THE PRODUCTION AND MANIPULATION OF /s/+ CONSONANT CLUSTERS BY PHONOLOGICAL DYSLEXICS

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by

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Abstract

This thesis examines the ways dyslexic children deal with English consonant clusters consisting of /s/ plus another consonant. The /s/ + consonant clusters were chosen due to their unique underlying representation, which is believed to affect the ways in which these particular clusters are acquired. The data were collected by administering a real-word repetition test (production), nonsense-word repetition tests (production) and remove-consonant tests (perception and manipulation) to twelve older dyslexics, aged 11-21 years. These results were compared to those of a seven-subject control group of children ages seven to eight. Findings indicate that results on nonsense word repetition tasks and on the standardized Peabody Picture Vocabulary Test predict reading level. Word and cluster frequency in normal speech have no impact on subjects' ability to repeat real English words. Dyslexics made use of immature phonological processes, as well as haphazard cluster reduction strategies. The control group consistently outperformed dyslexics on all tests, although the dyslexic group was twice as old.

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1. Introduction

The goal of this paper is to investigate the production, and manipulation of /s/ + consonant clusters in children with phonological dyslexia. /s/ + consonant clusters include /sp, st, sk, sm, sn, sl, sw, sf/. Patients with phonological dyslexia have sustained damage to the procedure for translating orthographic units smaller than whole words into a pronunciation, required whenever a spelling pattern is read that does not have a permanently stored description as a whole word (Caplan 1992:176). Phonological dyslexics exhibit poor ability in reading nonsense-words, but can often read real words with a high degree of accuracy (Cuetos et al. 1996:1). Furthermore, those with phonological dyslexia generally perform poorly on all phonological tasks and show difficulty using spelling-to-sound knowledge to produce novel words. Unlike other types of dyslexia, phonological dyslexics often have deficits in verbal working memory in addition to a phonological deficit. This disorder is thought to be caused by impaired representation and use of phonology, and may be a mild form of Specific Language Impairment (SLI) (Joanisse et al. 1998:136).

While children with phonological dyslexia may have some sort of delayed or disordered phonology, few specifics are known. This paper hypothesizes that /s/ + consonant cluster acquisition will prove to be particularly difficult for phonological dyslexics, as it is for both normally-developing children and for those children with disordered phonology.

This discussion will begin by outlining the theoretical assumptions that are relevant to the topic at hand, followed by a literature review which compares and contrasts /s/ +

consonant cluster acquisition (1) in normally developing children, (2) in children with disordered phonology, including SLI, and (3) in those children who suffer from phonological dyslexia. This will lead to hypotheses based on the literature review. The basic methodology, followed by the results of the study, and a general discussion of findings, will conclude the paper.

2. Theoretical Assumptions

This section deals with the theoretical assumptions that are relevant to the acquisition of /s/ + consonant clusters and helps explain why such clusters are so problematic. This includes a basic outline of the distinctive features of all English consonants to help explain why processes such as blending and assimilation occur and to introduce features that are relevant to /s/-clusters. The sonority-based features of these consonants are also discussed in order to later introduce the notion of syllable structure and the constraints found on English syllables. This is followed by a brief introduction to the timing tier, which distinguishes a single consonant from a consonant cluster. The idea is later introduced that /s/-clusters may really be single, complex consonants, whereas clusters like /br/ are two separate consonants. The discussion continues with a look into the representation of affricate consonants, as research has led some people to believe that affricates and /s/ + plosive consonant clusters have the same underlying representation and will therefore undergo similar acquisition processes. A short discussion of syllable structure and the syllabification of consonant clusters is also included, as there are several problems in using the normal English syllable structure and syllabification rules to syllabify /s/ + plosive clusters. This section concludes with the question of whether /s/ + plosive clusters are really represented in the same way as affricates. While this is not an issue central to the topic of this discussion, it is a relevant issue and warrants some mention with regard to the acquisition of /s/ + consonant clusters. The main concern here is that, if /s/ + plosive clusters are indeed represented as affricates are, then similar patterns of acquisition and acquisition problems are to be expected.

2.1 Distinctive features of English consonants

Phonemes (segmental sounds) are comprised of smaller units known as distinctive features, such as [±continuant] (a manner feature), [±voice] (a laryngeal feature), and [labial] (a place feature). All fricatives (e.g. /f,v,θ,ð,s,z,ʃ,ʒ,h/) are [+continuant] or are produced with a continuous airflow. All stops (e.g., /p,t,k,m,n/) are [-continuant] or are produced with a complete blockage of the oral cavity. Sounds such as /p,t,k,f,s,ʃ,ʧ/ are [-voice] or are produced with a voiceless state of the glottis. In contrast, the nasals /m/ and /n/ and the oral sounds /ð/, /v/, and /l/ are voiced. Finally, sounds such as /m,f,v,p/ are [labial], or produced with the involvement of one or both lips. Other consonants have different place features such as [coronal] or [dorsal] (O'Grady and Dobrovolsky 1996). See Appendix 1 for a comprehensive table of English consonants and their distinctive features.

Typically, a given consonant will have either the '+' or '-' value of a binary feature. However, the affricates /ʧ/ and /ʤ/ are unusual in that they are both [+continuant] and [-continuant]. This means they are phonologically both stops and fricatives (Lombardi 1990). For this reason, they are considered to be more complex than other consonants and therefore harder to acquire. As will be discussed later, /s/ + stop consonant clusters could be analyzed as single, complex affricates rather than as regular consonant clusters. Normally, the stop portion of the affricate is realized before the fricative portion; however, the fricative portion can be realized first (Bernhardt and Stemberger 1998:70), in which case sounds like [ˢt] would result.

When a process like blending occurs in acquisition, two consonants merge to form a single sound; for example, *swim* can be pronounced as *fim* [fɪm]. Blending is seen as taking some features from one sound (in this case /s/) and some features from another sound (/w/) and combining them together to form a new sound ([f]) (Crystal 1981:38). In this example, where /sw/ becomes [f], the [-voice] and [+continuant] features of /s/ and the [labial] feature of /w/ merge together to form the voiceless labio-dental fricative [f]. In summary, thinking of segments as being composed of smaller units, features, helps to highlight the unusual complexity of some consonants, and also to explain how some consonant clusters are simplified.

A special class of features are the sonority-based features, which, in the feature geometry approach, are housed in the root node (Kenstowicz 1994:453). I discuss these features in detail because they later help to point out another oddity of /s/-clusters involving how they are organized within a syllable. The features [±sonorant], [±approximant], and [±vocoid] define the major sonority classes of a language, namely obstruent (/p,t,k,b,d,g,f,v,θ,ð,s,z,ʃ,ʒ,ʧ,ʤ/) nasal (/m,n,ŋ/), liquid (/l,r/), and vocoid, which includes vowels and glides (/j,w/, as well as all the vowel sounds). The presence of these three features provides a possible way of creating a sonority rank: the class with more positive feature values gets the highest sonority ranking.

(1)	[sonorant]	[approximant]	[vocoid]	sonority rank
obstruent	-	-	-	0
nasal	+	-	-	1
liquid	+	+	-	2
glide	+	+	+	3

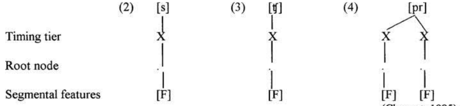
(Kenstowicz 1994:255)

For instance, an obstruent such as /t/, which has a sonority ranking of 0, is less sonorous than a nasal /m/ of a sonority ranking of 1, which in turn is less sonorous than a liquid like /l/, which has a ranking of 2. Glides such as /w/ and /j/ are assigned the highest sonority ranking of 3. This study assumes that stop consonants and fricatives are assigned the same sonority ranking.

2.2 The timing tier

The root node is dominated by the timing tier (Clements 1985:248). The timing tier represents the distinction between single consonants (including affricates) and consonant clusters. A brief discussion of the timing tier is important here as the difference between single consonant representation and consonant cluster representation is relevant to the representation of /s/ + consonant clusters.

Single consonants, including complex consonants such as affricates, are represented by one unit on the timing tier. Consonant clusters are represented by two or three units. This is illustrated by the following diagrams, where 'X' stands for a timing tier unit, '.' for the root node, and [F] for the distinctive features of a segment:



(Clements 1985)

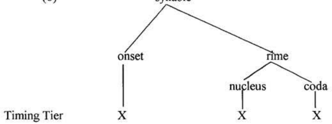
These diagrams show that single consonants, such as [s], and affricates, such as [ʧ], have identical representations with respect to the number of units found on the timing tier, while consonant clusters, such as [pr] and [spr], have a second or sometimes third unit on the timing tier. As will be discussed later, there is a debate about whether to represent /s/-clusters as single, affricate-like units or as two units such as [pr].

2.3 Syllable structure and syllabification of consonant clusters

This section will demonstrate that /s/ + stop consonant clusters syllabify differently from all other types of English consonant clusters and will help to exemplify just how different /s/ + stop clusters are when compared to the other English clusters.

In order to discuss syllabification, we must first introduce the basic structure of the syllable, which can be depicted as follows:

(6)



(Kenstowicz 1994:253)

The nucleus is obligatory in all syllables and may be followed by an optional coda, which, if present, consists of one or more consonants. The nucleus and the coda together form a constituent known as the rime; the nucleus and the coda form a tighter bond than the nucleus and the onset. An onset, which precedes the nucleus, is also optional and contains one or more consonants. The nucleus is generally considered to be the central part of the syllable as it is the only constituent that is obligatory (Kenstowicz 1994:252). While onsets are not obligatory, their presence is highly preferred.

The Sonority Sequencing Principle (SSP) governs the types of sounds that may appear in the constituents of a syllable, as well as the order in which sounds may appear. The SSP organizes the different classes of sounds according to their sonority; the sonority scale used by the SSP was shown earlier in (1) and is repeated in (7) below:

(7) vowels >> glides >> liquids >> nasals >> obstruents (Kenstowicz 1994:254)

This scale indicates that vowels are the most sonorous of all the sounds and obstruents are the least sonorous. The SSP states that syllables must rise in sonority from the onset to the nucleus and fall in sonority from the nucleus to the coda. The nucleus therefore contains the most sonorous element of any syllable (Kenstowicz 1994:255), while segments in the onset and coda are less sonorous.

As the syllabification of word-medial consonant clusters is relevant to one of the tasks found in this study, a brief discussion of such clusters is important. The following chart indicates how word-medial consonant clusters are syllabified:

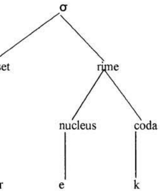
Table 1.

Cluster type	Coda of σ 1	Onset of σ 2	Example
obstruent + liquid	-	/tr/, /gw/	/ə.trækt/, /ə.gwa.nə/
obstruent + obstruent	/s/	/t/	/æs.tər/
obstruent + nasal	/p/	/n/	/æp.ni.ə/
nasal + obstruent	/n/	/d/	/ɪn.dʌjt/

As shown in table 1, obstruent-liquid clusters syllabify in the same onset, while for other clusters, including /s/ + plosive ones, the first consonant is syllabified into the coda of the first syllable, and the second consonant is syllabified into the onset of the second syllable. Three-consonant clusters beginning with /s/ syllabify differently and are not relevant to this discussion. Finally, if the syllable preceding an obstruent-liquid cluster is stressed, then the obstruent is ambisyllabic due to the process of Right Capture (Gussenhoven 1986).

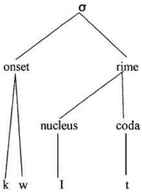
Another factor which affects the types of consonants permitted in an onset is the Minimal Distance Constraint (MDC). This constraint states that there must be a minimal distance between two consonants which appear in an onset. The minimal distance is defined with respect to the sonority scale and the SSP; English onsets, for example, must have a minimal distance of at least two sonority degrees in a canonical Englishonset (Clements 1990:317). In English, the MDC prohibits onsets that consist of an obstruent plus a nasal (*/pn/), since in this combination, there is only a minimal distance of one between /p/ and /n/. In comparison to the SSP, which is a universal constraint operative in all languages, the MDC has parameters which vary according to the specific language (Clements 1990:318). For instance, English has a minimal distance requirement of two, whereas German has a minimal distance of only one. (This captures the fact that German allows onsets such as /kn/ and /pn/, but English does not.) Both the SSP and the MDC govern the syllabification of sounds into syllables. Some examples of English syllabification are shown below:

(8)



'break'

(9)



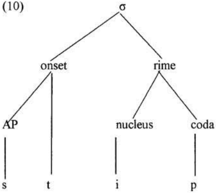
'quit'

As shown in (8), in the word 'break', the segments in the onset increase in sonority from the obstruent /b/ (sonority rank of 0) to the approximant /r/ (sonority rank of 2); the nucleus contains the most sonorous segment /e/ (sonority rank of 4) and the element in the coda, /k/, with a rank of 0, falls in sonority in comparison to the nucleus. A similar description also applies for (9), where the elements rise in sonority from the onset to the nucleus, and then fall from the nucleus to the coda.

Taking into consideration the facts presented above, there are many types of onsets that are not permitted in English since they would violate the SSP and the MDC. This include onsets consisting of two obstruents, */kp/, onsets consisting of a glide followed by a nasal, */wn/, and any other case in which the SSP or the MDC is not observed. One such type of onset which exists but which should be illegal is an onset comprised of /s/ followed by an obstruent, such as /p, t, k, f/. The resulting onset does not rise in sonority and would therefore be expected to violate both the Minimal Distance Constraint and the Sonority Sequencing Principle. However, word-initial clusters such as /sp/, /sk/, and other /s/ plus obstruent clusters are indeed found in English. Furthermore, the /s/ plus nasal clusters found in English also violate the MDC, as /s/ and /m,n/ have a distance of only one, instead of the required two. In other words, English words that start with /s/ plus consonant clusters cannot be syllabified like other English words.

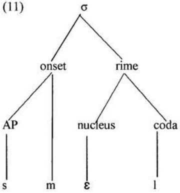
To accommodate these types of clusters, two different methods have been proposed. The first method is to have an appendix to the onset. The second method is to reanalyze /s/ + consonant clusters as a type of affricate. Both methods are discussed below. To accommodate /s/ + obstruent and /s/ + nasal clusters, a special appendix to the onset has been proposed, as illustrated below (Kenstowicz 1994:258):

(10)



'steep'

(11)



'smell'

The initial /s/ cannot be syllabified in the onset in example 10 because it would violate both the SSP and the MDC, as both /s/ and /t/ are obstruents. The cluster /sm/ in example 11 violates the MDC, which requires that the two consonants of an onset have a minimal distance of at least two. The traditional solution to these problems is to create a syllable-initial appendix and then syllabify /s/ as the appendix to the onset of the syllable, as shown in examples 10 and 11. Evidence from phonotactics for the syllable-appendix is discussed in Section 2.3.

Some phonologists propose that these problematic /s/ + stop[1] clusters are structurally different from all other types of clusters in that they are actually a single underlying unit, as opposed to two separate units. This type of analysis places /s/ + stop clusters in the same category as affricates like /ʧ/ and /ʤ/. The same kind of analysis has been used in Gothic, Old English, and Germanic, where /s/ + stop clusters have been analyzed as being similar to affricates (Barlow and Dinnsen 1998:3). Treating these clusters in the same way as affricates, as if they were single, yet complex segments, explains the unusual behaviour of /s/ + stop clusters when compared with all other English consonant clusters. (For a more in-depth look at the representation of affricates, see Appendix 2C.) This hypothesis would allow the word shown in example 10, 'steep' to now be syllabified in the following way, with /st/ taking the position of the onset as a single segment and therefore not violating either the SSP or the MDC:

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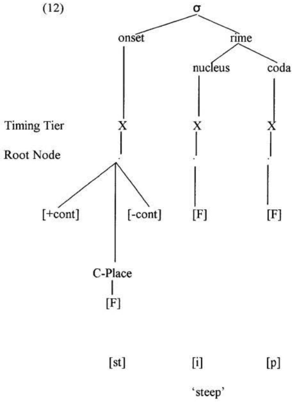
[1]Here, the term *stop* refers to both oral stops and nasal stops (i.e. /p,t,k,m,n,/).

(12)



In this approach, as in the other one, the unusual behaviour of consonant clusters consisting of /s/ + a plosive consonant can best be explained if such clusters have a different underlying structure than all other English consonant clusters. However, this analysis predicts that affricates and /s/ + plosive clusters should have the same type of patterning when it comes to speech errors and cluster reduction strategies, as well as parallel structure when represented using feature geometry. I review evidence below which indicates that /s/ + plosive clusters do pattern like affricates.

2.4 Are /s/ + stop consonant clusters affricates?

This section outlines some reasons why /s/ + stop consonant clusters may be considered to be like affricates: they exhibit atypical syllabification and they are acquired differently from all other clusters. Some evidence comes from Smit (1993, as cited in Barlow and Dinnsen 1998:5), who found that epenthesis (insertion) of a vowel between two elements of a consonant cluster is a common form of cluster simplification. However, epenthesis is not a common occurrence in the development of /s/ clusters in normally developing children. This is additional evidence for the idea that these types of consonant clusters are represented differently from all other types of English clusters and are perhaps single units of sound in their underlying representations (Barlow and Dinnsen 1998:5). The sonority sequencing facts mentioned in Section 2.3 above are also consistent with this single-consonant representation.

Data compiled from both normal and disordered developing systems demonstrate that affricates are often reduced to stop consonants (Goad and Rose 2002). This process is also common in the acquisition of /s/ + stop consonant clusters. This can be taken to mean that affricates and /s/ + stop consonant clusters both form a natural class because they are complex entities which are simplified at a stage in acquisition (Barlow and Dinnsen 1998:5). Thus the patterning of affricates can be used to shed some light on the unique way in which /s/ clusters behave both on the surface and underlyingly.

There is phonotactic evidence that suggests ways in which to distinguish elements that are functioning as single segments (affricates) from those that are considered sequences of two individual phonemes (consonant clusters). If no special statements are needed in order to syllabify a sound, then such sound is considered to be a single consonant. For example, if /s/ + stop sequences in English are analyzed as affricates, then no mention of appendices or other analyses is required. The fact that English consonant clusters such as /sf/ (which violates the MDC and the SSP) and /sm/ (which violates the MDC) need an appendix to the onset indicates that /sf/ and /sm/ are sequences of consonants rather than complex consonants, as /s/ + stop consonants may be. Further evidence is that in some languages, it is possible that consonant clusters may not be permitted in some environments, but apparent clusters like /ts/ are allowed, suggesting that /ts/ may in fact be one single segment. In other languages, like Canadian French, where [t] and [t^s] are in complementary distribution, we can assume that [t^s] is a single segment and an allophone of the phoneme /t/ (O'Grady and Dobrovolsky 1996: 51).

A further reason to consider /s/ + plosive clusters to be like affricates is their unusual phonotactics. English syllable structure does not allow clusters in which the two elements of the cluster share the same place of articulation (Kenstowicz 1994:257). This constraint prevents sequences like */tl/ (alveolar) and */pw/ (bilabial), and yet clusters such as /sl/ and /sn/ are allowed, even though both elements share the same alveolar place of articulation. Another way in which the /s/ + plosive clusters differ from other English consonant clusters is that they are the only clusters which allow a nasal consonant to be preceded by a fricative word initially (Barlow and Dinnsen 1998:3) and which allow two segments of equal sonority word-initially. (These types of clusters also violate the Sonority Sequencing Principle, as discussed in Section 2.3.)

The main reason I have chosen to concentrate only on consonant clusters beginning with /s/ is because of the predictions made possible by their unusual patterning.

2.5 Conclusion

The above sections have demonstrated that /s/ + plosive consonant clusters indeed do show patterning that is different from all other types of English consonant clusters. They can either be represented as affricates or as exceptional consonant clusters that require an appendix, in addition to the normal rules of syllabification. For the purposes of this paper, it is not necessary to decide between the two analyses, although some evidence in favour of the affricate analysis is found. The main point, instead, is that /s/ + consonant clusters are not only theoretically problematic but they also behave differently from other clusters in acquisition and pattern much like affricates. Continuing in this theme, the following discussion will show that normal and non-normal children have problems acquiring both affricates and /s/ + consonant clusters. This will illustrate that the problem of /s/-clusters and affricates is not limited to theoretical linguistics; it has its implications in the real world as well. Because normal and phonologically disordered children have difficulty in acquiring affricates and /s/ + consonant clusters, children with phonological dyslexia are also expected to show difficulties in this area.

3. Literature Review - The acquisition of /s/ + consonant clusters

The following sections will provide a review of /s/-cluster acquisition in normal acquisition, disordered acquisition, acquisition in children with Specific Language Impairment (SLI), and acquisition in phonological dyslexics. This review will lead to forming hypotheses about the acquisition of /s/ + consonant clusters in phonological dyslexics.

3.1 Acquisition in a normal system

3.1.1 The order of acquisition of individual sounds

In order to compare acquisition in dyslexics to that of normally-developing children, we first need to look at the process of acquisition in normal development. The following are several characteristics that are seen during the process of acquisition of sounds in normally developing children: labial consonants /p,b,m,f,v,w/are generally acquired first, followed by velars /k,g,ŋ /, alveolars /t,d,s,z/, postalveolars including the affricates /ʃ,ʒ,ʧ,ʤ/; the final sounds to be acquired are usually the dentals /θ,ð/. Fricative consonants /f,v,s,z,ʃ,ʒ/ are much easier to acquire when they are found in final position than when in initial position. Note that fricatives and affricates are, as a rule, acquired later. The vowel system in its entirety is usually acquired by three and a half years of age. The phoneme contrasts that are acquired first are those concerning voicing (e.g. voiced /d/ vs. voiceless /t/) and nasality (e.g. oral /b/ vs. nasal /m/). While these statements are relevant for the general process of acquisition, there is always some variability across children as to the exact order in which each child acquires the individual speech sounds (Crystal 1981:53). Note that the term 'acquired' (as used above) can be interpreted in several different ways. However, here it should be taken to mean that both the perception and the production of the sound have fully developed.

3.1.2 Normal acquisition of /s/ + consonant clusters

The acquisition of syllable structure is of particular relevance to consonant clusters. The process which is most commonly applied to consonant clusters by children is cluster reduction, which can be seen as a process which works to simplify phonotactic (syllable-based) structures (Grunwell 1981:95). Cluster reduction can be achieved in two main ways: by the omission or by the blending of sounds. Both of these patterns are often seen in consonant clusters with /s/.

Omission occurs when a sound that is present in the adult form of the cluster is deleted in the child's output, resulting in the production of a single consonant. This is seen when a word like *sky* is produced as [kaj], with the /s/ being deleted (Crystal 1981:38). Other examples include child outputs such as *stop* becoming [t ɔp] 'top', *small* becoming [mɔ :][2] 'maw', and *slide* becoming [lajd] 'lied'. Typically, it is the member of the cluster which is acquired later that gets omitted in the child's pronunciation (Ingram 1976:32). /s/ is typically produced later than /p,t,k/ and it is one of the later sounds to be fully acquired by children; it is almost always acquired after /p,t,k,m,w/, which are some of the sounds that are permitted to occur following /s/ in a consonant cluster (Crystal1981:34). The order of acquisition helps to explain why /s/ is usually the sound which is deleted in /s/ + consonant clusters.

Blending is an interesting way to simplify /s/ + consonant clusters. Some features of one of the members of the cluster are merged together with some features from another consonant to produce a single consonant. This can be seen when *smile* is produced as [m̥ajl]

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[2]The final /l/ sound is deleted here, probably due to the fact that the child is not yet producing coda consonants in every word. This is irrelevant to the initial consonant cluster reduction.

'mile', with a whispered /m/ (Crystal 1981:38). Here, the [-voice] feature of the /s/ (see Table 1 for features) is being combined with the bilabial and nasal features of the /m/ to produce a voiceless [m̥].

Another process also seen in children's outputs of consonant clusters is that of substitution (Ingram 1976:32). This is evidenced in words like *pray* being pronounced as [pwej], whereby the later acquired /r/ gets replaced by the earlier acquired [w] (Grunwell1981:96). This type of substitution is mainly seen in clusters involving liquids /l,r w,j/ and, interestingly enough, is not common in /s/ + consonant clusters.

3.1.3 Stages in acquiring clusters

All of the above processes (Section 3.1.2) fit into the four stages concerning the acquisition of consonant clusters (Greenlee 1974). Stage 1 involves the deletion of the cluster in its entirety. However, this first stage is not commonly observed, mainly due to the fact that deletion of the entire cluster would create a syllable without an onset, which is a more complex structure than one with an onset (Barlow and Dinnsen1998:2). The word /stip/ *steep* would be pronounced as [ip] in Stage 1. Stage 2 is the reduction of the cluster to a singleton or a single consonant phoneme (Barlow and Dinnsen 1998:2). [tip] would be the normal output for *steep* in Stage 2. In Stage 3, a consonant cluster is produced but one segment may be replaced with a different, usually more easily pronounced, phoneme, (as in the case of 'pray' being pronounced as [pwe] The final Stage, 4, is correct articulation of the cluster, in this case [stip] (Barlow and Dinnsen 1998:2).

3.1.4 Less common acquisition processes

There are also two less common processes seen in some children which are not regarded as part of the typical four-stage process of acquisition. The first is epenthesis, where a vowel is inserted between the first and second element of the cluster, resulting in a basic CV syllable structure (Ingram 1976:34). This type of process would produce structures like [kəlin] and [pəle] for the adult words *clean* and *play*. Epenthesis is not seen in /s/ + consonant clusters (Barlow and Dinnsen 1998:2). The second process is even more rare, and involves the movement of one of the elements in the cluster to somewhere else in the word (metathesis). This reduces the cluster by separating the two elements which form the cluster (Ingram 1976:34). This may be seen in words like *stew*, where the child's realization is [suwt] 'suit', with the /t/ as the second element of the cluster being moved to the end of the word. This process occurs in the acquisition of /s/ + consonant clusters.

3.2 Acquisition in a disordered system

3.2.1 Definition

The term 'disordered acquisition' can mean 'delayed' or 'deviant' in some way when the system is compared to a normally developing system. In comparison to the normally developing child, a child who exhibits phonological disorder can be identified by three major characteristics: demonstration of unknown processes, demonstration of uncommon processes, and persistence of early processes. Unknown processes include anything not seen in the course of normal child development. Uncommon processes are processes that are seen in normal development, but which are extremely rare. Persistence of early processes is especially common in children who exhibit phonological deviance, when a process that usually disappears in the early stages of development remains in use, even when the child is past the age when the process is normally phased out. The reduction of consonant clusters is especially common as a persisting process in disordered acquisition. This process usually ceases to apply by the age of four, but it continues to apply in the speech of much older children who have some sort of disordered phonology (Crystal 1981:46).

3.2.2 Phonological characteristics of disordered acquisition

A child with disordered acquisition has a restricted range and frequency of segments, thus resulting in fewer contrasts than may be seen in a normal system. There are therefore many homophones in the child's language. Another characteristic is a restricted range and frequency of combinations of segments, including consonant clusters, along with a restricted range of features, mainly those affecting place of articulation. This would cause problems in distinguishing between the stops /p/, /t/, and /k/. Children with disordered phonology often exhibit a very limited range of fricatives and non-nasal sonorants. They also show confusion in the area of voiced/voiceless and aspirated/unaspirated contrasts. The syllable structure tends towards a canonical CV.CV form, with only nasals perhaps appearing in the coda position. The glottal stop is often used as a replacement for any sound that may not be in the phonemic inventory and it is also used as a default onset. The vowel system is generally well-developed, with the only kind of reduction or simplification being a tendency to centralize some vowels. Perhaps the most telling characteristic of children with disordered phonology is the presence of a fairly wide range of sounds that do not exist in a normal child's inventory and are outside the regular articulatory possibilities of the language (Crystal 1981:47). This would include sounds such as clicks and voiceless laterals [ɬ] being included in an English-speaking child's inventory.

3.2.3 /s/-clusters in disordered phonology

The acquisition of /s/ + consonant clusters in children with disordered phonology is very similar to normal acquisition, but with a few distinguishing features. The process of consonant cluster reduction is very common in those with disordered phonology and the reduction of those clusters with /s/ is even more common than in clusters of other types (Chin and Dinnsen 1992: 261). Children with disordered phonology exhibit many of the same types of reduction strategies as are seen in normally developing children, in that /s/ + stop clusters are typically reduced to the stop (Tyler 1995:212). An example of this type of process is when the word 'stop' gets pronounced as [tɑp] 'top'. Children with disordered phonology also exhibit processes which are not seen in normally developing children. As had been previously stated, normal children most commonly reduce /s/ + stop clusters to a stop singleton. Children with disordered phonology use this strategy, but they also produce affricates and fricatives in place of the /s/-cluster, something that is not seen in normally developing children (Bond 1981:58). For example, 'steep' can be pronounced as [ʃip] 'sheep'. Substitution of a single segment for an affricate suggests that the affricate might be analyzed as a single segment. Reduction of affricates to a fricative is common in other languages as well, Basque being one example of such a language (Hualde 1987 as cited in Kenstowicz 1994:500).

Some phonologically disordered subjects who participated in a longitudinal study of phonological acquisition showed a lack of /s/ in clusters entirely, corresponding to Greenlee's Stage 2. As time passed, these same subjects were producing [θ] where /s/ was required, corresponding to Greenlee's Stage 3 (Elbert and McReynolds 1979; cited in Chin and Dinnsen 1992:261).

The results of another study showed that children who had some sort of disordered phonological system went through stages similar to normal children with respect to the acquisition of word initial consonant clusters. The children, who ranged in age from 3 years 4 months to 6 years 8 months, displayed a range of strategies in the reduction of /s/ clusters. One subject reduced the cluster /sl/ to [s] (Chin and Dinnsen 1992:263). This type of process for /s/-clusters shows some variability across children, however, because /s/ and /l/ are both acquired around the same time. One child may prefer to delete /s/, while another child may prefer to delete /l/ and keep /s/. For example, the same word, *sleep*, was reduced in a different way by another subject in the study. This child replaced /sl/ with [fw], where /f/ and /w/ are both acquired much earlier than /s/ and /l/. Another child demonstrated a rather unusual process when the cluster /sw/ of *swim* was replaced by a single consonant [f], producing [fɪm] 'fim'. This may be considered a case of blending, where the labial feature of /w/ and some features of /s/ combined to form one new segment /f/. While blending is a fairly common process, it is usually seen in clusters containing /s/ plus a nasal, and rarely seen in cases like [sw] in normal acquisition. Another uncommon substitution process was seen when another child gave [θta] as the form for *star*. This is rather unusual, as the phoneme

/θ/ is acquired later than the phoneme /s/ (Chin and Dinnsen 1992:263).

Children with SLI (Specific Language Impairment) are a special subgroup of children with disordered phonology. They develop similarly to normally developing children except the SLI children progress at a much slower rate (Fee 1995:199). For a more detailed description of Specific Language Impairment, see Appendix 2. The main difference between the two groups is that the SLI children have a much more limited phonemic inventory than the normal children when matched for age. However, the general order of acquisition remains the same for both groups (Fee 1995:199). In one study, SLI children and SLI adults both used processes of word-initial consonant cluster reduction almost twice as frequently as people with normal phonology (Fee 1995:204). The study also showed that the subjects, who ranged in age from 7 to 46 years, could produce target singletons with a relatively high degree of accuracy but when they were required to produce these same consonants as clusters, the degree of accuracy declined significantly (Fee 1995:204). This indicates that while the production of individual phonemes may not pose significant problems for those with SLI, the production of consonant clusters does create significant difficulty. What is also interesting is that even into adulthood, the production of consonant clusters continues to be quite problematic for those with SLI. These adults continued to use processes of cluster reduction, most frequently those that reduce the cluster to a single element. For most subjects, normal competence was never reached in terms of cluster production (Fee 1995:206).

These examples show that, while some children with disordered phonology and those with SLI go through many of the same processes as those with normal phonology, there are times when these children do exhibit processes which are not often seen in normal child development. In other cases, such as that of cluster reduction, what is typical for those with disordered phonology is the persistence of earlier processes.

3.3 Acquisition in phonological dyslexics

3.3.1 Phonological Dyslexia

Children with phonological dyslexia often display characteristics similar to children with disordered phonology, as overviewed below.

3.3.2 Acquisition of phonemes

A study on the acquisition of phonemes by dyslexics demonstrated that phonological dyslexics have difficulty perceiving vowel contrasts. The mean age of the children in this study was 14 years 5 months, an age where vowel perception should have already been well established (Dyck, Penney, and Perry 2002). For comparison, normally developing children are able to accurately perceive such sounds at 3 years 5 months of age (Crystal 1981:53).

Subjects in the same study also had difficulty in perceiving some phonemic contrasts involving consonant sounds. These difficulties were seen among nasals /m, n, ŋ /, among sonorants /l, r, w, j/, among fricatives /s, z, f, v, θ,ð/, and between affricates /ʧ,ʤ/ (Dyck, Penney, and Perry 2002). These types of perception difficulties suggest some sort of delayed or disordered phonology in dyslexics.

Dyslexics are also known to have subtle speech deficits. Some evidence is reviewed below.

3.3.3 /s/-clusters in phonological dyslexics

One study compared dyslexic children and normal, younger, reading-age-matched controls in their abilities on nonsense-word repetition and real-word repetition tasks. The dyslexic children showed similar results to the controls on tasks requiring the reading of real words. However, when the task required the reading of nonsense-words, the dyslexic children performed much more poorly than the normal children (Snowling 1981:231). While the phonological complexity of the syllable structure of the nonsense-words was a factor for both groups, it caused greater problems for the dyslexic group than the normal group (Snowling 1981:224). Regardless of the length of the word or the number of syllables it contained, the number of consonant clusters was a negative factor for the dyslexic group. When more consonant clusters appeared, the dyslexic group had more difficulty in reading the word (Snowling 1981:226). This research indicates that dyslexic children will likely have difficulty with consonant clusters. However, more research - such as the proposed project - is clearly needed.

3.4 Conclusion of Literature Review

3.4.1 Phonological dyslexia, disordered phonology, or a normal system?

As seen in the literature review above, children with dyslexia are unlike normally-developing children in many ways. Furthermore, they resemble children with disordered phonology. Both groups exhibit a developmental delay in phonology, which is evidenced by the existence of persisting processes. The main difference between dyslexics and those with disordered phonology is that only dyslexics are reported to have deficits in verbal working memory. Those with disordered phonology reportedly have no such memory deficits. Some studies say that, like those with disordered phonology, dyslexics do not have problems repeating real English words. However, this can be disputed, as it was evidenced in this study that the dyslexic group made errors repeating one-syllable, real English words. The reading deficits which are usually seen in dyslexics are likely not the source of the problem, but a consequence of the core deficit, which is a cognitive deficiency (or SLI) leading to disordered phonology. Such a cognitive deficit manifests mainly on the phonological perception and production side of language. In summary, what is clear is that dyslexics share many of the same characteristics which define disordered phonology.

4. Hypotheses

I propose that dyslexic children will deal with /s/ + consonant clusters in essentially the same ways as those children with disordered phonology, exhibiting processes of haphazard cluster reduction, persistence of early processes, and novel strategies that may vary from individual to individual. I also hypothesize that /s/-clusters will be the last of the consonant clusters to be acquired by phonological dyslexics and will prove to be the most problematic clusters, again due to the possibly unique underlying representation of these clusters. The sonority difference between members of the /s/-clusters is also expected to make a difference in acquisition, as clusters with a greater difference in sonority between the first and second elements of the cluster are expected to be acquired more easily than those with little or no difference in sonority. This means that clusters consisting of /s/ + a plosive consonant should be acquired later and should cause more problems than those consisting of

/s/ + nasal consonant or /s/ + approximant consonant.

Dyslexics are reported to have phoneme awareness deficits and an inability to manipulate individual phonemes. The remove-consonant tasks are expected to demonstrate this. In addition, since dyslexics have phonological memory deficits, they are predicted to have difficulty repeating nonsense-words, for which they have no representation in their long-term memory. The repetition tasks hope to support this theory.

5. Methodology

5.1 Introduction

The tests outlined in this section were created to address some of the questions raised in the literature review pertaining to the perception and production of /s/ + consonant clusters.

5.2 Test design

Three types of tests were designed by Tracy O'Brien and myself to investigate the production and perception of /s/ + consonant clusters (myself) and obstruent + approximant clusters (O'Brien) by phonological dyslexics. While this paper concentrates on only /s/ + consonant clusters, the words in the test include other types of consonant clusters collected by Tracy O'Brien, who focused on obstruent-approximant clusters. The joint testing system allows us to test more subjects and to collect a larger amount of data. We designed a Real-Word Repetition test, a Nonsense-Word Repetition Test (consisting of two parts), and a consonant-removal test, all of which are described in detail below. Nonsense-word repetition tests were chosen because dyslexics have reported inabilities to reproduce nonsense-words.

We chose one-and two-syllable nonsense-words to see if the number of syllables and word-length had an effect on the number of errors made. A real-word repetition task was also included to see if the subjects had difficulties simply repeating short English words. The other two tests examined phoneme manipulation, as dyslexics are reported to be very poor at manipulating sounds within words.

5.3 Tests administered

Before testing began, the consent form was explained orally to both the subject and his/her guardian. The instructions for each test were then explained to the subjects and they were given a practice item. In order to avoid skewing the results of the test, the practice items did not contain the target consonant clusters. The following are examples of the practice items for each test:

One-Syllable Nonsense-Word Repetition:

(14) Tester: Say *moke* Subject: *Moke*
Tester: Say *forn* Subject: *Forn*

Two-Syllable Nonsense-Word Repetition:

(15) Tester: Say *entáte* Subject: *Entáte*
Tester: Say *émtoll* Subject: *Émtoll*

Auditory Analysis and Real-Word Repetition

(16) Tester: Say *friend*.
Say *friend* without the [fffff] sound.
Say *friend* without the [rrrr] sound.

Tester: Say *smile*.
Say *smile* without the [sssss] sound.
Say *smile* without the [mmmmm] sound.

5.4 Testing

The subjects were each tested individually between late August 2001 and January 2002, immediately after their regularly scheduled tutoring session at a dyslexic clinic. Testing for each individual took approximately one hour. Some dyslexic subjects needed an additional session, mainly due to their inability to concentrate for long periods of time, so some subjects had to return a second time for the completion of the testing. The testing took place in room S-3067C, in the Psychology Department at Memorial University of Newfoundland. The control group was tested at their elementary school, but their testing time was approximately one half hour each.

5.5 Ethical consent

This research was approved by Memorial University's Interdisciplinary Committee on Ethics in Human Research (ICEHR). Furthermore, written consent was also required from each subject or his/her guardian prior to the commencement of any testing, and this consent form was explained orally to both the guardian and the subject. A copy of the consent form can be found in Appendix 3D.

5.6 The Tests

5.6.1 One -Syllable Nonsense-Word Repetition task

The One-Syllable Nonsense-Word Repetition task evaluates the production of one syllable nonsense-words with a CCVC word structure. The controlled variable is the word-initial consonant cluster. The test contains 27 nonsense-words presented in a random order.

The words are as unlike real English words or morphemes as possible.

The subjects were informed that the words that s/he were about to hear were "made-up" and did not have any English meaning. The tester then explained that the subject would hear a word presented on a tape which would be repeated twice. The tape was then paused and the subject was asked to repeat this word once and the response was recorded on tape. After administering the test, the subject's responses were analyzed, focusing on the words containing /s/ + consonant clusters. See the complete test in Appendix 3A.

5.6.2 Two-Syllable Nonsense-Word Repetition task

The second test was designed much like the first, except that the nonsense-words consisted of two syllables. This test was designed to elicit two-syllable nonsense-words with varying stress and word-medial consonant clusters. There were 52 words of a CVCCVC syllable structure, with half having the stress on the first syllable and half having the stress on the second syllable. The change in stress pattern was included to see if the stress placement within the word would affect the subjects' ability to produce the word-medial consonant cluster (see discussion in section 2.3). The order of the words was randomized. For the complete test, see Appendix 3B.

5.6.3 Remove-Consonant and Real-Word Repetition tasks

The third test was designed to examine the subjects' ability to remove individual consonants from words beginning with consonant clusters and also to see if subjects could repeat entire English words. This test was modeled after the Rosner test (Rosner and Simon 1971) to evaluate metaphonological awareness, included to enable comparison with other phoneme awareness studies. The remove-consonant test consisted of 78 items. There were 26 different English words with a CCVC word structure and the controlled variable was the initial consonant cluster. The test consisted of three tasks: remove the first consonant of the word (Remove C1), remove the second consonant of the word (Remove C2), and say the entire word to ensure that the participant could pronounce the words s/he was trying to manipulate (Real-Word Repetition). The subjects were therefore required to work with each word (and each cluster) three times. The list of words and tasks were randomized and then some items were reordered to avoid having two instances of the same word together. The tester then explained to the subject that s/he would be doing three tasks which would be heard on the tape. The instructions would be spoken once slowly, and then the tape would be paused. The subject may have requested for the instructions to be replayed. After the tape was paused, the subject would do what the instruction said and the response would be tape-recorded. The subject was also assured that sometimes the instruction would require a word to be produced that was not a real English word, but that this might be the correct response. However, the majority of the correct responses on both the Remove C1 and Remove C2 tasks were real English words. This test was designed to see if the subjects could actually produce the consonant clusters in real English words, test their phoneme manipulation skills, and to see whether they were aware that consonant clusters are composed of smaller units or segments. See the complete test in Appendix 3C.

5.7 Scoring

The scoring of the subjects' responses was performed by myself and Tracy O'Brien.

The task of transcribing the responses was divided between both of us, as was the decision of how to categorize the responses. When all responses were transcribed and scored, the entire corpus was checked by both myself and O'Brien.

The subjects' responses were assigned one of four categories: right, wrong, pass, or "sort of right" (also called displaced errors). Right responses were those where the subject responded with exactly the correct response. Wrong responses were those with incorrect production of the consonant cluster. If a subject chose not to respond to a target, the response was scored as pass. In instances where the given response had the correct production of the target consonant cluster, but had other errors within the word, the response was scored as "sort of right", which may also be called a displaced error. An example of such error would be the response [smæs] for the target /smæʃ/. The consonant cluster is produced correctly, but the final consonant is not correct. Later sections specify how these scores were used in statistical analyses.

5.8 Subjects

The dyslexic subjects participated in a tutoring program, run by Dr. Catherine Penney of Memorial University of Newfoundland's Psychology Department. All participants were diagnosed with dyslexia and were actively being tutored under the supervision of Dr. Penney. There were 12 dyslexic subjects in all, 7 female and 5 male ranging in age from 11.4 to 21.8 years, with a mean age of 15.8 years and a standard deviation of 3.5. The wide range in age helped to rule out any test errors that were age-based and would therefore reflect a normal stage in language development and also to discover commonalities that were not age-based.

Such commonalities would then be attributable to phonological dyslexia.

Several standardized tests were administered to all subjects at various times over a two-year period (2000-2002). The results of the Raven's Progressive Matrices test (Raven et al. 1996), which measures non-verbal reasoning, indicate that the subject population had about average non-verbal I.Q. with a mean standardized score of 101.6 and a standard deviation of 15.86. Six other standardized tests were administered and the standard scores are as follows: a word-identification test (mean= 56.92, s.d.= 25.89) and a word attack skills test (mean= 66.83, s.d.= 14.14), which measure the ability to read isolated words and to read nonsense-words; and a word comprehension test (mean = 66.33, s.d. = 23.15); all of these are subtests of the *Woodcock Reading Mastery Test* (Woodcock 1987). A passage comprehension test (mean= 69.08, s.d.= 23.70), the Peabody Picture Vocabulary Test (Dunn and Dunn 1981) (mean= 84.50, s.d.= 15.07), and the Test of Written Spelling (Larsen and Hammill 1994) (mean= 68.00, s.d.= 10.46) were also administered. All subjects scored at least two standard deviations below the mean on these six tests. These results suggest that the subject population as a whole had significant difficulties on the standardized language tests, while still having an average non-verbal I.Q. These results indicate that the subject population used in this experiment was indeed dyslexic.

The control group which was chosen consisted of seven subjects, ages seven to eight years, with a mean age of 8.6 years. These children were Grade 2 students at an elementary school and were recommended by their teachers as being average readers. Average readers were chosen to be part of the control group in order to compare them to the dyslexic group to determine if only bad readers display delayed phonology. A much younger control group was chosen to illustrate that any deficits that were exhibited by the dyslexic group but not the control group are due to delayed or disordered phonology and not due to age.

6. Results

This section compares the dyslexic group with the control group by looking at quantitative statistics based on the results of the Nonsense-Word Repetition tasks, the Real-Word Repetition task, and the Remove-Consonant tasks. In addition, the qualitative analysis section describes in detail the errors made on the tests by the dyslexic group, with some discussion of the few errors made by the control group.

6.1 Real-Word Repetition and Nonsense-Word Repetition Tasks

There were three repetition tasks given to the subjects, one involving the repetition of real English words, one in which they were asked to repeat one-syllable nonsense-words, and the third in which they were asked to repeat two-syllable nonsense-words. These three tests examined whether word length (number of syllables), as well as the word status (real vs. non-words) would have an effect on the number of errors the subjects made.

The dyslexic subjects' mean score on the real-word repetition task was 24.75 out of 26, with a standard deviation of 1.42. In comparison, the control group scored a mean of 25.57 out of 26, with a standard deviation of 0.79. This indicates, as was expected, that the control group had fewer errors than the dyslexic group; however, the difference between the two groups for this task was not significant ($t = -1.398$, $df = 17$, $p = 0.180$). On the One-Syllable Nonsense-Word Repetition task, the dyslexic group showed a mean score of 24.41

out of 26, with a standard deviation of 1.56, whereas the control group had a mean of 25.28 out of 26, with a standard deviation of 0.95. The difference between the two groups for this task was not significant ($t = -1.325$, $df = 17$, $p = 0.203$). On the Two-Syllable Nonsense-Word Repetition task, the dyslexic group scored a mean of 46.75 out of a possible 52, with a standard deviation 5.14, whereas the mean of the control group was 51.57 with a standard deviation of 0.79. The difference between the two groups here was significant ($t = -2.438$, $df = 17$, $p = 0.026$). For the dyslexics, the scores on the Real-Word Repetition task and the Two-Syllable Nonsense-Word Repetition tasks also correlated highly with each other ($r = 0.800$, $p = 0.01$) and the scores on the Real-Word Repetition task and the One-Syllable Nonsense-Word Repetition task correlated with each other ($r = 0.664$, $p = 0.05$). These results indicate that the repetition tasks demand the same type of processing by the subjects.

For the dyslexic group, a 3-way ANOVA, with the independant variable being error rate, showed that the difference in error rates between the three repetition tasks was significant ($F(2,22) = 4.138$, $MSe = 0.0022$, $p = 0.043$), indicating that a combination of word-length and word status were factors in the performance of the dyslexic group. In comparison, the control group's performance was not affected by either word-length or word status.

A t-test was also performed on the Two-Syllable Nonsense-Word Repetition task to see if stress placement affected dyslexics' performance. For this task, there were 52 tokens, half with initial stress and half with final stress. Dyslexic subjects performed worse on the final-stress condition. The means and standard deviations for the two stress conditions are as follows: initial stress (mean = 0.083, s.d. = 0.098), final stress (mean = 0.106, s.d. = 0.094).

There was a significant positive correlation between performance on the two types of tokens ($r = 0.704$, $p = 0.011$). If the subjects' number of errors was high on the tokens with initial stress, it would also be high for those tokens with final stress, and vice versa. However, the difference between the two types of tokens was not significant ($t = 1.048$, d.f. = 11, $p = 0.317$).

6.2 Remove-Consonant Tasks

Two tasks involved removing one of two consonants from a word-initial position. The first task, the Remove C1 task, involved removing the first of the two consonants and the second, the Remove C2 task, required subjects to remove the second consonant from the word-initial consonant cluster. For example, the Remove C1 task required subjects to remove the first consonant from words like *spill* and *sleep,* resulting in the responses *pill* and *leap.* The Remove C2 task required the subjects to remove the second consonant from the target word, which resulted in the responses *sill* and *seep.* The desired responses were mainly real English words.

For the Remove C1 task, dyslexic participants responded correctly 50% of the time, (mean = 0.50, s.d. = 0.31). For the Remove C2 task, the subjects responded correctly 43% of the time (mean = 0.43, s.d. = 0.37). There was a significant positive correlation between the two means ($r = 0.641$, $p = 0.05$), suggesting that the two types of tasks require the same type of processing skill. The difference between the percentage correct on the Remove C1 task and the Remove C2 task was not significant by a two-tailed test ($t = 0.802$, d.f. = 11, $p = 0.439$). However, the results of a less stringent, one-tailed t-test show that the difference was significant (t = 1.693, d.f. = 11, p = <0.05). As noted earlier, there were more errors on the Remove C2 task.

When compared to the control group, the dyslexic group had a much lower number of correct responses. The control group had a mean of 22.14 correct responses, with a standard deviation of 2.79 on the Remove C1 task and 22.71, with a standard deviation of 2.62 on the Remove C2 task. The difference in performance between the two groups was highly significant for both tasks: for the Remove C1 task, t = -2.885, df = 17, p = 0.010; for the Remove C2 task, t = -3.082, df = 17, p = 0.007. The control group outperformed a group that was, on average, twice as old.

For dyslexics, we examined the difference in error rate between the obstruent-approximant clusters (mean = 0.5093) and the /s/ + consonant clusters (mean = 0.6181)[3]. A t-test revealed a highly significant difference in the number of errors between the two types of clusters (t = 2.389, d.f. = 11, p= 0.000), with subjects performing worse on /s/-clusters. There was also a high positive correlation (r= 0.864, p= 0.000) between the number of errors on the two types of clusters, showing that the dyslexics tended to do poorly on all clusters.

An ANOVA was performed on the results of the remove-consonant tests to examine the effect of sonority difference between the first and second member of each cluster on the number of errors made. The independant variable was the error rate; the dependent variables were clusters differing in sonority by 0 degrees (/sp, st, sk, sf/), 1 degree (/sn, sm/), and 2

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[3]For the purpose of the calculation, /sl/ and /sw/ clusters were omitted from consideration, since they belong to both categories.

degrees (/sw, sl/). The results of the ANOVA ($F(3.33)=2.735$, $MSe = 0.09852$, $p= 0.059$) missed the 0.05 "cutoff" for significance. However, the sample of subjects was relatively small and not homogeneous. Given a larger, less heterogeneous sample, the results may have been more significant.

We examined whether word frequency affected dyslexics' performance on the remove-consonant tasks. The corpus from which the word frequency data was extracted was a compilation of written samples from published materials used in schools for grades three to nine. More than 5 million words of running text were analyzed from over one thousand publications (Carroll et al. 1971). With respect to word frequency and error rate, no significant correlation was found ($r = -0.153$, $p= 0.465$, $n = 25$). In looking only at /s/-clusters, similar results were found ($r = -0.045$, $p = 0.916$, $n = 8$). This indicates that word frequency does not condition the dyslexic subjects' ability to manipulate the sounds within the words. However, one interesting result was that there was a significant difference between the cluster /sf/ and all other /s/-clusters in terms of number of errors on all tests ($t = 4.617$, d.f. = 6, $p = 0.004$). There were a greater number of errors on the cluster /sf/ than on all the other /s/-clusters combined when the results of the all the tests were examined. There was, however, no significant difference in frequency between /sf/ and all the other /s/-clusters ($t = -0.511$, d.f. = 6, $p = 0.628$). The consonant and consonant cluster frequency data were taken from Roberts (1965).

6.3 Repetition Tasks and Remove-Consonant Tasks

The correlations between the number of errors for the repetition and the remove-consonant tests were examined. The number of errors on the Real-Word Repetition task and the Remove C1 task showed a significant positive correlation ($r = 0.602$, $p = 0.05$). However, the number of errors on the other repetition and remove-consonant tasks did not inter-correlate. For example, the One-Syllable Nonsense-Word Repetition task and the Remove C1 task show no significant correlation ($r = 0.462$, $p = 0.130$), although they did weakly correlate. The Two-Syllable Nonsense-Word Repetition task and the Remove C1 task also showed no significant correlation ($r = 0.481$, $p = 0.113$). Neither of the three repetition tasks showed any significant correlation with the Remove C2 task. The Remove C2 and the One-Syllable Nonsense-Word task showed no correlation ($r = 0.163$, $p = 0.613$); the Remove C2 and the Two-Syllable Nonsense-Word Repetition task showed no correlation ($r = 0.315$, $p = 0.318$); the Remove C2 task and the Real-Word Repetition task showed no significant correlation ($r = 0.450$, $p = 0.142$). The lack of significant correlations between the two types of tests indicated that there was only weak evidence for a correlation between production tasks (repetition tests) and manipulation tasks (remove-consonant tests). The only two tasks which showed any significant correlation, the Real-Word Repetition task and the Remove C1 task, both involved real English words (as opposed to nonsense-words), which suggests that word status affected the performance of dyslexics[4].

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[4]An interesting task for future research would be to create a remove-consonant task with nonsense-words. Would the subjects perform worse if they had to remove a consonant

6.4 Remove-Consonant Tasks and Standardized Tests

Comparing the results on both the Remove C1 and Remove C2 tasks and the standardized scores of the standardized tests, the ability to remove the second consonant of a cluster correlated more highly with the results of the standardized tests than the ability to remove the first consonant of a cluster. The Remove C2 task correlated with the following standardized tests: the Test of Written Spelling ($r = -0.733$, $p = 0.01$), the Word Identification Test ($r = -0.782$, $p = 0.01$), the Word Attack Skills Test ($r = -0.681$, $p = 0.05$), the Passage Comprehension Test ($r = -0.652$, $p = 0.05$), the Word Comprehension Test ($r = -0.754$, $p = 0.01$), and the Peabody Picture Vocabulary Test ($r = -0.742$, $p = 0.01$). The Raven's Progressive Matrices Test was the only one of the standardized tests which did not show a significant correlation with the Remove C2 test ($r = -0.698$, $p = 0.054$). This is understandable, as the Raven's Test required subjects to complete visual patterns and did not require any reading, writing, or verbal skills. In comparison, the Remove C1 task correlated only with two standardized tests: the Word Identification Test ($r = -0.676$, $p = 0.05$) and the Word Attack Skills Test ($r = -0.582$, $p = 0.05$).

Comparing the results found on both the Remove C1 and Remove C2 tests and the standardized tests, the ability to remove the second consonant of a cluster correlated much more highly with the results of the standardized tests than the ability to remove the first

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from a consonant cluster in a nonsense-word? If so, then the fact that the subjects were dealing with real words on these remove-consonant tasks may have affected the results, further indicating that word status was a factor in performance.

consonant of a cluster. There is a possible explanation for these results: perhaps anyone, even a bad speller/reader, can remove the first consonant of a given cluster, but only those who are better spellers/readers can have a low number of errors when it comes to removing the second consonant of a cluster[5]. This observation indicates that spelling and phonemic awareness are correlated. In conclusion, the more difficult Remove C2 task is a more sensitive predictor of reading and spelling scores, as well as of vocabulary size.

6.5 Nonsense-Word Repetition Tasks and Standardized Tests

Unlike the Two-Syllable Nonsense-Word Repetition task, the One-Syllable Nonsense-Word Repetition task did not show any significant correlations with any of the standardized tests: the Word Identification Test ($r = -0.358$, $p = 0.253$), the Word Attack Skills Test ($r = -0.345$, $p = 0.273$), the Passage Comprehension Test ($r = -0.286$, $p = 0.386$), the Word Comprehension Test ($r = -0.244$, $p = 0.444$), the Test of Written Spelling ($r = -0.133$, $p = 0.680$), the Raven's Progressive Matrices Test ($r = -0.229$, $p = 0.585$), and the Peabody Picture Vocabulary Test ($r = -0.037$, $p = 0.910$). These results indicate that phoneme production skills for one-syllable nonsense-words do not tell us much about the ability to perform on the given standardized tests.

Two standardized tests showed significant correlations with the Two-Syllable Nonsense-Word Repetition task: the Word Attack Skills Test ($r = -0.683$, $p = 0.05$) and the Word Comprehension Test ($r = -0.671$, $p = 0.05$). The other standardized tests did not

[5]It is possible that Universal Grammar will show that initial or final consonant deletion is easier than medial deletion, whether or not one is able to read.

correlate with the Two-Syllable Nonsense-Word Repetition task: the Word Identification Test ($r = -0.546$, $p = 0.66$), the Passage Comprehension Test ($r = -0.569$, $p = 0.054$), the Test of Written Spelling ($r = -0.326$, $p = 0.301$), the Raven's Progressive Matrices Test ($r = -0.398$, $p = 0.329$), and the Peabody Picture Vocabulary Test ($r = -0.296$, $p = 0.350$). This indicates that the ability to perform well on the Word Attack Skills Test, which requires the reading of made-up words, correlates with the ability to repeat two-syllable nonsense-words. In addition, the Word Comprehension Test correlated with the Two-Syllable Nonsense-Word Repetition task. The Word Comprehension Test requires the subject to point to one of four given pictures which correctly portrays the definition of a given vocabulary item. Like the Two-Syllable Nonsense-Word Repetition task, the Word Comprehension test requires reliance on verbal memory in that the subject must remember the definition in order to point to the correct picture. Both these findings suggest the presence of verbal memory deficits in dyslexics, replicating well-known findings. For reviews, see Brady 1991; Perfetti 1985; Wagner and Torgesen 1987.

6.6 Real-Word Repetition Task and Standardized Tests

The Real-Word Repetition task correlated with only one standardized test, the Word Attack Skills Test ($r = -0.590$, $p = 0.05$). The other tests did not correlate significantly at all: the Word Identification Test ($r = -0.444$, $p = 0.148$), the Passage Comprehension Test ($r = -0.454$, $p = 0.138$), the Word Comprehension Test ($r = -0.492$, $p = 0.105$), the Test of Written Spelling ($r = -0.183$, $p = 0.569$), the Raven's Progressive Matrices Test ($r = -0.186$, $p = 0.659$), and the Peabody Picture Vocabulary Test ($r = -0.201$, $p = 0.530$). Again, the scores on the

Word Attack Skills Test reflect the subjects' abilitiy to read made-up words; if the subjects' abilitiy to read made-up words is fairly well-developed, then s/he should also have a well-developed ability to repeat real English words, thus the low error rate on the Real-Word Repetition task. Overall, though, the subjects' abilities to repeat real English words did not otherwise correlate with their performance on the standardized tests.

6.7 Qualitative Error Analysis

There were a number of interesting results found when the dyslexics' errors for each task and /s/ + consonant clusters were examined. There were eight different /s/-clusters for each task, except for the Two-Syllable Nonsense-Word Repetition task, which had 16 tokens with duplicates of each cluster. These clusters were /sp/, /sm/, /sf/, /sn/, /st/, /sl/, /sk/, and /sw/. The following table gives the number of correct responses out of the number of possible instances for each cluster on each task, as well as information on cluster frequency from Roberts (1965):

Table 2. Cluster type and correct responses for repetition tasks

Cluster Type	Cluster Frequency	Real-Word Rep.	1σ Non-Word Rep.	2σ Non-Word Rep.		Total
				Initial Stress	Final Stress	
/sm/	0.06				6	6
/sf/	0.0	3	5	3	5	16
/sk/	0.2	1		2	6	9
/st/	1.54			2		2
/sw/	0.05			1	2	3

/sp/	0.2		1		2	3
/sn/	0.01			1	1	2
/sl/	0.06	1		4	2	7
Total		**5**	**6**	**13**	**24**	**48**

The cluster /sf/ (which is non-native to English and therefore uncommon) had, by far, the highest number of errors, followed by /sk/. /sl/ and /sm/ also had a notable number of errors. The cluster /st/ had the fewest number of errors. As shown in table 2, the frequency of these clusters in English does not seem to be the reason for the difference in errors, although /sf/ is the rarest cluster and also the one with the highest number of errors (Roberts 1965). /sf/ is also the only cluster consisting of two fricatives. However, the numbers of errors on the other clusters does not correspond to the frequency of the clusters.

Table 3. Cluster type and number of errors for remove-consonant tasks

Cluster Type	Cluster Frequency	Remove C1	Remove C2	Total
/sm/	0.06	4	7	11
/sf/	0.0	6	10	16
/sk/	0.2	10	9	19
/st/	1.54	10	7	17
/sw/	0.05	5	6	11
/sp/	0.2	7	7	14
/sn/	0.01	8	9	17
/sl/	0.06	6	8	14
Total		**56**	**63**	**119**

The difference in the number of errors does not vary much from cluster to cluster on these tasks. /sk/ was the cluster with the highest number of errors, followed by /st/ and /sn/. The clusters with the fewest number of errors were /sm/ and /sw/. Again, cluster frequency did not seem to have much of an effect, as /sm/ and /sw/ are less common than /st/ and /sk/ (Roberts 1965), yet /sm/ and /sw/ had the lowest number of errors on this task. The results shown in Table 3 are consistent with those discussed in the quantitative analysis section, where no significant correlation between number of errors and cluster frequency was found.

6.7.1 The Repetition Tasks

The following table illustrates the errors seen on the three repetition tasks and the types of phonological processes employed by the subjects. Any response that is underlined indicates that the subjects' response is a real English word. These results are organized according to the type of phonological process which was employed. The number in brackets following the subjects' responses indicates the number of times this response was given; the underlined responses are those which are also real English words.

Table 4. Processes and errors on the repetition tasks

Process		Real-Word Rep.	1σ Nonsense-Word Rep.	2σ Nonsense-Word Rep.
Epenthesis		sphere - [səfir] (2)		
/r/-insertion				óskep - ['oskrɛp]
Cluster Simplification				ésfem - ['ɛsɛm] - ['ɛsɛv] pesmáte - [pə'met] tesfóop - [təs'up]
Metathesis				peskáke - [spə'dek] - [ɛs'kep]
σ-Deletion				pespáke - [spek]
Stress Change				tesláре - ['tɛs,lep]
Gliding		skate - [sjet]		tesláре - [tə'swep]
Substitution	**/sf/→[sp]**	sphere - [spir]	sfote - [spot] (5)	ésfem - ['ɛspɛm] tesfóop - [təs'put] - [təs'but][6]
	sC → zC			máslep - ['mɑzlɛp] - ['mɑzlIp] áswin - ['æzwIn] pesmápe - [pIz'met] óskep - ['ozkɛp] pásnek - ['pæznɛk] pesmápe - [tə'zmep] teswápe - [tə'zwet]
	/sf/→/sw/			tesfóop - [tə'swup] (2)

[6]This output was included here as /p/ and /b/ differ only in voicing.

Process	Real-Word Rep.	1σ Nonsense-Word Rep.	2σ Nonsense-Word Rep.
Misperceptions 'sort of right' responses (also called displaced errors)			tesfóop - [təs'put] - [təs'but] teswápe - [tə'zwet] - [tə'swet] (2) óstat - ['ostæk] peskáke -[pəs'ket] (2) - [pəs'kek] (2) tesnápe - [tə'snek] pesmápe - [tə'zmep] - [pə'smet] (3) - [pɪ'zmet] pespáke - [təs'pek]
Consonant Harmony			óstat - ['oskæk]
Production of a real English word	slap - [flæp]		

The main type of process was substitution of one of the consonants of the cluster, usually the second consonant. Errors of misperception were other common error types, and these also included those responses in which the target cluster was produced correctly, but with other errors within the word.

A 5% error rate was seen upon looking at /s/ + consonant clusters in the Real-Word Repetition task. While there were only five errors out of a possible 96 made by the dyslexic group, three of these were on the same word *sphere* /sfir/. Overall, for this task, we saw two instances of substitution of the second element of the cluster, two of /ə/ epenthesis, and one rhyming response. The three clusters involved in these five errors were /sf/, /sk/, and /sl/.

Out of the 98 token /s/-clusters on the One-Syllable Nonsense-Word Repetition task, there were six errors, which means that 6% of the words were repeated incorrectly. The results were quite interesting in that, of the six errors, five were on the cluster /sf/, in the target word *sfote* /sfot/. All five of these errors on the cluster /sf/ were substitution errors and all replaced the second element, /f/, with the sound [p], producing [spot] as the response. The only other target word which elicited any errors was *spim* /spIm/. In all, the One-Syllable Nonsense-Word Repetition task saw a total of six responses that were not scored as correct. Five of these errors were on the cluster /sf/ and were scored as wrong. The sixth incorrect response was on the cluster /sp/ and was scored as "sort of right", as the cluster was correctly produced, but there were other errors withing the word. Substitution was the only real phonological process used by the subjects on this task.

Overall, the Two-Syllable Nonsense-Word Repetition task was the harder of the three repetition tasks, with the percentage of errors increasing from 5% on the Real-Word Repetition task, to 6% on the One-Syllable Nonsense-Word Repetition task, to 20% on the Two-Syllable Nonsense-Word Repetition task. There were not only more *errors* on the Two-Syllable Repetition task, there were also more *error types*. There were more instances of substitution on this task than on the other two repetition tasks, and this task saw the first instances of misperception errors thus far.

6.7.2 The Remove-Consonant Tasks

The most common error on the two remove-consonant tasks was the deletion of the entire consonant cluster. Specific errors of this type are listed in the following table, with the number of instances of each error in brackets and any responses which are real words are underlined:

Table 5. Deletion of entire consonant cluster on the remove-consonant tasks

Remove C1 Task	Remove C2 Task
sphere - [ir] (2)	sphere - [ir] (6), [er] (1) = 7
snap - [æp] (6)	snap - [æp] (4)
skate - [et] (7), [ek] (1) = 8	skate - [et] (4)
stack - [æk] (8)	stack - [æk] (3)
spill - [Il] (4)	spill - [Il] (5)
sweet - [it] (5)	sweet - [it] (4)
smash - [æʃ] (4)	smash - [æʃ] (3)
slap - [æp] (5)	slap - [æp] (2)

On the Remove C1 task, 77% of the subjects' errors were due to the removal of the entire consonant cluster rather than only the first element of the cluster. On the Remove C2 task, 49% of the errors made were also due to the removal of the entire cluster instead of only the second element. Many of the subjects' responses resulted in real English words because of this process, as is shown by the underlining in Table 5 above.

For many of the other errors on these two tasks, the subjects responded with real-word outputs that sounded much like the target word, and the majority of the time, these outputs did not have any consonant removed. The following table illustrates the errors of this type:

Table 6. Output errors which resemble the target word

Remove C1	Remove C2
snap - [pæp] (1), [kræk] (1) = 2	snap - [sæk] (1), [sIp] (1) = 2
slap - [slIp] (1)	smash - [stæʃ] (1)
spill - [mIl] (1)	slap - [skræp] (1)
stack - [skræk] (1)	sphere - [spir] (1)
sphere - [rir] (1), [frIl] (1)	skate - [sek] (1), [stet] (1) = 2
	slap - [læp] (1)
	stack - [ækt] (1), [træk] (1) = 2

There were several responses given for the Remove C2 task for which the subjects incorrectly removed the first consonant of the cluster rather than the second. The following is a list of such error types. The underlined responses show that errors were real English words:

Table 7. Removal of incorrect consonant for Remove C2 task

Remove C2		
slap - [læp] (2)	spill - [pIl] (1)	smash - [mæʃ] (1)
snap - [næp] (1)	sweet - [wit] (1)	

There were several other errors which were made by subjects, but that were relatively rare, such as the process of /r/-insertion and consonant harmony. These, along with several others, are listed in the following table:

Table 8. Other errors on the remove-consonant tasks

Process	Remove C1	Remove C2
/r/-insertion	stack - [skræk] (1)	stack - [skræk] (1)
/ə-/insertion or hesitation		spill - [spəIl] (1) stack - [səæk] (1) smash - [səæʃ] (1) sweet - [swə] (1)
Consonant Harmony		skate - [skek] (1)
Metathesis and Deletion		slap - [sol] (1)
Repetition of Word		sphere - [sfir] (1) skate - [sket] (1)

It is interesting to note that all of the responses which had /ə/ inserted between the two elements of the cluster were given by the same subject, who obviously had a consistent strategy for performing on the Remove C2 task. The Remove C1 task saw a total of 56 incorrect responses, with 53 being wrong and three being a 'pass'. Out of a possible 96 tokens, there was an error rate of 58% on this task. The Remove C2 task had a higher error rate, at 65%, out of 96 tokens. There was a total of 62 errors, with six of those being scored as 'sort of right', 4 being passes, and 52 wrong.

There were a higher number of errors on the Remove C2 task than the Remove C1 task, and while both tasks showed errors on all eight clusters, there was a wider range of errors on the Remove C2 task. In addition, the Remove C2 task had a higher number of *different* error types for each target word. For example, for the cluster /sk/ in the word *skate*, the Remove C1 task had three different types of errors. The same word in the Remove C2 task had five different types of incorrect responses. The same can be said for each of the other seven clusters. The Remove C2 task seemed to cause more difficulty for the subjects, hence the higher number of errors and the wide variety of responses given for each target word.

6.7.3 Comparison: Dyslexic Group and Control Group

Comparing the errors made by the dyslexic group with those made by the control group, there were significantly fewer errors on all tasks by the control group. However, both groups used similar phonological processes. The following table illustrates the numbers and types of errors made by the control group on all five of the tasks:

Table 9. Errors made by the control group on all tasks

Process	Real-Word Rep.	1σ Nonsense-Word Rep.	2σ Nonsense-Word Rep.	Remove C1	Remove C2
Epenthesis	sphere - [səfir]				
Substitution	sphere - [spir]	sfote - [spot]			
Cluster Simplification		sfote - [fot]	ésfem - ['ɛsɛm]		
Deletion of Entire Cluster				snap - [æp] smash - [æs][7] stack - [æk] sweet - [it] spill - [Il]	
Removal of Wrong C					sphere - [fir]
Consonant Harmony				snap - [pæp]	

The common thread between both the dyslexic group and the control group was that /sf/ caused the greatest difficulty for the subjects. The other cluster which caused problems for the control group was /st/, whereas the dyslexic group had a high number of errors on /sk/. There were no random or unusual processes exhibited by the control group, unlike the dyslexic group. The responses given by the control group were much more predictable in terms of the processes that would be used. The control group used a subset of the processes used by the dyslexic group, but with less frequency. Furthermore, the dyslexic group exhibited some unusual and uncommon processes like /r/-insertion that were not used by the control group.

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[7]Note that the final /ʃ/ was changed to [s] here.

The presence of such processes in the results of the dyslexic group, as well as their absence from the results of the control group, indicates that the dyslexic group does indeed have disordered phonology. The high number of errors by the dyslexic group also indicates that children with dyslexia do have serious problems in either manipulating and producing phonemes.

6.8 Summary of Qualitative Analysis

There are many similarities and differences between the three repetition tasks and the two remove-consonant tasks. One of the most striking observations, in fact, is the *lack* of similarities found in the responses between the two types of tasks. For the repetition tasks, subjects frequently employed the process of substitution, usually of the second consonant. On the rare occasions when one element of a cluster *was* deleted, it was unpredictable as to whether it would be the first or the second consonant phoneme; notably, there were no instances where the entire cluster was omitted. In contrast, for the two remove-consonant tasks, the common trend was to simply delete the entire consonant cluster and produce only the rime of the word. The repetition tasks saw the use of many phonological processes, such as substitution, voicing assimilation, cluster reduction, metathesis, and epenthesis. The remove-consonant tasks, on the other hand, saw little use of such processes, with the only exception being epenthesis.

The processes that were used on the remove-consonant tasks (deletion of whole cluster, deletion of the wrong consonant, and repetition of the whole word) suggest that the subjects were not properly analyzing the clusters. Deletion of the entire cluster suggests that the subjects were unable to analyze the cluster into two discrete phonemes, and were probably unaware that the cluster was actually composed of two elements. In contrast, the types of processes seen in the repetition tasks suggest misperception or misanalysis of phonemic contrasts.

There were also noticeable differences in the clusters which had the highest numbers of errors on each task. On the repetition tasks, there were many errors on /sf/ and very few errors on /sn/. There were also many errors on the cluster /sf/ on the remove-consonant tasks, but there were also a lot of errors on /sn/ as well. In fact, there were no consistencies between the two types of tasks in terms of which cluster had the most or the fewest errors, except for /sf/. As was already suggested, /sf/ is the least frequently occurring cluster in English, and this may have some impact on why there are so many errors on this cluster. Another reason for the numerous errors on this cluster on both types of task is that it is the only word-initial cluster in English which is composed of two fricatives. This cluster violates both the Sonority Sequencing Principle and the Minimal Distance Constraint, and these may be factors in the high number of errors. It is also important to note that the four clusters consisting of /s/ plus a stop consonant (/sk/, /sp/, and /st/) had some of the highest error rates. This suggests that /s/ plus plosive consonant clusters are analyzed in the same way as affricate consonants (see Section 2.6). These results also indicate that the difference in degrees of sonority between the first and second elements of a cluster may have an effect on the ease with which such clusters are acquired by dyslexics. The four clusters which have two elements of the same sonority (/sf/, /sp/, /st/, /sk/) also had some of the highest error rates on this task. /sn/ was another cluster which also had a high number of errors (perhaps due to the same place of articulation of both /s/ and /n/).

7. Discussion

This experiment has shown that dyslexics perform significantly worse on clusters comprised of /s/ plus a consonant than on obstruent-approximant clusters. This was the expected result, due to the possibly unique underlying representation of many /s/-clusters as was discussed in Sections 2.3 and 2.4.

The fact that /sf/ consistently had a high number of errors on all tasks and also caused the control group some trouble cannot be explained by saying that /sf/ is an affricate, since affricates require a stop portion. However, as explained earlier, /sf/ is the only consonant cluster in English which consists of two fricatives of the same sonority, and violates the MDC and the SSP, and thus really does not conform to English phonotactics.

When considering word status and word length as factors in error rates, we find that the combination of longer words and nonsense-words predicted a higher number of errors. There was also a wider range of error types for longer (two-syllable) words than for one-syllable words. In addition, there were more errors and more errors types for both one- and two-syllable nonsense-words than for real words, suggesting the importance of word status. Similarly, several of the errors made on the repetition tasks involved the production of a real English word rather than a nonsense-word, indicating that word status had an effect on some subjects' responses. If there was a real English word which sounded much like the target nonsense-word, the subjects were likely to produce the English word. In summary, the performance of the dyslexic group improved when they had phonological representations in their long term memory, but this also influenced the direction of their errors on the nonsense-word repetition tasks. There, many of the responses were real words instead of the target nonsense-words.

In terms of stress position on the Two-Syllable Nonsense-Word Repetition task, the effect of stress placement was not statistically significant, although there were more errors made on the words with final stress. The changes in stress placement did affect some subjects when the stress was on the first syllable of the word in that the subjects would often change voiceless /s/ to voiced [z]. Except for the voicing of /s/, the types of errors found in words with initial versus final stress were similar.

These results tell us that dyslexics perform better on tasks which allow them to rely on word representations that they have already encoded in their long term memory, and that tasks such as a Two-Syllable Nonsense-Word Repetition task which force them to quickly encode and recall information are taxing and often result in a high number of errors.

There were several errors caused by misperception, mainly those involving a voiceless plosive. Often, there were random substitutions of voiceless plosives in word-final position, indicating that the subjects could not correctly perceive the difference between /p/, /t/, and /k/ in word-final position[8] Conversely, there was a tendency to retain /s/ in the deletion errors

[8]There may be dialectal influences at work here. Word-final voicing contrasts are weaker/stronger in different dialects of English.

made in the repetition tasks, possibly due to its more acoustically salient features than the other member of the cluster. This suggests that acoustic saliency was a factor when choosing which consonant of a cluster to delete.

Frequency of words and clusters did not influence the types and number of errors found on the five tasks. Except for /sf/, word frequency did not correlate with the number of errors on the Real-Word Repetition task or on the remove-consonant tasks. Similarly, the frequency of a given consonant cluster did not show any correlation with the number of errors for that cluster.

The high number of errors on the remove-consonant tasks indicate that the dyslexic group had significant difficulties in manipulating consonant phonemes and also in distinguishing between one individual phoneme and a consonant cluster. This was especially evident when consonant clusters consisting of two phonemes were replaced with those consisting of three phonemes. The inability to separate phonemes is one of the major problems in those with dyslexia. The errors on the remove-consonant tasks tell us nothing about the status of /s/-clusters as affricates, since the error strategy of removing the whole cluster was used for both the /s/-clusters and the other type of cluster (obstruent-approximant) found on these tasks. However, the fact that the number of errors on /s/-clusters was higher than on the other types of clusters indicates that there is *some* underlying difference between the two types of clusters. These errors again suggest perseverance of earlier processes.

These results support the majority of the hypotheses stated earlier in Section 4. The theory that dyslexics have disordered phonology and will exhibit perseverant and unusual phonological processes was supported by the fact that the dyslexic group made more errors on all tasks than the control group, despite the large age difference between groups. Dyslexics persevered in using immature phonological processes to a much greater degree than the much younger control group, indicating delayed phonology. Furthermore, the dyslexics used the same processes as the control group, but also employed uncommon and unusual processes.

The Two-Syllable Nonsense-Word Repetition task supported the idea that dyslexia involves a verbal memory deficit, as there were a significantly high number of errors on this task than on those with shorter stimuli, and the dyslexics performed much worse than the controls. The effect of word length also supports this notion, as word length, which requires the use of verbal recall, adversely affected the performance of the dyslexic group, but not the controls. Similarly, dyslexics who performed poorly on the Two-Syllable Nonsense-Word Repetition task also performed poorly on the Word Comprehension test, both of which test the verbal recall ability.

The results of the remove-consonant tasks supported the hypothesis that dyslexics have phoneme awareness deficits, as the dyslexic group performed significantly worse on both remove-consonant tasks than the control group. The dyslexics showed a greater tendency to delete the entire consonant cluster than did the controls, which indicates that they are unable to segment onsets into phonemes. The Remove C2 task proved to be a more sensitive predictor of reading and spelling ability, as it correlates with more standardized scores than the Remove C1 task.

8. Conclusion

The results of this study have shown that dyslexics have phonological and memory deficits, as well as difficulties with phoneme manipulation tasks. Consonant clusters consisting of /s/ plus another phoneme are especially difficult for dyslexics to manipulate and produce. This leads to the notion that there are most likely some perception deficits in those with dyslexia as well, although perception was not the main focus of this paper. The fact that /s/-clusters need special rules for syllabification (either a syllable-initial appendix or syllabification like affricates) reinforces their proposed uniqueness. The real consequences of the special nature of these clusters were exhibited in the performance of the dyslexic group in this study and illustrates the implications of such a different underlying structure in the real world.

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Appendix 1

Distinctive features of English consonants

The following chart lists the distinctive features of the consonant phonemes found in English, excluding the approximants /w y r l/. The 'y' symbol is used to indicate a '+' value of a binary feature; '-' indicates the absence of a binary feature; '0' indicates the presence of a unary feature.

	p	b	t	d	k	g	f	v	θ	ð	s	z	ʃ	ʒ	ʧ	ʤ	m	n	ŋ	h
vocoid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
approximant	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y
sonorant	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	y	y
voice	-	0	-	y	-	y	-	y	-	y	-	y	-	y	-	y	y	y	y	-
continuant	-	-	-	-	-	-	y	y	y	y	y	y	y	y	±	±	-	-	-	y
nasal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	y	y	y	-
lateral	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
labial	0	0					0	0									0			
coronal			0	0					0	0	0	0	0	0	0	0		0		
anterior			y	y					y	y	y	y	-	-	-	-		y		
distributed			-	-					y	y	-	-	y	y	y	y		-		
dorsal					0	0													0	

(Halle and Clements 1983:33)

Appendix 2

A. Defining SLI

The term 'Specific Language Impairment', also referred to as SLI has been chosen as a replacement for earlier terms that defined much the same problems as seen in those who are now considered to have SLI. This new terms replaces labels such as 'developmental dysphasia', 'developmental aphasia', 'delayed language', and 'specific developmental language disorder'. The term SLI does not attempt to address whether the language skills are delayed or disordered and instead uses the notion of 'impairment' to circumvent this problem. The word 'specific' is especially important in the use of this label as it indicates that language impairment is present in an otherwise normally developing child (Bishop 1997:21).

A widely accepted list of diagnostic criteria comes from Stark and Tallal (1981) as cited by Bishop (1997:26). This list is as follows:

- normal hearing on pure tone screening
- no known history of otitis media
- no emotional or behavioural problems sufficiently severe to merit intervention
- performance IQ of 85 or above
- normal neurological status
- no peripheral oral motor or sensory deficits
- articulation age no more than six months below expressive language stage
- in children aged seven years or above, reading age no more than six months below language age
- language age at least 12 months lower than chronological age or performance mental age, whichever was the lower
- receptive language age at least six months lower than chronological age or performance mental age, whichever was the lower
- expressive language age at least 12 months lower than chronological age or performance mental age, whichever was the lower

While these criteria do not address all the questions that have been raised in the process of compiling such a list, and nor are they accepted by all researchers in the field, they do provide a basis for diagnosing a child with SLI.

B. Natural phonology

There are many ways in which a child's phonological system may differ from that of an adult. Under one view, Natural Phonology, there are numerous rules and processes that may be taking place in order for a child to produce unadult-like forms. This sort of view sees the child using the adult linguistic forms as the input, then by applying some rule(s) or process(es), the child produces his own form as the output (Crystal 1981:37). There are three major classes of rules involved in this transformation of adult forms into child forms: substitution processes, assimilatory processes, and syllable structure processes (Crystal 1981:37-38).

C. The representation of affricates

The following discussion outlines the five different types of representations that have been proposed for the representation of affricates.

The first proposal concerning the treatment of affricates came from Jackobson et al. (1951) (as cited in Bernhardt and Stemberger 1998:70. They proposed that the affricates /ʧ/ and /ʤ/ carry the feature [+strident] and are therefore [+strident] stops. This classification was enough to separate these affricates from other stops, as no stop carries the feature [+strident]. They maintained that no feature was necessary to represent the change from a stop-like articulation to a fricative-like articulation because the change in manner of articulation was seen as a result from the way in which strident stops were phonetically implemented. Simply put, they treated affricates like single consonants.

Chomsky and Halle (1968 as cited in Bernhardt and Stemberger 1998:70) proposed that affricates were in fact stops with an extra manner feature called [delayed release]. This idea was derived from an analysis where the release of the stop is very slow and during this slow release, a fricative-like element is produced. However, this feature is no longer used in modern phonology, and again, they also treated affricates like single consonants.

The development of non-linear phonology led to a new view of affricates. Clements and Keyser (1983) (as cited in Bernhardt and Stemberger 1998:70) maintained that affricates were composed of two, somewhat separate components: a stop followed by a fricative part. For example, /ʧ/ is actually /t/ followed by /ʃ/; however, both elements share a timing unit rather than having two separate timing units. This analysis considers affricates to be single consonants with ordered [+ continuant] and [- continuant] feature values. However, this approach is no longer used.

Another analysis arose with the development of non-linear phonology which claimed that affricates were a single segment but were specified for both [-continuant] and [+continuant]. That is, each affricate had a [-continuant] feature at the beginning of the representation and a [+continuant] feature at the end of the representation (Bernhardt and Stemberger 1998:70).

Lombardi (1990) (as cited in Kenstowicz 1994:501) proposed that instead of the [continuant] feature being ordered, the positive and negative values of the [continuant] feature exist on two different tiers and are thus phonologically unordered. This allows the

[+continuant] and [-continuant] features to be accessible by the sound to the left of the affricate or by the sound to the right. She further asserts that the stop-fricative sequencing is then imposed at the level of phonetic implementation (Kenstowicz 1994:501).

Another proposal is that affricates are actually a species of stops and should be treated as though they are underlying stops (Steriade 1989 as cited in Kenstowicz 1994:502). Steriade maintains that there is a [+ continuant] component as well as the [- continuant] feature. The important point in Steriade's model is that stops and affricates are categorized under the more general heading "plosive" which entails two positions: a closure followed by a release (Kenstowicz 1994:502). This idea can be shown in the following way:

Ao = [- continuant]
Af = [+ continuant, - sonorant]
Amax = [+ continuant, + sonorant]

Ao Af — affricate   Ao Amax — stop (released)   (Kenstowicz 1994:503)

Both the affricate and the stop begin with a closure phase, but the affricate has the release properties that indicate a fricative. Therefore, affricates and stops are similar on two levels: they both have two phases (unlike fricatives, approximants, and unreleased stops, which have only one phase) and they both have a component to indicate closure. They differ in their release properties and it is in this areas that affricates are comparable to fricatives (Kenstowicz 1994:503)

APPENDIX 3

A.One-Syllable Nonsense-Word Repetition Test

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	
thrope	
bloot	
slib	
quat	

Nonsense-Word Repetition, One-Syllable Subject # _______

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

B.Two-Syllable Nonsense-Word Repetition Test

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	
setráke	
ósmoop	
tekrápe	
gáplet	
póbleck	
sípret	
peskáke	
mebráck	
tekwáke	
ésfem	
nefláck	
sethwáke	
óstat	
máslep	

Nonsense-word repetition 2-syllable

Subject # ________

pásnek	
máspet	
bíthwig	
metwáke	
pegwápe	
kethráke	
áswin	
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

C.Remove-Consonant/ Real-Word Repetition test

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	
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**	

Auditory analysis test (word-initial consonant clusters)

Subject # ________

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**	
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**	

Auditory analysis test (word-initial consonant clusters)

Subject # ________

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	
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: 'thwack' is fairly 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.

D.The ethical consent form

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 or at other times convenient to the participant.

Participant's Initials _________

Consent form for participation in phonology of dyslexia project

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.

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.

Participant's Initials _________

Consent form for participation in phonology of dyslexia project

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: ____________________

****

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)