test the ability to delete segments from the same set of word-initial consonant clusters. It was expected that the

[2] However, metaphonological tasks were also developed for this study in order to compare performance on phonological and metaphonological tasks involving the same set of obstruent+approximant clusters.

dyslexic subject group would make errors, suggesting that they have difficulty segmenting clusters; this task would provide further evidence that the dyslexics lack phoneme awareness. A unique aspect of this study is that <u>all</u> obstruent+approximant clusters were tested and that both perception/production and metaphonological manipulation of these clusters was tested.

The hypothesis that dyslexics have disordered phonology was also explored by correlating the results from this study's tests with scores from standardized non-verbal IQ tests and standardized tests of reading and spelling. Assuming that language is modular, verbal test scores should not correlate with non-verbal test scores if the subject has a modular language deficit; i.e.,, the subjects' non-verbal I.Q. should be normal while only the 'language module' is abnormal. The standardized tests had been administered to the dyslexic subject group prior to the testing for this study and are described in Section 4.3. It was expected that the dyslexic group's experimental scores and their standard scores on tests of reading and spelling would correlate; however, no correlation was expected between dyslexics' non-verbal IQ scores and other scores. Several alternative explanations to the phonological deficit hypothesis were also considered: 1) whether English word frequency accounts for dyslexics' error rates, and 2) whether cluster frequency in English account for dyslexics' error rates.

A control group consisting of normally-reading grade two children was tested in order to establish which of the dyslexics' errors was unique to the dyslexic group. It was expected that the control group would perform near ceiling on the nonsense-word repetition test and the consonant-removal tasks. It was also expected that few of the language processes that were used by the dyslexic subject group (e.g. cluster reduction) would be used by the control group. The following chapter describes in detail this study in which dyslexics' production and ability to manipulate obstruent+approximant clusters was explored.

4. Methodology

4.1 Test design

Two types of tests were developed in order to examine the perception/production and manipulation of obstruent+approximant clusters and s-clusters. (See Appendix B for copies of the tests). A *consonant-removal test*, (modeled after Rosner and Simon 1971), which tests metaphonological ability or phoneme awareness, was carried out to test performance on deleting segments from word-initial consonant clusters. A list of 78 items with the structure CCVC was used. The items were commonly used English words, with the exception of item 10, [θwæk], which is an onomatopoeic word, included because there are otherwise no common words available with an initial [θw] cluster and a CCVC syllable structure. Three tasks were required: remove the first consonant and pronounce the result; remove the second consonant and pronounce the result; and say the entire word (a simple repetition task).

A *nonsense-word repetition task* was carried out in two parts. In the first part, one-syllable nonsense words with a CCVC structure tested performance on repeating word-initial consonant clusters without the semantic factor of word-hood. The test was made up of a randomized list of 26 nonsense words that were as unlike real words/morphemes as possible. (See Appendix B for copies of the tests). In the second part of the test, two-syllable nonsense words with a CVCCVC word structure tested performance on word medial consonant clusters and examined the effects, if any, of initial versus final stress on cluster production. A randomized list of 52 items was presented, half with stress on the first syllable and half with stress on the second syllable. (One of the clusters [bɹ] was erroneously presented to the subjects with initial stress only. This had the effect of making the proportion of errors smaller for this set of data; however, we did not consider this a problem since the results would be skewed against our hypothesis that dyslexics have disordered phonology, which ideally requires a higher percentage of errors).

4.2 Testing

Each reading-disordered subject was tested individually, in one or two hour-long sessions, depending on the subject's ability to focus on the task. Testing was carried out over a time-period spanning from September through December, 2001. The instructions for each test were recorded on audiotapes. The tests were performed in a quiet room in the Psychology Department of Memorial University of Newfoundland; the answers were tape-recorded and transcribed by the testers, Susan Mugford and Tracy O'Brien. Answer sheets were also scored at the time of testing and were later double-checked by the testers for accuracy with the tapes. Responses were coded as *wrong* if the subject erred on the target cluster (e.g., repeated [kwejk] as [kejk]). Responses were coded as *right* when the subject got the cluster as well as the remainder of the word correct. Responses where errors were made on segments <u>other</u> than the target cluster were recorded as *displaced errors* (e.g., repeating [təswejp] as [təswejt].

Control subjects were tested in sessions that lasted approximately thirty minutes. Testing was completed in one day, on June 19, 2002. The instructions for each test were played from the same audiotapes as they were for the reading-disordered group. The tests were carried out in a quiet classroom at Hazelwood Elementary School, St. John's, Newfoundland; the answers were tape-recorded and transcribed. Scoring was carried out in the same way as it had been for the reading disordered group.

4.2.1 Test Administration and Pre-test Instruction

Before each consonant-removal task, the tester explained to each subject that s/he would be doing three tasks and that the tasks would be played on audio tape. The instructions were heard once and the tape paused; the subject had the opportunity to request that the instructions be repeated. When the tape was paused the subject was to give the response asked by the instructions and then the tape was resumed. Each subject was informed that the session would be tape-recorded. The tester explained that some of the responses may not be English words, but that they could be correct responses. The tester provided the following examples of the test *questions*:

Tester:	"Say *friend*."	(Repetition Task)
	"Say *friend* without the [fff] sound." ("*Rend*" is the desired result).	(Remove C1 Task)
	"Say *friend* without the [rrr] sound." ("*Fend*" is the desired result).	(Remove C2 Task)

Before each repetition task, the tester explained to each subject that a word would be played three times on tape. When the tape was paused the subject was to repeat the word once; the response would be recorded on tape. Each subject was informed that the words were made-up and had no English meaning. The tester provided the following types of practice items before beginning the test:

Tester:	say *entáte.*	Subject: *entáte.*
Tester:	say *émtoll.*	Subject: *émtoll.*

The target s-clusters and target obstruent+approximant clusters were not used in the instruction portion of the testing in order to avoid giving the subjects the opportunity to practice producing the target clusters.

4.3 Subjects

4.3.1 Reading-Disordered Subject Group

A total of twelve reading disordered subjects took part in this study, 7 females and 5 males. The dyslexic subject group had a wide age-range, from 8 years, 8 months to 19 years, 1 month, with a mean of 14 years, 5 months. The wide age range allowed us to look for non-age-based commonalities. However, there were no correlations between age and our test scores, eliminating age as a factor in performance. At the time of testing the participants were all undergoing tutoring in the reading clinic of Dr. Catherine Penney of Memorial University of Newfoundland's Psychology Department. The participants had no known hearing problems and no speech deficits were identified.

Prior to this study, the participants had been given 4 subtests of the *Woodcock Reading Mastery Test* (Woodcock 1987). We used the *Word Identification* (Word ID) and *Word Attack* subtests, which measure the ability to read isolated words and to read nonsense words. The subtests are comprised of 1) isolated, phonetically regular syllables, 2) nonsense words, and 3) low frequency, phonetically regular real words. For example, the subject would be required to read nonsense words such as "op" or real words such as "pat." Subjects also completed the *Passage Comprehension* subtest, which requires the subject to read a short passage and fill in a missing word. They also completed the *Word Comprehension* subtest, which tests subjects' understanding of synonyms, antonyms, and analogies. Also administered were the *Test of Written Spelling* (TWS; Larsen and Hammill 1994), which requires the subject to print words that are presented orally by the examiner, and the *Raven's Progressive Matrices* (Raven 1976), a measure of non-verbal IQ that requires a subject to fill in a gap in a pattern by choosing the picture that fits from a choice of four. Subjects also completed the *Peabody Picture Vocabulary Test – Revised* (PPVT; Dunn & Dunn 1981), an oral test of vocabulary that requires a subject to select the picture from a choice of four that best matches the meaning of the word that is presented orally by the examiner. The results of the standardized tests are presented in table 4.1 below.

Table 4.1. Results of Standardized Tests for Reading Disordered Group

Test	Mean Quotient Standard Score	Standard Deviation	Minimum	Maximum
Word Identification	56.92	25.89	14	90
Word Attack	66.83	14.14	44	85
Passage Comprehension	69.08	23.7	23	101
Word Comprehension	66.33	23.15	19	94
Test of Written Spelling	68.00	10.46	60	93
Raven's Matrices	101.63	15.86	83	131
Peabody Picture Vocabulary	84.50	15.07	60	109

The results of the standardized tests revealed below-average reading skills among the reading disordered group. These scores place our reading disordered subject group in the bottom 2-3 percent of the population for reading and spelling scores. In comparison, the results of the Raven's indicated average non-verbal skills among the reading disordered group. The PPVT score was 0.5 below average, indicating below-average vocabulary skills.

4.3.2 Control Group

A total of seven normally-reading control subjects took part in the study, including 3 females and 4 males. Twelve subjects in the control group would have been preferable for the control group for between-group statistical purposes; however, only seven participants were available. At the time of testing the participants were all in grade two at Hazelwood Elementary School in St. John's, Newfoundland. The control group comprised an age-range from 7 years, 6 months to 8 years, 5 months, with a mean of 8 years. To ensure that subjects had no speech, reading, or hearing deficits, educators at Hazelwood Elementary referred to school records and their own knowledge of the students to select normally-reading students.

4.4 Ethical Consent

This project received ethical approval from Memorial University's Interdisciplinary Committee on Ethics in Human Research (ICEHR). Written consent was also obtained from each participant and/or the participant's parent or guardian. The consent form was explained orally. See Appendix C for copies of the consent forms.

5. Results

This section describes the types and results of analyses that were carried out on the data. Quantitative (statistical) analyses were carried out, comparing the dyslexic group to the control group and looking for significant factors and/or trends in performance on the tasks. Section 5.1 describes the results of the statistical analyses. Qualitative analyses were also carried out on the errors (primarily on the dyslexics' errors) to see if they display disordered phonology. The results of the qualitative analyses are described in sections 5.2 and 5.3.

5.1 Results of Quantitative Analysis

5.1.1 Reading-disordered Group Performance on Experiment Tests

Table 5.1 shows that the reading-disordered group had mean scores of about 90 percent or better on the repetition tests and 50 percent or lower on the consonant-removal tests. This suggests that the subjects have better perception and production skills but poorer metaphonological ability. Table 5.1 below shows the percentage correct on the experiment tests[3].

[3] Percentages were sometimes used to compare results between the experiment tests because the number of trials on the tests differed (i.e., 26 trials for the Real-word Repetition, 26 trials for the Non-word Repetition One Syllable, 52 trials for the Non-word Repetition Two Syllables, 26 trials for the Remove Consonant One test, and 26 trials for the Remove Consonant Two test). Raw scores were used to compare results on the experiment tests when the numbers of trials on the tests were equal. The numbers presented as decimals in parentheses throughout the text (i.e., that describe the mean, standard deviations, etc.) are quotients; they do not represent percentages.

Table 5.1. Results of Experiment Tests for Reading-disordered Group

Test	Mean Correct	Standard Deviation	Minimum	Maximum
Real-word Repetition	95%	5%	85%	100%
Non-word Repetition One Syllable	94%	6%	81%	100%
Non-word Repetition Two Syllables	90%	10%	73%	100%
C1-deletion	50%	31%	4%	92%
C2-deletion	43%	37%	0%	92%

5.1.1.1 Repetition Tests

Comparing the mean percentages of correct answers, there was a significant positive correlation between scores on the real-word repetition task and on the two-syllable non-word repetition scores, ($r=.800$, $p<.01$). Real-word repetition scores also correlated significantly with one-syllable non-word repetition scores ($r=.664$, $p<.05$). These results confirm that the repetition tests are comparable measures of the same ability. However, the correlation between the one and two syllable non-word repetition tests was not significant ($r=.546$, $p>.05$).

A dependent *t* test was performed on the results from the repetition of two-syllable non-words with initial stress and two-syllable non-words with final stress. The *t* test calculated a statistic based on the mean percentages of errors from the repetition of two-syllable non-words with initial stress (Mean = .0833, s.d.=.0982) and two-syllable non-words with final stress (Mean = .1058, s.d.=.0944). The percentage of errors included both instances where the subject did not give a response and instances where the subject made an overt error. The test was carried out in order to determine whether stress placement was a factor in repetition of clusters. The t test indicated that there were no significant differences in error rates based on stress placement in the two-syllable non-word repetition task: ($t(11)=-1.048$; $p>.05$). Furthermore, a significant positive correlation was found between errors on words with initial stress and errors on words with final stress ($r=.704$, $p<.05$). This finding indicates that if subjects do poorly repeating words with initial stress, they will do poorly repeating words with final stress and vice versa.

A repeated measures ANOVA with 3 levels of the factor 'stimulus type' was conducted to determine whether there were significant effects on error rate in the word repetition task of stimulus type. Two factors determined stimulus type: 1) semantic value, or "word-hood," and 2) word length (number of syllables). The ANOVA was calculated on percentage of errors for the word repetition tasks (real-word repetition (Mean=.05, s.d.=.05), one-syllable non-word repetition (Mean=.06, s.d.=.06), and two-syllable non-word repetition (Mean=.10, s.d.=.10)). The dependent variable in the ANOVA was the number wrong, including instances where the subject did not give a response. The ANOVA indicated that the main effect of stimulus type was significant: ($F(2,22)=4.138$; $MSe=.0022$; $p<.05$). This indicates that a combination of word-hood and word length affected performance; there were fewer errors on real words than on non-words and fewer errors on shorter words than on longer words. This finding about word length suggests that dyslexics may have a short-term memory deficit which inhibits their ability to repeat multisyllabic words. Word-hood and word length did not affect controls' performances on repetition tasks. In fact, as shown in table 5.4, the control group performed slightly better on the two-syllable non-word repetition task than on either the one-syllable non-word repetition or the real word repetition tests. These results indicate that one-syllable repetition tests tax dyslexics' production and perception skills less than the two-syllable repetition task. As well, the perception and production skills of children with normal language development are not hindered by word-hood and word length, at least not to the same degree as dyslexics.

5.1.1.2 Consonant Removal Tests

To examine the factors influencing dyslexics' performance on the consonant removal tests, scores were looked at that included both *right* responses, where the subject responded with an answer that was entirely correct, and *displaced errors* responses, where the subject responded with an answer that included the correct target consonant cluster but had other errors. For example, if the subject were asked to say "skate" without the [k] sound and replied 'sake,' the response would have been recorded as a *displaced error.* There was a significant correlation between scores on the C1-deletion and C2-deletion tasks ($r=.641$, $p<.05$) (this can be seen in table 5.2). This confirms that both remove-consonant tasks tap the same ability, but the C2-deletion was more difficult.

A dependent *t* test was carried out to determine whether the position of a consonant in a cluster is a factor in consonant removal tasks. The dependent variable was the mean percent correct from the removal of C_1 (Mean = .5000, s.d.=.3086) and removal of C_2 (Mean = .4327, s.d.=.3664). The one-tailed *t* test indicated that the position in a cluster of a consonant targeted for removal was a significant factor in performance on consonant removal tasks: ($t(11)=1.693$; $p<.05$). This indicates that the dyslexics had more trouble manipulating C_2 in each cluster than they did C_1 in each cluster. There are implications for future research which might find more significant results by testing less severe dyslexics by giving them the more taxing Remove- C_2 task.

A second *t* test was performed on the mean error rates from the C1-deletion and C2-deletion tasks of the consonant removal test to determine whether sonority distance between consonants in a cluster is a factor in consonant removal performance. The *t* test compared the removal of consonants from obstruent+approximant clusters with 2 degrees of sonority distance (sl, pl, bl, kl, gl, fl, pɹ, bɹ, tɹ, fɹ, kɹ, gɹ, fɹ, θɹ) (Mean error = 48.51%, s.d.=.3362) and from clusters with 3 degrees of sonority distance (sw, tw, dw, kw, gw, θw) (Mean error= 55.56%, s.d.=.2828). The *t* test indicated that the effect of sonority distance is a significant factor in consonant removal tasks: ($t(11)=-2.384$; $p<.05$). Participants performed more poorly if the clusters differed by 3 degrees of sonority than if the clusters differed by 2 degrees of sonority. However, there was a significant positive correlation ($r=.96$, $p<.01$) between errors on clusters with 2 degrees of sonority distance and those with 3 degrees of sonority distance, indicating a strong tendency for subjects to err on clusters of 2 degrees of sonority distance if they also erred on clusters of 3 degrees of sonority.

Participants performed worse both on (1) clusters differing by three degrees of sonority, such as C/w/, and (2) clusters of equal sonority distance, such as /sk/[4], than on clusters differing by two degrees of sonority, such as /pl/. (As shown throughout section

[4] S-initial clusters were studied by S Mugford.

5.3, C/w/ clusters were the most error-prone and underwent the most processes, when compared to other obstruent+approximant clusters. They were problematic both in the repetition tests and in the consonant-removal tests.) These findings indicate that some factor *other than* sonority is at play. It may be the complexity of segments that is a factor in dyslexic's performance on phoneme manipulation tasks and not sonority per se. For example, evidence from Smit (1993, as cited in Barlow and Dinnsen 1998:5) indicates that s-clusters can be analysed as affricates and C^w clusters may be labialized consonants. Therefore, dyslexics could analyse clusters of equal sonority or those differing by three degrees of sonority as single complex segments, rather than as a cluster made up of separate segments, as shown in (1). Note that the timing tier '•' = one segment and the feature tier uses symbols as shorthand for a single complex of features.

(1)	Single complex segments		vs	Consonant clusters	
	C_1	C_1		C_1C_2	C_1C_2
Timing tier	x	x		x x	x x
Features	s t	d w		s t	d w

A correlation was calculated between English word frequency (expressed as a percentage of instances per thousand words by Carroll, Davies and Richman (1971)) and consonant-removal error rate to determine whether the frequency of the real-words used in the consonant-removal test influenced the error rate on the test. The correlation was not significant (r=.124; p=.05), indicating that word frequency was not a factor in determining error rate on this task of metaphonological ability.

To summarize, three factors affected subjects' performance on the consonant removal tasks. The variables that were found to affect consonant deletion included task (removal of C_1 versus C_2), sonority, and type of cluster (s-clusters versus obstruent+approximant clusters). Word frequency was not found to affect performance on the consonant removal tasks.

5.1.1.3 Repetition and Consonant Removal Tasks

Results on the repetition and consonant removal tasks were put together to examine factors that may have affected dyslexics' overall performance. The factors were cluster frequency, and cluster type: C/w/ clusters versus C/l, ɹ/ clusters. A number of correlations were also carried out to compare dyslexics' performance on repetition and consonant removal tasks. The results of these analyses are described below.

A correlation was calculated between English cluster frequency (expressed as a percentage of instances per thousand words by Roberts (1965)) and error rate on all tests to determine whether the frequency of the obstruent+approximant clusters used in the repetition and consonant removal tests influenced the error rates on the tests. The correlation was not significant ($r=.339$; $p>.05$), indicating that cluster frequency was not a factor in determining error rate on any of the tasks designed for this experiment.

A *t* test was performed to determine whether there was a significant difference in performance on clusters containing /l/ or /ɹ/ (pl, bl, kl, sl, gl, fl, pɹ, bɹ, tɹ, fɹ, kɹ, gɹ, fɹ, θɹ) versus clusters containing /w/ (tw, dw, kw, sw, gw, and θw) on all tasks. The *t* test calculated a statistic based on the *total* mean numbers wrong for all tasks combined, including *displaced errors*, for the C/l/ and C/ɹ/ clusters (Mean = 13.62, s.d.=3.52) and for the C/w/ clusters (Mean =22.8, s.d.=9.26).The t test indicated that the effect of cluster-type was a significant factor in all tasks designed for this experiment: ($t(16)=-3.148$; $p<.01$). This indicates that the dyslexic participants made significantly more errors on clusters containing /w/ than they did on clusters containing /l/ or /ɹ/. On average, /w/ clusters (Mean frequency=.0622, s.d.=.1159) were found to be less frequent than /l, ɹ/ clusters (Mean frequency=.1991, s.d.=.1987), however a t test indicated that the difference in frequencies was not significant, ($t(16)=1.809$, $p>.05$).

Correlations were calculated between the dyslexics' scores on the three repetition and two consonant removal tests. The scores are summarized in table 5.2.

Table 5.2. Correlations Between Dyslexics' Experiment Test Scores

	Repetition Tasks			Consonant Removal Tasks	
	Real Word	One-syllable Non-word	Two-syllable Non-word	Delete C_1	Delete C_2
Real Word	-	-	-	-	-
One-syllable Non-word	.664*	-	-	-	-
Two-syllable Non-word	.800**	.546	-	-	-
Delete C_1	.621*	.551	.671*		-
Delete C_2	.481	.261	.518	.641*	-

* Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

The cases where there were no correlations occurred when dyslexics performed very well on one test but poorly on the other, as described below. Real word repetition correlated with one-syllable non-word repetition and with two-syllable non-word repetition only because of near-ceiling effects on all 3 tests. Similarly, two-syllable non-word repetition and one-syllable non-word repetition did not correlate because the dyslexics performed so poorly on the two-syllable task and so poorly on the one-syllable task. C1-deletion correlated with real-word repetition and with two-syllable non-word repetition, but not with one-syllable non-word repetition. In general, this indicates a correlation between the ability to produce clusters and the ability to manipulate them. (The exception here is because of poor performance on C1-deletion versus good performance on one-syllable non-word repetition). On the other hand, C2-deletion was only correlated significantly with C1-deletion – both tax the same ability. The lack of correlation between C2-deletion and all repetition tests is because the dyslexics did so poorly on C2-deletion but so well on repetition tasks, in comparison.

To summarize, dyslexics have some difficulty on repetition tests, but much more difficulty with consonant-removal tasks, as shown in tables 5.1 and 5.2. This finding indicates that dyslexics' phoneme manipulation skills are much worse than their perception and production skills. However, the dyslexic group also performed consistently (and on the two-syllable non-word repetition, significantly) worse than the control group on production tasks, even though the dyslexic group was, on average, twice as old as the control group, as discussed in section 5.1.3.1.

5.1.2 Comparisons between Experiment & Standardized Test Results

Correlations were carried out to compare dyslexics' scores on the experiment tests to those of the standardized tests. Table 5.3 shows these correlations; significant findings are discussed in the following sections. Correlations were also calculated both between age and the standardized verbal test scores and between age and the experiment test scores; however, no significant correlations were found.

Table 5.3. Correlations Between Dyslexics' Standardized Test Scores & Experiment Test Scores

	Real Word	One-syllable Non-word	Two-syllable Non-word	Remove-C_1	Remove-C_2
Word Identification	.444	.358	.552	.786**	.895**
Word Attack	.590*	.345	.691*	.764**	.868**
Passage Comprehension	.454	.286	.575	.601*	.794**
Word Comprehension	.492	.244	.673*	.607*	.878**
Test of Written Spelling	.183	.133	.330	.610*	.793**
Raven's	.186	.229	.404	.324	.791*
Peabody Picture Vocabulary	.201	.037	.298	.423	.771**

*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

5.1.2.1 Comparison of Repetition Tasks & Standardized Tests

For the most part, there were no significant correlations between non-word repetition scores and standardized test scores. However, there was a significant correlation between two-syllable non-word repetition scores and standardized scores on the Word Attack test ($r=-.691$, $p<.05$), indicating the tendency for large numbers of errors on the two-syllable non-word repetition task to be correlated with low scores on the word attack task. This result correlates auditory perception and production of nonsense words with visual decoding and production of nonsense words. (The Word Attack Test measures the ability to read nonsense words). There was also a significant correlation between two-syllable non-word repetition scores and standardized scores on the Word Comprehension test (r=-.673, p<.05), indicating a tendency for the error rate to increase on the non-word repetition task as scores decrease on the word comprehension test. This result correlates production of non-words with word comprehension. No significant correlation was found between two-syllable non-word repetition scores and standardized scores on the Passage Comprehension test (r=.575, p=.05). There was a significant correlation between real-word repetition scores and standardized scores on the Word Attack test (r=.590, p<.05), indicating a tendency for errors to increase on real-word repetition task as they do on the word attack test. This result correlates auditory perception and production of real-words with visual decoding and production (i.e., reading aloud). There were no significant correlations between the scores on the real-word repetition test and any of the other standardized test scores.

5.1.2.2 Comparison of Consonant Removal and Standardized Tests

As shown in Table 5.3, the consonant removal tasks were significantly correlated with all standardized tests, except the non-verbal skills test, Raven's. There were significant correlations between the C1-deletion scores and standardized scores on the Word Identification test (r=.786, p<.01) and the Word Attack test (r=.764, p<.01). These results show a relationship between phoneme awareness and visual decoding and production (reading aloud), replicating other findings in the literature. There were significant correlations between the C1-deletion scores and standardized scores on the Passage Comprehension test (r=.601, p<.05) and between the C1-deletion scores and standardized scores on the Word Comprehension test (r=.607, p<.05). These results support a relationship between phoneme awareness and production with comprehension in reading. There was a significant correlation between the C1-deletion scores and standardized scores on the Test of Written Spelling ($r=.610$, $p<.05$). This result supports a moderately strong positive relationship between C1-deletion scores and standardized Test of Written Spelling scores.

5.1.3 Performance of the Control Group on Experiment Tests

In contrast to the dyslexic group, the control group had mean scores of 97 percent or better on the repetition tests and 85 percent or better on the consonant removal tests. These results suggest that the control subjects had good perception, production, and metaphonological skills, especially when compared to the dyslexic group who were twice as old on average. The control subjects' scores on the experimental tests verify that errors by the dyslexic group were not attributable to test design. Table 5.4 below shows the control group's results on the experimental tests.

Table 5.4. Results of Experiment Tests for Control Group

Test	Mean Percent Correct Score
Real-word Repetition	0.98
Non-word Repetition One Syllable	0.97
Non-word Repetition Two Syllables	0.99
Remove Consonant One	0.85
Remove Consonant Two	0.87

A repeated measures ANOVA was performed on the mean percentages correct in the repetition tasks (real word repetition, one-syllable non-word repetition, and the two-syllable non-word repetition) with three levels of the factor stimulus type. Two factors determined stimulus type in the repetition tasks: 1) semantic value, or "word hood," and 2) word length (number of syllables). The ANOVA indicated that the main effect of stimulus type was not significant in control performance on the word repetition tasks, ($F(2,12)=.533$; $MSe=.357$; $p>.05$).

5.1.3.1 Control Group Compared to Reading-disordered Group

t tests were carried out comparing the results of the control group to the results of the dyslexic group on each of the five tasks: real word repetition, one-syllable non-word repetition, two-syllable non-word repetition, C1-deletion, and remove-C_2. The *t* tests calculated statistics based on the *total* numbers of errors for each task, including instances where the subject did not give a response *(passes)*. The *total* mean numbers of errors for the control group and dyslexic group are summarized in table 5.5 below.

Table 5.5. Mean Total Number of Errors and Omissions

Test	Control Group	Dyslexic Group
Real-word Repetition	0.43	1.25
Non-word Repetition One Syllable	0.71	1.58
Non-word Repetition Two Syllables	0.43	5.25
Remove Consonant One	3.86	13.00
Remove Consonant Two	3.29	14.75

No significant differences in error totals were found on the real word repetition task ($t(17)=1.620$; $p>.05$) or the one-syllable non-word repetition test ($t(17)=1.506$; $p>.05$), although there was a tendency for the dyslexic group to perform worse than the control group. However, the *t* tests indicated significant differences in error rates between the control group and the dyslexic group on the two-syllable non-word repetition test ($t(17)=3.188$; $p<.01$), the C1-deletion task ($t(17)=3.592$; $p<.01$), and the C2-deletion task ($t(17)=3.921$; $p<.01$). These findings indicate that the dyslexics were significantly worse than younger children with normal reading and spelling at repeating two-syllable non-words and removing consonants from clusters. The results also indicate that the dyslexics were not significantly worse than younger normally-reading children at repeating real words or one-syllable non-words. However, the fact that these much older dyslexics significantly underperformed the control group on a repetition task points to disordered phonology.

5.2 Results of Qualitative Analysis

The data gathered from the repetition and consonant removal tests designed for this experiment were analyzed qualitatively to determine what types of errors the participants made, what linguistic processes were used, and whether the processes tended to be syllable-based or feature-based. The purpose of this analysis was to determine whether the dyslexic group exhibited errors that are typical of delayed and/or disordered phonology, as described in section 3.1. Patterns of dyslexic errors on the repetition and consonant removal tests were examined and then compared to the errors and processes displayed by the control group.

5.2.1 Repetition Tasks

Analysis of dyslexic performance on the three repetition tasks yielded interesting general observations. First of all, there was persistence of processes that normally disappear at a much younger age in normal language development. Furthermore, the control group did not display any such processes even though they were much younger than the dyslexic group. Secondly, there was evidence of processes that are not seen commonly or at all in normal language development but that are typical of disordered phonology. Thirdly, the dyslexics made more errors on the two-syllable non-words than on either of the shorter one-syllable real and non-words. The specific errors and processes that were produced by the dyslexics on the three repetition tasks are provided in table 5.6 below.

Table 5.6 Dyslexic Cluster Errors and Processes in Repetition Tasks

Process	1 Syllable Real Word		1 Syllable Non-word		2 Syllable Non-word	
	Target	**Response**	**Target**	**Response**	**Target**	**Response**
Cluster reduction	/θw/	[θ]	/θw/	[θ]	/θɹ/	[θ]
	/tw/	[t]	/gw/	[g]	/dw/	[w]
	/gw/	[w]				
Substitution	/kw/	[tw]	/fɹ/	[θɹ]	/θɹ/	[pɹ] [fɹ]
	/sl/	[fl]				
					/bɹ/	[gɹ]
	/sk/	[sj][5]			/dw/	[gw]
					/θw/	[fw] [sw]
	/θw/	[fw]			/pl/	[kl]
					/fr/	[θɹ]
					/fl/	[θl]
					/sf/	[sw]
C_2 Substitutions[6]	/θw/	[θɹ],[fɹ]	/fl/	[θɹ],[θl]	/gw/	[dɹ] [gɹ]
		[fl]	/θw/	[θɹ]	/θw/	[θɹ]
			/gw/	[gɹ]	/gl/	[gɹ]
		[fw]			/pl/	[pɹ]
	/dw/	[dɹ]			/kw/	[kɹ] [gɹ]
					/tw/	[tʃɹ]
					/θw/	[fl], [sl] [zw]
					/kɹ/	[kl]
					/pɹ/	[pl]
					/sp/	[sl]
Gliding			/fɹ/	[fw]	/sl/	[sw]

[5] Interestingly, this is the only production of [j] on any of the tests.
[6] These were substitutions in which the second C in the cluster (the approximant) was substituted; there were also errors on C_1 in a few cases.

Process	1 Syllable Real Word		1 Syllable Non-word		2 Syllable Non-word	
	Target	Response	Target	Response	Target	Response
ə-epenthesis			/θw/ /dw/ /bl/	[θəw] [dəw] [bəl]		
Post-stress Voicing[7] (only possible in 2 syllable non-word)					/sw/ /kɹ/ /sl/	[zw] [gɹ] [zl]
ɹ-insertion					/sk/	[skɹ]
Metathesis					/sæklɪp/	[sæplək]
Stop insertion					/səklæs/ /nəflæk/	[səklæsk] [nəflækt]
C-deletion & Metathesis					/mijbɹæk/	[mijgɹə]
Displaced errors Word-final consonant replaced by /p, t, k/ (target otherwise correct)					**Target Words Affected** /təkɹejp/ /sæklɪp/ /sijpɹət/ /bægwɛt/ /gæplət/ /gæplət/ /təfɪejp/ /pəgwejp/	/təswejp/ /pəsmejp/ /kəθɹejk/ /tədwejk/ /təglejk/ /səgɹejk/ /bægwɛt/ /mətwejk/

Other displaced errors on the two-syllable non-word repetition are discussed shortly.

As table 5.6 shows, there is evidence of delayed phonology in the responses from the dyslexics. The dyslexics displayed perseverance of strategies that simplify syllable structure, including cluster reduction, metathesis, epenthesis, and consonant deletion. The general substitution errors (including displaced errors) that are shown in Table 5.6

[7] Two of these substitutions conform to English phonotactics, in that there is no voiceless [s] after stressed vowels in English.

mainly suggest misperception. Misperception is especially suggested by the fact that the substitution errors 1) involve easily confusable contrasts such as those between fricatives and those between word-final stops (/p, t, k/); and 2) increase when word-length increases (increase in word-length taxes verbal recall). The substitution errors in which C_2 was replaced yielded a number of interesting observations. First of all, in CLA we see a pattern, gliding, in which /l, ɹ/→[w, j]. While the dyslexics used this process, indicating perseverance, it was not common. As described in section 5.1.1.3, dyslexics performed significantly worse on C/w/ clusters than on C/l, ɹ/ clusters. Furthermore, the dyslexics randomly replaced /l/→[ɹ] and /ɹ/ →[l]. However, the substitution /w/→[l, ɹ] was much more common than these processes of substitution and gliding. The substitution of Cw→Cɹ was more frequent than Cw→Cl, which only occurred on the target cluster /θw/. This pattern of substitution was expected as /w/ and /ɹ/ share the feature [labial] (as discussed in section 2.1). These facts suggest overgeneralization (a stage in the learning of rules or representations – here, a stage in acquisition of consonant contrasts). It appears that the dyslexics have learned of the existence of the /l, ɹ/ contrast but overgeneralize the [±lateral] contrast to C_2 all of the time (i.e., oversupply /l/ and /ɹ/). This indicates that the dyslexics have not completely reached the stage of correctly using the /l, ɹ/ contrast. Fricative substitution, nasalization and stopping did not occur in the testing. All are processes that occur in normal language acquisition and the absence of their use suggests that while the dyslexics may not have acquired the contrast between /l, ɹ/, they have acquired the more major phonemic contrasts between, for example, fricatives and liquids.

As discussed in section 3, cluster reduction is a syllable-based process; substitutions are feature-based processes. Both types of processes were expected in responses from the dyslexic subjects. These are processes that are typical of normal language acquisition; however, children usually stop exhibiting them at a young age. Lateralization is uncommon in normal language development but occurs in dyslexic reading errors. Rhotic substitution was not expected. Gliding was expected to occur on C/ɹ/ clusters to produce C/w/, but instead the dyslexic subject group tended to replace /w/ with /ɹ/: /dw/→[dɹ].

As discussed above, lateralization and rhoticization really seem to be instances of overgeneralization. The errors that the dyslexics made on the word-initial consonant clusters in the one-syllable non-word repetition test were typically cluster reduction, substitution, and ə-insertion. The control group erred three times: two were substitutions on target /θw/, producing [fw] and [sw], and once was devoicing of target /gw/ → [kw]. Errors were made by the dyslexic group on 58.3% of the attempts made at the target cluster /θw/ in the nonword [θwajn]. Fricative substitution, cluster reduction, and ə-insertion are processes that occur in normal language development. These processes were used by the dyslexic subject group which had a much older average age (14 years, 5 months) than children with normal language development who use these processes. Fricative substitution is a feature-based process; cluster reduction and ə-insertion are syllable-based processes. ə-insertion occurred in order to create a more canonical CVCV syllable structure.

The dyslexic subject group made more errors on the two-syllable non-word repetition task than on the other repetition tasks. Errors in the two-syllable task were on the target word-medial consonant clusters and on other segments in the words. Responses where errors were made on segments other than the target cluster were recorded as *displaced errors*. For example, dyslexic subjects frequently repeated the cluster correctly but made substitutions on the word-final consonant. One such case was repeating [təswejp] as [təswejt].

The dyslexic group used syllable-based processes (ɹ-insertion and cluster reduction) less frequently than feature-based processes (substitutions). Reduction only occurred on two clusters, /θɹ/ and /dw/. This disagreed with my hypothesis that cluster reduction would be a frequent process used by the dyslexic group. The fact that substitution was a more frequent process indicated that the dyslexics were attempting to produce 2-consonant onsets. In other words, the dyslexics were aware that the onsets were made up of two consonants, not one.

The majority of the errors that subjects made on the target words that were recorded as *displaced errors* were final-consonant errors. All *displaced errors* occurred in the two-syllable non-word repetition task. Of the thirty-six *displaced errors* responses that contained obstruent+approximant clusters, twenty-five contained errors on the final consonant of the word. As can be seen, substitutions of the word-final plosives [p,t,k] were common. However, the dyslexic group also made errors on the word-initial consonant of the two-syllable non-word repetition test. These errors and processes are summarized in table 5.7.

Table 5.7. *Displaced errors* and Processes on Initial Consonants in two-syllable non-word repetition test

Process	Target Words Affected	Response
Substitution	/mɑkɹɛp/	[bɑkɹɛp]
	/təkɹejp/	[ðəgɹejk]
	/pəsmejp/	[təsmejp]
	/powblɛk/	[kowblɛk]
	/mətwejk/	[nətwejk]
Lateral-insertion	/sæklɪp/	[slæklɪp]
	/səθwejk/	[sləflejk](& substitution)
	/səplejk/	[sləplejk]
Voicing	/tədwejk/	[dəkwejk]
Voicing & metathesis	/səθwejk/	[ðəzwejk]
Consonant deletion	/bɪθwɪg/	[ɪflɪg](& substitution)

Once again, the feature-based process, substitution, was the most frequently used process. As before, we see random substitutions amoung the plosives [p,t,k]; substitutions of consonants with the same point of articulation but different manners of articulation- [b, m], [t, θ]; substitution of perceptually similar sounds – [[f, θ], [m, n]; voicing assimilation of various types; and metathesis. The novel data here was the creation of a word-initial cluster [sl] that had characteristics similar to the word-medial clusters produced – [kl, fl, pl].

A number of conclusions about the state of dyslexics' phonology can be made, based on the results of the qualitative analysis on the errors in the repetition tasks. Syllable-structure simplification strategies were relatively uncommon. This suggests that onsets are relatively well-developed; (the dyslexics know when onsets have consonant clusters and they try to produce them). However, it appears that feature or consonant contrasts, especially between /l, ɹ, j/ are not completely acquired. It also seems that dyslexics are at risk for misperception, especially of word-initial and word-final /p, t, k/.

5.2.2 Consonant Removal Tests

Analysis of dyslexic performance on the two consonant removal tasks yielded interesting general observations. First of all, the processes that occurred in the consonant removal tasks were mostly different from those used in the repetition tests. The most frequent processes in the repetition tests were cluster reduction and substitution. On the consonant removal tests, the most frequent processes were omission of an entire cluster, removal of the wrong consonant, and simple repetition without removal of any consonant. Secondly, there were more errors and more types of errors on the C2-deletion task than on the C1-deletion task.

The dyslexic subject group made errors on all of the twenty obstruent+approximant clusters. The most frequent error on the consonant removal tasks was omission (Ø) of the entire cluster, which occurred on every cluster. Other errors included not removing any consonant (NR), removing the wrong consonant (WC), substitution, and lateralization. The specific errors and processes that were produced by the dyslexics on the two consonant removal tasks are provided in table 5.8. The numbers of occurrences of responses are indicated in brackets. Responses not bracketed occurred once. The total number of trials for each cluster was twelve – once per subject.

Table 5.8. Errors and Processes on the Consonant Removal Tests

Process	C1 Deletion		C2 Deletion	
	Target Cluster	**Response**	**Target Cluster**	**Response**
Omission	/sl/	Ø (5)		Ø (3)
	/pl/	Ø (3)		Ø (5)
	/bl/	Ø (6)		Ø (3)
	/kl/	Ø (6)		Ø (3)
	/gl/	Ø		Ø (2)
	/fl/	Ø (3)		Ø (4)
	/pɹ/	Ø (3)		Ø (3)
	/bɹ/	Ø (5)		Ø (3)
	/tɹ/	Ø (3)		Ø (7)
	/fɹ/	Ø (7)		Ø (4)
	/kɹ/	Ø (5)		Ø (4)
	/gɹ/	Ø (3)		Ø (4)
	/θɹ/	Ø (5)		Ø (6)
	/sw/	Ø (5)		Ø (4)
	/tw/	Ø (7)		Ø (4)
	/dw/	Ø (5)		Ø (4)
	/kw/	Ø (7)		Ø (6)
	/gw/	Ø (4)		Ø (5)
	/θw/	Ø (4)		Ø (4)
	/dɹ/	Ø (3)		Ø (3)
WC	/gl/	[g]	/sl/	[l] (2)
	/pl/	[p]	/pl/	[l]
	/pɹ/	[p]	/sw/	[w]
	/kɹ/	[k]	/bl/	[l] (2)
	/θɹ/	[θ]	/kl/	[l] (2)
	/kw/	[k]	/gl/	[l]
	/dɹ/	[d] (2)	/pɹ/	[ɹ]
			/bɹ/	[ɹ]
			/kɹ/	[ɹ] (3)
			/gɹ/	[ɹ]
			/tw/	[w]
			/dɹ/	[ɹ] (3)
NR (simply repeated the word)	/kɹ/	[kɹ]	/kl/	[kl]
	/sl/	[sl]	/gl/	[gl]
	/dw/	[dw]	/fɹ/	[fɹ] (2)
	/dɹ/	[dɹ] (2)	/kɹ/	[kɹ]

NR (simply repeated the word)	/θw/	[tw]	/dɹ/ /gw/ /fl/ /pɹ/ /tw/ /bɹ/	[dɹ] [gw] [fl] (2) [pɹ] [tw] [pɹ]
Removal of correct consonant, but substitution of remaining consonant	/fɹ/ /fɹ/ /θw/ /fl/ /kw/ /gw/	[n] [l] [l] [ɹ] [ɹ] [ɹ]	/θɹ/ /θw/ /θw/	[t] (2) [f] (2) [t]
NR & substitution in C_1 or C_2			/kw/ /gw/ /dw/ /θw/	[kɹ] [gɹ] [gɹ] [fl]
WC & Substitution of C_2			/θw/ /kw/ /gw/	[ɹ] [l] [l]
ə-insertion			/bl/ /fl/ /t ɹ/ /θw/	[bəl] [fəl] [t əɹ] [θəw]
Other			/sl/	[skɹ]

A number of conclusions about the state of dyslexics' phonology can be made, based on the results of the qualitative analysis on the errors in the consonant removal tasks. Unlike repetition tests, the errors in the consonant removal tests (omission of the entire cluster, removal of the wrong consonant) suggest that the dyslexics have a phoneme awareness deficit. Like the repetition tests, it appears that feature or consonant contrasts are not completely acquired. This was reflected in the substitution processes that the dyslexics used, namely, /ɹ/→[n, l], /l/→[ɹ], /w/→[ɹ, l]. Finally, like the repetition test, it also seems that dyslexics are at risk for misperception. This was reflected in the dyslexics' misperception/substitution of C_1: /θ/→[t, f], /g/→[d].

The dyslexic group also made liquid-substitution errors on some s+obstruent clusters (results are included here because liquids occurred in the targets). For the word [sfɹ], responses included [ɹɪɹ] and [fɪl], with substitutions of liquids occurring in both cases. For the item [snæp], one subject answered [kɹæk]. When asked to remove [n] from [snæp], one subject responded [læp]. When asked to remove [t] from [stæk], one response was [skɹæk] and another [t ɹæk], a rhotic being inserted in both cases. In some of these cases the subject produced a real-word response that sounded like the target. In other cases there was random insertion of liquids, indicating a lack of ability to distinguish two consonants from three consonants.

5.2.3 Control Group Compared to Dyslexic Group

Overall, the dyslexic group made more errors and more types of errors than the control group on all tests. As shown in Table 5.9, the control group made only substitution-type errors on the non-word repetition tests. On the consonant removal tests, the errors were all either omission of the entire cluster, removal of the wrong consonant, or no removal of any consonant. These results indicate that the control group had stronger perception/production and metaphonological skills than the dyslexic group, despite being much younger than the dyslexics.

Table 5.9. Control Group Errors on All Tasks

Process	1 Syllable Real Word	1 Syllable Non-word	2 Syllable Non-word	C1 Deletion	C2 Deletion
Substitution	-	/θw/→[sw] /gw/→[kw] /θw/→[fw]	/θw/→[fw] /dw/→[gw]	-	-
Omission of Entire Cluster	-	-	-	/kw/→Ø (2) /gw/→Ø /θɹ/→Ø (2) /gl/→Ø /fl/→Ø (2) /tw/→Ø /dɹ/→Ø /fɹ/→Ø (3) /sw/→Ø /dw/→Ø	/kw/→Ø (4) /gw/→Ø (3) /tɹ/→ Ø /kɹ/→Ø /pl/→Ø /θɹ/→Ø /θw/→Ø /dw/→Ø
Wrong C Removal	-	-	-	/θɹ/→[t] (2) (also substitution) /bl/→[b]	-
No C removal	-	-	-	/gw/→[gw] /fl/→[fl]	/gw/→[gw] /kw/→[kw] /fl/→[fl] /tɹ/→[tɹ]

The dyslexic subject group made a number of errors on the word-initial obstruent+approximant clusters in the real word repetition component of the consonant-removal test; the control group made no errors. The dyslexic group made errors on 6 clusters in the one-syllable non-word repetition test, while the control group erred on 2. The dyslexic subject group made errors on 15 of the 20 obstruent+approximant clusters in the two-syllable non-word repetition. The errors that were made were typically substitutions (including rhotic substitution), voicing, lateralization, gliding, and cluster reduction. In contrast, the control group made only two feature-based errors on this test: substitution of [fw] for /θw/ in target /səθwejk/ →[səfwejk] and substitution of [gw] for [dw] in target /pɪdwɑk/→[pɪgwɑk].

The control group made far fewer errors on the C1-deletion test than the dyslexics did. No substitutions were made at all by the control group. The control group made 19 errors on the C2-deletion task. For /θɹ/, the subject correctly removed /ɹ/ but substituted [t] for /θ/. Interestingly, while the dyslexic group made frequent substitutions on the remove-consonant tasks, this was the single case of substitution by the control group on the two remove-consonant tests combined[8]. Furthermore, the dyslexic's use of substitution processes was pervasive in the repetition tasks; however, the control group used them only five times: three times on the one-syllable repetition, and twice on the two-syllable repetition. It seems that there is a tendency for dyslexics to use feature-substitution processes, while children with normal language development stop using them at a young age.

5.2.4 Summary of Results (Qualitative Analysis)

The qualitative analysis of the errors and processes produced by the dyslexic subject group in the repetition and remove-consonant tests indicates that dyslexics display characteristics of both an immature level of language acquisition and disordered

[8] It is possible that this substitution error was influenced by dialect.

phonology. The dyslexic group produced errors and used processes that are typical of much younger, normally developing children, for example omission and cluster reduction. However, their use of deviant processes such as lateralization, frequent rhotic substitution, and ɹ-insertion parallels processes that are typical of individuals with disordered phonology.

5.3 Discussion

The purpose of this study was to investigate whether dyslexics have disordered phonology. This hypothesis was tested by examining dyslexics' production of approximants in clusters, dyslexics' metaphonological ability to manipulate approximants both as singletons and in clusters, and by comparing results to those of a control group with no known language deficits. When the patterns of errors were examined, it was revealed that the dyslexic group consistently used processes that are characteristic of disordered phonology and processes that are typically produced by much younger children with normal language development. It was found that the dyslexics, unlike the control group, made errors that were influenced by factors such as consonant position in a word, word-hood, word-length, and sonority distance.

When the overall performance of the dyslexic group was compared to that of the control group, it was found that the dyslexics did significantly worse on the two-syllable non-word repetition and the consonant removal tests than the much younger control group. The dyslexic group also frequently used language processes that are typical of much younger, normally developing children. These findings indicate that, at the very least, dyslexics are delayed in their acquisition of phoneme awareness when compared to children with normal language development. Many of the strategies that the dyslexics used are normally only present in much younger subjects. For example, the use of substitution, cluster reduction, and gliding are common to young normally developing children, but are characteristic of phonologically disordered people, regardless of age. The use of these processes by the dyslexic group, who had a mean age of 14 years, 5 months, but not by the much younger normally developing control group, is suggestive of a disordered phonology.

Examination of the patterns of errors that the dyslexics made revealed that they used processes that are typical of people with disordered phonology. The dyslexic group frequently used lateral and rhotic insertions, lateralization, and rhotic substitution in the experiment tasks. None of these processes were used by the control group and they are not typical to normal language development. The lateral and rhotic <u>insertions</u> suggest incomplete acquisition of syllable structure. Furthermore, the <u>substitutions</u> of approximants (/l, ɹ, w, j/) suggests that dyslexics have an incompletely acquired set of approximant contrasts. In fact, it may be the case that the substitution processes are not separate processes as such, but are instead instances of incomplete acquisition of the approximant contrasts.

The results of this study suggest that dyslexics not only have disordered phonology, but may also have related verbal memory deficits. Table 5.3 showed that two-syllable non-word and Word Comprehension were correlated positively. For both of these tasks, the subject must remember either a non-word or a verbal explanation in order to perform. As well, word-length and word-hood were shown to affect dyslexics' performance on repetition tasks, but not controls'. This suggests that dyslexics lack the verbal memory capacity that normally developing children have.

The results of this study replicate the findings of previous studies which show that dyslexics have a phoneme awareness deficit; however this study has uncovered more specific findings. The dyslexic group performed much worse on the consonant removal tasks than the control group. Furthermore, the dyslexics randomly substituted approximants for one another in the consonant removal task, again indicating lack of complete acquisition of contrasts between /l, ɹ, w, j/.

Factors that negatively affected dyslexics' performance included position of a consonant in a cluster, word-hood and word-length, and sonority. The dyslexic group made more errors on removing the second consonant from a cluster than on removing the first consonant from a cluster. Dyslexics performed worse on longer words than on shorter words and worse on non-words than on real words. Sonority distance between consonants in a cluster and a related factor, complexity, were shown to affect dyslexics' performance. First, on the obstruent+approximant clusters, performance was worse on C/w/ clusters. Second, /s/C and C/w/ clusters are more complex, and proved to be most troublesome to the dyslexics than all other obstruent+approximant clusters.

The factors of age, stress, word frequency, and cluster frequency were examined as possible causes for dyslexics' errors. Word frequency and cluster frequency did not have an effect on dyslexic performance, ruling out the possibility that dyslexics make more errors on sounds that do not often occur in English. Findings also showed that age is not a factor in dyslexics' performance on tests of reading and spelling ability, ruling out the possibility that age-related (developmental) improvements in reading and spelling skills would affect test scores. It was also shown that stress placement in a word is not a factor in dyslexic performance.

5.3.1 Conclusion

This study has yielded a number of conclusions about dyslexics' treatments of approximants specifically, and more broadly, the nature of dyslexics' phonological development. Overall, both the repetition tests and the consonant removal tests show that the dyslexics display near-mastery at the timing tier level. They usually manage to repeat clusters (although not always the target ones), and they can perform consonant removal tasks to some extent. The tests also show that, at the segmental level, dyslexics have incomplete acquisition of the distinction between /l, ɹ, w/. A number of factors were found to trigger errors on words that contain obstruent+approximant clusters, including consonant position in a word, word-hood, word-length, and sonority distance. When making these errors, dyslexics use processes that are typical of normal child language development. The use of these normal processes by much older children such as the subject group in this study, however, is symptomatic of disordered phonology. Furthermore, the use of processes that are unknown to normal language development but that are characteristic of disordered phonology indicates that dyslexics have disordered phonology.

In addition to having phoneme awareness deficits, dyslexics have now been demonstrated to have specific phonological deficits. In particular they appear to have incomplete acquisition of the l/ɹ contrast.

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Appendices

Appendix A: Relevant Definitions

Laterals and Rhotics

Laterals are usually defined as those sounds which are produced with an occlusion somewhere along the mid-saggital line of the vocal tract but with airflow along one or both sides of the occlusion (Ladefoged and Maddieson 1995). Laterals "are sounds in which the tongue is contracted in such a way as to narrow its profile from side to side so that a greater volume of air flows around one or both sides than over the center of the tongue' (Ladefoged and Maddieson 1995: 182). Voiced lateral approximants are the most frequent type of lateral and are produced with an occlusion in the dental/alveolar region. This articulation, however, is not universal and the area of contact may extend further back in the mouth. It is also possible for the closure at the front to be incomplete. In other words, slight variations in the place of articulation of lateral approximants result in the production of a number of different speech segments, all of them lateral approximants.

Rhotics, or r-sounds, exhibit a wide variety of manners and places of articulation (Ladefoged and Maddieson 1995). The most prototypical members of the class of rhotics are trills made with the tip or blade of the tongue (/r/). These central members of the class show phonological relationships to the heterogeneous set of taps, fricatives and approximants which form the remainder of the class. Rhotics may be fricatives, trills, taps, approximants, r-coloured vowels, or any combination of these. "The most common places of articulation are in the dental/alveolar area, although post-alveolar (retroflex)

/r/'s are not unusual, and in some languages /r/'s have a uvular articulation" (Ladefoged and Maddieson 1995:216).

Features of English Consonants

[±] is used to indicate binary features; 0 indicates the presence of unary features. Place and manner features for [l, ɹ, w, j, s, n, ʊ] are discussed in Section 2.2.

Table A1 Feature Matrix for Some English Consonants

	p	b	t	d	k	g	f	v	z	θ	ð	ʃ	ʒ	tʃ	dʒ	m	ŋ	h	ʔ
[sonorant]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+*	+*
[approximant]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+*	+*
[vocoid]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[voice]	-	+	-	+	-	+	-	+	+	-	+	-	+	-	+	+	+	-	-
[constricted glottis]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
[spread glottis]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
[labial]	0	0					0	0								0			
[coronal]			0	0					0	0	0	0	0	0	0				
[anterior]			+	+					+	+	+	-	-	-	-				
[distributed]			-	-					-	+	+	+	+	+	+				
[strident]	-	-	-	-	-	-	-	-	+	-	-	+	+	+	+	-	-	-	-
[dorsal]					0	0											0		
[nasal]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+		
[continuant]	-	-	-	-	-	-	+	+	+	+	+	+	+	-	-	-	-	+	-
[delayed release]	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-

(after O'Grady and Dobrovolsky 1992:72)

* Halle & Clements SPE (1965) claim that laryngeals are sonorants. Nothing hinges on this claim.

As shown in Table 1, distinctive features uniquely characterize single consonants as well as classes of sounds (which share features). Classes of sounds tend to pattern alike. As discussed in Section 2, this is the case with [l, ɹ, w, j, s, n, ʊ], which have a number of features in common.

Definitions of Disordered Phonology and Dyslexia

"Children with speech disorders are a heterogeneous group, their disorders differing in severity, symptomatology, and response to treatment" (Dodd, Holm and Wei 1997:230). Such variability has made it difficult for professionals to agree on a single definition for each type of language disorder, or even to agree on the existence of some disorders. This section defines disordered phonology and dyslexia as they are considered in this paper[9].

Disordered Phonology

A disability in phonology results from an abnormal relationship between the "abstract" phonological system and the phonetic realization of that system (Crystal 1987:44). The *phonological system* refers to the unpronounceable, hence "abstract," system of speech segments (i.e. phonemes) that a person has stored. A phoneme may have a number of possible pronunciations without affecting the perception of the segment. The *phonetic realization* of a phoneme refers to the actual pronunciation of the phoneme. For example, a phoneme /p/ may be phonetically realized as [p], as in 'spill' [spIl] or as [p^h] as in 'pill' [p^hIl]. Either way, the sound is perceived as a form of the phoneme /p/.

"There are three ways in which the relationship between these two levels of language organization can be abnormal" (Crystal 1987: 44):

[9] Specific Language Impairment (SLI) is not included in the paper at this point. It would be a useful inclusion in that it would provide further support for phonological deficits in language impairments; however, the focus of this paper is restricted to dyslexia and its relatedness to disordered phonology.

(i) The phonological system is normal, but its phonetic realization is abnormal (e.g. immature or deviant pronunciations of phonemes, but without the range and pattern of phonemic use being affected);

(ii) The phonological system is abnormal, but its phonetic realization is normal (e.g. the range of phonemes used may be considerably delayed, but their pronunciation is within normal limits);

(iii) Both the phonological system and its phonetic realization are abnormal, delay or deviance affecting both aspects of the analysis.

Crystal goes on to acknowledge that (i) better defines a "phonetic disability" while (ii) and (iii) apply to phonological disability.

Dodd et al. (1997: 230), in a study of the error patterns of two preschool speech-disordered children bilingual in Cantonese and English, also define disordered phonology in two ways:

(1) the speech is marked by deviant, but consistent, errors: i.e. the use of consistent error types that are atypical of normal phonological development (e.g. deleting all syllable initial consonants);

(2) the speech is marked by inconsistent errors: i.e. variable pronunciation of the same words or phonological features (e.g. vacuum cleaner pronounced as [dɪʌkm kinʌ], [fahkum timʌ], and [bwahkjum kinʌ]).

Crystal (1987: 47) also provides a list of characteristics that are common to phonological disability. The presence of these characteristics in the output of a dyslexic child supports the idea that a phonological deficit underlies dyslexia.

Crystal (1987) points out the presence of a restricted range and frequency of segments and of segmental combinations, which means that the child has fewer contrasts in their segmental inventory (e.g. /p/b/, /t/d/, /g/k/) and fewer possibilities for combinations (e.g. /sp/, /bl/). There is also a restricted range of features, especially affecting place of articulation, which means that the child may not be able to produce entire classes of sounds. For example, if the feature [labial] is absent the child will have difficulty articulating any sounds that are produced with the lips (i.e. /p, b, f, v, m/).

Crystal (1987) goes on to identify an extremely limited range of fricatives and non-nasal sonorants. This means that the child's phonetic inventory would be extremely limited and it would be difficult for the child to make many adult-like productions. Phonologically disabled children are also likely to confuse the contrast between voice and voiceless (e.g. /b/ vs. /p/), indicating that they are unable to perceive the difference in phoneme quality between a sound that has vocal cord vibration and a sound, in the same place of articulation, that does not.

Phonologically disordered children generally do not produce consonant clusters; however, use of the glottal stop ([ʔ]) as a substitute form is pervasive. An example of this tendency is provided in a study by Grunwell and Yavas (1988: 6) on a 9 year old English speaking boy with disordered phonology. The boy did not produce any consonant clusters, reducing all targets to a single consonant. Consonants in word medial or word final positions were realized as glottal the vast majority of the time. There were 22 target productions in word medial position. Of these 22, the boy uttered nothing for 4, got 6 correct (but only after having produced a glottal on a previous attempt) and produced a glottal 18 times. There were 19 target productions in word final position. Of these 19, the boy uttered nothing for 1 and produced a glottal 18 times.[10]

The vowel system is relatively well-developed in children with disordered phonology.

Children with disordered phonology tend to produce basic syllable structures of the canonical CVCV form, for example [papa]. As illustrated in the example borrowed from Grunwell and Yavas, they have an enormous amount of difficulty producing consonants in code position even if they have acquired the segment and can produce it word initially. It should be noted that this difficulty with coda consonants occurs in the early stages of consonant acquisition in normally developing language. However, even infants are able to babble sequences of sounds with the forms CVC, CCV and CCVC (Archibald and Libben 1995:72). On the other hand, glottal stops are consonants. Therefore, the child with disordered phonology is attempting to produce syllables more complex than CVCV but is unable to produce the target coda consonant and omits it or substitutes a glottal stop instead.

Dyslexia

Despite the prevalence of dyslexia, controversy continues in regard to its definition, characteristics, and diagnosis (Roberts and Mather 1997:236). Three major subtypes of dyslexia have been described: phonologic, orthographic, and mixed

[10] This evidence shows that the child has not yet acquired a complete phonological system. He is able to produce consonants word initially, but not word internally or word finally where they would be in coda position.

dyslexia, which is a decoding or encoding disability that is caused by a combination of both phonologic and orthographic processing deficits; (ibid: 237).

Orthographic dyslexia, according to Roberts and Mather (1997: 239), refers to "a problem with the acquisition of decoding or encoding skills that is caused by difficulty with rapid and accurate formation of word images in memory." Orthographic dyslexics have difficulty in storing mental representations of words, especially phonetically irregular words. The problems underlying this type of dyslexia are related directly to memory and coding skills that allow representation of printed letters and words and not to poor phonological processing. Caplan (1987: 225) refers to this type of dyslexia as *Surface Dyslexia* and defines it as an inability "to recognize written words on a purely visual basis. They have trouble reading aloud words that are irregularly spelled. Rather than recognizing words visually, these patients apparently sound out the words on the basis of correspondences between letters and sounds."

Given these definitions of dyslexia, the affected person would have trouble learning the phoneme-grapheme correspondence between the hard and soft pronunciations of 'c':

Hard: C = [k] cat

Soft: C = [s] ice

Most often, the dyslexic will use the most common pronunciation of the grapheme, which inevitably leads to errors in reading and writing. For example, an orthographic dyslexic might read "cat" as [kæt] correctly, but misread "ice" as [Ik]. In this example, the dyslexic has identified /k/ as the phoneme corresponding to the grapheme 'c' and will produce [k] all or most of the time.

Phonological dyslexia refers to "a problem with the acquisition of decoding or encoding skills that is caused by difficulty manipulating and integrating the sounds of a language effectively" (Roberts and Mather 1997:240). Roberts and Mather go on to acknowledge that efficient phonological processing skills are needed to learn to read and write successfully and that phonological deficit is the most common characteristic of individuals with dyslexia. The phonological dyslexic is unable to segment, analyze, and synthesize speech sounds and is identifiable by their phonetically inaccurate misspellings. Snowling (1981: 225) defines phonological dyslexia similarly as an inability to produce novel words due to poor grapheme-phoneme knowledge; the patient exhibits poor performance on phonological awareness tasks and deficits in verbal working memory. Phonological dyslexics are frequently unable to segment words into individual sounds most likely because of an impaired representation and use of phonology.

Based on these definitions of phonological dyslexia, the affected person would have difficulty distinguishing between similar-sounding phonemes, for example b/p or d/t. Given the word "bat" [bæt], for example, the dyslexic might read [tæp] or write "pig."

It is important to note that in the example provided for the misreading of "ice" the orthographic dyslexic can hear, or perceive, the difference between the phoneme /k/ and the phoneme /s/. Their difficulty lies in identifying the correct grapheme, in this case ‘c,’ so that they can read or spell the given words. In the examples provided for the phonological dyslexic, this person would be unable to perceive the difference between /t/ and /d/ or between /p/ and /b/. Therefore their chances of reading or spelling correctly are compromised as well as their ability to discern the proper semantics of spoken language.

Acquisition of Phonological Rules

In looking at how a child treats a particular sound or class of sounds, it is not enough to examine the segments as they exist in the child's current phonemic inventory. It is beneficial to study the processes that lead to a particular production. Three main classes of processes can be identified for normal child language acquisition in which the adult linguistic form is the input and the child's form is the output (Crystal 1987:37):

(i) Substitution processes are common to acquisition, whereby a target sound is replaced by the production of some other sound. There are a number of examples of substitution processes: *stopping,* whereby fricatives are replaced by stops (e.g. “say” [tej]); *fronting,* whereby velars and palatals are replaced by alveolars (e.g. “coat” [dʊt]); *gliding,* whereby /l/ and /ɹ/ are replaced by /w/ or /j/ (e.g. “leg” [jeg]); and *vocalization,* whereby syllabic consonants are replaced by vowels (e.g. “apple” [apʊ]).

(ii) Assimilatory processes occur when a segment in one position in a word causes a segment in a nearby position to become more like or identical to it. There are three main examples of assimilation: *consonant harmony,* whereby a consonant in one position within a word or syllable becomes more like or identical with one from another position in the same word/syllable (e.g. "dog" [gag]); *vowel harmony,* whereby a vowel in one position within a word or syllable becomes more like or identical with one from another position in the same word/syllable (e.g. "flower" [fawa]); *voicing,* whereby a consonant becomes voiced after a vowel, and devoiced in syllable-final position (e.g. "pig" [bIk]). (iii) Syllable structure processes are processes of simplification of the adult form. There are four common syllable structure processes: *cluster reduction,* whereby elements in an adult consonant cluster are omitted or blended, so that a singleton consonant is produced (e.g. "sky" [kaj]); *final consonant deletion,* whereby the last consonant in a CVC syllable is omitted, leaving an open syllable (e.g. "bike" [baj]); *unstressed syllable deletion,* (e.g. "banana" [nana]); *reduplication,* whereby a syllable (usually in CV form) is repeated and a disyllabic word thus produced (e.g. "ball" [bʌbʌ]).

Appendix B: Tests of Obstruent+approximant Clusters

Nonsense-word repetition, one-syllable Subject # _______

gwate	
cleg	
preet	
smate	
sfote	
skib	
stob	
plock	
brote	
swib	
thwine	
spim	
grote	
dwen	
krays	
gleep	
trode	
flune	
drate	
snock	
twide	
frood	

Nonsense-word repetition, one-syllable Subject # ______

thrope	
bloot	
slib	
quat	

Test design:

Nonsense words
CCVC word structure
variable controlled for: initial consonant cluster
words were as unlike real words/morphemes as possible

Instructions to tester:

Explain the consent form and get the subject or guardian to sign.

Explain to the subject that s/he is going to be repeating words that s/he hears on the tape. The words are made-up words that don't have any meaning. On the tape each word will be repeated twice and then the tape will be paused. After hearing the word, the subject will say what s/he heard and his/her response will be recorded on tape.

Then use the following practice items to familiarize the subject with the task.

Practice items for the tester:

Say moke	...	moke
Say forn	...	forn
Say foop	...	foop
Say loke	...	loke

Nonsense-word repetition 2-syllable Subject # _______

teswápe	
mákrep	
pesmápe	
táthrit	
óbrack	
téeflek	
tebláge	
tedwáke	
tepráke	
sekláss	
tesláре	
segráke	
átrock	
cádrok	
dótwig	
tesnápe	
tesfóop	
tedráke	
pespáke	
sepláke	
sácklep	

Nonsense-word repetition 2-syllable Subject # _______

setráke	
ósmoop	
tekrápe	
gáplet	
póbleck	
sípret	
peskáke	
mebráck	
tekwáke	
ésfem	
nefláck	
sethwáke	
óstat	
máslep	
pásnek	
máspet	
bíthwig	
metwáke	
pegwápe	
kethráke	
áswin	

Nonsense-word repetition 2-syllable Subject # _______

tífrog	
óskep	
ígreb	
íkwis	
tegláke	
pídwock	
mestáck	
ígleb	
tefrápe	
bágwet	

Nonsense-word repetition 2-syllable Subject # _______

Test design:

nonsense words
CVCCVC word structure
two syllable
initial vs. final stress
medial consonant cluster

Instructions to tester:

Explain the consent form and get the subject or guardian to sign.

Explain to the subject that s/he is going to be repeating words that s/he hears on the tape. The words are made-up words that don't have any meaning. On the tape each word will be repeated twice and then the tape will be paused. After hearing the word, the subject will say what s/he heard and his/her response will be recorded on tape.

Then use the following practice items to familiarize the subject with the task.

Practice items for the tester:

Say entáte	...	entáte
Say émtoll	...	émtoll
Say árnet	...	árnet
Say wentóof	...	wentóof

Auditory analysis test (word-initial consonant clusters) Subject # ______

1. Say **spill** without the "**s**" sound	
2. Say **twine**	
3. Say **sphere** without the "**f**" sound	
4. Say **bleed** without the "**b**" sound	
5. Say **snap** without the "**n**" sound	
6. Say **frail** without the "**f**" sound	
7. Say **flab**	
8. Say **Gwen** without the "**w**" sound	
9. Say **slap** without the "**l**" sound	
10. Say **thwack** without the "**th**" sound	
11. Say **sphere**	
12. Say **stack** without the "**s**" sound	
13. Say **place** without the "**p**" sound	
14. Say **quake** without the "**w**" sound	
15. Say **track** without the "**t**" sound	
16. Say **slap** without the "**s**" sound	
17. Say **stack**	
18. Say **crave** without the "**r**" sound	

Auditory analysis test (word-initial consonant clusters) Subject #

19. Say **skate**	
20. Say **thread** without the "**th**" sound	
21. Say **place**	
22. Say **frail** without the "**r**" sound	
23. Say **brace**	
24. Say **stack** without the "**t**" sound	
25. Say **crave**	
26. Say **spill** without the "**p**" sound	
27. Say **frail**	
28. Say **smash**	
29. Say **dwell** without the "**d**" sound	
30. Say **snap**	
31. Say **sphere** without the "**s**" sound	
32. Say **sweet**	
33. Say **place** without the "**l**" sound	
34. Say **dread**	
35. Say **quake** without the "**k**" sound	
36. Say **Gwen**	

Auditory analysis test (word-initial consonant clusters) Subject #

37. Say **sweet** without the "**w**" sound	
38. Say **pray**	
39. Say **grain** without the "**g**" sound	
40. Say **dwell**	
41. Say **pray** without the "**p**" sound	
42. Say **brace** without the "**r**" sound	
43. Say **clap**	
44. Say **bleed** without the "**l**" sound	
45. Say **slap**	
46. Say **glow** without the "**g**" sound	
47. Say **track** without the "**r**" sound	
48. Say **brace** without the "**b**" sound	
49. Say **flab** without the "**f**" sound	
50. Say **smash** without the "**m**" sound	
51. Say **twine** without the "**t**" sound	
52. Say **thread** without the "**r**" sound	
53. Say **clap** without the "**l**" sound	
54. Say **track**	

55. Say **twine** without the "**w**" sound	
56. Say **quake**	
57. Say **snap** without the "**s**" sound	
58. Say **crave** without the "**k**" sound	
59. Say **clap** without the "**k**" sound	
60. Say **thwack**	
61. Say **Gwen** without the "**g**" sound	
62. Say **spill**	
63. Say **glow** without the "**l**" sound	
64. Say **grain**	
65. Say **dread** without the "**r**" sound	
66. Say **bleed**	
67. Say **flab** without the "**l**" sound	
68. Say **grain** without the "**r**" sound	
69. Say **thwack** without the "**w**" sound	
70. Say **pray** without the "**r**" sound	
71. Say **dwell** without the "**w**" sound	
72. Say **skate** without the "**k**" sound	

Auditory analysis test (word-initial consonant clusters) Subject #

73. Say **smash** without the "**s**" sound	
74. Say **glow**	
75. Say **dread** without the first "**d**" sound	
76. Say **skate** without the "**s**" sound	
77. Say **thread**	
78. Say **sweet** without the "**s**" sound	

Auditory analysis test (word-initial consonant clusters) Subject # ________

Auditory analysis test (word-initial consonant clusters)

CCVC word structure
common words— exception: 'thwart' is CCVCC and uncommon
variable controlled for: initial consonant cluster

Three tasks:

remove first consonant
remove second consonant
say entire word

List was randomized, and then some lines were moved to avoid having two instances of the same word together.

Instructions to tester:

Explain the consent form and get the subject or guardian to sign.

Explain to the subject that s/he is going to be doing three tasks which s/he will hear on the tape. The instructions will be spoken once slowly, and then the tape will be paused. If the subject wishes, any instruction can be replayed. After the tape is paused, the subject will do what the instruction says, and his/her responses will be tape-recorded.

Now familiarize the subject with the three types of instructions:

Say 'friend'.
Say 'friend' without the [fffff] sound.
Say 'friend' without the [rrrrr] sound.

Say 'smile'.
Say 'smile' without the [ssssss] sound.
Say 'smile' without the [mmmm] sound.

Make sure the subject understands that sometimes the instructions will ask him/her to produce something that isn't a real word. For example, if you 'say "smile" without the [mmmm] sound,' then you will be saying 'sile.' This is the right answer, even though it isn't a real word.

Appendix C: Consent Forms

Consent Form for Dyslexic Group (attached)
Consent Form for Control Group (attached)

Consent form for participation in phonology of dyslexia project

TITLE: Phonology of Dyslexia

INVESTIGATORS: Dr. Carrie Dyck, Department of Linguistics, Memorial University of Newfoundland and Dr. Catherine Penney, Department of Psychology, Memorial University of Newfoundland.

You or your child has been asked to participate in a research study to investigate speech processing abilities. Participation in this study is voluntary. You or your child may withdraw from this study at any time and withdrawal will not prejudice you or your child in any way.

Information obtained from you or your child during this study will be kept confidential. Information may be given to senior undergraduate students or to graduate students for purposes of data analysis. Test results for individual students will be released to parents or guardians, or to the participant if he or she is an adult. Test results will be released to school personnel upon written request from parents or guardians or from the adult participant. If the results of this study are published, individual participants will not be identified. The results from individuals will be combined and findings for groups of participants will be reported. If individual data are reported, the individuals will be referred to by either a number or a pseudonym (false name). No information which could be used to identify individuals will be published.

1) Purpose of the study

The purpose of the study is to investigate your speech processing abilities.

2) Description of experimental procedures and tests

Participants will be tested on their ability to delete sounds from words and their ability to perceive slight differences in words.

The tests will be given after Reading Tutoring sessions between February and April 2000 or at other times convenient to the participant.

3) Duration of the participant's involvement

The test administration will take approximately one hour.

4) Potential benefits

Participants will receive a written report on the results of their testing upon request. The project may help in developing treatment strategies but there will probably be no direct benefit to participants.

Participant's Initials ________

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5) Liability statement

Your signature indicates consent for your participation, or that of you child or ward, in the project. It also indicates that you have understood the information regarding the research study. In no way does this consent waive your legal rights nor does it release the investigator from legal and professional responsibility.

6) Additional information

If you wish to discuss the implications of participation in this research study with an individual who has no involvement with the project, you may contact Dr. John Evans, Head, Department of Psychology, Memorial University of Newfoundland, at 737-8495.

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Signature Page

I, ______________________________________, the undersigned agree to

participate or allow my child or ward,

______________________________________, to participate in the research

study described above.

Any questions have been answered and I understand what is involved in the study. I realize that participation is voluntary and that there is no guarantee that I or my child or ward will benefit from involvement in the study.

I acknowledge that a copy of this form has been given to me.

____
(Participant's signature)

______________________________________ Age:
____
(Signature of Minor Participant)

Date: ______________________________________

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To the best of my ability I have fully explained the nature of this research study, I have invited questions and provided answers. I believe that the participant fully understands the implications and voluntary nature of the study.

____
(Investigator's signature)

General instructions for testers

Equipment:
•1 tape-recorder to play the instructions
•1 tape-recorder to record the responses
•1 reliable microphone—Tracy, use the one you borrowed from AV services in Education; don't use the little ones provided with the tape-recorders, as they are not reliable, even with new batteries.

Arrange room with Dr. Penney.

Individual instructions for each test are on the last page of each test.

Tests must be administered in a different order for each subject. Each test is numbered, and the order is written on the master list.

Do the tests in two sessions; one session for your consonant-cluster tests, and a separate session for the remaining tests.

For each subject
•record pertinent information on the master list
•clearly label each tape with the subject number
•put the subject number on each test
•get the subject to sign the consent form; this is a *different* consent form from the one that Dr. Penney uses, so this one must be signed as well.

After taping, transcribe subjects' responses on the tests. You should both transcribe each subject's tape in order to double-check the transcription. If you have questions, clearly mark the problems and we'll resolve them later.