Investigating the Potential of a Test of Non-word Discrimination as a Screening Tool for Persisting Speech Sound Difficulties

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Contents

Abstract ........................................................................................................................................... 1
Terminology & Abbreviations........................................................................................................... 2
Introduction....................................................................................................................................... 3
  Prevalence and consequences of Speech Sound Disorders ............................................................... 3
  Classification of Speech Sound Disorders....................................................................................... 4
  Nature of Deficits in Children with SSDs...................................................................................... 5
  Speech perception ........................................................................................................................... 7
Phonological representations ............................................................................................................ 8
Identifying phonological processing deficits: Non-word repetition, non-word discrimination and real word discrimination ......................................................................................................................... 9
  Non-word repetition – speech output task ...................................................................................... 9
  Non-word Discrimination – speech input task ............................................................................. 11
  Real word discrimination – speech input task ............................................................................ 11
Benefits of early identification and efficacy of interventions: ......................................................... 13
Motivation for this study .................................................................................................................. 14
Research Aims .................................................................................................................................. 14
Methodology ...................................................................................................................................... 16
  Ethical Approval and Consent ......................................................................................................... 16
  Experimental Design ..................................................................................................................... 16
  Participants ...................................................................................................................................... 16
Assessments administered ............................................................................................................... 17
  Assessments administered at initial assessment: ....................................................................... 17
  Assessments administered at Time 2 ........................................................................................... 20
Procedure........................................................................................................................................ 20
Reliability.......................................................................................................................................... 21
Scoring of NWD and RWD tasks .................................................................................................... 21
Analysis ............................................................................................................................................ 22
Results.............................................................................................................................................. 23
Overview of results .......................................................................................................................... 23
Statistical analysis of data ................................................................. 25
Discussion ............................................................................................. 27
Main Findings ....................................................................................... 27
Clinical Implications ........................................................................... 28
Limitations: ........................................................................................... 29
Conclusions: ......................................................................................... 29
References ............................................................................................. 30
Appendix A - Test of Auditory (NWD) Discrimination ................................ 37
Appendix B - Test of Real word Discrimination ........................................ 39
Abstract

**Background:** Children with Speech Sound Disorders (SSDs) make up the largest client group for Speech Therapy services in Ireland and worldwide. Children with SSDs form a heterogeneous group and difficulties can be attributed to one or more of a number of possible underlying deficits. In order to best design and implement targeted and individualised treatment, more sensitive screening tools need to be developed that will aid in the prioritisation of caseloads and ensure children requiring clinician-directed intervention receive it.

**Objectives:** The potential of a new screening tool as a prognostic indicator will be examined.

**Methods:** 11 children with SSD aged between 3;2 and 4;05 were recruited from waiting lists of local SLT clinics. At initial assessment, non-standardized tests of non-word discrimination and real-word discrimination were administered as well as the Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dodd et al. 2002), a standardized test of phonology. Improvement in percentage of consonants correct (PCC) on the DEAP was measured again eight weeks later. Original scores on both NWD and RWD tests were compared to improvements in PCC.

**Results:** The children who scored above threshold on the test of NWD also scored the highest in a test of RWD. These children also made the biggest improvement as measured by DEAP PCC over eight weeks compared with the children who scored below threshold on NWD.

**Conclusions:** Findings are consistent with the theory that a test of NWD may be a more sensitive predictor of whether children’s phonological systems will improve without intervention than factors such as severity alone. Further research is needed with a larger sample size to see if results prove significant.

**Keywords:** speech sound disorder, phonology, speech perception, phonological representation, non-word discrimination, percentage consonants correct.
Terminology & Abbreviations

**Phonological representation:** The qualitative contrasts in sound which can be used to convey qualitatively different meanings in any given language (Pierrehumbert 1990)

**Lexical representation:** means of keeping information about words (Stackhouse & Wells 1997)

**Lexicon:** a store of words (Stackhouse & Wells 1997)

**Phonological processing:** the cognitive skills underlying the processing and production of speech (Stackhouse & Wells 1997)

**Top-down processing:** an activity whereby previously stored information is helpful and used (Stackhouse & Wells 1997)

**Bottom-up processing:** an activity which requires no prior knowledge and can be completed without accessing stored linguistic knowledge from the lexical representations (Stackhouse & Wells 1997)

**SLT:** Speech and Language Therapist

**SSD:** Speech Sound Disorder

**NWR:** Non-word repetition

**NWD:** Non-word discrimination

**RWD:** Real word discrimination

**PCC:** Percentage of consonants correct

**Ax:** Assessment

**T1:** Time 1

**T2:** Time 2
Introduction

Children with Speech Sound Disorders (SSDs) make up the largest client group for Speech and Language Therapy (SLT) Services in Ireland and worldwide. Children with SSD are those who have a “clinically notable delay or difference in speech sound acquisition that cannot be explained by significant cognitive, sensory, motor, or structural deficits” (Shriberg 1980). Children with SSDs form a heterogeneous group and difficulties can be attributed to one or more of a number of possible underlying deficits. There is a need for interventions which target these deficits. In order to best design and implement individualised treatment based on specific deficits, more sensitive profiling and screening tools need to be developed that will aid in the prioritisation of caseloads and ensure those children requiring clinician-directed intervention receive it (Wright 2013). There is no one task that will identify the children who are at risk for persisting speech difficulties; rather a collection of tasks examining speech input and output processing (Stackhouse et al. 2007). Here, the potential of one such speech input task as a screening tool for deficits in auditory perception/discrimination, namely a task of non-word discrimination (NWD), is considered. Non-word discrimination (NWD) has recently been suggested as a way of measuring phonological representation in children with SSDs, without the confounding variables of articulation planning and execution (Reuterskiöld-Wagner et al. 2005).

Prevalence and consequences of Speech Sound Disorders

SSDs account for a large percentage of referrals to SLT services and are a high prevalence condition (Law et al. 2000; McLeod & Harrison 2009). Broomfield and Dodd (2004a) reported that of 1100 children referred to a UK SLT service over a 15-month period, almost one-third (320) presented with primary SSDs and the American Speech Speech-Language-Hearing Association reported in their 2012 school survey (ASHA 2012) that approximately 93% of school-based SLTs reported that they served children with SSDs more than any other disorder. Children with SSDs are shown to be at risk for delayed development of phonological awareness (Rvachew 2007) and these difficulties are, in turn, linked to poorer reading skills in children with SSDs when compared to their typically
developing peers, especially if the speech-sound disorder is persistent and/or associated with a concomitant language disorder (Larrivee & Catts 1999; Nathan, Stackhouse, Goulandris & Snowling 2004; cited in Rvachew 2007). Research indicates that if SSDs are not resolved, many of these children will go on to experience problems in the areas of literacy acquisition (Nathan et al. 2004; Overby et al. 2007) and social relationships (Crowe Hall 1991). Information from longitudinal studies such as Felsenfeld et al. (1992; 1994; 1995) has shown that individuals with SSDs may experience difficulties with communication skills and education into adulthood.

**Classification of Speech Sound Disorders**

Classification of subgroups of SSDs has been of interest of late precisely because the heterogeneity of this group has been recognised (Tyler 2011). Recent research on the diagnosis of SSDs has moved beyond the “dichotic notion” of articulation vs. phonology to one of multiple diagnostic subgroups (Baker 2006). Such classification systems are relevant for the testing of existing treatments and the development of new treatments “uniquely suited for a specific subtype” (Taylor 2011, p. 93). However, while most agree on the existence of these subgroups, there is no consensus on what constitutes a particular subgroup and how best to differentially diagnose them (Baker 2006). Tyler (2011) summarised a number of existing classification systems, stating that, at present, these systems are based either on aetiology (Shriberg 2010) surface speech patterns (Broomfield & Dodd 2004) or underlying deficits (Stackhouse & Wells 1997). The latter classification system, that examining underlying deficits, is of interest to this study.

The heterogeneity of this group of children manifests itself in the nature and severity of the disorder and in the children’s response to treatment (Dodd 2005), in that many of these children’s phonological errors will resolve without therapy, or with minimal therapy while others continue to have long term and persistent difficulty in the acquisition of age-appropriate speech sound production skills and often will not respond to typical therapy approaches for the remediation of speech sound errors (Cabbage 2015). Persisting difficulties can manifest themselves as multiple or isolated speech sound production errors and can result in long-term enrolment in speech therapy services (Cabbage 2015).
So why is it that a subset of these children have persisting difficulties, why is it that their speech production errors do not respond as readily to treatment and how can SLTs ascertain which of the children with SSDs on their caseload will fall into this category and will go on to have persisting difficulties? To understand this, it is necessary to look in more detail at the nature of deficits in children with SSDs.

**Nature of Deficits in Children with SSDs**

There has been much debate around the proposed deficits underlying SSDs. Dodd, whose classification (1995) is widely used in the differential diagnosis of subtypes of SSDs, does not recognise a group for whom weak acoustic perceptual representations of words would lead to weak or inaccurate phonological representations and subsequent SSD. Dodd’s classification categorises children into subgroups based on their surface phonological error patterns. These proposed subgroups are articulation disorder, phonological delay, consistent phonological disorder and inconsistent phonological disorder and each presents with different surface speech error patterns (Dodd et al. 2005). Dodd’s classification attributes a number of deficits to the different subtypes. While there has been no specific underlying deficit identified for phonological delay, it is hypothesized that consistent phonological disorder could be the result of impaired ability to derive phonological constraints and that inconsistent phonological disorder could be a result of a deficit in phonological planning (Dodd & McCormack 1995). Rvachew & Brosseau-Lapré (2012) however, maintain that acoustic-phonetic representations are the foundation of speech perception and phonological awareness skills and that a deficit in this area could result in, or contribute to SSDs. In two studies examining the relationship between speech perception and speech production errors in 5 year-old children with articulation disorder, Rvachew & Jamieson (1989) assessed speech perception with a word identification test which contrasted the specific phonemes that were associated with production errors in the sample. The tests were carried on the 5 year-olds with phonological impairment, adults and 5 year-old children without any speech difficulties. They identified a subgroup of children with phonological impairment who could not discriminate between word initial /s/ and /ʃ/ (sh). In addition, the two groups differed
substantially in their performance on a task of categorical perception with the same phonemes (Rvachew & Jamieson 1989). The researchers concluded that, for a subgroup of children who have a phonological impairment, production errors may reflect speech perception errors.

More recently, researchers have been questioning the role of speech perception and phonological processing in children with SSDs. Although children with SSDs have difficulties with speech production, it is being suggested that a subset also have difficulties with speech perception, and this dual deficit may be an indicator of those who will go on to have more persistent SSDs (Cabbage 2015; Rvachew & Brosseau-Lapré 2012). Rvachew & Brosseau-Lapré (2012) suggested that 50% of children with SSDs have concomitant speech accuracy and phonological processing deficits. Munson et al. (2005), in their study of phonological knowledge in typical and atypical speech and language development, proposed four types of phonological knowledge: perceptual knowledge; knowledge of the acoustic and perceptual characteristics of speech sounds, articulatory knowledge; knowledge of the articulatory characteristics of speech sounds, higher-level phonological knowledge; higher level knowledge of the ways that words can be divided into sounds, and sounds can be combined into meaningful sequences in words, and social indexical knowledge; the knowledge of the ways that variation in pronunciation can be used to convey social identity (Munson et al. 2005). The authors suggested that children with SSDs can be differentially impaired in any of these areas, so while some may be impaired only in the area of articulation others may show substantial deficits in perceptual and articulatory knowledge (Munson et al. 2005).

Because of the heterogeneous nature of this group, it is imperative that SLTs identify the underlying deficit(s) for each child, as it is possible that different responses to therapy, or indeed, no response at all, could be due to the fact that the specific underlying deficit for that individual child is not being targeted. Rvachew & Grawburg (2006) highlight the importance of assessing speech perception in children with SSDs as they suggest that it is the deficits in this area which lead to the phonological awareness and later literacy difficulties seen in some children with histories of SSD. In order to target deficits, there is a need to develop tools which help us identify these deficits more accurately and
efficiently (Stackhouse et al. 2007; Wright 2014). Assessment of speech perception will be examined in more detail later.

**Speech perception**

Speech perception is “the process of transforming a continuously changing acoustic signal into discrete linguistic units” which starts developing in the first year of life and continues into late childhood (Rvchew & Grawburg 2006, p.76; Hazan & Barrett 2000). Simply, it is how different sounds and combinations of sounds in any given language are heard, interpreted and understood by the listener. There are various models of speech perception but common to most is the assumption of a multistage process in which auditory processing mechanisms extract acoustic details, the acoustic representation is converted into phonetic units and then a hierarchically organised phonological representation is constructed and used in lexical access (Rvachew & Grawburg 2006). Speech perception, in short, involves accessing acoustic–phonetic and phonological representations of words. (Rvachew & Grawburg 2006).

The relationship between speech perception and speech production is not well understood. Cabbage (2015) has recently focused and condensed findings from research on speech perception in children with persistent SSD in order to inform practice. This research is based on the assumption that a child who has difficulty perceiving certain speech sounds may have difficulty producing said sounds correctly (Cabbage 2015). To explain the impact of speech perception difficulties, Cabbage uses the example of individuals with a hearing impairment who may struggle to articulate certain phonemes “which rely heavily on speech perception and auditory feedback...as opposed to visual...or tactile feedback” (Cabbage 2015, pp.18-19). The fact that individuals with hearing impairment have more difficulty with these phonemes which rely on speech perception and auditory feedback lends evidence to the importance of speech perception for speech production (Cabbage 2015). So how exactly do deficits in speech perception or auditory perceptual deficits as they are also known, affect speech production? To understand this, it is important to explore the concept of phonological representation.
Phonological representations

Phonological representation describes the “qualitative contrasts in sound which can be used to convey qualitatively different meanings in any given language” (Pierrehumbert 1990, p.375). It is the phonological information a child has for a particular word or words (Sutherland & Gillon 2007). It describes the underlying sound structure of words stored in long-term memory (Locke 1983; Sutherland & Gillon 2007). The phonological representations of younger children may contain mainly general acoustic information with a number of marked phonetic characteristics to help them differentiate certain words from others (Sutherland & Gillon 2007). Sutherland& Gillon (2007) note that a well-developed phonological representation is believed to contain both auditory and visual information (e.g. a phoneme and a lip movement) about a word that enables it to be perceived and differentiated from others. In their 2007 study they looked at phonological representations in relation to children with speech sound disorder. In order to examine the relationship between performance on phonological representation tasks and measures of speech production, phonological awareness and early print decoding, the researchers looked at the performance of nine children aged 3;09 to 5;03 with moderate or severe speech impairment on three occasions over a 12-month on a receptive task designed to tap into phonological representations and measures of speech production and phonological awareness (Sutherland & Gillon 2007). Results showed that children with speech impairment had more difficulty identifying correct and incorrect productions of words and identifying accuracy of newly learned non-words when compared to seventeen children of the same age with typical speech development. They also found correlations between performance on phonological representation and phonological awareness measures (Sutherland & Gillon 2007). The researchers concluded that poor underlying phonological representations will result in difficulties when completing listening, speaking and phonological awareness tasks.

So what is the relationship between speech perception and phonological representations and more importantly the relationship between phonological representations and speech accuracy? Findings from a number of studies (e.g. Anthony et al. 2011; Sutherland & Gillon 2007) show that children with SSD, as a group, show deficits in phonological
representations (Bowen 2015). But is this the case for all children with SSDs? Bowen (2015) emphasises the importance of assessing phonological representation in children with SSDs as, within the group, there are a number whose phonological representation skills are within normal limits thus influencing prognosis (Bowen 2015). Cabbage (2015) carried out a review of a number of studies which have reported that not all children with SSDs may have perceptual difficulties, that it is only a subset of children with SSDs who have difficulty perceiving phonemes produced in error e.g. the above mentioned Rvachew & Jamieson (1989) study and Broen et al.’s (1983) study. This implies that, for this subset of children, the stored phonological information is poorly organised or incomplete. Cabbage (2015) describes this as a difficulty with how some children with SSDs encode and/or store acoustic and phonological information about phonemes and words. So if, even within the group of children with SSDs, there are some children who have poor phonological representations, then the importance of a tool to identify these children accurately becomes apparent.

Identifying phonological processing deficits: Non-word repetition, non-word discrimination and real word discrimination

In this section the usefulness of three different tasks which tap into phonological processing (Reuterskiöld-Wagner et al. 2005) will be discussed, namely tasks of non-word repetition, non-word discrimination and real word discrimination.

Non-word repetition – speech output task

Speech repetition tasks in general provide diagnostic information about children’s output processing (Stackhouse & Wells 1997). Non-word repetition (NWR) has been considered and used as a measure of short-term memory since it is impossible during such a NWR task to access lexical knowledge in long-term memory as lexical representations do not exist for the non-words that make up these tasks. (Baddeley 1986; Gathercole, & Baddeley 1990a cited in Reuterskiöld-Wagner et al. 2005). The mechanisms underlying NWR are admittedly not well understood (Reuterskiöld-Wagner et al. 2005). Gathercole
et al. (1992) proposed that NWR assesses children’s ability to *construct* transient phonological representations of non-words as well as the phonological loop’s ability to *retain* them (cited in Reuterskiöld-Wagner et al. 2005). As non-words do not have lexical representations, the child has to assemble a new motor programme in order to produce the new word (Stackhouse & Wells 1997). It has been suggested that the child possibly uses the stored programmes for similar known/real words to help them assemble this motor programme (Dollaghan et al. 1995). Children who have deficits with bottom-up processing will have problems with this task (Stackhouse & Wells 1997). A large number of lexicalisations of the non-words by the child (i.e. producing a similar sounding real word instead of the non-word) can be indicative of this (Stackhouse & Wells 1997). NWR tests involve *both* input and output processing and good performance on this task requires robust speech input and output systems (Sutherland & Gillon 2007). So, in children with SSDs who we know have output problems, it is not possible to definitively tell from their performance on this task if they have input difficulties as well.

Given the above information, it must be asked if NWR tasks are an appropriate way of assessing phonological processing in children with SSDs given their speech production difficulties. Sutherland and Gillon (2007) predict that children with weak speech output systems will struggle with these tasks, even if they are able to develop accurate underlying phonological representations. Reuterskiöld-Wagner et al. (2005) reviewed a number of studies examining NWR which tried to accommodate production errors in responses in different ways: Montgomery (1995) used non-words made up only of phonemes present in the child’s phonemic inventory; Gathercole & Baddeley (1990b) gave credit to children for errors caused by consistent substitutions of phonemes and in other studies (e.g. Bishop et al. 1996), children with phonological problems which manifested as context-bound substitutions have been excluded (Reuterskiöld-Wagner et al. 2005). In another study Sahlen et al. (1990) recorded and transcribed repetitions phonemically and credit was given for each consonant that was correctly repeated in the right position of the non-word i.e. omissions and substitutions were scored as incorrect and phoneme distortions were scored as correct (Reuterskiöld et al. 2005). There seems to be a lack of consistency in how the NWR tasks are administered and scored across
studies. Therefore it is proposed that a test of non-word discrimination may be a more suitable task to identify input processing difficulties in children with SSDs.

**Non-word Discrimination – speech input task**

In recent years the potential of a non-word discrimination (NWD) task as a screening tool to assess deficits in speech perception is being considered. Reuterskiöld-Wagner et al. (2005) proposed that a test of NWD could eliminate the “confounding influence of speech production processes” in children with SSDs altogether and would also mean easier scoring procedures than those needed for NWR (p.685). NWD tasks are an adaptation of the aforementioned tests of NWR and can vary in their presentation. Relevant to this study are those that involve the presentation of spoken/recorded pairs of non-words i.e. two stimuli, that are either identical or that differ by one phoneme (Stackhouse & Wells 1997). The child is then asked to identify whether the words are the same or different. Examples of NWD tasks that follow this same/different formula were developed by Bridgeman & Snowling (1988), Stackhouse (1989) and more recently by Reuterskiöld-Wagner et al. (2005).

NWD tasks are input tasks that test auditory or perceptual processing. Because, like in NWR, the stimuli in these tasks are novel, the child cannot draw on stored knowledge about the task items (Stackhouse et al. 2007) and they do not have to compare the stimuli to items in their lexicon to complete the task (Stackhouse & Wells 2001). They also do not require output from the child and as such solely target phonological recognition (Stackhouse & Wells 2001). NWD tasks should therefore identify those children who have a specific deficit in forming acoustic perceptual representations leading to weak phonological representations which in turn would affect speech accuracy.

**Real word discrimination – speech input task**

An objective of testing auditory discrimination is to “establish if the child has enough input processing skills to distinguish between similar sounding words and to store precise
representations of those words in the lexicon” (Stackhouse & Wells 1997 p.31). Auditory discrimination can also be tested with real words. Unlike a test of NWR or NWD, the stimuli in these tests are not novel. These tasks can also vary in their presentation. Traditional auditory discrimination tasks involve pairs of real words which are the same or that differ from each other by one phoneme e.g. LOSS and LOT (Stackhouse & Wells 1997). Another type is the auditory lexical task where the stimulus words or pairs of words are the same or that differ by means of an incorrect production e.g. HOSPITAL and HOSPIPAL (Stackhouse & Wells 1997). Also possible is a Yes/No picture auditory discrimination task by which a picture stimulus is presented to the child and the child has to respond yes/no to the examiner’s question e.g. picture of a FISH and the question “Is this a FISH?” / “Is this a FIS?” (Stackhouse & Wells 1997). The orally presented words can be correct productions of the real words or incorrect productions. The latter test, in which the words differ by one phoneme representing common phonological errors, will be of interest to this study. For the purpose of this study and for simplicity, this Yes/No picture auditory lexical task will be referred to simply as a real-word discrimination (RWD) task.

The real word auditory discrimination tasks outlined above are input based. As the words involved are common real words it is supposed that the child will have lexical representations for these items (Stackhouse & Wells 1997). To complete this task, the child has to access their representations for the words presented (Stackhouse & Wells 1997).

Stackhouse and Wells (1997) caution that clinicians must be aware of what exactly is being assessed by a specific test. Because the input-based tests above (both NWD and RWD tasks) are assessing different things it is possible for a child to score high on one and to “fail” another depending on the individual’s processing strengths and weaknesses (Stackhouse & Wells 1997) RWD tasks can be supported by top-down processes (Stackhouse & Well 1997). As the words used for RWD must be familiar to the child, usually words chosen for these tasks are words with a low age of acquisition which the child is likely to have heard multiple times prior to the task (Stackhouse & Wells 1997). In this way they will have been able to build up more detailed and accurate lexical and phonological representations, so there is redundancy in the process. In NWD the child cannot be supported by top down processes as there is no representation to refer to
It is for this reason that the administration of just one task can be misleading. The more tasks administered, the more information is garnered about what and where the underlying deficit is.

**Benefits of early identification and efficacy of interventions:**

So what are the advantages of developing a screening tool for auditory discrimination deficits? This study was based on the hypothesis discussed previously that only a subset of children with SSDs will have deficits in auditory perception/discrimination. A recent study by Wright (2013) investigated whether the qualitative differences observed in different groups of children with SSDs reflect deficits in different underlying cognitive or other abilities that are not found in those with typically developing speech and whether these underlying deficits differed between subgroups.

In Wright’s (2013) study 85 monolingual English speaking children between the ages of 3;0 and 5;11 were assessed on a number of measures examining underlying ‘cognitive skills’, speech accuracy, language skills and non-speech oro-motor skills. A test of NWD was used to assess auditory perceptual/discriminatory skills. 74 children were identified as having SSDs and 39% of these presented with good NWD (above the mode of 11 in the test of NWD) (Wright, personal communication, 04 May 2015). 66 of the same cohort of children were reassessed two years later (aged 5;0-7;11). All of the children who had scored above the mode set as criterion for measuring good NWD in the test of auditory discrimination at time 1 had resolved at follow up (Wright 2014). These findings lend weight to the theory that a test of NWD might be predictor of which children’s difficulties are likely to improve. Identifying which children are more likely to have persistent difficulties will help clinicians prioritize caseloads and tailor interventions to target the underlying deficits.

Results from a randomised control trial conducted by Rvachew & Brosseau-Lapré (2012) with 64 francophone children found that an input-based intervention for children with SSDs who were identified as having concomitant difficulties with speech accuracy and phonological processing (as indicated by measures of speech perception, phonological
awareness, and phonological memory) resulted in similar gains to intervention focusing on speech output. They argue that because some this subset of children will have deficits in phonetic processing, more specifically difficulties with acoustic-phonetic representations, that these children require access to “high-quality, but structured, speech input” as a way of strengthening both the processing efficiency and the phonological representations (Rvachew & Brosseau-Lapré 2012 p.31). The fact that intervention for speech perception/phonological processing deficits has proved to be effective strengthens the argument and motivation for developing a way to identify those children who will benefit from it.

**Motivation for this study**

If indeed a subset of children with SSDs have difficulties both with input and output processing, it stands to reason that they may be slower to resolve than children with output deficits alone. If that should be the case, therapists could prioritise them for early treatment to address both types of deficit. This study aims to build on the research carried out by Wright (2013; 2014). To this end, the same test of NWD will be used in this study to identify which children in a group of children with SSDs present with concomitant auditory perceptual difficulties. Their performance on a measure of speech accuracy will be tested over time to see if there is a difference in the performance of the groups with good vs. poor NWD.

**Research Aims**

Drawing on the reviewed literature the research aims are:

- To investigate what proportion of children in a small sample of children with SSDs showed deficits on a test of NWD,
- To ascertain whether scores on the test of NWD correlated with scores on a test of RWD to investigate if problems with auditory discrimination are a possible cause of poor phonological representations,
• To investigate whether scores on the test of non-word discrimination can predict which children with SSDs are more likely to improve over time as measured by the Diagnostic Evaluation of Articulation and Phonology (DEAP).

In order to investigate the above, children’s scores on tests of non-word discrimination and real-word discrimination will be examined in relation to their PCC scores on the Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dodd et al. 2002) on two occasions.
Methodology

Ethical Approval and Consent

Ethical approval for the study was granted by the Research Ethics Committee, University Hospital Limerick. Informed written consent was obtained from the parents of participants prior to their child’s participation.

Experimental Design

The data for this study was drawn from participants in an intervention efficacy study that used a between-groups repeated measures design with pre- and post-treatment measures for an intervention group vs. a control group (delayed treatment group). Results of the efficacy study are not reported here.

Participants

This study analysed data gathered from participants originally recruited for a study examining the efficacy of a home programme for children with SSDs. Thirteen participants who had been referred to local SLT services because of speech sound difficulty and who were awaiting assessment were recruited from the waiting lists of said services. Inclusionary criteria included: aged between 3;0 and 4:11 years of age, monolingual English speaking and with a speech sound difficulty. Exclusionary criteria included: bilingual children, children who were already in receipt of speech and language therapy, children with speech deficits due to structural or organic causes and children with an additional diagnosis of cognitive sensory difficulties. Thirteen children (8 boys and 5 girls) were originally recruited and participated in the home programme study. At initial assessment, the age range of the thirteen children was between 3:02 and 4:08, with a mean age of 3;10. Five of the thirteen children had previously received intervention for their speech sound disorder. The children’s diagnoses were made according to criteria set
out by Dodd et al. in the Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dodd et al. 2002). Four of the thirteen children were diagnosed with phonological delay, eight were diagnosed with consistent phonological disorder and one child was diagnosed with inconsistent phonological disorder.

Assessments administered

Assessments administered at initial assessment:

1. *Diagnostic Evaluation of Articulation and Phonology (DEAP)* (Dodd et al. 2002):
   - The DEAP diagnostic screener was administered according to the instructions in the manual in order to establish what speech errors the child was presenting with and to screen the consistency of the child’s productions. Utterances were recorded and transcribed. Inconsistency score was calculated.
   - The phonology subtest of the DEAP was administered according to the instructions in the manual in order to record the Percentage Consonants Correct (PCC). The child was presented with 50 picture stimuli and asked to name them. Productions were recorded, transcribed and analysed.

2. *Test of Non-word Discrimination*
   - This was an input processing task using a procedure similar to that described in (Dodd et al. 2008; Dodd and McIntosh 2008), Reuterskiöld-Wagner et al. (2005) and McAllister Byun (2012). It was intended to provide insight into the child’s phonological encoding ability and/or auditory discrimination as shown in, for example, the representation of the location of boundaries between phonemes.
   - The stimuli comprised 16 pairs of non-words (7 of one syllable and 9 of 3 syllables) where 8 pairs were identical, and eight differed. Three 1 syllable and 5 three-syllable non-words were repeated identically by the speakers. The remaining non-words pairs differed by one phoneme in word medial or word final position, which was substituted by another that differed by one feature of place, voice or manner. Medial and word final position were chosen to make
sure the task was challenging: experimental studies of adult perception have found that phonemic contrasts are perceived more accurately in initial/prevocalic relative to final/postvocalic contexts (Fujimura et al. 1978; Redford & Diehl 1999). The stimuli were presented in a predefined order where the discrepant pairs were randomly intermixed with the identical pairs and children were asked to make a same/different judgement about non-word utterances produced by two Hiberno-English speakers.

- The stimuli were presented to children on a computer screen showing video of two similar looking young women (sisters) who were sitting side by side. Shoulders, neck and full head were included in the image. The woman on the left presented the first item of the trial while the woman on the right watched. The second woman then turned to the camera and repeated the non-word, with or without a discrepancy. The child was told that the first girl was going to say a “funny word” and her sister had to copy her and say it “just like her”. Before each trial the investigator said “Ready?” to focus the children’s attention. After the presentation of each trial the child was asked “Did she say just what her sister said?” or “Did she get it right?” by the investigator. This phrasing was chosen to avoid the same/different concept, which might not be established in the younger children.

- Children had to answer “yes” or “no” and their response was marked on a score sheet. The score awarded was the number of items that the child correctly discriminated as same or different. The total score was marked out of 16. The stimuli for the task are shown in Appendix A.

- The task was designed to avoid the subject completing it by comparing targets at a superficial, strictly phonetic level. In tasks with a low memory load, listeners show sensitivity to within-category phonetic distinctions as well as phonemic contrasts (Werker & Logan 1985). In this task, non-words in a pair were separated by a pause while the second speaker turned to the camera and were produced by different voices. To compare the members of a pair, the child must hold the target non-words in memory and adapt to phonetic qualities of a different voice. It was thus designed to induce phonological encoding of non-word targets and rule out a superficial phonetic comparison.
3. Test of Real Word Discrimination

- A non-standardized test of RWD was administered to assess the children’s phonological representations. This was another input processing task using a procedure similar to that described in Locke (1980) and Carroll & Snowling (2004). In Locke’s task the stimuli presented were influenced/based on the child’s errors and a control error is included. The RWD task administered in this study was modified in that the stimulus items were identical for each child regardless of their individual errors so that the same test could be administered to the group regardless of their surface speech patterns. A control error was also not included. The task in this study was also similar to that used in Carroll & Snowling’s (2004) study in that a puppet was introduced to the child and was used to present the words, trial items were incorporated to make sure the child understood the task, stimulus words varied in syllable length and incorrect productions of words differed from correct productions by just one phoneme. However, the task presented in this paper was modified in that 1, 2 and 3 syllable words were used and picture stimuli were presented as well as the orally presented words.

- Task: The child was presented with a picture stimulus for 4 trial items and 25 real words chosen for their high frequency & low age of acquisition. The lead researcher in the assessment session controlled a hand puppet who “said” the word for the item in the picture. The child was asked to watch the puppet rather than the SLT student. The puppet either produced the word correctly or produced it incorrectly (produced a word that differed from the correct production by one phoneme reflecting phonological errors e.g. pɛnsɪl ->pɛnθɪl). Two of the four trial items and 12 of the test words were correct productions and two trial items and 13 of the test words were incorrect productions.

- The child was asked to identify if the puppet said each word correctly/incorrectly by pointing to a picture of a green happy face (yes) or red sad face (no) in response to a question “Did he say that right?” (the child’s understanding of which
face meant yes/no was tested during the trial items). Verbal answers were also accepted if supplied but were not required.

- The child’s answer was marked on a score sheet. The score awarded was the number of items that the child correctly discriminated right or wrong. The total score was marked out of 25. The stimuli for the test can be found in Appendix B.

4. Case History

- A case history was obtained from the caregiver to obtain information on the child’s developmental and communication milestones.

Two other tests were administered as part of the efficacy study but are not reported here.

Assessments administered at Time 2

1. The phonology subtest of the DEAP

- The same 50 stimulus items were administered but new stimulus pictures were used and the stimulus items were administered in a different and randomized order to Time 1. This was to minimize the chances of practice effects. Stimulus pictures were similar in style to original DEAP pictures in that they were simple illustrations in colour. Again, utterances were transcribed, recorded and rechecked by both assessors in each case. PCC was calculated and recorded.

Two other tests were administered as part of the efficacy study but are not reported here.

Procedure

Once enrolled in the study, each child was assessed by a pair of final year SLT Masters students in a quiet clinic room. Each assessment session was assigned a lead student SLT assessor and a second student SLT who acted as an observer. Both researchers made online transcriptions of the child’s speech and scored the other tests during the session.
Each assessment lasted approximately 45-60 minutes and the primary caregiver(s) was/were present throughout the assessment. During the administration of the tests the child’s case history was obtained from a caregiver and this was discussed after test administration. Two of the thirteen children did not complete the test of non-word repetition at initial assessment.

Following initial assessment the thirteen participants in the home programme efficacy study were randomly allocated to a treatment now and treatment later group by having the principal caregiver choose a coloured token from a bag (red = treatment now, yellow = treatment later). The treatment now group consisted of 7 children (5 boys and 2 girls) and treatment later group consisted of 6 children (3 boys and 3 girls) and was to act as the control group. Of the eleven children whose data is included in this study (those who completed test of NWD) 5 were in the treatment now group (3 boys and 2 girls) and six were in the treatment later group (3 boys and 3 girls).

After eight weeks, all participants (from both treatment now and treatment later groups) were reassessed. These follow-up assessment sessions lasted approximately 30 minutes and again, the child’s primary caregiver(s) was/were present throughout the session.

**Reliability**

*DEAP Phonemic Transcriptions (single word and connected speech)*

All responses were recorded using an OLYMPUS WS-832 Digital Voice Recorder. As this study was part of a wider study there were eight researchers in total involved in assessing the thirteen children; two researchers per assessment session. Transcriptions were checked against the audio recordings by both researchers and against each other in each case to ensure accuracy of transcription and PCC calculations. In cases where there was not 100% agreement between the original two researchers the transcriptions and PCC calculations were independently rechecked by a third rater and the final PCC scores presented in this paper represent 100% agreement between two raters.

*Scoring of NWD and RWD tasks*
Scoring of these tasks was completed by the observing researcher.

**Analysis**

Data from the 11 children who completed all necessary tests for this study (test of non-word discrimination, test of real word discrimination and DEAP at time 1 & 2) was analysed as one group in the absence of a treatment effect from the home programme. Data was analysed using SPSS22 for Windows (IBM 2013). The raw data was first coded and then entered into SPSS Data Editor and saved as a data file.

Because of the small sample size *nonparametric* statistical tests were used for analysis of results. Nonparametric tests are “inferential tests that make very few assumptions” about the data and its distribution (Brace et al. 2012, p. 13). The following tests were run:

- **Spearman’s rho correlation** – to examine the relationship between participant’s scores on tests of NWD and RWD and change in DEAPP
- **Mann-Whitney U test** – to examine the changes in DEAP PCC over eight weeks for the group of children with good NWD vs. poor NWD.

Output was then examined and reported.
Results

Overview of results

Originally, data from the participants was to be analysed based on whether they were allocated to the treatment now or treatment later groups in the intervention study mentioned above i.e. analyse the improvement in DEAP PCC for treatment now & later groups in relation to original NWD and RWD scores. In the absence of a treatment effect from the original study for which the children were recruited (i.e. while change occurred, the control group made as much improvement as the group who received treatment), participants results were analysed as one data set. Two of the original thirteen participants did not complete the test of NWD at initial assessment so their data was excluded from the analysis. Data from the remaining 11 children was analysed together. This group of 11 consisted of 6 boys and 5 girls ranging in age from 3;02 to 4;05 (mean age 3;10). Three of the 11 presented with phonological delay and eight presented with consistent phonological disorder.

The first aim of this research study was to investigate the proportion of children in a small sample of children with SSDs who showed deficits in NWD. Results are outlined below.

Figure 1. Results on Test of Non-word Discrimination
The figure above shows all the scores of all 11 participants a test of NWD. Previous research using this test calculated a threshold using the mode of 11 to differentiate those with good non-word discrimination from those with poor discrimination skills (Wright 2013; Wright 2014). In the aforementioned study, participants with SSDs who scored above the mode of 11 on a test of auditory/non-word discrimination resolved by follow-up assessment (Wright 2014). Threshold is marked by the bold black line in the figure above. As can be seen in the figure, only two of the eleven participants scored above threshold on the test of NWD; participant 3 scored 14/16 and participant 10 scored 15/16. All other participants scored below threshold with scores ranging from 8-10/16. Therefore 2 of 11 children were deemed to have good discrimination skills and 9/11 (approx. 82%) of the group demonstrated poor NWD skills.

Figure 2. Results on Test of Real word Discrimination

The above figure shows the scores for all 11 participants on the test of real-word discrimination. Scores were marked out of a total of 25. This was a non-standardised test and no threshold was set. However, it is clear that the two children who scored highest in the test of non-word discrimination also scored highest on the test of real-word discrimination; participant 3 scored 25/25 and participant 10 scored 24/25. However a
number of other participants scored high (over 20) on the test of RWD (participants 2, 9, 11) despite not scoring above threshold on the test of NWD.

**Table 1: NWD and RWD scores at assessment T1 and DEAP PCC scores at assessment T1 and T2**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Age at Ax T1</th>
<th>NWD /16</th>
<th>RWD /25</th>
<th>DEAP PCC T1</th>
<th>DEAP PCC T2</th>
<th>DEAP St. Score T1</th>
<th>DEAP St. Score T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>3;06</td>
<td>10</td>
<td>14</td>
<td>75</td>
<td>84</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>3;11</td>
<td>9</td>
<td>24</td>
<td>65</td>
<td>65</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>4;05</td>
<td>14</td>
<td>25</td>
<td>71</td>
<td>82</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>3;10</td>
<td>8</td>
<td>16</td>
<td>62</td>
<td>62</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>3;02</td>
<td>8</td>
<td>18</td>
<td>29</td>
<td>33</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>3;04</td>
<td>8</td>
<td>19</td>
<td>55</td>
<td>50</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>3;11</td>
<td>10</td>
<td>13</td>
<td>50</td>
<td>49</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>3;06</td>
<td>10</td>
<td>19</td>
<td>63</td>
<td>61</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>4;02</td>
<td>8</td>
<td>21</td>
<td>63</td>
<td>62</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>4;01</td>
<td>15</td>
<td>24</td>
<td>64</td>
<td>71</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>4;05</td>
<td>8</td>
<td>24</td>
<td>59</td>
<td>60</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

As evidenced above, both children with good NWD, participant 3 and participant 10, made clinically significant improvement in PCC despite having no therapy during the 8 weeks between assessments. Clinically significant in this case refers to a positive change in standard score on the DEAP. These changes can be seen in the above table. One other child (participant 1) made a clinically significant improvement in DEAP standard score, but had received therapy during the intervening 8 weeks. This child also scored near the threshold in NWD skills.

**Statistical analysis of data**

It was investigated whether scores on the test of NWD correlated with scores on a test of RWD, a measure of phonological representation and whether there was a correlation
between scores on NWD, RWD and improvement in DEAP PCC using a Spearman’s nonparametric test of correlation:

- There was no significant correlation between scores on NWD and RWD ($r_s=.200$, N=11, p=.556, two tailed)
- There was no significant correlation between scores on NWD and change in DEAP PCC ($r_s=.435$, N=11, p=.181, two tailed)
- There was no significant correlation between scores on RWD and change in DEAP PCC ($r_s=.291$, N=11, p=.385, two-tailed)

From the above results it can be seen that there was no significant correlation between any of the variables and that neither scores of NWD and RWD are associated with the amount of improvement over time.

A Mann-Whitney U test was used to investigate whether children with good NWD made more change in DEAP PCC and DEAP Standard Score than those with poor NWD skills. This test showed that the group with good NWD made significantly more improvement in DEAP Standard Score ($U=1.5, Z=-2.054, p=0.040$), but the amount of improvement in DEAP PCC was near but did not reach significance ($U=1, Z=-1.894, p=0.058$).
Discussion

Main Findings

A summary of this study’s research aims and main findings are outlined below:

**Aim 1:** To investigate what proportion of children in a small sample of children with SSDs showed deficits in NWD.

**Findings:** 9 of the 11 of participants scored below the previously established threshold of 11 on the NWD screener. 2 children scored above threshold indicating good NWD skills. This was a much smaller proportion of children with good non-word discrimination than shown in the study by Wright (2013) in which 39% of the children with SSDs demonstrated good NWD. However, with a sample size of 11, no strong conclusions can be drawn from these findings.

**Aim 2:** To ascertain whether scores on the test of NWD correlated with scores on a test of RWD to investigate if problems with auditory discrimination are a possible cause of poor phonological representations

**Findings:** As evidenced in the results, the two children that scored above threshold on the test of NWD scored the highest in a test of RWD implying these children demonstrated good auditory discrimination skills for both real and non-words. However, there was no statistically significant correlation between the scores on the two tests. A number of participants scored highly in the test of RWD despite not scoring well on the test of NWD. The fact that children could have good phonological representations for (high frequency/low age of acquisition) real words despite having poor NWD could be explained by those children relying on top-down processing skills to compensate for weaker bottom-up processing skills (Stackhouse & Wells 1997). The fact that the stimulus words for the RWD test were high frequency, low-age of acquisition means that it is likely the participants had multiple exposures to these words prior to doing the assessment. This implies a redundancy in processes as the participants may have had enough exposure to these words to build up good phonological representations for these real
words despite not having good auditory perceptual skills as measured on the test of NWD. This implies that a test of RWD is not as strong a predictor as NWD of which children will improve as it is not as sensitive at assessing the underlying deficit.

**Aim 3:** To investigate whether scores on the test of non-word discrimination can predict which children with SSDs are more likely to improve over time as measured by the Diagnostic Evaluation of Articulation and Phonology (DEAP)

**Findings:** Findings from this study show that the children with scores above the threshold established by Wright (2013) on a measure of NWD at Time 1 improved more over an eight-week period, even without therapy, when compared to those with lower scores on NWD at Time 1. This is consistent with results reported in Wright (2013) which suggested that NWD may be useful as a predictor of which children are more likely to improve regardless of whether they receive therapy or not. It does not predict how much improvement the children are likely to make. There was no significant correlation between scores on the test of NWD and improvement in PCC showing that these scores are not associated with the amount of improvement over time.

**Clinical Implications**

The results have implications for the assessment of children with SSDs. The use of a test of NWD as a screening tool could aid in the prioritisation of children with SSD, in that those less likely to recover spontaneously, i.e. those more likely to have persisting difficulties could be identified earlier and prioritised to receive direct intervention. However, further research is needed in this area to develop such a tool. Such a tool would ideally then be part of any routine assessment of a child with SSD, giving clinicians vital information about a child’s underlying deficit, with the added advantage of being able to tailor intervention to target this deficit.
Limitations:

The main limitation in this study is the small sample size. With a sample size of 11, results must be interpreted with caution. Results showed that the amount of improvement in PCC was much greater for the children with good NWD than those with poor NWD and while the difference only approached significance statistically, further testing of the hypothesis with a larger sample size is warranted. It is important not to make strong conclusions based on these results.

The eight-week time period between assessments T1 and T2 was relatively short. Participants will be assessed again eight weeks after assessment T2 and again in two years. Gathering longitudinal information about the clients is recommended and necessary to track progress in both good NWD and poor NWD groups.

Conclusions:

Despite the small sample size, findings from this study are positive and are consistent with the theory that a test of NWD may be useful as a predictor of which children with SSD are likely to resolve either spontaneously or with small amounts of therapy. Further research is needed with a larger sample to size to see if results are replicated and if they prove significant. Should results prove significant on further trials, it could prove a useful tool for prioritisation and to guide therapy. A standardized test of auditory perception/discrimination would ideally guide clinicians’ assessment and management of clients with SSDs. It would aid in the differential diagnosis of those with potentially transient difficulties as opposed to those at risk of persisting difficulties.
References


Wright, A. (2014) ‘The search for a cause in speech sound disorders (SSDs): Do children with speech sound disorders have underlying cognitive deficits not found in those with typically developing speech and do these differ between subgroups?’, Paper presented at the Speech Pathology Australia National Conference, May 18th to 21st, Melbourne, Australia.

Appendix A - Test of Auditory (NWD) Discrimination
Test of auditory discrimination  Code:____________
Total Correct: 1 syll. _______ 3 syll:_______Total:__________

<table>
<thead>
<tr>
<th>Production 1</th>
<th>Production 2</th>
<th>Feature diff.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. mɛp</td>
<td>mɛp</td>
<td></td>
<td>S D</td>
</tr>
<tr>
<td>2. tʃɛʃən</td>
<td>tʃɛʃən</td>
<td>P</td>
<td>S D</td>
</tr>
<tr>
<td>3. tʌz</td>
<td>tʌd</td>
<td>M</td>
<td>S D</td>
</tr>
<tr>
<td>4. ɡʌmɛɬʌm</td>
<td>ɡʌmɛɬʌm</td>
<td></td>
<td>S D</td>
</tr>
<tr>
<td>5. nɪɡ</td>
<td>nɪd</td>
<td>P</td>
<td>S D</td>
</tr>
<tr>
<td>6. taz</td>
<td>taz</td>
<td></td>
<td>S D</td>
</tr>
<tr>
<td>7. sɪɬɛɪnɡ</td>
<td>sɪɬɛɪnɡ</td>
<td></td>
<td>S D</td>
</tr>
<tr>
<td>8. ʋɑɬɛɪnɡ</td>
<td>ʋɑɬɛɪnɡ</td>
<td>M</td>
<td>S D</td>
</tr>
<tr>
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<td>temɛti</td>
<td></td>
<td>S D</td>
</tr>
<tr>
<td>10. dat</td>
<td>dat</td>
<td></td>
<td>S D</td>
</tr>
<tr>
<td>11. dɪzalʌp</td>
<td>dɪzalʌp</td>
<td></td>
<td>S D</td>
</tr>
<tr>
<td>12. fas</td>
<td>faʃ</td>
<td>P</td>
<td>S D</td>
</tr>
<tr>
<td>13. sɪɗɬali</td>
<td>sɪdəli</td>
<td>Aff</td>
<td>S D</td>
</tr>
<tr>
<td>14. bɛnɪsɛn</td>
<td>bɛnɪsɛn</td>
<td></td>
<td>S D</td>
</tr>
<tr>
<td>15. tɛp</td>
<td>tɛb</td>
<td>V</td>
<td>S D</td>
</tr>
<tr>
<td>16. mɛtɪmæn</td>
<td>mɛkɪmæn</td>
<td>P</td>
<td>S D</td>
</tr>
</tbody>
</table>

Administration:

Each slide contains a video clip of Girl 1 and Girl 2, side by side
Administrator clicks to play clip: Girl 1 says production 1, then Girl 2 says production 2
Child is asked “Did she say just what her sister said?”
Appendix B- Test of Real word Discrimination
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>fish</td>
<td>Yes</td>
</tr>
<tr>
<td>T2</td>
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<tr>
<td>T3</td>
<td>fis</td>
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<tr>
<td>2</td>
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<td>4</td>
<td>pɛnθil</td>
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</tr>
<tr>
<td>5</td>
<td>bridge</td>
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<td>6</td>
<td>spaghetti</td>
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<td>7</td>
<td>flower</td>
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</tr>
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<td>8</td>
<td>crocodile</td>
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</tr>
<tr>
<td>9</td>
<td>tat</td>
<td>Yes</td>
</tr>
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<td>10</td>
<td>dɛdi</td>
<td>Yes</td>
</tr>
<tr>
<td>11</td>
<td>jauan</td>
<td>Yes</td>
</tr>
<tr>
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<td>20</td>
<td>lion</td>
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<tr>
<td>21</td>
<td>hɔɹt</td>
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</tr>
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<td>22</td>
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<tr>
<td>23</td>
<td>pillow</td>
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<tr>
<td>24</td>
<td>tɛlibiʃan</td>
<td>Yes</td>
</tr>
<tr>
<td>25</td>
<td>su</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Total score /25