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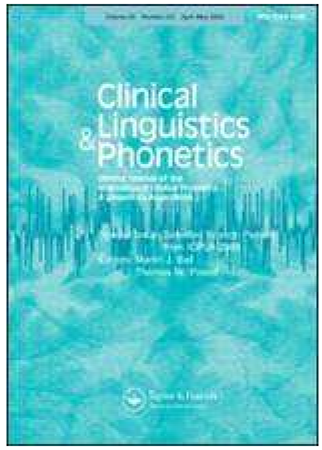

Phonology, morphology and speech processing development in Greek-speaking children

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Phonology, morphology and speech processing development in Greek-speaking children

A psycholinguistic framework for speech processing (Stackhouse & Wells, 1997) was adopted to investigate the development of phonological and morphological skills in children learning Greek. It was investigated whether morphological items pose specific challenges in terms of speech processing. Two groups of typically developing children aged 3.0-3.5 years (N= 16) and 4.6-5.0 years (N=22) respectively were assessed longitudinally at three assessment points six months apart. A range of phonologically-based and morphologically-based experimental speech processing tasks were administered to address the research question, along with language comprehension and production assessments to ensure that the children were developmentally typical. Stimuli of minimal phonological difference and minimal morphological difference respectively were used. Phonologically-based experimental stimuli were used to assess performance differences across properties such as voicing, manner and place of articulation, in addition to variation in phonotactic structure. Morphologically-based experimental stimuli were used to assess the impact of characteristics such as verb tense and possessive pronouns. Stimuli were incorporated into tasks of real word and nonword auditory discrimination and repetition, to assess input and output processing. Items were matched across tasks, so that comparisons could be made. On most of the matched tasks there was no significant difference in performance accuracy between morphological and phonological conditions. Moreover, a significant relationship was found between domains. It is suggested that morphological items, compared to phonological items, do not pose specific challenges in terms of speech processing. The clinical implications of these findings for assessment and intervention are discussed.

Keywords: phonology; morphology; psycholinguistic framework; speech processing; Greek

Introduction

Theoretical accounts of language development and research data from children with speech and language difficulties point to a connection between phonological and morphological skills. Investigation of language acquisition in typically developing (TD) children may illuminate links between the two domains and reveal factors underpinning language impairment.

From a theoretical point of view the language system can be considered to work as a whole unit with interactions between linguistic levels (Crystal, 1987). Children with developmental language disorders (DLD), formerly known as specific language impairment (SLI), often exhibit considerable difficulties with morphemes of short duration, encountered in weak syllables of words (Leonard, 1998). Linguistic theories aim to account for the influence of phonetic/ phonological constraints on morphological expression. One well-known theory of SLI, the Surface Hypothesis, puts emphasis on "consideration of the important role that the physical properties of speech are assumed to play"(Leonard, 1998, p. 247). In the same direction, the Prosodic Licensing Hypothesis (Demuth & Tomas, 2016) attributes the omission of unstressed clitics to phonological factors and specifically to prosodic phonology.

From a clinical perspective, there is a growing body of evidence from children with speech difficulties that suggests a relationship between speech production and the ability to realize grammatical morphemes. Speech production difficulties could explain a considerable amount of morphological errors of 4-5 year old English-speaking children with childhood apraxia of speech (CAS), though their limited expressive language skills were not entirely attributed to motoric constraints (Murray, Thomas, & McKechnie, 2019). The ability to produce consonant clusters correlated with the accuracy of grammatical morpheme realization, irrespective of the phonological context in which morphemes occurred, in 4-5 year old English-speaking children with phonological impairment (PI) (Howland, Baker, Munro, & McLeod, 2019). Moreover, 4-5 year old German-speaking children with PI have been found to perform significantly below their TD peers with respect to spontaneous use of the dative case (Hasselaar, Letts, & McKean, 2019). Despite the fact that none of the errors observed could be directly attributed to speech problems, the authors considered that phonological input processing skills could potentially be a barrier to the acquisition of case marking.

Expressive language skills and interactions between phonology and morphology have been investigated in children with co-morbid speech and language impairment. Input processing constraints along with limitations both in phonological and morphological output processing have been identified (Tyler & Mcomber, 1999). Preschool age children with co-morbid difficulties did not differ from children with language difficulties alone on the total number of speech sound errors; however, they showed a greater number of omission errors, indicating a restricted linguistic system (Macrae & Tyler, 2014). The morpheme production performance of children with co-morbid difficulties was significantly poorer than that of children with language difficulties alone (Haskill & Tyler, 2007).

Regarding children with language difficulties, inflectional production accuracy has been linked to phonological factors. A relationship has been observed between final cluster reduction in monomorphemic words and the omission of consonantal inflections in Italian and English-speaking children with SLI (Bortolini & Leonard, 2000). The production of finite morphemes, especially past tense production, was vulnerable to the manipulation of the phonological complexity characteristics of the target words. English-speaking children with SLI encountered greater difficulty in past tense production when the verb stem (Norbury, Bishop, & Briscoe, 2001) or the past tense suffix (Marshall & Van Der Lely, 2007) included a consonant cluster. Greek-speaking children with SLI performed better in past tense formation for verbs requiring a stressed syllabic augment for example ['γrɐfo] I write (present)- ['εγrɐpsɐ] (past) as opposed to [xo'ɾεvo] I dance (present) - ['xorεpsɐ] (past) (Mastropavlou, Petinou, Tsimpli, & Georgiou, 2019). Moreover, investigation of the role of phonotactic cues on the comprehension of passive sentences in English (Marshall, Marinis, & van der Lely, 2007) showed that typically developing controls, rather than children with SLI, benefit from phonotactics to perceive a form like hugged as a particle. Based on the findings, the authors called for studies of typical language acquisition to consider the interaction between different levels of linguistic representation.

Developmental discrepancies in performance accuracy for inflectional realization have been observed between children of different ages, participating as language and age matched controls in SLI studies. Finite verb morphology composites of younger TD children (language matched controls, mean age 3;6) were significantly lower than the composites of age matched controls (mean age 5;4), even when finite verb morphology was calculated by including only those details of morphology that formed a single phonological word (Polite & Leonard, 2006). Significant development in morphology production occurs during the pre-school years, which may be related to phonological factors.

In summary, research in the field of speech sound disorders (Howland et al., 2019) and specific language impairment (Norbury et al., 2001) indicates that phonological factors may, to some extent, account for difficulties with the production of morphology. While speech production difficulties do not inevitably result in inaccurate production of morphemes (Marshall & Van Der Lely, 2007; Murray et al., 2019), the presence of speech production difficulties puts children at risk. Although phonetic constraints on the realization of grammatical morphemes are well acknowledged for children with speech and/ or language difficulties, morphological development as a function of the gradual maturation of speech processing skills has not yet, to the best of our knowledge, been investigated in TD children. As the basis for a more comprehensive assessment, it is clearly important to have a picture of typical speech processing skills development for morphological along with phonological elements of language. Since different levels of morphological development have already been observed between TD children of different age, it is likely that investigation of morphological development in parallel with speech development in TD children will shed further light on the interaction between the two domains. This issue was addressed in the present study through an investigation of TD Greek-speaking children.

Greek is a highly inflected language. A variety of morphemes are used to indicate gender, number and case for nouns; person, number, tense and voice for verbs (Holton, Mackridge, & Philippaki-Warburton, 1997). In morphologically rich languages the words of a child from the outset contain grammatical endings and prefixes (Stephany, 1981), simply because the production of bare word stems is never found in the adult language and is therefore ungrammatical (Katis, 1992).

Principles of psycholinguistics have been used to investigate both typical and atypical speech development (e.g. Vance, Stackhouse, & Wells, 2005; Pascoe, Stackhouse, & Wells, 2006). While much of the existing literature focuses on English speaking children, the psycholinguistic approach has also been used successfully to profile Greek children with speech sound disorders (Geronikou and Rees, 2016). Within the simple psycholinguistic paradigm (Stackhouse & Wells, 1997) it is assumed that a number of input processes occur when a child listens to spoken language and a number of speech output processes occur when a child is speaking. Linguistic information is also stored in the form of phonological representations (word form), semantic representations (word meaning), grammatical representations (word class, derivational rules) and motor programs (specific articulatory gestures required for production) that enable a child to understand and produce spoken language.

In the present study, a psycholinguistic perspective is adopted to investigate the development of phonological and morphological skills in children learning Greek, a language characterized by rich inflectional morphology. While morphemes by definition carry some grammatical information, at the phonological level each morpheme also consists of one or more particular sounds that differentiate it from other more or less similar morphemes. The central hypothesis to be investigated is that the successful acquisition not only of phonological characteristics (i.e. perceptually distinct units of sound that differentiate the meaning of words), but also of morphological characteristics (i.e. meaningful, grammatical units of spoken language), depends on the accuracy and efficiency of speech processing skills.

Although different morphological rules apply in different languages, morphological components are used in every language. The longitudinal study of the acquisition of a language with complex morphology may elucidate aspects of the organization of lexical representations (stored linguistic knowledge), including grammatical representations, which may not be feasible to study in morphologically simpler languages. Investigating speech processing and the development of morphology in Greek may thus inform theories of language acquisition and speech processing. From a clinical perspective it may provide useful information in assessing a child's baseline skills, informing intervention and mapping progress over time.

In order to investigate whether morphological items pose specific challenges in terms of speech processing for TD pre-school aged Greek-speaking children the following research questions are addressed:

(1) Is there significant development in performance between time points on language measures and speech processing measures?

(2) If there is development of speech processing skills taking place at the age between 3.0-6.0 years, do the stimulus characteristics, namely differences of a phonological or a morphological nature, affect the performance of children?

(3) If there is development of speech processing skills both for phonological and morphological elements of speech, is the development of phonological vs. morphological elements of speech supported differentially by stored linguistic knowledge?

(4) If the processing of phonological items and the processing of morphological items pose similar demands for the speech processing system, then is there a relationship between processing of phonological and morphological items when (a) level and (b) modality of processing are similar?

Method

Design:

A cross-sectional longitudinal design was used to investigate aspects of speech and language development for the age range between three and six years in two groups of typically developing children. Children were assessed three times with an intermission of six months between each assessment, so that any change observed could be attributed to development. The study design can be seen in figure 1.

Insert figure 1 about here

Participants:

Two groups of typically developing children participated in the study. The decision to have two groups as opposed to a single group was taken on pragmatic grounds. In the Greek educational system children can transition from day care to kindergarten from the age of four years onwards and tracking children across this transition, across multiple institutions, is challenging. Thus, in order to increase the possibility that participating children would be attending the setting, where they were initially recruited, Group 1 participants were children attending a day-care setting, aged 3.0-3.5 and Group 2 participants were children attending a kindergarten school, aged 4.6-5.0 at the beginning of the study. Thirty-eight children in total participated in the study: 16 children in Group 1 and 22 children in Group 2. Parental consent and child assent was gained prior to testing.

All children had Greek as their primary language. All children passed a hearing screening test, in order to ensure they would be able to complete the input tasks. Participants either had no vision problems or vision problems that were corrected with glasses. A diadochokinetic task was used in order to check that there were no structural or functional abnormalities of articulators.

Tasks and materials used:

The evaluation material comprised (i) published language assessments and (ii) experimental tasks of speech processing where items of phonological and morphological interest were included. Stimuli were matched across input and output tasks so that direct comparisons of performance could be made.

Language tasks were used a) to establish that participating children are typically developing and b) to provide a comprehensive evaluation of their language skills, with detailed information concerning the development of morphology both for comprehension and production. This is because both speech skills and language skills need to be measured to investigate whether the development of morphology occurs concurrently with the development of speech processing skills.

Published language tests:

The Diagnostic Verbal IQ test (Stavrakaki & Tsimpli, 2000) was used to ensure that children had typically developing language skills. The DVIQ is designed specifically for Greek speakers and aims to assess the receptive and expressive skills of preschool children aged 2; 6 to 6; 5 years. It is in the process of standardization and preliminary norms are available. Three subtests were used: (i) the production of morphology and syntax (DVIQP), (ii) comprehension of morphology and syntax (DVIQC) and (iii) sentence repetition (DVIQSR). Tasks resemble the equivalent subtests of the widely used Clinical Evaluation of Language Fundamentals (CELF; Semel, Wiig, & Secord, 1996).

Experimental tasks:

In order to assess input and output processing the following experimental tasks of speech processing were used. These included:

(1) Real word auditory discrimination (RWAudD), to assess the ability to discriminate between words with different (a) phonological (RWAudDPhon) and (b) morphological (RWAudDMor) elements from auditory presentation only.

(2) Nonword auditory discrimination (NWAudD), to assess the discrimination of speech sounds without reference to (a) phonological (NWAudDPhon) and (b) morphological (NWAudDMor) representations.

(3) Real word repetition (RWRep), to assess the ability to produce (a) phonological (RWRepPhon) and (b) morphological (RWRepMor) elements, when a model is given and stored linguistic knowledge may be used to support performance.

(4) Nonword repetition (NWRep), to assess the ability to produce sounds related to (a) phonological (NWRepPhon) and (b) morphological (NWRepMor) elements without reference to representations.

Performance on repetition tasks was scored for whole word (WW) and percentage of consonants correct (PCC) accuracy. WW accuracy is used as a broad measure of change over time on tasks that pose different requirements in psycholinguistic terms while PCC accuracy is used as a more sensitive measure that can track minor changes over time even if the production of the word as a whole remains inaccurate (Newbold, Stackhouse, & Wells, 2013).

Experimental stimuli: Phonological minimal pairs

Phonological minimal pairs were used to evaluate processing of perceptually distinct units of sound that distinguish one word from another, located in the word stem, for example /ˈniçi/ *(nail)* /ˈnifi/ *(bride).* Phonological properties such as voicing, manner and place of articulation, and phonotactic structure such as consonant clusters or closed syllables were taken into consideration, to ensure broad representation of the Greek phonological system. Matching nonwords were created by keeping the phonotactic structure and consonants the same and changing the stressed vowel to ensure that nonwords would have the stress and phonotactic structure of real Greek words of corresponding length (Maridaki-Kassotaki, 2002). The complete set of phonologically-based stimuli can be seen in appendix 1 (real words) and appendix 2 (nonwords).

Experimental stimuli: Morphological minimal pairs

Morphological minimal pairs were used to evaluate processing of meaningful units of language that change the grammatical function of a word such as masculine and feminine gender, present versus future tense. Morphological minimal pairs are not necessarily phonological minimal pairs although they may be. For example in the pair /tonɛɐ'ftotu/ (*himself*) and /tonɛɐ'ftotis/ (*herself*) the phonotactic structures used for masculine and feminine are different. On the other hand, the pair /tɐ'izun/ (*are feeding*) and /tɐ'isun/ (*will feed*) is a phonological minimal pair where the contrast of /s/-/z/ is used to signal present in contrast to future tense. Elements differentiating one word from another are located in the word suffix. Items included in the DVIQ subtests were used to derive pairs of stimuli of minimal morphological difference. Matching nonwords were created by keeping intact the real word component that manifests the morphological difference whilst changing the stressed vowel in the word stem to generate nonwords, for example /tonɛɐ'ftatu/, /tɐ'ɛzun/. The complete set of morphologically-based stimuli can be seen in appendix 3 (real words) and appendix 4 (nonwords).

Administration of tasks

Children were assessed individually in a quiet room within the school setting. All experimental tasks were administered via a computer. Real words and nonwords presented were pre-recorded to ensure that all the participants would listen to each stimulus under exactly the same conditions regarding rate, loudness and other prosodic features.

Auditory stimuli were recorded using Audacity 1.3 Beta (Unicode) with a project rate of 22050 KHz using the single input channel with External Microphone IDT high definition. All recorded stimuli were normalized through the normalization function of Audacity to a maximum output level of -2.4dB. Given that word length varied from 2-5 syllables and that primary stress can be on any of the last three syllables, it was considered that normalization of the complete set of stimuli for duration and prosody would result in unnatural-sounding stimuli.

Headphones were used to minimize the impact of background noise. Performance accuracy on input tasks was automatically scored by the computer and corrective feedback was provided in the case of a wrong answer. Output productions were transcribed on-line by the first author and recorded with an Olympus digital recorder placed 20cm in front of the child to be checked at a later stage if necessary. In all tasks a prompt was given prior to stimuli presentation. In detail, the experimental tasks were administered as follows.

(1) Real word auditory discrimination: There is a large space-ship at the top, with two smaller space-ships below. A girl appears in the top space-ship and says a word ‘X’ as ['kupɐ] *(cup)*. A second girl appears in the lower left hand ship and says a word ‘A’ as ['kupɐ] *(cup)*. A third girl appears in the right hand space-ship and says a word ‘B’ as ['skupɐ] *(broom)*. The child’s task is to click on the girl in one of the smaller space-ships who matched the girl in the top space-ship (i.e. whether A or B was the same as X). Girls are used to indicate that auditory stimuli are real words that the child could expect to recognize.

(2) Nonword auditory discrimination. There is a large space-ship at the top, with two smaller space-ships below. An alien appears in the top space-ship and says a nonword ‘X’, as ['θεci]. An alien appears in the lower left hand space-ship and

says a nonword ‘A’, as ['θεci]. An alien appears in the right hand space-ship and says a nonword ‘B’, as ['fεci]. The child’s task is to click on the alien in one of the smaller space-ships who matched the alien in the top space-ship (i.e. whether A or B was the same as X). Aliens are used to indicate that the auditory stimuli are not real words that the child could expect to recognize.

(3) Real word repetition: A cartoon that looks like a human being appears and says a word; once the child repeats the word the cartoon, under the experimenter’s control, moves slightly and the next word is heard.

(4) Nonword repetition: An animal cartoon appears and says a nonword; once the child repeats the stimulus, the cartoon under the experimenter’s control moves and the next nonword is heard. Animals are used to indicate that auditory stimuli are not real words that the child could expect to recognize.

Inter-rater reliability

In order to ensure the reliability of scoring performance in output tasks, in addition to the first author who scored all items, a Greek-speaking qualified speech therapist scored approximately 10% of the total number of recordings from data collected from eight children at T1. An inter-rater reliability analysis using the Kappa statistic was performed to determine consistency. The Kappa coefficient was: DVIQP (0.758), RWRepPhonWW (0.845), RWRepMorWW (0.822), NWRepPhonWW (0.727), NWRepMorWW (0.756), indicating a strong agreement according to Landis & Koch (1977).

Results

Development of skills over time

In order to address the first research question, regarding development in performance between time points on language measures and speech processing measure, means, standard deviations and ranges were calculated for number of items correct for each age group at each assessment point (table 1). The Kolmogorov Smirnov test and visual inspection of the histograms were initially used to ensure that data were normally distributed and then Repeated Measures Anova was used to compare performance.

Insert table 1 about here

Language tasks

There was a main effect of time on all language subtests for both groups: Group 1 DVIQP ($F_{(2,14)}$=68.86, p<0.001), DVIQC ($F_{(2,14)}$=19.46, p<0.001), DVIQSR ($F_{(2,14)}$=13.16, p=0.001); Group 2 DVIQP ($F_{(2,17)}$=20.70, p<0.001), DVIQC ($F_{(2,17)}$=12.46, p<0.001), and DVIQSR ($F_{(2,12)}$=5.16, p=0.024).

Real word auditory discrimination

In real word auditory discrimination, a task used to assess the discrimination of real words that share different phonological or morphological characteristics, there was a main effect of time for both groups in both conditions: Group 1 RWAudDPhon ($F_{(2,13)}$=19.11, p<0.001), RWAudDMor ($F_{(2,14)}$=23.24, p<0.001); Group 2 RWAudDPhon ($F_{(2,16)}$=32.14, p<0.001), RWAudDMor ($F_{(2, 16)}$ = 5.68 p=0.014).

Nonword auditory discrimination

In nonword auditory discrimination, a task used to assess the discrimination of speech sounds without reference to phonological or morphological representations, there was a main effect of time for both groups in both conditions: Group 1 NWAudDPhon ($F_{(2,14)}$=9.86, p=0.002), NWAudDMor ($F_{(2,14)}$=15.23, p<0.001); Group 2 NWAudDPhon ($F_{(2,16)}$=15.25, p<0.001), NWAudDMor ($F_{(2,16)}$=50.07, p=0.020).

Real word repetition

In real word repetition, a task used to assess the production of real words with different phonological or morphological characteristics, there was a main effect of time for Whole Word (WW) accuracy in all conditions: Group 1 RWRepPhonWW ($F_{(2,13)}$=15.08, p<.001), RWRepMorWW ($F_{(2,13)}$=8.71, p=.004); Group 2 RWRepPhonWW ($F_{(2,16)}$=3.65, p=.049), RWRepMorWW ($F_{(2,16)}$=4.28, p=.048). A main effect of time for Percentage Consonants Correct (PCC) accuracy was observed for Group 1 RWRepPhonPCC ($F_{(2,13)}$=12.10, p=0.001), RWRepPhonPCC ($F_{(2,13)=}$7.58, p=0.007); Group 2 RWRepPhonPCC ($F_{(2,16)}$=70.08, p=0.006) but not for RWRepMorPCC.

Nonword repetition

In nonword repetition, a task used to assess the production of different phonological and/or morphological characteristics without reference to representations, there was a main effect of time in all conditions i.e. for Group 1 NWRepPhonWW ($F_{(2,13)}$=11.71, p=.001), NWRepMorWW ($F_{(2,13)}$=19.16, p<.001), NWRepPhonPCC ($F_{(2,13)}$=10.44, p=0.002), NWRepMorPCC ($F_{(2,13)}$=13.10, p<0.001); Group 2 NWRepPhonPCC ($F_{(2,17)}$=6.07, p=.010), NWRepMorPCC ($F_{(2,14)}$=4.89, p=.025), NWRepPhonPCC ($F_{(2,17)}$=60.07, p=0.010), NWRepMorPCC ($F_{(2,14)}$=4.89, p=0.025).

In summary, the results of the normative study reveal a main effect of time in language skills and speech processing development. In order to investigate differences between time points, pairwise comparisons with Bonferroni adjustment for multiple comparisons were performed. Results are summarised in table 2.

Insert table 2 about here

Comparison of performance between domains

Regarding the second research question, it was explored whether linguistic domain, i.e. phonology or morphology, affects performance. It was investigated whether comparable speech processing skills are involved in processing of phonological and morphological characteristics. Performance was compared in tasks that tap the same level of processing i.e. real word auditory discrimination and real word repetition. For each level a 3 (Time: T1, T2, T3) by 2 (Domain: Phonological, Morphological) Repeated Measures ANOVA was performed with age group (Group 1, Group 2) as the between group factor with Bonferroni adjustment for multiple comparisons.

Real word auditory discrimination

The analyses showed a main effect of time for both groups: Group 1 ($F_{(2,13)}$=29.95, p<0.001), Group 2 ($F_{(2,16)}$=16.70, p<0.001). There was not a main effect of linguistic domain for Group 1 ($F_{(1,14)}$=1.84, p=0.197) or for Group 2 ($F_{(1,17)}$ =1.73, p=0.205). The main effect of time arose because children could successfully discriminate more items over time. Performance of the two groups can be seen in figure 2.

Insert figure 2 about here

Real word repetition (WW scoring)

The analyses showed a main effect of time for both groups: Group 1 ($F_{(2,13)}$=15.74, p<0.001); Group 2 ($F_{(2,16)}$=4.62, p=0.026). There was not a main effect of linguistic domain for Group 1 ($F_{(1,14)}$=1,28, p=.419); for Group 2 there was a just significant linguistic domain effect in favour of Phonological items ($F_{(1,17)}$=4,60, p=0.047). Comparison of means did not indicate a statistically significant difference between the two tasks at any of the assessment points. Performance of the two groups can be seen in figure 3.

Insert figure 3 about here

Real word repetition (PCC scoring)

The analyses showed a main effect of time for both groups: Group 1 ($F_{(2, 13)}$=110.07, p<0.002); Group 2 ($F(_{2, 16})$=6.53, p=0.008). For Group 1 there was a main effect of linguistic domain ($F(_{1,14})$=80.01, p=0.013). Paired–samples t–tests showed that performance on RWRepPhonPCC was significantly lower than performance on RWRepMorPCC at T1 ($t_{(15)}$=-2.59, p=.021) and at T2 ($t_{(15)}$=-2.80, p=.014). However, this domain effect on performance was not evident at T3.For Group 2 group the main effect of linguistic domain missed significance ($F(_{1,17})$=3.91, p=0.064). Performance of the two groups can be seen in figure 4.

Insert figure 4 about here

Comparison of performance between different levels of processing

Regarding the third research question, it was explored whether stored representations may support lower level processing for phonological and morphological elements, i.e. an effect of lexicality. Performance was compared in tasks that tap different levels of processing for stimuli that otherwise share the same properties i.e. Real Words vs. Nonwords. A 3 (Time: T1, T2, T3) by 2 (Lexicality: Words, Nonwords) Repeated Measures ANOVA, was performed with age group (Group 1, Group 2) as the between group factor with Bonferroni adjustment for multiple comparisons. There was no Lexicality effect in input processing. Analysis yield a main effect of Lexicality for both groups in all output conditions: PhonRepWW Group 1 ($F_{(1,14)}$=9.60, p=.008), Group 2 ($F_{(1,15)}$=13.06, p=.003); MorRepWW Group 1 ($F_{(1,14)}$=11.46, p=.004), Group 2 ($F_{(1,15)}$=7.73, p=.014); PhonRepPCC Group 1 ($F_{(1,14)}$=14.45, p=.002), Group 2 ($F_{(1,17)}$=12.23, p=.003); MorRepPCC Group 1 ($F_{(1,14)}$=52.29, p=.001), Group 2 ($F_{(1,15)}$=22.38, p=.001). Performance of the two groups can be seen in figure 5.

Insert figure 5 about here

The relationship between processing of phonological and morphological elements

Regarding the fourth research question, it was investigated whether there is a relationship between processing of phonological and morphological elements. It was hypothesized that there would be a relationship between performance on phonologically-based and morphologically-based items when (a) the level was similar, i.e. both tasks used real words; and (b) the modality of processing was similar, i.e. both input or both output.

To examine the relationship between performance on phonological and morphological items in real word auditory discrimination, Pearson correlations were calculated within and across time for RWAudDPhon and RWAudDMor tasks. The correlation matrix for Group 1 can be seen in table 3 and for Group 2 in table 4. Scores in RWAudDPhon and RWAudDMor were significantly associated within time points at T2 and T3 with a significant probability level of $p < 0.05$ for Group 1; at T1 and T3 with a significant probability level of $p < 0.05$ for Group 2.

Insert table 3 about here

Insert table 4 about here

To examine the relationship between performance on phonological and morphological items in real word repetition, Pearson correlations were calculated within and across time for RWRepPhon and RWRepMor tasks scored for the WW accuracy. The scoring for the WW accuracy was used, because it captures major changes in the accurate production at the word level as compared to PCC that may reflect small differences at the level of a phoneme. Moreover, in some cases the correct production of a specific phoneme is essential for the proper indication of a morpheme, as for example in the pair /tɐˈizun/ (are feeding) vs. /tɐˈisun/ (will feed). The correlation matrix for Group 1 can be seen in table 5 and for Group 2 in table 6. Performance accuracy on RWRepPhon and RWRepMor is significantly associated within time at T1, T2 and T3 for both groups, with a highly significant probability level of $p<0.001$. Significant positive correlations were also found across time between RWRepPhon and RWRepMor at all time points for Group 1.

Insert table 5 about here

Insert table 6 about here

Discussion

This study set out with the aim of investigating the speech processing of phonological and morphological characteristics of words in typically developing Greek-speaking children.

With regard to the first research question the results indicate that there is significant development in performance between testing points on speech processing measures and language measures for each group. The finding that significant development of speech processing and language skills occurs between 3;0 and 6;0 years is not surprising, given previous findings that older children outperform younger ones on phonological mean length of utterance and finite morpheme production (Polite & Leonard, 2006). Nevertheless, it should be noted that in certain tasks Group 2 at T1 (children aged 4;6 – 5;0) scored lower than Group 1 at T3 (children aged 4; 0 – 4; 6).

Better performance of Group 1 at T3 can probably be attributed in part to a practice effect, as the Group 1 children had already had experience of undertaking these tests on at T1 and T2. Moreover, Group 1 participants at T3 had been attending a day-care setting at least since T1. Participants in Group 2 were recruited in a kindergarten school, which they had attended for a few months and it is possible that some of them had not attended a day-care setting at a younger age. Tomasello (2003) suggests that the development of language links to the need for cooperation in social interaction. The experience of social interaction within a context of preschool education, at least for one year, may have promoted the development of language skills in Group 1.

With regard to the second research question, it was investigated whether comparable speech processing skills are involved in processing of both phonological and morphological characteristics of spoken language. Differences of a phonological or a morphological nature do not seem to affect performance. The results of this study show that there is not a significant difference in input processing between phonologically-based and morphologically-based items as assessed in real word auditory discrimination. Turning to output processing in repetition tasks, there was a performance discrepancy between the two scoring methods used. When percentage consonants correct (PCC) was used, a linguistic domain effect was found in favour of morphological items for Group 1; Whole word scoring showed a just significant overall linguistic domain effect in favour of phonological items for Group 2. It may be the case that these variations are due to stimuli characteristics.

Blocks of phonological and morphological stimuli were not balanced in terms of word length or phonotactic structure for a number of reasons. In terms of phonology, pairs of minimal phonological difference are found mainly in words of 2-3 syllables, as in longer words there are differences in more than one phoneme; to track developmental change, phonological stimuli were designed to be challenging in terms of phonotactic structure, including consonant clusters and closed syllables. In terms of morphology, when morphological prefixes or endings are added to the word stem, the word length increases; since the aim was to control for morphological characteristics representative of the Greek language, it was not possible to control for length and phonological complexity of stimuli in morphological blocks. With regard to word length, this is a well established factor affecting young children's performance in various tasks (Gathercole & Baddeley, 1990; Vance et al., 2005). With regard to phonological complexity, data from English speaking children indicate that grammatical morphemes in singleton contexts were significantly less challenging than in consonant clusters (Howland et al., 2019). Thus, selecting stimuli that were not equally balanced in phonological and morphological blocks could be a bias, picked up by the sensitive PCC scoring that yielded a morphological domain advantage at the younger end of the age range. However, the broader measurement of phonetically accurate whole words did not replicate the findings of PCC segmental analysis. At an early stage of development children may not have mature phonetic skills to articulate noticeable phonetic contrasts (Scobbie, Gibbon, & Hardcastle, 1996). Syrika, Edwards, Fangfang, & Beckman (2008) showed that Greek-speaking children aged 2;0 – 5;0 years were attempting to produce speech characteristics that would only become apparent with spectral analysis. It is possible that Group 1 participants at T1 and T2 would intend to mark phonological differences however articulatory skills were immature to express subtle differences in taxing phonological context.

With regard to the third research question, it was explored whether stored representations may support lower level processing for phonological and morphological elements of speech. It could be predicted that stored linguistic knowledge might have more effect on morphological development, as individual morphemes are meaningful elements of language whereas individual phonemes are not. However, in the present study there was no difference between phonological and morphological conditions with regard to lexicality. In output tasks, real word repetition performance was significantly more accurate than performance on nonwords i.e. novel stimuli, for which new motor programs had to be generated. It thus seems that top-down processing had an advantageous effect on speech production and that children in both groups made use of existing lexical representations to support real word repetition. This result is in line with findings that speech production skills cannot fully account for the linguistic errors observed in children with CAS (Murray et al., 2019) or language difficulties (Owen, Dromi, & Leonard, 2001).

With regard to the fourth research question, potential relationships between processing of phonological and morphological elements were investigated. It was hypothesized that positive correlations would be found between processing of phonological and morphological stimuli, across input tasks as assessed with real word auditory discrimination and across output tasks as assessed with real word repetition.

Auditory discrimination scores for phonological and morphological items were significantly associated within time (i.e. synchronically) at T2 and T3 for Group 1 as well as at T1 and T3 for Group 2. These results on the input side suggest that a relationship exists to some extent between performance on phonological and on morphological tasks. This in turn suggests that the development of adequate phonological recognition skills, required for the auditory discrimination of phonological elements, is associated with the development of phonological recognition skills for the auditory discrimination of morphological elements.

Performance on real word repetition of phonological and morphological items was significantly associated within time (synchronically) at T1, T2 and T3 for both groups and diachronically across all time points for Group 1. This suggests that production of morphemes relates to the ability to produce phonological elements of the language. The degree to which children have developed the necessary skills to generate the motor programs required for the task of real word repetition for phonological items, relates to the development of these skills for morphological items. On the production side, correlations were found at every time point for both groups between performance on tasks of phonological and morphological interest. This indicates that output skills for phonological and morphological elements are strongly related. This is not surprising, given that the accurate production of morphemes has been found to depend on the phonological context in which they are realized. Morphological production accuracy may be subject to phonological complexity, such as the presence of consonant clusters in the verb stem (Norbury et al., 2001) or in the past tense suffix (Marshall & Van Der Lely, 2007). Results on the input side are less conclusive about a relationship between performance on phonological and morphological tasks. This may be attributable to the fact that performance on input tasks can be affected by the intrusion of extraneous requirements of the tasks such as random choice, as well as memory and attention requirements that are sometimes higher than for output tasks.

Similarities in developmental pattern were observed for input and output processing of morphological and phonological items. Strong relationships between performance accuracy for morphological and phonological items in tasks tapping the same level of processing were also found. On the basis of these findings it can be suggested that in normal development, speech processing for morphological affixes develops simultaneously with the processing of phonological elements of word stems, which relate to the semantic properties of the word itself. It can also be hypothesised that difficulties with the accurate comprehension or production of morphemes may in part result from an underlying impairment of speech processing skills, i.e. an underlying difficulty with discrimination or production of the sounds or sound combinations that occur in morphological affixes.

Clinical implications for assessment and intervention planning

From a clinical perspective, the study indicates that the tasks used are sensitive in detecting developmental progression. As it is important to evaluate the performance of children with speech difficulties in comparison to norms (Vance et al., 2005) the data reported here can be used to assess whether an individual child learning Greek is following the anticipated course of development. For a child who does not follow the typical developmental stages, assessment of speech processing may be informative as to the skills in which this child deviates from the norm. Clinicians practising with Greek-speaking children may therefore benefit from the tasks and the data from typical development presented in this paper. The current findings have already been used for the assessment, intervention planning and evaluation of morphophonological intervention outcome in a Greek-speaking child with speech difficulties (Geronikou, Vance, Wells, & Thomson, 2019).

There are wider implications for clinical practice, irrespective of the complexity of the morphological system of a specific language. Whatever language the child is learning, it is important to investigate whether the difficulties that a child is having with the production of morphology mirror the child's speech production difficulties. Murray et al., (2019) suggest that language assessment should be preceded by speech assessment since the child may not have the necessary output skills for the accurate realization of morphophonemes, or adequate input processing skills to differentiate between similar sounding morphemes. Although phonological factors cannot fully account for inaccurate production of morphemes, phonological factors cannot be ruled out (Polite & Leonard, 2006). In order to explore such diagnostic issues it is helpful to be able to use morphological and phonological tests that are carefully matched, as was done for Greek in the present study.

Turning to intervention planning, the finding that the processing of morphological elements is related to processing of phonological elements should be taken into consideration for children with speech and/or language difficulties. When the absence of morphological suffixes relates to final syllable deletion, (as in /tonɛɐ'ftotu/ *himself* and /tonɛɐ'ftotis/ *herself* both realised by the child as [tonɛɐ'fto] *self)* the production of polysyllabic words may need to be targeted. As it has already been noted for English speaking children, phonology may constitute an obstacle (Tyler & Mcomber, 1999) that needs to be addressed in addition to morphosyntactic limitations (Owen et al., 2001). When a child fails to produce morphemes that constitute a pair of minimal phonological difference (as in /tɐ'izun/ *are feeding*-/tɐ'isun/ *will feed),* auditory discrimination could potentially be a target for intervention. If a child intends to differentiate between two similar sounding morphemes but is not successful, the possibility that the child is making a covert contrast (Syrika et al., 2008) should be considered, as this could influence whether intervention first focuses on establishing accurate phonological representations prior to the establishing of accurate motor programs (cf. Stackhouse & Wells, 1997: 209-213). In any case the child will ultimately need to be guided in the development of distinctive motor programs in a way that reflects the distinctions observed in adult speech, so that the distinction that the child makes become apparent to listeners. When a child has difficulty with the production of particular sounds that are necessary for the accurate realization of morphemes, intervention should incorporate the production of those sounds in morphological contexts. Consideration of morphology in the context of the child's developing speech processing system is thus warranted from a clinical perspective, as well as being of broader theoretical interest for research in children's speech and language development.

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Declaration of Interest

The authors have no declarations of interest to report.

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Appendix 1 Real word stimuli pairs of minimal phonological difference

Distinctive feature	Stimulus A	Stimulus B
voicing	/ku 'bi/ *button*	/ku 'pi / *paddle*
	/'xomɐ/ *soil*	/'ɣomɐ/ *eraser*
place	/tɐ'ksi/ *taxi*	/tɐ'psi/ *pan*
	/'θici/ *case*	/'fici/ *seaweed*
	/jɐ'ʎɐ/ *glasses*	/jɐ'jɐ/ *grandmother*
	/kɐlɐ'mɐcɐ/ *straws*	/pɐlɐ'mɐcɐ/ *clapping*
	/'çɐri/ *hand*	/'çɐli/ *eel*
	/'ɲifi/[1] *bride*	/'ɲiçi/ *nail*
metathesis	/'ðrɐci/ *dragons*	/'ðɐkri/ *tear*
	/kɐ'vuri/ *crab*	/ku'vɐri/ *skein of thread*
Cluster reduction	/'sfikɐ/ *wasp*	/'sikɐ/ *figs*
	/'supɐ/ *soup*	/'skupɐ/ *broom*
	/'stomɐ/ *mouth*	/'somɐ/ *body*
	/'xomɐtɐ/ *soil*	/'xromɐtɐ/ *colours*
	/'ɣrɐfi/ *writing*	/'rɐfi/ *shelf*

Appendix 2 Nonword stimuli pairs matched to real words of minimal phonological difference

Distinctive feature	Stimulus A	Stimulus B
voicing	/cɛ'bi/	/cɛ'pi/
	/'xumɐ/	/'ɣumɐ/
place	/tɐ'kso/	/tɐ'pso/
	/'θɛci/	/'fɛci/
	/jɐ'ʎo/	/jɐ'jo/
	/kɐlɐ'mɛcɐ/	/pɐlɐ'mɛcɐ/
	/'çuri/	/'çuli/
	/'ɲɛfi/	/'ɲɛçi/
metathesis	/'ðroci/	/'ðokri/
	/rɐ'vuci/	/ru'vɐci/
Cluster reduction	/'sfɛkɐ/	/'sɛkɐ/
	/'sɐpɐ/	/'skɐpɐ/
	/'stɐmɐ/	/'sɐmɐ/
	/'xɐmɐtɐ/	/'xrɐmɐtɐ/
	/'ɣrufi/	/'rufi/

Appendix 3 Real word stimuli pairs of minimal morphological difference

Morphological function	Stimulus A	Stimulus B
Noun+Pronoun: masculine vs. Feminine	/zo'ɐci tis/ *her pet*	/zo'ɐci tu/ *His pet*
	/sɐ'ftin/ *to her*	/sɐ'fton/ *to him*
	/tonɐ'ftotu/ *himself*	/tonɐ'ftotis/ *herself*
Number: Singular vs. plural	/'ɣɐtɐ/ *Cat*	/'ɣɐtɛs/ *Cats*
	/mɐ'nɐviðɛs/ *grocery men*	/mɐ'nɐvis/ *grocery man*

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[1] The phoneme /n/ may be realized as [ɲ] in the dialectal speech of some speakers of Greek. For the present study the dialectic variant [ɲ] used in the area where data was collected was used.

Verb: 3rd person singular vs. plural	/zi'jizodɛ/ *they are weighted*	/zi'jizɛtɛ/ *it is weighted*
	/ɐgɐ'ʎɐzodɛ/ *are hugging*	/ɐgɐ'ʎɐzi/ *is hugging*
Tense:Present vs. future	/tɐ'izun/ *are feeding*	/tɐ'isun/ *will feed*
	/koli'bisun/ *will go swimming*	/koli'bun/ *are swimming*
	/'pɛzi/ *plays*	/'pɛksi/ *play*
	/'fɐi/ *Will eat*	/'ɛfɐɟɛ/ *ate*
	/ci'mɐtɛ/ *is sleeping*	/cimi'θi/ *to sleep*
Tense:Present vs.Past	/'ðini / *gives*	/'ɛðosɛ/ *gave*
	/'pɛtɐksɛ/ *flew*	/pɛ'tɐi/ *flies*
	/'vjicɛ/ *Got out*	/'vɟɛni/ *Gets out*

Appendix 4 Nonword stimuli pairs matched to real words of minimal morphological difference

Stimulus A	Stimulus B
/zo'ɛci tis/	/zo'ɛci tu/
/sɛo'ftin/	/sɛo'fton/
/tonɛɐ'ftɐtu/	/tonɛɐ'ftɐtis/
/'ɣotɐ/	/'ɣotɛs/
/mɐ'noviðɛs/	/mɐ'novis/
/zi'ɣɐzɛtɛ /	/zi'ɣɐzodɛ/
/ɐgɐ'ʎɛzodɛ/	/ɐgɐ'ʎɛzi/
/tɐ'ɛzun/	/tɐ'ɛsun/
/kɐli'bisun/	/kɐli'bun/
/'pɐzi/	/'pɐksi/
/'foi/	/'ɛfojɛ/
/ci'mɛtɛ/	/cimɛ'θi/
/'ðuni/	/'ɛðusɛ/
/'pɛtoksɛ/	/pɛ'toi/
/'vɟiku/	/'vɟenu/

Table 1 Performance accuracy for each age group at each assessment point for published language tasks and experimental tasks of speech processing

Task	Maximum Score	Group 1			Group 2		
		T1	T2	T3	T1	T2	T3
		3;0-3;5	3;6-4;0	4;0-4;5	4;6-5;0	5;0-5;5	5;6-6;0
		M (S.D)	M (S.D)	M (S.D)	M (S.D)	M (S.D)	M (S.D)
DVIQ P	24	8.19 (3.82)	10.81 (4.34)	15.11 (3.01)	11.31 (3.13)	15.91 (4.18)	16.16 (2.29)
DVIQ C	31	14.95 (3.15)	18.93 (3.33)	21.02 (3.61)	19.52 (5.02)	24.82 (2.89)	26.02 (2.23)
DVIQ SR	48	29.31 (12.51)	42.52 (4.81)	45.75 (2.32)	43.21 (5.41)	45.93 (2.71)	45.21 (5.09)
RWAudDPhon	30	19.06 (4.86)	21.81 (4.15)	24.86 (2.47)	23.90 (3.99)	25.47 (1.90)	27.39 (1.94)
RWAudDMor	30	19.18 (3.70)	22.06 (3.73)	26.31 (2.91)	24.72 (3.99)	26.31 (3.63)	27.44 (2.87)
NWAudDPhon	30	18.56 (3.98)	19.18 (2.66)	23.50 (3.27)	22.54 (3.75)	25.84 (2.95)	26.05 (2.75)
NWAudDMor	30	19.81 (3.45)	21.63 (3.81)	25.88 (3.07)	25.55 (3.75)	27.57 (2.11)	28.00 (2.00)
RWRepPhonWW	30	17.38 (7.77)	20.69 (7.11)	24.60 (5.95)	22.50 (6.49)	26.79 (5.11)	27.00 (3.66)
RWRepMorWW	30	16.50 (7.64)	20.88 (9.07)	22.93 (8.19)	22.73 (5.73)	25.89 (7.32)	26.11 (5.95)
RWRepPhonPCC	100%	79.63 (16.52)	86.61 (12.85)	92.47 (9.21)	92.40 (8.17)	95.83 (6.84)	96.10 (4.76)
RWRepMorPCC	100%	84.40 (15.20)	90.79 (10.51)	93.23 (8.57)	96.04 (7.65)	96.02 (7.82)	96.48 (5.60)
NWRepPhonWW	30	16.19 (7.54)	19.75 (7.13)	22.53 (5.94)	23.80 (5.46)	25.30 (5.19)	25.67 (4.46)
NWRepMorWW	30	14.75 (7.34)	16.69 (7.74)	21.73 (7.96)	23.47 (7.97)	24.00 (7.12)	24.37 (6.44)
NWRepPhonPCC	100%	77.68 (15.84)	84.17 (15.08)	89.44 (9.12)	90.94 (8.48)	94.05 (6.93)	95.08 (4.85)
NWRepMorPCC	100%	77.23 (17.30)	86.57 (12.56)	89.44 (11.47)	92.29 (11.31)	92.92 (10.62)	92.85 (8.61)

Notes: DVIQ=Diagnostic Verbal IQ Test (Stavrakaki & Tsimpli, 2000), P=Production, C=Comprehension, SR= Sentence Repetition, RW= Real Word, NW=Nonword, AudD=Auditory Discrimination, Rep=Repetition, Phon=Phonological, Mor=Morphological, WW=accuracy of the whole word, PCC=Percentage of Consonants Correct

Table 2 Statistically significant differences in performance accuracy between time points for each age group for published language tasks and experimental tasks of speech processing

Task	Group 1			Group 2		
	T1 vs T2 p values	T2 vs T3 p values	T1 vs T3 p values	T1 vs T2 p values	T2 vs T3 p values	T1 vs T3 p values
DVIQ P	0.018	<0.001	<0.001	0.001		<0.001
DVIQ C	0.002		<0.001	0.002		<0.001
DVIQ SR	<0.001	0.015	<0.001	0.022		
RWAudDPhon		<0.001	<0.001		0.006	<0.001
RWAudDMor	0.012	0.001	<0.001			0.009
NWAudDPhon		0.008	0.003	0.005		<0.001
NWAudDMor		0.003	<0.001			0.016
RWRepPhonWW	0.019	0.019	<0.001			0.041
RWRepMorWW	0.021		0.003			
RWRepPhonPCC	0.009	0.021	<0.001	0.028		0.004
RWRepMorPCC	0.005		0.004			
NWRepPhonWW	0.005	0.027	0.001			
NWRepMorWW	<0.001		<0.001			
NWRepPhonPCC	0.005	0.045	0.001	0.007		0.026
NWRepMorPCC	0.001	0.021	0.001	0.019		

Notes: DVIQ=Diagnostic Verbal IQ Test (Stavrakaki & Tsimpli, 2000), P=Production, C=Comprehension, SR= Sentence Repetition, RW= Real Word, NW=Nonword, AudD=Auditory Discrimination, Rep=Repetition, Phon=Phonological, Mor=Morphological, WW=accuracy of the whole word, PCC=Percentage of Consonants Correct

Only statistically significant group differences are presented

Table 3 Correlations between performance on phonological and morphological items in real word auditory discrimination tasks for Group 1

	T1RWAudD Phon	T2RWAudD Phon	T3RWAudD Phon	T1RWAudD Mor	T2RWAudD Mor	T3RWAudD Mor
T1RWAudDPhon						
T2RWAudDPhon	0.608**					
T3RWAudDPhon	0.336	0.819**				
T1RWAudDMor	0.358	0.249	0.253			
T2RWAudDMor	0.341	0.616**	0.669**	0.274		
T3RWAudDMor	0.135	0.551**	0.682**	0.450	0.390	
**. Correlation is significant at p< 0.05						
Notes RWAudD = Real Word Auditory Discrimination, Phon=Phonological, Mor=Morphological						

Table 4 Correlations between performance on phonological and morphological items in real word auditory discrimination tasks for Group 2

	T1RWAudD Phon	T2RWAudD Phon	T3RWAudD Phon	T1RWAudD Mor	T2RWAudD Mor	T3RWAudD Mor
T1RWAudDPhon						
T2RWAudDPhon	-0.133					
T3RWAudDPhon	0.696**	0.191				
T1RWAudDMor	0.547**	0.356	0.676**			
T2RWAudDMor	-0.146	0.154	-0.008	0.088		
T3RWAudDMor	0.343	-0.163	0.525**	0.546**	0.043	
**. Correlation is significant at p< 0.05						
Notes RWAudD = Real Word Auditory Discrimination, Phon=Phonological, Mor=Morphological						

Table 5 Correlations between performance on phonological and morphological items in real word repetition tasks for Group 1

	T1RWRep Phon	T2RWRep Phon	T3RWRep Phon	T1RWRep Mor	T2RWRep Mor	T3RWRep Mor
T1RWRepPhon						
T2RWRepPhon	0.843*					
T3RWRepPhon	0.756*	0.800*				
T1RWRepMor	0.807*	0.815*	0.583**			
T2RWRepMor	0.726*	0.853*	0.763*	0.642*		
T3RWRepMor	0.759*	0.833*	0.822*	0.656*	0.952*	

*. Correlation is significant at the 0.01 level (2-tailed).
**. Correlation is significant at $p< 0.05$

Notes RWRep = Real Word Repetition, Phon=Phonological, Mor=Morphological

Table 6 Correlations between performance on phonological and morphological items in real word repetition tasks for Group 2

	T1RWRep Phon	T2RWRep Phon	T3RWRep Phon	T1RWRep Mor	T2RWRep Mor	T3RWRep Mor
T1RWRepPhon						
T2RWRepPhon	0.292					
T3RWRepPhon	0.259	0.854*				
T1RWRepMor	0.731*	0.226	0.295			
T2RWRepMor	0.309	0.902*	0.683*	0.143		
T3RWRepMor	0.373	0.881*	0.864*	0.298	0.889*	

*. Correlation is significant at the 0.01 level (2-tailed).
**. Correlation is significant at $p< 0.05$

Notes RWRep = Real Word Repetition, Phon=Phonological, Mor=Morphological

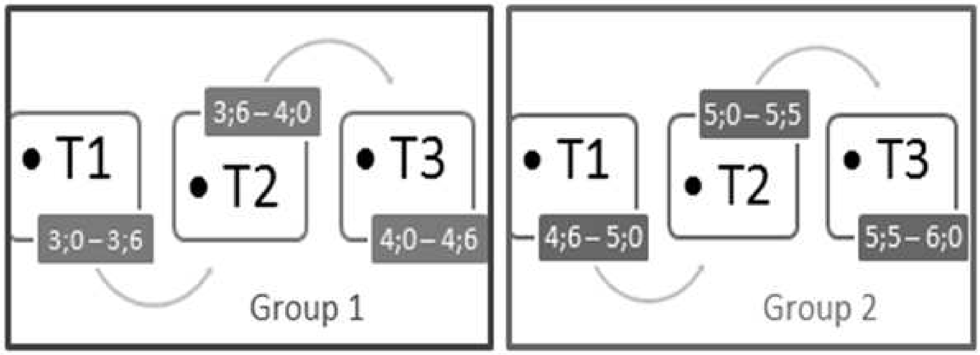

Figure 1 Schematic representation of the time points and the age of the children in each group during data collection used for comparison of assessment performance in each task

160x61mm (96 x 96 DPI)

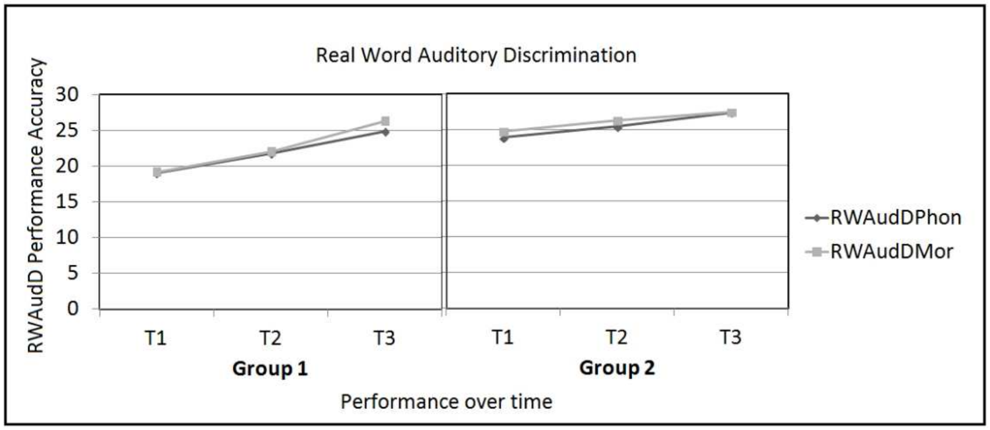

Figure 2 Comparison of real word auditory discrimination performance between domains

310x140mm (96 x 96 DPI)

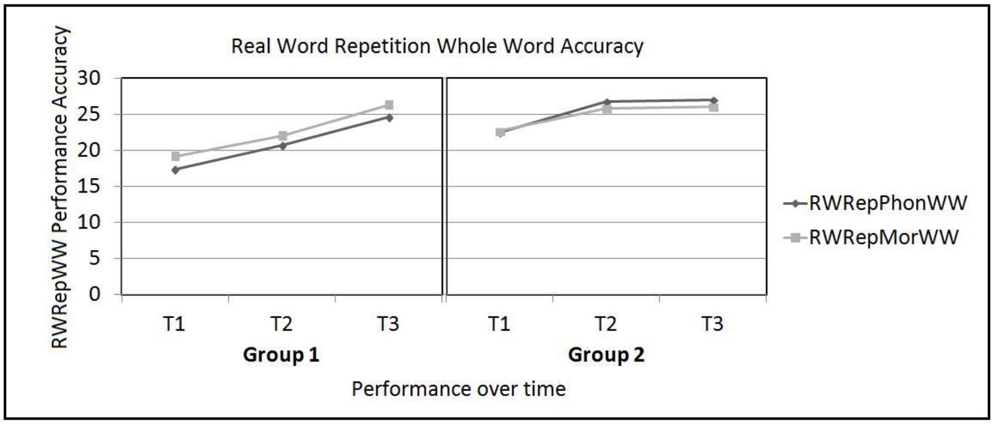

Figure 3 Comparison of real word repetition performance between domains (whole word accuracy)

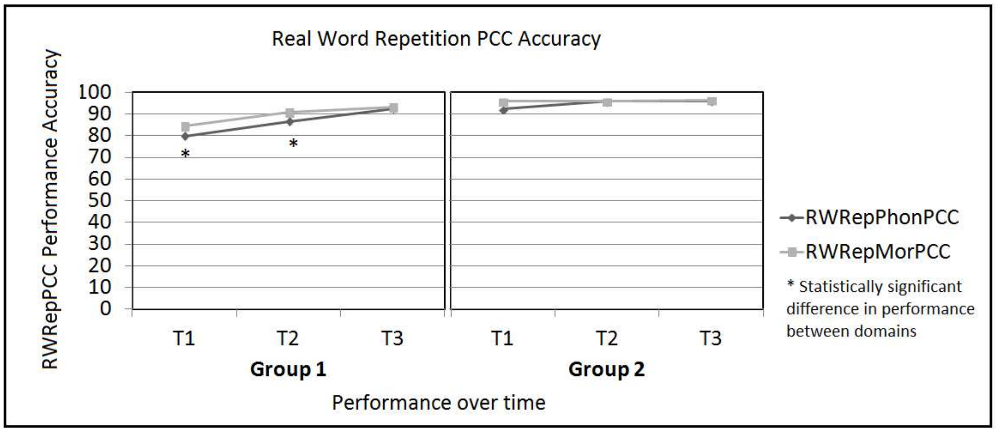

Figure 4 Comparison of real word repetition performance between domains (Percentage of Consonants Correct accuracy)

308x136mm (96 x 96 DPI)

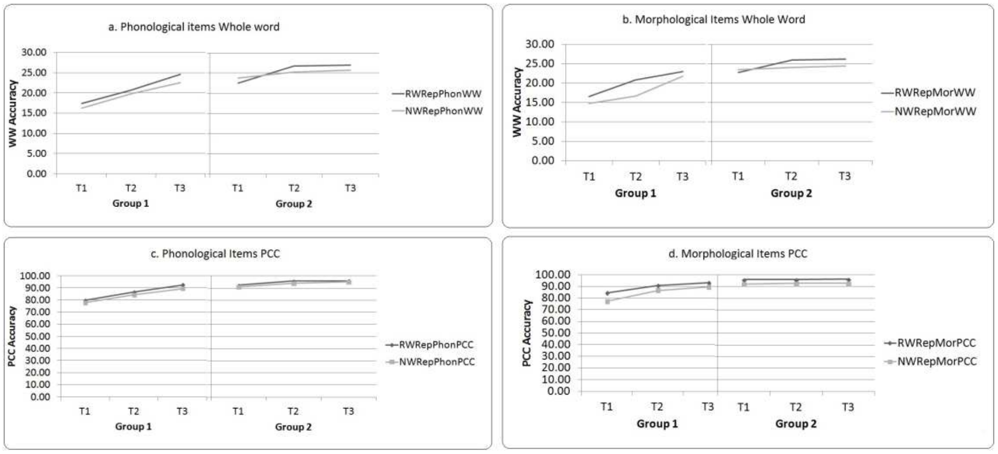

Figure 5 Comparison of repetition performance between levels of processing