Young children’s performance on novel cognitive linguistic tests. What can we learn from it?

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Abstract

Background: 10-15% of preschool children and 6% of school aged children have a speech sound disorder (SSD) (Williams, 2003). Currently, the cause of the majority of SSDs is unknown. Some researchers posit that deficits in cognitive linguistic skills such as rule derivation, auditory discrimination and memory may underlie some types of SSD. However, no research has been carried out to create norms for a wide range of cognitive function tasks in Typically Developing Children (TDC).

Aims: 1) To establish norms for young children’s performance on a range of cognitive assessments. 2) To investigate whether there is a progression with age across the battery of novel cognitive assessments. 3) To research whether there is a relationship between PCC and performance on the cognitive tests. 4) To establish whether SES has an impact on children’s performance.

Method: 58 Typically Developing Children (TDC) (3;0-5;08) from a city in the Mid-West of Ireland were assessed using the phonology subtest of the Diagnostic Evaluation of Articulation and Phonology (DEAP, Dodd et al. 2002) as well as five cognitive assessments which aim to assess non-word similarity, numerical concepts, auditory memory, pattern recognition and knowledge of phonological legality. SPSS was used to compute the mean, median and standard deviation for each age in each subtest. Associations between socioeconomic status and performance were also investigated.

Results: Normative data revealed that the mean scores on all five novel cognitive tests increased with age. The results showed that children from DEIS schools performed more poorly on the majority of cognitive tests. There were no statistically significant correlations between speech accuracy and the cognitive linguistic assessments beyond the contribution of age.

Conclusions: The disassociation between speech accuracy and the scores on the cognitive battery of tests may suggest that deficits in these areas are not the underlying cause of SSDs. However, this a tentative conclusion and further research with a larger, more balanced sample is warranted.

Keywords; Socio economic status, Phonology, Cognition.
Introduction

“To produce a spoken word a child uses a stored representation, created from input information, to assemble a plan that is constrained by their knowledge of a phonological system” (Chiat, 2000 as cited in Dodd and Crosbie, 2011 p617).

Normal speech development involves the interaction of four components (Bowen, 2009);

- An auditory perceptual component, which is the ability to attend to and perceive linguistic input, this is supported by the McGurk effect (Burnham and Dodd, 2004).
- A cognitive component, which is the ability to retrieve, organise and store linguistic input and compare it with output (Dodd and Crosbie, 2011).
- A phonological component which is the organisation of sound patterns (Dodd et al., 2005)
- A oro-motor component which is the motoric production of speech sounds (Dodd et al., 2005)

10-15% of preschool children and 6% of school-aged children have a speech sound disorder (SSD) (Williams, 2003). Studies have identified some risk factors for SSDs, such as an underlying hearing impairment but the cause of the majority of SSDs is unknown (Dodd & McIntosh, 2008).

Previous literature has highlighted the heterogeneity of speech development by looking at the various areas of breakdown associated with speech disorders of no known aetiology. This variability includes severity, type of error patterns made and co-morbidity with language difficulties (Holm, et al., 2007). There is a paucity of research analysing the underlying abilities affecting this variability. Some researchers have posited that deficits in cognitive linguistic skills such as rule derivation and pattern recognition may underlie some types of SSD (Dodd et al., 1989; Dodd and McIntosh, 2008). This research is valuable clinically, as it could influence the effectiveness of choosing a correct therapy to target the underlying deficit (Dodd, et al., 2005).
The focus of this review is to discuss and evaluate the pertinent literature regarding development of phonology, as well as examining the evidence for underlying cognitive abilities involved in phonological acquisition.

**Speech Development**

*Typical Speech Development*

It is important as clinicians we use the theory to inform practice and practice to inform the theory. Phonological development begins with unlearned responses such as babble, gesture, crying and vocalizations (Hulit and Howard, 2002). However, the majority of studies of phonological development centre on first meaningful words, as it allows the researcher to compare the production to the functional form of the word (Stoel-Gammon 2011).

Ferguson and Farwell (1975) suggest that children’s initial utterances are learned as a whole, “phonic core” (p437), and they are not aware of the individual phonemes which create a word. Consequently, learning first words is a slow process.

It is hypothesised that when a child learns a number of words, phonological rules of the cognitive-linguistic system are accessed to create a rule based system, rather than a holistic system (Ferguson and Farwell, 1975). Ingram (2002) argues that this occurs when a child develops 50 words, however more recent research by Vogel Sosa and Stoel Gammon (2006) presents data of a small sample indicating that intra-word variability does not occur until children reach 150-200 words and are producing combinatorial speech. The variability of productions between children could be accounted for by either reaching a phonological limit, or a choosing between accuracy at one point of a word rather than the other (Vogel Sosa and Stoel Gammon, 2006). Duggirala and Dodd (1991) believe that children derive word structure from their original lexicon, and this accounts for the variability between children. As more words are added, children reorganise their phonological system to add new, more complex constraints. This reorganisation, would also account for the fact that as children are developing they make similar error patterns.
Atypical speech development

Speech difficulties allow us to gain further insight into the skills which contribute to both normal and abnormal speech production. Dodd describes three subgroups of phonological disorders based on their error patterns (Dodd et al. 2005);

- Phonological delay occurs when a child produces typical speech patterns that would be expected in a younger child.
- Inconsistent speech disorder occurs when children use no predictable error patterns in speech. For example, produces the same word differently three times in a row.
- Consistent speech disorder (also referred to as atypical consistent speech disorder and deviant consistent phonological development in the literature) is consistent use of non-developmental error patterns in their speech.

Speech Development in Socio-Economically deprived areas

There is a multitude of research carried out on the negative effect of low socioeconomic status on vocabulary and language development (Hoff, 2003; Hoff and Tiane, 2005). Bowey (1995) found differences in phonological sensitivity, word level reading and arithmetic in children from lower socioeconomic backgrounds. Despite this, research by Bishop (1997) found that the link between socio-economic background and speech impairment is weak. This was further supported by Dodd et al. (2003) when they grouped children by their socio-economic status, and found that a low socioeconomic status had no negative effect on speech accuracy across all age groups.

Cognitive skills underlying speech.

The core executive function abilities include rule derivation, flexibility, temporal ordering, memory, abstract thinking, flexibility and use of feedback (Mc Intosh and Dodd, 2008; Crosbie et. al 2009). This section of the paper, will review the literature which relates to executive functions, which are also referred to as cognitive-linguistic abilities in the literature.
Phonological Legality

Phonological legality involves being able to identify the rules that govern how phonemes are used contrastively in a child’s native language in order to create phonological constraints. Dodd et al.,(1989) compared children with delayed phonological development to children with consistent and inconsistent speech disorder and a typically developing control group, on their ability to distinguish legal (e.g./flʌt/) versus illegal (e.g./vlʌt) constructs in non-words.

This experiment found that children with a consistent phonological disorder, showed no awareness for phonologically legal non-words, thus identifying that they have no understanding of rules governing their phonology.

In an earlier study comparing the spelling abilities of typically developing children to those with phonological delays and disorder, children with consistent phonological disorder showed no faithfulness to orthographic rules with their spelling errors, for example brsk for brisk. In contrast, errors of typically developing children were phonological mis-spelling, for example sittee for city (Dodd and Cockerill, 1986 as cited in Dodd and Leahy, 1989). Dodd concluded that a central cognitive-linguistic ability exists and this is a necessary component to abstract phonological rules in both spoken and written systems (Dodd and Leahy, 1989).

Although clinically significant results were obtained, individual differences existed between the responses to the phonological task (Dodd and Leahy, 1989). The method of testing involved choosing a name for a character that could have been influenced by the child’s preference rather than their knowledge of a rule governed phonological system. These individual differences could also have been influenced by age or language ability. Therefore further research is needed to focus on the developmental trajectory of phonological rule development.

Rule abstraction

As previously mentioned, one of the core elements of executive function is rule derivation (McIntosh and Dodd, 2008; Banich, 2009). Recent research by Dodd and McIntosh (2008) formally assessed a child’s speech and allocated them into two groups; children with atypical speech development and those with typical speech development.
Each group carried out a non-linguistic task, which aimed to assess the children’s ability to explicitly derive rules. They found that children with speech difficulty performed more poorly at deriving rules from the task, compared to the typically developing control group. This provides us with evidence to suggest that children who have delayed or a consistent speech disorder have difficulty deriving rules of their native phonology.

However, no similar research was carried out in children with an inconsistent phonological disorder. More pertinent clinical information about the specific underlying skills involved in speech acquisition and atypical speech could have been obtained if the children had been differentially diagnosed into sub-groups of speech sound disorders.

A follow up study by Crosbie et al. (2009), carried out the same non-linguistic rule abstraction task on subgroups with atypical speech and a control group. The results were more specific and they revealed that children with consistent speech disorder had the most significant difficulty at rule abstraction. Conversely, research carried out on rule abstraction abilities of two year olds with atypical speech development found that there was no positive correlation between speech accuracy, and rule derivation in two year old children (Dodd and McIntosh, 2010). This implies that investigating the developmental trajectory of rule abstraction in children, may provide information on its relationship to speech development. It is possible, however, that the difficulty may lie in the complexity of the rule’s concept, rather than simply a difficulty with abstracting rules.

Therapy for children with a speech impairment, in the absence of a cognitive deficit, involves teaching phonological rules to target the surface issue. Nevertheless, research has shown that following therapy children have later been found to have difficulty with literacy, which is another rule governed system (Crosbie et al. 2009). This adds to the hypothesis that children, who on the surface present with phonological difficulties, perhaps, have an underlying difficulty to derive rules affecting not just their speech.

**Pattern Recognition**

Pattern recognition is an unlearned ability that is present before formal schooling (Papic and Mulligan, 2007). These findings that children with speech impairment, and particularly children with consistent speech disorder, have more difficulty with non-verbal rule derivation and cognitive flexibility may indicate that their difficulty lies in a
central deficit of pattern recognition ability or rule abstraction of their native phonology rather than what appears on the surface as a difficulty producing sounds (Dodd and Crosbie, 2011).

**Summary**

This paper has outlined the theoretical underpinnings and developmental data to support speech acquisition. It has reviewed the role of executive function skills in speech development. It has concluded that cognitive-linguistic skills have a role to play in phonological development, by highlighting the effect of a cognitive-linguistic deficit in consistent speech disorders.

**Conclusion**

This review of the literature has emphasised that there is no known aetiology for the majority of speech sound disorders. Consequently, speech and language therapists currently can only target the surface symptoms of speech sound disorders in therapy rather than the underlying cause. It can be difficult to ascertain the correct therapy approach to take (Crosbie, 2004). However, if therapy is correctly chosen, it can induce a system wide change.

Improving our knowledge of the deficits underlying speech difficulties, will allow us to provide the evidence base for an effective and efficient therapy approach to target the underlying cause of speech sound disorders rather than surface deficits. This is imperative as it is both cost effective and more efficient for both the clinician and the child.

Crosbie (2009) believes that typical speech acquisition enables us to understand disordered phonological development. To the author’s knowledge, no study has covered a wide range of executive function tasks and compared them to phonological development. Our study aims to fill this gap in the literature by looking at the development trajectory and performance of typically developing children on a range of novel executive function assessments. This research will inform a larger research study which aims to compare the normative data of the executive function tasks to that of children with speech delays and disorders.
Research Objectives

This research aims to;

- Develop normative scores for the cognitive battery of tests for children aged 3-5.
- Investigate whether there is a progression with age across the battery of novel cognitive assessments.
- Determine whether there is a relationship between PCC and performance on the cognitive tests.
- Establish whether SES has an impact on children’s performance.
Methodology

Participants

Inclusionary and Exclusionary Criteria

This study aimed to recruit children between the age of 3 and 5;11 years old from schools and pre-schools in a city in the mid-west of Ireland.

The inclusionary criteria for participation in this study were that the children were monolingual. Bilingual and multilingual children were excluded from the recruitment criteria in order to prevent the potential interaction of multiple phonemic systems affecting the research outcomes. Participants who were referred to, or in receipt of speech and language therapy were also excluded from the study. Other research is currently being carried out regarding the cognitive linguistic abilities of children with speech disorders. However, the study reported here was specifically aimed at investigating the cognitive linguistic abilities of children with typically developing speech. Finally, participants with behavioural impairments, intellectual difficulties and sensory impairments were not asked to participate at this time.

Characteristics of the Sample

58 children between the ages of 3;0 and 5;08 were recruited for this study. The three oldest participants were excluded from the study, as they were a small group who presented with severe to moderate speech sound impairments which skewed the five year old data.

The mean age of the 55 participants (3;0 - 5;05) was 51.98 months (SD = 8.52). Gender was not normally distributed; there were 33 female participants and 25 male participants.

Participants from areas of disadvantage were included in this study. Delivering Equality of Opportunity in Schools (DEIS), is a school support programme for educational inclusion carried out in schools in educationally disadvantaged areas. The inclusionary criteria of the DEIS programme provide a standardised system for identifying and quantifying levels of disadvantage (DEIS, 2005). It focuses on the educational needs of
children from pre-school to second level education. 21 of the participants were recruited from educationally disadvantaged areas. The distribution of the sample is illustrated in table 2.1 below.

<table>
<thead>
<tr>
<th>Total No.</th>
<th>DEIS Participants</th>
<th>Non-DEIS participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 years</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>4 years</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>5 years</td>
<td>12</td>
<td>0</td>
</tr>
</tbody>
</table>

Recruitment

Convenience sampling was used. Principals of Schools and pre-schools in a city in the mid-West of Ireland were sent a letter outlining the details of the study and they were invited to participate. Principals were made aware of the exclusionary criteria. If they agreed to participate, consent forms and parent-information sheets were sent to the school or pre-school, and the principal distributed these forms to all of the appropriate parents. Parents contacted the teacher or the researchers with the signed consent form, if they wanted their child to take part.

Assessment

Children were assessed at their schools or pre-schools in a quiet space. The assessments were set at a pace suitable for the individual child. They took 45 minutes on average. The assessors were Speech and Language Therapy students in the final year of a Master’s programme. The children sat at a small table at a 90 degree angle from the researcher, so that the assessor and the participant could see the pages of the flip-book. Two researchers were present for each assessment session. One researcher administered the tests, transcribed the phonology test and scored the novel assessments. The other researcher observed and also transcribed and scored the tests.
**Ethics**

Ethical approval for the research was granted by the University of Limerick, Faculty of Education and Health Science Research Ethics committee. Parental consent was obtained for each child. Anonymity of the sample was ensured by coding each assessment sheet with a number which corresponded to number on the child’s consent form. The consent forms and the assessment sheets were filed separately.

**Materials**

Speech Assessment

The children’s speech was assessed using the phonology subtest of the *Diagnostic Evaluation of Articulation and Phonology* (DEAP, Dodd et al. 2002). It requires the participants to name the 50 pictures presented to them. The DEAP administration procedure was followed, and the appropriate prompts were provided when the child did not know a word (Dodd, 2002). The assessor provided positive feedback, to encourage the children to cooperate. Word productions were transcribed phonetically. Productions normal for local dialect were counted as correct. Quantitative analysis was carried out in order to calculate the Percent Consonants Correct (PCC).

**Design of Novel Assessments**

These tasks aimed to investigate the cognitive linguistic abilities of participants through five enjoyable, motivating activities.

*Task1. Test of Non-Word Similarity* The aim of the *assessment of non-word similarity* is to investigate children’s phonological perception, to see how accurately a child hears, encodes and stores what they hear in order to make the comparison between the two non-words.

The children were presented with 16 short videos on a laptop of students producing non-word pairs. Eight of the non-word pairs were identical and eight of the non-word pairs differed by one phoneme. The phoneme which differed, differed only by one feature; place, manner, voicing or affrication. The child was told that the second
speaker is meant to reproduce the word identically. The child listened to the speaker producing a nonsense word, the second speaker then repeated it. The participant then had to identify whether the non-word was correctly repeated by the second student. The raw score was calculated based on the number of tasks correctly calculated. The use of videos on a laptop intended to increase the children’s motivation as well as preventing any variability of the pronunciation of words between participants, or time between the two outputs.

**Task 2. Test of Numerical Concepts** Previous research by Bhargava and Kirova (2002) investigated the developmental trajectory of early mathematical skills. They outlined three mathematical concepts, which were central to early mathematical and scientific thinking. Firstly, *matching and one to one correspondence*, this investigates logical thinking and the fundamental component of the conservation of number. Secondly, *classifying sets*, which is a higher order cognitive process investigating the child’s ability to identify the sameness between concepts. Thirdly, *order and seriation*, this is the foundation of our number system.

*The assessment of numerical concepts* is based on the research of mathematical concepts. The tasks were child orientated, using plastic cutlery and a number of toy farm animals. The assessment looked at the child’s ability to match one to one correspondence, match similar items, as well as to investigate class inclusion and class exclusion. It also assessed the child’s ability to sequence by size. The raw score was calculated from the number of tasks correctly completed.

**Task 3. Test of Auditory Memory.**

The aim of this test is to establish the word span length of a child’s auditory memory. Animal names were used rather than digit span, as early piloting found that children repeated digit names randomly in the same way they count. Gathercole (2005) found that memory abilities are closely related to a child’s vocabulary knowledge, literacy and mathematical abilities. This test aims to investigate if there is a correlation between word span length and phonological abilities.
The children listened to a list of single syllable animal names produced by the researcher, and they were then asked to repeat this list. Children under five began with a list of two animals. If they correctly repeated two out of three of the 2-word lists they would progress to a 3-word list. If they correctly repeated two out of the three of the 3-word lists, they would progress to a 4-word list. Children who were over five years of age began at the 3-word lists. The raw score was calculated dependent on the last block of repetitions passed (i.e. the last block that they scored 2 out of 3 or better).

**Task 4. Test of Pattern Recognition.**

The aim of the task is to investigate the children’s ability to derive a non-linguistic rule to create a pattern. This will be then compared with their ability to derive phonological rules

The participants were presented with a sequence of 6 shapes, which made up a pattern, followed by an empty space. They were required to select the correct shape from a group provided, and to place it in the empty space in order to continue the pattern on the top line. The children were then asked if this is the correct shape to complete the sequence, if he responded no he was given another chance to pick the correct coloured shape to complete the sequence. The sequences increased in complexity by increasing the dimensions of difference, using shapes, colour and size. The child’s score is the number of correct patterns they complete.

**Task 5. Test of Phonological Legality.** Children’s ability to discriminate between two sound contrasts in their native language is acquired by two years of age (Dodd and McIntosh, 2008). This assessment aims to establish how a typically developing child’s understanding of rules governing their phonology relates to their ability to produce phonologically correct outputs on the DEAP.

Children were introduced to the task by explaining that aliens speak a funny language that sounds different to our language. They were told they would hear two words which they had never heard before. One word would sound like our words, and one would sound like a funny alien word. The non-words were written in IPA script on a pair of cards. The assessor held out the card that they read the word from but did not show the written word. The children’s task was to identify the funny alien word and put that card
into the alien box. Each pair of words was repeated by the assessor until the child made a choice. Half the pairs were produced with the legal word first, and half with the illegal word.

**Reliability and Validity**

Construct and face validity of the five novel assessments have been discussed and addressed in a related study (Wright, A. unpublished doctoral thesis for submission in 2014).

The sessions were recorded on a Dictaphone. Inter-rater reliability measures were taken for both the phonemic transcriptions and the novel assessments. Broad transcriptions were made on-line during the assessment sessions, by two researchers. Point to point agreement was calculated for both correct and incorrect realizations. Any differences in transcription were re-transcribed from the audio-recordings and agreed between the two transcribers. In the event of a non-agreement, the transcribers listened to the recordings and came to an agreed conclusion. The agreed transcription was used for the analysis. The overall mean correspondence for transcriptions was 94.25%. Reliability data was also taken for the novel assessments. The assessments were all double marked. Ten of the tests were randomly selected to investigate their reliability. The mean reliability for the novel assessments was 99.82% across ten randomly selected tests.

**Analysis**

PCC on the DEAP phonology sub-test was calculated according to instructions on the manual. Quantitative analysis was carried out using SPSS Version 21 for Windows (SPSS, 2011). Descriptive statistics were used to examine the distribution of age, gender and educational disadvantage. Means, Standard Deviations (SDs), minimum and maximum scores were calculated for each age group. Differences in scores between year groups were investigated using Kruskal-Wallis as the data was not normally distributed. When appropriate, the Mann Whitney U test with the Bonferroni correction was carried out, to see where the statistical differences lay. The differences in performance between DEIS were carried out in the same way. The phonological Legality task was normally distributed and so it was analysed using the one way between group analysis of variance (ANOVA). Potential relationships between scores on the novel assessments a) age and
b) PCC were investigated using Spearman’s Rank Orders correlation, as the sample was small.
Results

Normality of Distribution

The five novel assessments and PCC were assessed for normality, using the Shapiro-Wilk Test. This revealed that all of the variables violated the assumption of normality, except for Phonological Legality which was normally distributed ($p > .05$). The results are summarised in table 3.1 below.

<table>
<thead>
<tr>
<th>Test of N/W Similarity</th>
<th>Numerical Concepts</th>
<th>Auditory Memory</th>
<th>Pattern Recognition</th>
<th>Phonological Legality</th>
<th>PCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>P values</td>
<td>.015</td>
<td>.001</td>
<td>.000</td>
<td>.000</td>
<td>.237*</td>
</tr>
</tbody>
</table>

* $p > .05$

Ceiling and Floor Effects

Ceiling effects occur when the novel assessment’s highest score is unable to assess a participant’s level of ability (Rehabilitation Institute of Chicago, 2010). Floor effects occur when the novel assessment’s lowest score is unable to assess a participant’s level of ability (Rehabilitation Institute of Chicago, 2010). The Institute of Chicago quantify floor and ceiling effects as ‘excellent’ if 0% of the participants scored at floor or ceiling level, ‘adequate’ if the less than 20% of participants scored either the highest or the lowest score on the assessment, and ‘poor’ if more than 20% of the participants scored above ceiling.

The presence of ceiling and floor effects were calculated in order to investigate the sensitivity of the tests.

This results indicate that there are no ‘poor’ floor effects across any of the age groups. The ceiling effect for the Numerical Concept assessment in five year olds was
‘poor’, indicating that it was unable to detect differences in numerical ability between the highest scoring children. The results of the ceiling and floor effects are illustrated in table 3.2 below.

| Table 3.2. Floor and Ceiling Scores for all of the Novel Assessments |
|---------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                                | N/W Similarity | Numerical Concepts | Auditory Memory | Pattern Recognition | Phonological Legality |
| Age 3 (n= 18)                  | Floor Ceiling | Floor Ceiling | Floor Ceiling | Floor Ceiling | Floor Ceiling |
| Age 4 (n=25)                   | 0% 4%         | 0% 4%         | 4% 0%         | 0% 16%        | 0% 0%         |
| Age 5 (n= 12)                  | 0% 8%         | 0% 25%        | 0% 0%         | 0% 17%        | 0% 8%         |

Chance
The assessments of Non-Word Similarity and Phonological Legality each offered a choice between two answers. Consequently, participants had a 50% chance of selecting the correct answer. A one sample t-test was thus conducted to investigate whether participants’ scores differed from the chance level.

Results showed that participants’ performance ($M=11.18$) was significantly higher than chance performance ($M=8.00$), $t(54) = 8.63$, $p < .001$ on the Test of Non-Word Similarity. Participants performance on the Phonological Legality Test ($M=6.91$) was significantly higher than chance performance ($M=6.00$), $t(54) = 3.13$, $p<.005$.

These scores indicate that the mean scores of the assessments in this sample were greater than the influence of chance alone.

Normative Data
The mean scores and standard deviations were calculated for each of the novel assessments and the speech accuracy task in order to investigate the participant’s performance on the tests.
Speech Accuracy

The results showed that older children out-performed younger children on the speech accuracy measures, as illustrated in table 3.3.

<table>
<thead>
<tr>
<th>Table 3.3. Mean and standard deviations for PCC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PCC (Max = 100)</strong></td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>+ 2 SD</td>
</tr>
<tr>
<td>+1 SD</td>
</tr>
<tr>
<td>+ 0.5 SD</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>-0.5 SD</td>
</tr>
<tr>
<td>-1 SD</td>
</tr>
<tr>
<td>-2 SD</td>
</tr>
</tbody>
</table>

Test of Non-Word Similarity

The mean score for the whole sample was 11.18 (SD = 2.74). The mean score increases with age as listed in table 3.4.

<table>
<thead>
<tr>
<th>Table 3.4. Mean and Standard Deviations of all age groups on the Discrimination of non-word similarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Max Score=16)</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>+2 SD</td>
</tr>
<tr>
<td>+1 SD</td>
</tr>
<tr>
<td>+0.5 SD</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
</tr>
<tr>
<td>-0.5 SD</td>
</tr>
<tr>
<td>-1 SD</td>
</tr>
<tr>
<td>-2 SD</td>
</tr>
</tbody>
</table>
Numerical Concepts

The mean score of the whole group was 7.11 ($SD = 2.09$). The mean score increases with age as listed in table 3.5.

**Table 3.5. Mean and Standard deviations of all age groups on the numerical concepts assessment.**

<table>
<thead>
<tr>
<th>(Max Score=10)</th>
<th>Age 3</th>
<th>Age 4</th>
<th>Age 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2</td>
<td>9</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>+1</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>+0.5</td>
<td>7</td>
<td>8</td>
<td>&gt;9</td>
</tr>
<tr>
<td>Mean</td>
<td>6</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>-0.5</td>
<td>5</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>-1</td>
<td>4</td>
<td>5</td>
<td>&lt;8</td>
</tr>
<tr>
<td>-2</td>
<td>2</td>
<td>3</td>
<td>7</td>
</tr>
</tbody>
</table>

Auditory Memory

The mean scores increase slightly with age as indicated in the Table 3.6. The limited range of scores means that there was a lot of overlap between ages.

**Table 3.6. Normative data for the test of Auditory Memory**

<table>
<thead>
<tr>
<th>Auditory Memory (Max = 7)</th>
<th>Age 3</th>
<th>Age 4</th>
<th>Age 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2SD</td>
<td>5.22</td>
<td>5.57</td>
<td>5.26</td>
</tr>
<tr>
<td>+1SD</td>
<td>4.31</td>
<td>4.53</td>
<td>4.59</td>
</tr>
<tr>
<td>+ .5 SD</td>
<td>3.85</td>
<td>4.00</td>
<td>4.25</td>
</tr>
<tr>
<td>Mean</td>
<td><strong>3.39</strong></td>
<td><strong>3.48</strong></td>
<td><strong>3.92</strong></td>
</tr>
<tr>
<td>-.5 SD</td>
<td>2.93</td>
<td>2.96</td>
<td>3.59</td>
</tr>
<tr>
<td>-1SD</td>
<td>2.47</td>
<td>2.43</td>
<td>3.25</td>
</tr>
<tr>
<td>-2SD</td>
<td>1.56</td>
<td>1.39</td>
<td>2.59</td>
</tr>
</tbody>
</table>
Pattern Recognition

The mean score for the whole sample was 6.91 ($SD = 3.90$), with a minimum of 0 and a maximum of 12 score. The mean score increases dramatically with age as displayed in table 3.7.

### Table 3.7 Mean and standard Deviation of all age groups on the test of Pattern Recognition

<table>
<thead>
<tr>
<th>Pattern Recognition (Max score -12)</th>
<th>Age 3</th>
<th>Age 4</th>
<th>Age 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2 SD</td>
<td>9</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>+1 SD</td>
<td>6</td>
<td>11</td>
<td>&gt;11</td>
</tr>
<tr>
<td>+.05</td>
<td>5</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Mean</td>
<td>3</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>-.05SD</td>
<td>2</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>-1SD</td>
<td>--</td>
<td>4</td>
<td>&lt;9</td>
</tr>
<tr>
<td>-2SD</td>
<td>--</td>
<td>--</td>
<td>8</td>
</tr>
</tbody>
</table>

Phonological Legality

The mean score and standard deviations for each group are listed in table 3.8. The mean score increases with age.

### Table 3.8 Mean and standard Deviation of all age groups on the test of Phonological Legality.

<table>
<thead>
<tr>
<th>Phonological Legality (Max= 12)</th>
<th>Age 3</th>
<th>Age 4</th>
<th>Age 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2 SD</td>
<td>10</td>
<td>11</td>
<td>---</td>
</tr>
<tr>
<td>+1 SD</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>+0.5 SD</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Mean</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>-.5 SD</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>-1SD</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>-2SD</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
**Effect of Age on Norms**

In order to enable comparisons to be made on a common scale, Z-scores were calculated. The line graph below (Figure 3.1) shows the impact of age on the mean score for each of the tests. The trend was in a gradual upward direction, indicating that increased age positively affected the mean across all tests.

![Graph showing increasing mean across all ages](image)

**Figure 3.1** A line Graph with an increasing mean across all ages.

**Analysis of Variance**

In order to investigate whether there was a significant difference between age groups on their performance on the novel assessments, a Kruskal-Wallis test was carried out.
Test of Non-Word Similarity

A boxplot of distribution showed that there were no outliers in any of the age groups. A Kruskal-Wallis test revealed a statistically significant difference in the scores across the three different age groups (Age3, Age4, Age5) ($\chi^2 (2, n=55) = 10.425, p=.005$). A Mann-Whitney U test was carried out to identify where the differences lay. This test revealed that the difference between the scores of the three year old participants and the scores of five year old participants were statistically significant, with the planned post-hoc Bonferroni adjustment corrected to .017 for the Alpha Values ($p=.001$). There was no significant difference between three year olds’ scores and four years olds’ scores ($p=.111$), or between the performance of four year olds and five year olds ($p=.076$).

Numerical Concepts

A boxplot of distribution showed that there were no outliers in any of the age groups. A Kruskal-Wallis test revealed a statistically significant difference in the scores across the three different age groups (Age3, Age4, Age5) ($\chi^2 (2, n=55) = 17.004, p=.000$). There was no significant difference between the performance of four and five year olds, when the Bonferroni correction was adjusted to .017 ($p= 0.032$). However, a significant difference in performance between three and four year olds ($p= 0.10$) and three and five year olds ($p= .000$).

Auditory Memory

There was no significant difference in the scores across the three age groups when tested using the Kruskal-Wallis ($\chi^2 (2, n=55) = 2.820, p=.244$).

Pattern Recognition

The Kruskal-Wallis Test revealed a significant difference between the age groups ($\chi^2 (2, n=55) = 21.436, p=.000$). A Mann-Whitney U test indicated that the group ages 3 and the group aged 4 were statistically different, with the planned post-hoc Bonferroni
adjustment corrected to .017 for the Alpha Values (p= .001). There was also a significant
difference, between three year old’s scores and five years old’s scores (p= .000). There
was no significant difference between the performance of four year olds and five year
olds, (p= .076).

**Phonological Legality**

A one-way between groups analysis of variance (ANOVA) was conducted to explore the
impact of age on phonological legality. There was no statistically significant difference
between the scores of the different age groups: \( F = (2, 52) = 2.339, p = .107 \).

**Correlations**

**Age, PCC and Performance**

A Spearman’s Rank Order Correlation was used to investigate whether there was a
relationship between either a)age or b)speech, with performance on the five novel
assessments; Auditory Perception, Numerical Concepts, Auditory Memory, Pattern
Recognition, Phonological Legality and PCC.

Table 3.9 illustrates that age was significantly correlated with all of the
assessments, with the exception of Auditory Memory which was approaching
significance.

Table 3.10 illustrates that PCC was significantly correlated with Numerical
Concepts \( (r_s(55) = .298, p = .027) \), Pattern Recognition \( (r_s(55) = 0.451, p = 0.01) \) and Age in
Months \( (r_s(55) = 0.359, p = 0.07) \) This indicates the correlation should be adjusted for age
in months in a partial correlation analysis

**Table 3.9 Correlation between age and the five novel assessments**

<table>
<thead>
<tr>
<th>AGE</th>
<th>PCC</th>
<th>N/W Repetition</th>
<th>Numerical Concepts</th>
<th>Auditory Memory</th>
<th>Pattern Recognition</th>
<th>Phonological Legality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation Coefficient</td>
<td>.359**</td>
<td>.432**</td>
<td>.602**</td>
<td>.256</td>
<td>.680**</td>
<td>.331*</td>
</tr>
<tr>
<td>Significance</td>
<td>.007</td>
<td>.001</td>
<td>.000</td>
<td>.060</td>
<td>.000</td>
<td>.13</td>
</tr>
</tbody>
</table>

**Correlation is significant at the .01 level. * Correlation is significant at the .05 level.
Table 3.10. Correlation between PCC and the five cognitive tests.

<table>
<thead>
<tr>
<th>PCC</th>
<th>PCC</th>
<th>AudPer</th>
<th>NumCon</th>
<th>AudMem</th>
<th>PattRec</th>
<th>PhonoLeg</th>
<th>Age in Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation Coefficient</td>
<td>1.000</td>
<td>.197</td>
<td>.298*</td>
<td>.081</td>
<td>.451**</td>
<td>.129</td>
<td>.359**</td>
</tr>
<tr>
<td>Significance</td>
<td>.149</td>
<td>.027</td>
<td>.557</td>
<td>.001</td>
<td>.348</td>
<td>.007</td>
<td></td>
</tr>
</tbody>
</table>

Spearman’s Correlation. *p<.05, **p<.01

Partial Correlations Analysis was used to explore the relationship between PCC and Numerical Concepts while controlling for the effects of age. It caused the significant correlation to disappear ($r = .180, p = .192$). The correlation between Pattern Recognition and PCC is also affected by age ($r = .214, p = .120$). However, the partial correlation results should be interpreted with caution, as the assumptions of normality, linearity and homoscedasticity were not met.

Gender Effects

Age in months did not differ significantly between boys ($n=22, M=52.41$) and girls ($n=33, M=51.70$) $U= 330.00, p= .570$. However, girls performed better than boys across the majority (4/6) of the assessments; numerical concepts, auditory memory, phonological legality and speech accuracy.

DEIS Effects

To begin with, a series of Mann Whitney- U tests were carried out to investigate the possibility of slight age differences between these groups. Participants in the 3 year old DEIS group ($n= 13, M=42.62$) were significantly older than those in the non-DEIS group, ($n= 5, M= 38.4$), $U= 8.500, p= .017$.

The opposite is true for four year olds as illustrated in table 3.9 below, as the non- DEIS group ($n = 17, M= 56.06$) are significantly older than the DEIS group ($n= 8, M= 51.38$), $U= 16.500, p = .001$. 
Table 3.9 Mean ages and Mean PCC of DEIS and Non-DEIS participants.

<table>
<thead>
<tr>
<th></th>
<th>DEIS</th>
<th>Non-DEIS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Age</td>
<td>Mean PCC</td>
</tr>
<tr>
<td></td>
<td>(in months)</td>
<td>(in months)</td>
</tr>
<tr>
<td>3 year olds</td>
<td>42.62</td>
<td>88%</td>
</tr>
<tr>
<td>4 year olds</td>
<td>51.38</td>
<td>92%</td>
</tr>
</tbody>
</table>

Children aged three from DEIS schools performed better on the speech accuracy test (Mean PCC = 87.85 SD = 10.67 n=13) than the non-DEIS three year old group (Mean PCC =82.6, SD = 10.68, n=5). However, this may be due to the fact that they are 4 months older than the non-DEIS group. Despite this, the three year old children from non-DEIS schools performed better at Numerical Concepts (mean = 6.4 SD = 2.07), Auditory Memory (Mean = 3.2 SD = .837) and Phonological Legality (Mean = 7, SD = 2) subtests. This is illustrated in figure 3.3.

Children aged four from DEIS schools (92.49 n=8) performed similarly to the Non-DEIS group (Mean 91.9 SD = 7.18 n=17), on the speech accuracy test. However, by age four children from non-DEIS schools perform better across all five of the cognitive tests and illustrated in Figure 3.3.

Figure 3.2 Illustrates the difference in raw scores between children aged 3 from DEIS and Non-DEIS schools.
Figure 3.3 Illustrates the difference in raw scores between children aged 4 from DEIS and Non-DEIS schools.
Discussion

This study aimed to establish the norms for a range of novel tests of cognitive-linguistic skills, and to examine whether the raw scores show a progression with age. The purpose of a normative study is to act as a basis for interpretation of the novel assessments (Fromm-Auch and Yeudal, 1983). This research also aimed to see if there was a relationship between speech accuracy (measured by PCC) and performance on these tests. Finally, the study intended to establish whether children’s performance on these novel assessments were affected by SES. Within this section, the results of the five novel assessments and speech accuracy test, will be discussed in relation to their sensitivity and suitability for use in this population, prior to discussing and the contribution of this analysis.

Norms

The five novel assessments were carried out on the normative population in order to gather data which explains normal variability in cognitive linguistic skills between the ages of three and five (Dodd and Leahy, 1989).

All of the assessments differentiated well between the children, as there was considerable variability between the scores. The majority of the tests (4/5) presented with adequate ceiling and floor effects (Rehabilitation Institute of Chicago, 2010).

Discrimination of Non-Word Similarity

There are two pieces of evidence from our results which support children’s increased ability to discriminate between phonemes with increasing age. Firstly, the children’s mean scores in the test of non-word similarity increased with age across the sample. Secondly, as the children got older the percentage of participants scoring above chance increased, indicating that they were consciously listening, storing and discriminating between the two utterances. This is in line with previous literature by Rvachew et al. (2003) which found that typically children correctly perceive the correct pronunciation more often than children with speech sound disorder.

Further research on children with speech sound disorders would indicated whether this assessment is sensitive to the differing abilities.
The results showed a significant difference between three year old and five year olds indicating that the performance between these age groups may be generalizable to a larger population. This is not the case between the three and four year old age group, and the four and five year old age group. However, this may be a result of our modest sample size being unable to detect small effects between the age groups. It may also be contributed to the progression occurring at rates across units different to year groups. For example, 3; 00 to 3; 06 may have been a significant different to children 3; 07 – 4; 00.

Numerical Concepts
The sequential development of Mathematical Concepts with age found by Bhargava and Kirova (2002) was further supported by the increasing mean scores found in this study. There was a significant difference found between three and four year olds as well as between three and five year olds. There is no significant difference between the scores of four and five year olds. Despite this, the results present a large significant correlation between age and numerical abilities.

25% of the five year old sample reached ceiling indicating that the numerical concepts test is not sensitive enough to detect a variety of strengths in the children’s mathematical abilities above this age. The test is more sensitive to the normal variability in three and four year olds abilities of numerical reasoning. This is demonstrated by the scores being more widely dispersed across the age range. The consistent high score across the five year old group may be due to the effect of formal teaching on the development of mathematical and numerical skills, as all five year old participants were attending Junior Infants in Primary School (Department of Education, 1999).

Auditory Memory
The mean age of this sample was 4 years and 4 months and the mean score on the test of Auditory memory was 3.56 (SD=.939, range 0 – 5). Previous research by Gathercole, Adams & Hitch (1994) investigated digit span in 71 typically developing children with a mean age of 4;1 . The results were slightly lower than what we observed, the children scored a mean score of 2.94 (SD =.69, range = 1-5).

However, the Auditory Memory assessment was the only test that did not find significant differences between age groups. Despite this, the general trend of the mean
score was increasing with age (see Figure 3.1). The lack of significance between ages, as well as the fact that the mean increases very slightly (by .09) between aged 3 and age 4 indicates that the test needs to be more sensitive to subtle differences between the age groups.

Pattern Recognition
Mean scores on the pattern recognition test increase with age across the sample. The three year old sample demonstrated floor effects, but they are at an adequate level (Rehabilitation Institute of Chicago, 2010). The four and five year old groups have ceiling effects at adequate levels (Rehabilitation Institute of Chicago, 2010). Age is correlated largely with pattern recognition abilities. There was a significant difference between three and four year olds and three and five year olds. This indicates that the pattern recognition test is suitable for use with the general population at this age. However, there is no significant difference between four and five year olds.

Papic and Mulligan (2007) argue that pattern recognition is an unlearned ability, present before formal schooling. However, a caveat of their study is that they do not mention specific mean age of the sample used in the study. Our study supports this research, as four year olds scored a mean score of 8 indicating that they can successfully identify a pattern.

Phonological Legality
Children’s knowledge of their rule governed phonological system increases with age. This is indicated by their increased mean scores in the phonological legality test as they get older. This is further supported by a higher percentage of older children scoring above chance than younger children, as well as a medium correlation between increasing age and increasing abilities on the assessment. The normal distribution of the scores indicates that this test suitable for use in this sample. However, this may not be generalizable outside of the sample as results were not statistically significant.

Our results indicate that it is not until four years of age that the children demonstrate an awareness of phonological rules by the majority (56%) of the group. The results support previous literature by Dodd et al. (1989) that found that 4;4 ear old
typically developing children show an awareness of what is phonologically legal and illegal.

**Speech Accuracy**

The correlation between age and PCC supports previous literature researching the normative data for the DEAP (Dodd et al., 2003; Dodd et al. 2011).

Previous research by Dodd and McIntosh (2008) found that poor rule abstraction, a cognitive linguistic task, is associated with poor speech accuracy. The results of this study showed that there was no direct correlation between speech accuracy and any of the five novel assessments beyond the contribution of age.

Comparison between children with speech sound disorders and typically developing children may indicate the contribution of cognitive linguistic skills to this area of research, however our study excluded these participants. This study has shown that in the typically developing sample there is no evidence to show that these cognitive linguistic skills are related to PCC.

**Effect of Socio Economic Status**

Investigation of the effect of DEIS was warranted as the statistical differences between the norms for DEIS and non-DEIS indicate that separate norms must be established for the cognitive battery of tests so that comparisons can be made on a like to like basis.

Our research found that there was no statistical different was found in the speech accuracy measure indicating that the speech norms are applicable for lower SES. This supports previous literature by Dodd, et al. (2003). This was shown by the fact that children from DEIS schools performed equally well on the DEAP phonological assessment.

Despite similar phonological accuracy scores, children from a DEIS background performed more poorly overall at the cognitive linguistic tasks. This further supports the aforementioned evidence, that there is a disassociation between PCC and Cognitive-
Linguistic abilities. However, we must reach this conclusion with caution, as no measures were taken to evaluate the effects of attention which may have been the underlying difficulty affecting the children’s performance as the cognitive linguistic tests were carried out after the speech assessment.

Findings with relation to socio-economic status must be interpreted with extreme caution as SES can be measured by different parameters; occupation, education and income. Consequently these results may not be directly applicable to all low SES populations.

Limitations

Naturally, this study presented with some limitations which must be considered. As previously mentioned, the small sample size may not have been able to detect subtle significant differences within the data. The sample contained no five year olds from DEIS schools, as well as consisting of 38% DEIS children. This is a major over-representation of this population.

Additionally, the children who participated in this study were put forward by their parents, and consequently the results, may be affected by help-seeking bias. Finally, no test-retest reliability data was carried out, to measure the tests stability over time (Paul and Norbury, 2012).

Clinical Implications and Recommendations

The significance of this research should not be overlooked. The normative data has been established. This enable current research to being carried out in order to identify whether consistent speech sound disorder causes variability from these norms.

This research also has considerable theoretical implications for the understanding of cognitive linguistic abilities and speech. From what we have seen, typically developing
children in this population showed no association between speech accuracy and the cognitive linguistic tests.

The impact of DEIS on the participant’s scores is also hugely interesting. Previous research has been carried out on children from lower-SES with regard to a more limited vocabulary as a result of a poorer language learning environment (Hoff, 2003). However, little research has been carried out with regard to the development of underlying cognitive abilities in this population.

The results indicated that performance of children from a low SES background was improving more slowly with age than the typically developing cohort. This needs to be further investigated with a more balanced sample, across a wider range of ages.
References


Leahy, M., Murphy, N., Dodd, B. (2011) The Diagnostic Evaluation of Articulation and Phonology; An Irish Standardisation, United Kingdom, Pearson.


