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THE ROLE OF PHONOLOGICAL SKILLS IN NONWORD REPETITION AND READING TASKS IN CHILDREN DIAGNOSED WITH DEVELOPMENTAL LEARNING DISORDERS

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ABSTRACT

Phonological processing is the skill used to attach meaning to sounds. It is part of the fundamental tools integrated when using spoken or written communicative forms. Another integral subcategory of phonological processing is phonemic awareness. This skill is used when manipulating phonemes in spoken words and attaching meaning to them. In turn, mastering this skill is what allows us to generalize this skill into literacy. These are important skills that children develop and utilize as they learn to read, write, and spell. Traditional assessments that evaluate phonemic awareness and phonological skills include nonword repetition and nonword reading tasks. Twelve children between the ages of 8;2 and 11;1 years old with no neurodevelopmental disorders participated in this study. The parents of two children reported they struggled with reading and one participant received speech therapy for articulation from a Speech-Language Pathologist. The tests were administered online through Zoom. Tests included were the Rapid Automatized Naming (RAN), Test of Nonverbal Intelligence-4 (TONI-4), subtests of the Test of Integrated Language & Literacy Skills (TILLS), and Test of Phonological Structure (ToPhS). Three questions that we aim to answer is: 1) Are there correlations among RAN, ToPhS, Nonword Repetition, and Phonemic Awareness and is there a correlation between RAN, ToPhS, Nonword Repetition, and Nonword Reading? 2) Can a child's performance on the NonWord Reading subtest of the TILLS be predicted by the ToPhS, RAN, and Nonword Repetition subtest of the TILLS? 3) Can a child's performance on the Phonemic Awareness subtest of the TILLS be predicted by the ToPhS, NonWord Repetition subtest of the TILLS, and RAN? The results from this study demonstrated that there was a statistically significant correlation between Nonword Reading and ToPhS and a small significant correlation between Nonword Reading and RAN (sum of subtests Colors and Objects). There was no correlation with

Phonemic Awareness and the other tests administered. To obtain regressions with a small sample size, some scores had to be transformed. This is an exploratory study and to analyze the data, we used scaled scores for NWRead, NWRep, RAN. For ToPhS scores an arcsin transformation was applied to approximate a normal distribution. Scores for PA were transformed using a Box-Cox transformation. We acknowledge that a sample size of 12 is small for regression analysis. Since this is an exploratory study, we decided to continue with the analysis and interpreted the results with caution. The results yielded provide future directions that we can take to further explore the predictive value of these tasks for phonological processing.

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Para mis padres y amigos:

No pude creer que esta oportunidad de estudiar en una universidad con prestigio y con profesores sabios llegaría a mi vida. Yo sé que tuve que tomar esta oportunidad para explorar todo lo que el mundo ofrece. Mis padres vinieron a este país para dar mis hermanos y yo las oportunidades que no tenían en su patria. Dejaron atrás familia, amigos, costumbres, y una humilde vida sabiendo que los obstáculos que les esperaban en los EE. UU. lo iban a superar porque tenían fe. Sus esfuerzos en asegurarse que sus hijos tenían todo lo que necesitaban para salir adelante en su educación fue mi inspiración a tomar esta oportunidad de estudiar en un lugar lejos de casa. Era un testamento de la fe que mis padres me dieron para avanzar mi vida y les quise mostrar que su Karencita estaba creciendo. Fue muy difícil para todos, pero yo sé que tome la decisión correcta y espero que mis experiencias sean admiradas por mi familia, mi gente, y mis futuros hijos. Gracias, papá, mamá, mi familia, y todos mis amigos por apoyarme en un embarco que no pude lograr sin ustedes.

Chapter 1
Introduction

The purpose of this study is to investigate the relationship between scores on standardized tests of language and reading and a child's phonological processing skills. Within phonological processing is phonological awareness which is categorized as the ability to identify, manipulate, and process phonemic units auditorily or orally (Milankov et al., 2021), phonological working memory, and phonological retrieval (Wagner & Torgesen, 1987). Phonological awareness is a pertinent part of reading and literacy (Milankov et al., 2021). Phonological working memory is an area in the brain that is used to store information about sounds. This is especially used when children learn to read and spell. Typically developing children use phonological processing skills when they are beginning to develop their reading and literacy skills. When learning to read, children must be able to use phonological retrieval skills such as accurately segmenting, retrieving, and recognizing graphemes (letters) and phonemes (sounds) to process the word. These skills are strengthened as children continue to be exposed to new words through reading or conversational opportunities.

The use of nonword reading tasks is a way to assess a child's phonological processing skills. Nonwords are words that do not exist and carry no meaning in the child's language (i.e., a nonword in English would be "plick"). Nonwords are used to assess a child's ability to decode (apply letter/sound knowledge) and use phonological processing skills to read novel words that the child has not been exposed to, according to the grapheme-phoneme correspondence rules of their language. Language and reading disorders are related to phonological processing abilities because of the breakdown children experience at the phonological level and its effect on learning

new words using foundational reading skills. Children that begin to exhibit a reading disorder will most likely have a breakdown in phonological awareness (Share, 2011).

Researchers have used nonword repetition tasks to determine phonological processing skills for individuals that have developmental language disorder (DLD) or other reading and learning disorders. Nonword repetition tasks require the child to listen to a nonword through audio recording or live presentation from the clinician and then repeat the word that was spoken/heard. Another key component used during nonword repetition tasks is the child's phonological working memory which is where phonemic information is stored for sound manipulation (Wagner & Torgesen, 1987). A developmental language disorder is defined as having difficulty using and processing language while a developmental speech sound disorder (SSD) is characterized by difficulty producing the speech sounds of the first language. For children with these disorders, tasks like nonword repetition prove to be difficult because they have poor phonological processing abilities, which can include phonemic awareness, phonological awareness (Metsala, 1999) and phonological working memory. Essentially, this can be studied through various modes including brain imaging studies, both invasive and noninvasive.

Studies of brain activity associated with nonword repetition tasks are consistent with the behavioral differences observed in children with speech and language disorders such as the inability to repeat nonwords. The brain activity of someone that is completing a nonword repetition task shows reduced brain activity in the inferior frontal and posterior temporal region. Children that have DLD have mostly left lateral cortical and motor area activation whereas typically developing children have brain activation in the bilateral posterior temporal cortices (posterior superior temporal gyrus/sulcus), the left tempo-parietal junction, bilateral frontal

regions (anterior insula/inferior frontal gyrus, ventral motor cortex supplementary motor area), bilateral thalamus (although much reduced in the typically developing children in the control group), and the cingulate gyrus (Pigdon et al., 2020). Typically developing children showed brain activation that was consistent with previous studies that involved nonword repetition tasks with typically developing adult participants using fMRI.

Further differences that demonstrate a typically developing individual's processing of nonwords were observed in a study by Perrachione et al. (2017) on typically developing adults with no learning or reading disorders. In this study, they observed increased bilateral brain activation in the superior temporal gyrus, inferior frontal gyrus, and supplementary motor area as participants required the use of their phonological working memory. Activation in the left superior temporal gyrus was reported during the nonword task. Results from this study provide insight on the areas of brain activation that are typically used during word repetition and nonword repetition tasks. We know from previous studies that reading disorders such as dyslexia stem from difficulty with phonological processing. The results of this study are enlightening with regards to the importance of phonological awareness and its benefit for nonword repetition tasks.

Children diagnosed with reading/learning disorders or language disorders may have difficulty learning new information because of poor phonological processing. This leads to delays in academic settings and an inability to adequately translate their phonological processing skills to reading, writing, and spelling. Dyslexia is a neurodevelopmental disorder defined as "difficulty in learning to decode and spell" (Snowling et al, 2020). Decoding is known as the ability to make letter-sound correspondence and correctly pronounce written words. Dyslexia is often exhibited as having trouble reading new words and applying the grapheme-phoneme correspondence rules of English to them. The 'triangle model,' as suggested by Mark Seidenberg

and James McClelland, includes semantic, phonological, and orthographic units as key elements that help with word recognition (Snowling et al., 2020). DLD (also known as specific language impairment, or SLI) occurs in the early stages of word learning, syntax and vocabulary. Phonological information is also processed differently, and breakdowns in encoding new words into the phonological loop are characteristic of DLD (Woods et al., 2014).

Children with DLD often have small vocabularies for their age (Leonard, 2014), and vocabulary size is related to nonword repetition abilities. Typically developing children with larger vocabulary size, in comparison with their peers, with smaller vocabulary size, were more accurate in low-frequency sequences of nonwords (Edwards et al., 2004). A theory as to why children with low vocabulary were less accurate could be their inability to properly store sounds in their phonological working memory. This creates a cycle of poor word decoding because of phonological deficits. As a result of poor decoding children have difficulty storing sounds in their phonological working memory.

For children that have DLD, their inability to properly manipulate phonological sounds affects their ability to apply foundational skills for nonword repetition tasks. In an article by de Bree et al., (2007), they found that children with DLD performed far more poorly because of their phonological processing skills. Children with DLD experience the same phonological processing deficit as their peers with dyslexia, however, children with DLD have other cognitive deficits. In the same study, de Bree et al., (2007) found that Dutch children with dyslexia demonstrated a better Percent Phoneme Correct (PPC) than their DLD peers. Children with dyslexia began to decrease in accuracy at the five syllable nonword length whereas children with DLD began to decrease at the four syllable nonword level. In the follow-up study by de Bree et. al., (2010) the differences demonstrated by both groups suggests that these learning disorders

should not be grouped together and should be treated individually. Their similarity in poor performance on nonword repetition tasks should not dictate the differences that they can exhibit in academic settings and in learning words.

Previous studies have established the correlation between phonemic awareness and nonword repetition abilities. Sutherland & Gillon (2005) reported in a study on preschoolers with moderate-severe speech impairment and their difficulty learning nonwords compared to children without speech impairments. They also found that performance on the nonword repetition task had some correlation with phonemic awareness. The ToPhS is another test that aims to find how accurate children with language disorders are on nonword repetition tasks. We will use this as an independent variable, predictor, of phonemic awareness because of the phonemic awareness skills necessary for decoding nonwords. The difference between ToPhS and other nonword repetition tasks is that the nonwords vary in five different parameters with syllabic onset, rhyme, word-end, and unfooted syllable in the left or right position as opposed to having one metric (i.e., follows English phonology and morphology). Gallon et al. (2007) found that children's accuracy on ToPhS decreased as the nonwords' phonological complexity increased. Phonological complexity is defined as the syllabic and stress pattern of a word.

Measuring skills related to phonological processing

In this study, to evaluate ways to measure phonological processing skills we used standardized assessments and experimental tasks. The standardized assessments that this study will focus on are the Test of Integrated Language and Literacy Skills (TILLS) and the Rapid Automatized Naming test (RAN). The TILLS includes nonword and phonemic awareness tasks

that will allow us to examine the associations between nonword repetition and phonemic awareness skills. The RAN provides a measure of phonological processing that is predictive of reading abilities but has not previously been investigated with relation to nonword repetition. The means through which this study was provided allowed us to use the TELE-TILLS; this was a modified version of the TILLS made for administration through remote access due to the COVID-19 pandemic.

The TILLS is a standardized test that was developed for assessing the language and literacy skills for school-aged children and adolescents (Mailend et al., 2016). The TILLS assesses two language levels which are sound/word level and sentence/discourse level. Additionally, the four modalities are listening, speaking, reading, and writing. The three subtests that were selected for the present study were: Phonemic Awareness (PA), Nonword Repetition (NWRep), and Nonword Reading (NWRead). Phonemic awareness can be measured in different ways. Of the three subtests in the TILLS, we will be using PA and NWRead as the dependent variables because of the crucial component of phonemic awareness in decoding abilities.

The Phonemic Awareness subtest is used to assess a child's phonemic awareness skills for nonwords. It is important to use nonwords to determine the student's ability to apply the phonemic rules of English to forms they have not previously encountered. A typical phonemic awareness task asks students to manipulate sounds within a word. In this subtest, the student heard a nonword given by the examiner and was asked to repeat the word without the first sound. The student is holding the nonword within their short-term memory and isolating the initial sound then producing the nonword without the initial sound. This task can be difficult for students that have poor phonological processing skills and may incorrectly produce the nonword.

A practice item on the PA subtest is “stam.” Children may remove the initial consonant cluster instead of removing the initial consonant.

The Nonword Reading (NWRead) subtest required students to read nonwords presented on a PowerPoint and screen shared through Zoom. The nonwords presented increased in difficulty and number of syllables. The items in the NWRead includes some identical items from the NWRep subtest. Some transfer between subtests could influence student’s score because of familiarity.

In the NonWord Repetition (NWRep) task, students heard a prerecorded audio of the nonwords and were asked to repeat them. These nonwords followed the morphological and phonological structures of typical English words. The NWRep will be used as an independent variable, predictor, of phonemic awareness. It should be noted that unlike the nonwords in the ToPhS, the nonwords used in the subtests of the TILLS followed English morphological and phonological structures. For example, words presented in the subtests had English morphological endings like “-ology” or “-cian,” that we see at the end of words like “biology” or “clinician.” The phonological structures observed in these subtests also followed English word structures including consonant cluster beginnings and endings (i.e., “glenders” or “rask”).

The RAN is another test that integrates phonological processing skills in addition to other components that are important in reading skills that can be used as a predictor of reading abilities in children (Manis, et al., 1999). The two subtests of the RAN that we used in this study are Objects and Colors. In these subtests, the participant is asked to quickly name the objects on the stimulus book, presented in a grid, and asked to do the same for the colors task. The RAN has been previously used as a predictor of future reading abilities for children because it is displayed similar to the structure of typical book reading (Cummine et al., 2015). The visual stimuli

presented are pretested for familiarity and it is presumed this test measures the ability for word retrieval and production in the phonological form. The RAN is another independent variable that will be used to determine if success in phonological awareness measured by the RAN is similar to those measured by Nonword Repetition tasks or if there will be a difference in information about phonological awareness. Although the RAN was found to be independent of phonemic awareness in Stappen and Reybroeck (2018), they each contribute to literacy acquisition respectively.

The Test of Phonological Structure (ToPhS) is another nonword repetition task. A notable difference from the nonwords in the TILLS, is its structure. It focused on English word structure and prosodic complexity (syllabic and metrical stress) structure rather than phonological complexity. The ToPhS was administered through an audio recording suitable for presentation through Zoom. A research assistant in this study recorded the words and maintained the prosodic constituents for each nonword. An example of a nonword in the ToPhS task is "bədrɛ́mpəri." Upon reading these nonwords before recording, the complexity of the structure made us believe it would be difficult for children to reproduce.

The Test of Nonverbal Intelligence 4 (TONI-4) was also administered to the participants. The TONI-4 is an assessment that determines the individual's problem-solving skills without the requirement of language (Ritter, Navruz, & Bae, 2011). It removes cultural boundaries that some standardized tests have and instead requires individuals to figure out the patterns within a given stimuli. The TONI-4 was used as a cognitive measure in our study to determine the ability of the student's intellectual abilities independent of language. It is not predicted that it the TONI-4 will have correlations with phonemic awareness; therefore, it provides a way to confirm the specificity of the associations among the independent and dependent variables.

Table 1. Description of Tests Used in the Present Study

Test	Subtest	Acronym	Description
Test of Integrated Learning and Literacy Skills (TILLS)	• Nonword Reading	• NWRead	The TILLS assesses the skills necessary for language and literacy. The subtests targeted in this study assess the participant's ability to decode novel words, their speech perception and ability to reproduce novel words, and their awareness of individual phonemes.
	• Nonword Repetition	• NWRep	
	• Phonemic Awareness	• PA	
Rapid Automatized Naming (RAN)	• Colors • Objects		The RAN assesses the participants ability to effortlessly retrieve information in an automatic manner. The subtests utilized for this study had the participants name colors and objects (dog, book, star, hand,)
Test of Phonological Structure (ToPhS)	---		The ToPhS is a task used in an experimental study to assess a child's ability to repeat nonwords of varying prosodic complexity.

The Present Study

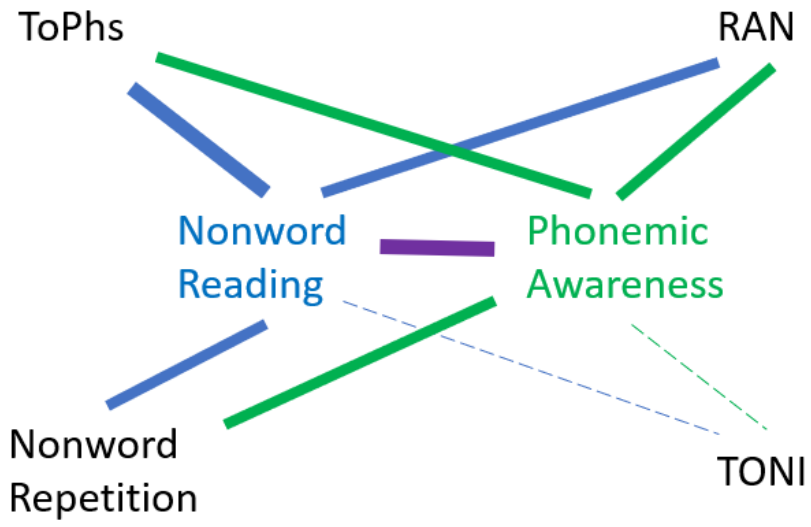
With the previous research setting the foundation for the impact phonological processing skills like phonemic awareness haves on reading and comprehension, we intend to examine the relationship between A) the student's score on the phonemic awareness and nonword reading subtests from the TILLS, and B) nonword repetition as measured by TILLS and ToPhS, as well as RAN performance.

This investigation aims to answer the following questions: 1) Are there correlations among PA, NWRead, RAN, ToPhS, and NWRep? 2) Can a child's performance on the

NonWord Reading subtest of the TILLS be predicted by the ToPhS, RAN, and Nonword Repetition subtest of the TILLS? 3) Can a child's performance on the Phonemic Awareness subtest of the TILLS be predicted by the Test of Phonological Structure (ToPhS), NonWord Repetition subtest of the TILLS, and Rapid Automatized Naming (RAN)? We predict that PA is associated with the NWRep, RAN, and ToPhS, and that NWRead is associated with NWRep, ToPhS, and RAN. We predict there would be little to no relationship between each of the two dependent variables, nonword reading, phonemic awareness, and the TONI. Figure 1, shown below, depicts our hypotheses regarding the correlations among assessments.

Figure 1.

Hypotheses regarding correlations among assessments



Note. Dependent variables are Nonword Reading and Phonemic Awareness. *Dashed lines signify a small or nonexistent correlation. A solid thin line signifies some correlation, and a bold thick line signifies a strong correlation.*

Our prediction is that there will be strong correlations among PA, NWRead, RAN, NWRep, and ToPhS. This is depicted in the figure above as bold lines. Based on previous research, we know that a correlation between nonword reading tasks and phonemic awareness exists. The correlations of NWRead and PA with TONI-4 are predicted to have little to no reliability and a dashed line is depicted in the figure. This is because the TONI-4 assess the participant's intelligence and reasoning skills through nonlinguistic stimuli.

Methods

Participants

We enrolled 12 participants for this study. The age requirement was 8-11 years old with the youngest being 8;2 ranging to 11;1 (mean 9;5). Five males and 7 females were recruited. All participants were non-Hispanic, one was Black, and the remaining participants were White or White/Asian. Participants were recruited using the First Families database and the PACT database; these are databases managed by Pennsylvania State University entities, listing families who have indicated willingness to participate in research. Parents were contacted and asked a series of questions to determine eligibility and provide consent. Once parents agreed, the child participant was asked to provide assent to participate in the study. Information from the parent report stated that no child had atypical hearing, no history of ADHD, Autism Spectrum Disorder, or any other neurological disorder. Two children received support for reading and one other child had an IEP for articulation goals in preschool and kindergarten.

Procedures

A parent questionnaire collected information about race, ethnicity, academic experience, and history of speech, language, and reading problems (if any). Once participants were deemed eligible to participate in the research, they were scheduled to participate in two sessions through Zoom. Participation through Zoom requires a stable internet connection and access to Zoom annotations (Stamp feature) in substitution for the student's typical in-person response. In the first session, the graduate student researcher administered the standardized assessments: TONI-4, TILLS, RAN, and ToPhS. On the second session the graduate student researcher administered a verbal fluency task and four other online tasks through Gorilla, an experiment platform, that includes tasks like inhibitory control, word monitoring, and processing speeds. The present study focused on the TILLS, RAN, and ToPhS assessments completed in the first session.

Materials

Test of Phonological Structure (ToPhS)

The ToPhS was developed as a nonword task that assessed the ability of grammatically impaired children with specific language impairment (SLI) to repeat nonwords based on the prosodic complexity of the word. This task focused on the prosodic complexity of words. For example, difficulty of nonwords was based on the position of stress, initial consonant presence, final vowel presence, and consonant presence on the rime. Scores are derived by computing the percent phonemes correct for words at four levels of complexity.

Rapid Automatized Naming (RAN)

Two subtests of the RAN were used for this study: Objects and Colors. The graduate student researcher dictated the instructions based on the manual and the participant named objects or colors as fast as they could. There were five rows of 10 stimuli. The student was asked to name the colors or objects, moving across each row from left to right until they reached the last stimulus. The colors were red, green, black, yellow, and blue. The objects were, dog, chair, hand, star, and book. Scaled scores are derived according to the instructions in the manual based on the time required to name all items. In addition, the number of errors and self-corrections may be considered. The "sum of RAN" includes the total score from the subtests used in the study (Objects and Colors) to create one variable.

Test of Integrated Language and Literacy Skills (TILLS)

The TILLS is a standardized test that is often used to assess school-age children's language- literacy skills at the sound/word level and sentence/discourse level. While taking the test, students were asked to listen, give an oral response, or read. The three subtests we focused on were Phonemic Awareness (PA), Nonword Repetition (NWRep), and Nonword Reading (NWRead). Each of these subtests were administered based on the instructions in the manual and practice items were administered to ensure the student understood the instructions. In the Phonemic Awareness subtest, the student listened to nonwords and was asked to repeat them without the initial consonant. In the Nonword Repetition task, the student listened to an audio of prerecorded nonwords and was asked to repeat them. In the Nonword Reading subtest, the

student was asked to read nonwords presented to them virtually through Zoom's share screen feature. Scaled scores are derived according to instructions in the manual.

This thesis is part of a larger grant-funded study within the Pennsylvania State University Communication Sciences and Disorders Department as well as the Psychology Department. Additionally, other tasks in the study were not expected to predict the use of phonemic awareness and were not included in the study. These tasks included a processing speed task titled Modality Shift, where the participants were presented with audio and visual information and asked to respond when either stimulus was presented (Williams, et al., 2013). An inhibitory control task presented as the Stop Signal task was also not indicative of phonemic awareness as this was not a measure of language. A word monitoring task was also implemented in the experiment, but a study by Montgomery (2006) found that children with SLI had trouble processing the language in word monitoring tasks due to "inefficient higher-order linguistic processing operations" (Montgomery, 2006) and not phonetic abilities.

Results

Means and standard deviation of the variables used in the analyses are reported in Table 2. The means and standard deviations reported for ToPhS and PA are for untransformed data, so that the numbers reported in the table reflect the score the child received on the test. The score for RAN Colors subtest and RAN Objects subtest were separated and a mean was determined for each.

Table 2. Descriptive Statistics of Assessments

Assessments	*M*	*SD*
TONI-4	105.08	12.35
RAN (Objects)	96.00	16.62
RAN (Colors)	97.17	20.85
PA	8.36	3.33
NWRep	8.75	3.36
NWRead	8.25	2.14
ToPhS	0.8383	0.17

To address our prediction of the correlation between PA and TONI as well as Nonword Reading and TONI, we ran a nonparametric correlation. Given the sample size of this study, we were able to yield some interesting preliminary results. As part of our analysis, we decided to run a nonparametric correlation. These tests are used when data is not distributed normally and/or the sample size is small.

To address our hypothesis of the non-significant correlation between PA and NWRead, a spearman correlation was used. Table 1 shows the correlations between TONI and NWRead, NWRep, ToPhS, respectively. There were negative non-significant correlations between the TONI and PA scores. There were positive non-significant results between TONI and NWRead, NWRep, and ToPhS, respectively. This is what we expected since the TONI is a measure of intellectual ability rather than an assessment that evaluates phonological skills. The language measures should be largely independent of nonverbal cognitive ability.

Table 3. TONI-4 Correlation

Assessments	TONI
TONI	--
PA	-0.123
NWRead	0.399
NWRep	0.343
ToPhS	0.278

To address our first question: Is there a correlation between RAN, ToPhS, Nonword Repetition with phonemic awareness and is there a correlation between RAN, ToPhS, Nonword Repetition with nonword reading, a continued analysis of the tables resulted in the following: Table 4. indicated there was no significant correlation for phonemic awareness with NWRead. There was a small and nonsignificant correlation with the NWRep and RAN. However, former studies have shown there to be little to no evidence with correlation between RAN and nonword repetition tasks. One thing to note from the results is that there was a nonexistent correlation between PA and NWRead which is remarkable considering that phonemic awareness is often used to decode words and nonwords.

Table 4. Spearman Correlation for all Assessments

Assessments	PA	NWRead	NWRep	ToPhS
PA	--	--	--	--
NWRead	-0.090	--	--	--
NWRep	0.377	0.168	--	--
ToPhS	0.107	0.590*	0.208	--
RAN Objects	-0.191	0.588*	0.004	0.166
RAN Colors	-0.068	0.623*	0.089	0.195
Sum of RAN	-0.148	0.634*	0.018	0.150

*. Correlation is significant at the 0.05 level (2-tailed).

To address the second question, a regression model was used to determine the correlation between the dependent and independent variables. The results for NWReading shown below (Table 3) with predictors as NWRep, ToPhS and RAN, only resulted in significance for ToPhS ($R = .610$, $R^2 = 0.36$, $p = 0.050$). The results from this analysis depict two different nonwords having some correlation with NWReading. This could be a result of the small sample size or an indication of skills with nonwords with similar English morphology transferring to nonwords with no English morphology attached. It should be noted that the nonwords in the NWRep and NWReading subtests contain a majority of words that are the same. The results shown describe the opposite, demonstrating that there could be more to skills required to complete the task. An ANOVA was conducted to show the prediction of NWRead with NWRep, ToPhS, and RAN. The result show there was marginal contribution from these variables for NWRead [$F (3, 11) = 3.996$, $p = .052$)] and reached significance.

Table 5. NWReading Regression Table

	R^2	R^2 change	F Change	p
NWRep	0.015	0.015	0.155	0.702
ToPhS	0.372	0.357	5.111	0.050
Sum of RAN	0.600	0.228	4.554	0.065

To continue to address the third question, a regression model was used. The results for PA (Table 4) demonstrate no significance for NWRep, ToPhS, or RAN. The results for NWRep ($R = .112$, $R^2 = 0.013$, sigf$\Delta = 0.758$), ToPhS ($R = .270$, $R^2 = 0.073$, sigf$\Delta = 0.521$), RAN ($R = .398$, $R^2 = 0.158$, sigf$\Delta = 0.466$). The R^2 is small and did not reach significance for either

assessment. The result of this analysis shows contradicting results compared to the previous results from research showing the correlation between phonemic awareness and nonword repetition tasks. The ToPhS also uses phonological complexity in the nonword tasks, however, this was not reflected in the results. The RAN is supposed to demonstrate the phonological processing with respect to reading abilities but did not have an impact in this investigation. This could be due to the small sample size (n = 12) and future investigations could provide more information with a larger sample size. An ANOVA was conducted to compare the impact of phonemic awareness with NWRep, ToPhS, and RAN. The result show there was no contribution from these variables for phonemic awareness [F (3, 9) = 0.376, p = .774)] and did not reach significance.

Table 6. PA Regression Table

	R^2	R^2 change	F change	p
NWRep	0.013	0.013	0.101	0.758
ToPhS	0.073	0.060	0.456	0.521
Sum of RAN	0.158	0.085	0.607	0.466

Discussion

The results from this investigation will answer the three main questions that were presented earlier. The first question we aimed to answer is if there are correlations among RAN, ToPhS, NWRep, PA, and NWRead. The results indicated that RAN and ToPhS were significantly correlated with NWRead. However, in the regression analysis, neither RAN nor Nonword Repetition significantly predicted Nonword Reading. There was, however, a marginal association

for ToPhS and Nonword Reading. This brings us to the conclusion that the phonological skills used in ToPhS translates to the phonological skills used in nonword reading. It is important to note that the subtests used from the TILLS, Nonword Reading (our dependent variable) and Nonword Repetition (our independent variable) had a small non-significant correlation. The words the participants used in Nonword Repetition had a majority of the same words the participants were exposed to for Nonword Reading. This could be the result of a small number of participants involved in the study and the difference between the complexity of the few different words in the nonword repetition task and the nonword task. It is interesting that the words in the ToPhS task had phonological complexities that were not similar to those in the nonword reading task, yet there was a correlation between the two. For example, in the ToPhS a word that participants encountered was "bədrɛ́mpəri." The structure of the word followed syllabic and metrical foundations of English, but it is not a word that closely resembles an English word. On the other hand, words in the TILLS had stimuli such as "mistation" where the morphological ending "-tion" is typically seen in English words. The TILLS presented participants with morphological complexities, as do most nonword repetition tasks. This means that although the words that participants encounter are nonwords and follows the same structure as English words (consonant clusters, morphological endings), the words themselves are not English words with any meaning.

The second research question resulted in a marginally significant prediction of NonWord Reading by ToPhS. There were no other correlations found with Nonword Reading and TONI, RAN, and NWRepetition. Nelson and Plante (2022) found in their study of the administration of the TELE-TILLS, that the Nonword Repetition task was unreliable. The reason for this discrepancy is that typically, when administering the test in person, the audio for the Nonword Repetition is in close proximity to the participant and the environment is controlled to

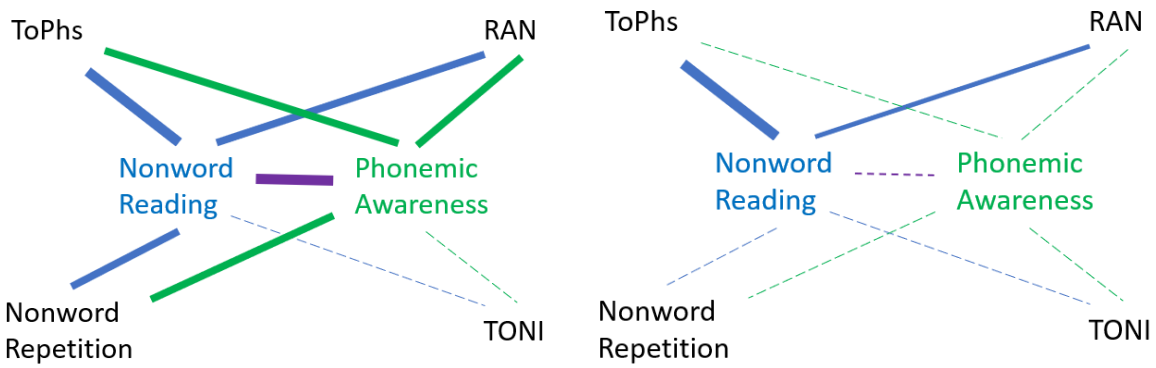
reduce noise. When administering this subtest through Zoom, some participants did not wear headsets in their study and as a result there were discrepancies for the reliability of the administration for the TELE-TILLS and in-person TILLS. In our study, students were encouraged to wear headphones or earphones during this study. This is part of the responsibility of the participants and the parents to ensure all instruments are present, but environmental noise and internet issues also proved to be problematic. The results for the non-significant correlation for Nonword Reading and Nonword Repetition could possibly be explained as a result of the modifications required for administering the Nonword Repetition subtest. There was a positive correlation with the RAN, but it was over the statistically significant value ($p > 0.05$). It should be noted that in the regression analysis, RAN had a small unreliable predictive value compared to the ToPhS.

The third research question found that there were no significant correlations between PA and Nonword Repetition, TONI, RAN, ToPhS. The results showed that they were above the statistically significant number of $p < 0.05$. Phonemic awareness skills are skills used when reading nonwords as previous studies have proved to show, but our results were contradictory of that result. There was no correlation between PA and Nonword Repetition, which requires the participant to listen to the phonemes of the nonwords and repeat them. The ToPhS, which is a similar task to the Nonword Repetition task, also proved to have no significance with PA. A larger population of participants for future studies can demonstrate if the inconsistencies were truly a result of population size or the dependent (PA) and independent variables (ToPhS, RAN, Nonword Repetition, TONI).

One interesting result from this study is that although the ToPhS was more complex than the words presented on the NWRead task, participants performed well. Common errors that

were seen in the results were substitution errors where the “th” sound was substituted for a “f” sound. The participant that exhibited these errors was the participant whose parent reported they struggled with reading. Although the words were not displayed, we know that previous studies have shown the relationship between phonological working memory and nonword repetition tasks. Since phonological working memory is a component of phonological processing, this could be a possibility as to why the child struggled more than other participants with this task. Additionally, the audio could have affected their perception and other participants also exhibited similar errors as well as some omitting sounds and syllables.

Figure 2 Comparison of Hypothesis and Results



Dashed lines signify a small or nonexistent correlation. A solid thin line signifies some correlation and a bold thick line signifies a strong correlation.

A hypothesis established in this study is that the dependent variables would not be correlated with TONI-4. This is because the TONI-4 assesses the participants nonverbal

intelligence. In the larger study that this investigation is part of, the TONI-4 was included to show the capabilities of the participants. After running a regression model and ANOVA, the results showed that there was no correlation between Nonword Reading and TONI-4, and there was no correlation between PA and TONI-4. Our hypothesis was proved to be correct, however, we also hypothesized that Nonword Reading would be correlated with Nonword Repetition, but the results proved otherwise. As stated previously, there was a marginal correlation between Nonword Reading and ToPhS, and a positive correlation between Nonword Reading and RAN ($p = 0.06$). Our results for PA showed that there were no correlations between PA and RAN, ToPhS, Nonword Repetition.

Limitations

From testing through Zoom, we learned about the feasibility of reaching a more diverse population that would otherwise be difficult to achieve if this were done in person. Participants and their parents found it easy to navigate through Zoom because they had remote learning experience during the COVID-19 pandemic. Some kids that were not familiar with the tools on Zoom (stamp tool) were receptive to directions given using the help of their parents. Since this exploratory study was administered through Zoom, it required participants to have reliable internet connection and a compatible laptop with a web camera that supports Zoom. There were some occasions when administering through Zoom resulted in an audio lag. Some participants also had internet connectivity issues that resulted in dealing with technical difficulties in the middle of the session. These are issues that could have affected the quality of the study in a way that could be controlled by modifying the administration.

Another limitation this study experienced is the lack of instructions available for administering the standardized tests remotely. The only test that provided accommodating

instructions for administering the standardized tests remotely was the TILLS. The other standardized tests like the RAN or TONI-4 did not provide instructions for administering the test remotely and instructions were administered as close to the original instructions provided when administering the test in person.

Based on the results yielded for the correlations among NWRead, ToPhS, and RAN there is a relationship that connects them. However, NWRead was not predicted by the RAN after accounting for NWRep and ToPhS. Currently, there is not much information on how automatized naming tasks predict a child's ability when reading nonwords. One hypothesis for the possible correlation among NWRead and RAN is that they both require receiving input and expressing it verbally. Future studies can continue to explore the predictability of these two assessments to determine if the results in this exploratory study have a significance.

Future Directions

As stated previously, the limitations of this study include the mode of administration. In a remote setting, the participants are placed with the responsibility to have access to all of the items needed to participate in the study. Although some participants had these items and internet connection, the quality of the internet or the environment proved to not be stable for some participants. A solution to this problem is to provide stations in public areas such as libraries and send a research assistant to the area to help with administrative and technical support.

Along the same topic, a possibility of a small number of participants could also be the lack of tools and internet connection available to them. This would put participants that wished to participate at an automatic disadvantage and disqualification for participation. By setting a

station where participants are able to participate in the study with the tools provided, we could reach a larger number of participants.

Another possibility of future directions would be to include assessments that have remote instructions readily available so as not to compromise the validity of the test. The research clinicians did their best to maintain the instructions and find viable ways to administer the test remotely based on the instructions provided for in-person administration, but the use of these tools required participants to be somewhat knowledgeable of using the Zoom tools (taking over mouse control, using stamp).

Conclusion

Traditionally, phonemic awareness tasks, nonword reading, nonword repetition tasks and automatized naming tasks have shown to be correlated with each other. The results of our study when running a linear regression model showed that NWRead and ToPhS had a statistically significant correlation ($p = 0.05$). There were no other correlations with the other assessments (TONI, RAN, NWRepetition). When finding if PA and TONI, RAN, NWRep were correlated, there were no statistically significant numbers reported. This is contradictory to what previous studies have shown where PA has some correlation to traditional nonword repetition tasks. The non-significant correlation between PA and NWRep should be taken with caution as Plante and Nelson have found that the TELE-TILLS administration of this subtest was unreliable when administering remotely. The results were unreliable with the dependent variables (PA, NWRead) and NWRep could be the result of its unreliability when participants are listening to the stimuli through Zoom and audio is compromised. We acknowledge that the sample size was small for a regression analysis, however, we decided to continue with a regression analysis as

this is an exploratory study. The small sample size could also be a reason as to why the results predicted in other studies were not reflected in our study. The results of this study provide insight as to what future directions could be taken to improve the study, such as increasing the sample size and obtaining a more diverse population to further explore the effects of phonological processing among nonword reading/repetition tasks, phonemic awareness, and automatized naming tasks.

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