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Abstract

This case study examined the relationship between phonological processing abilities and reading skills of three young adults who had a history and formal diagnosis of a reading, writing, and/or auditory processing impairment. In addition to a standardized reading assessment, the participants were asked to complete a series of assessments that measured a specific aspect of auditory or visual phonological processing abilities including phonological awareness, phonological memory, and rapid automatic naming skills. These assessments included the Decoding Subtest of the Phonological Awareness Test (PAT-2), the Gray Oral Reading Test (GORT-5), and the Comprehensive Test of Phonological Processing (CTOPP-2). Processing of degraded signals using the SCAN-3 screening was also assessed to determine if pass/fail performance on this measure had any relationship to current reading performance. Results from the assessments were then examined to determine if there was a relationship between phonological processing ability and reading skills in young adults with histories of reading, writing, or processing deficits. Despite histories of diagnosed reading disabilities, all three participants demonstrated average to high average performance on the formal reading measures. They also demonstrated average performance for auditory and visual phonological processing skills. The results, however, indicated that two of the participants demonstrated numerous errors in decoding basic syllable shapes on one of the phonological processing assessments.

Phonological Processing Abilities and Reading Skills in Young Adults

Phonological processing involves three major types of skills: awareness, memory, and rapid automatic naming. Phonological awareness is one's ability to identify and manipulate units of spoken language such as words, syllables, and phrases (Yopp, 1992). Some phonological awareness skills include recognizing when words rhyme, producing rhyming words, or being able to delete, add, or manipulate sounds or syllables in words. Phonological memory refers to coding phonological information for temporary storage in working or short-term memory (Rodrigues & Befi-Lopes, 2009). This area of memory stores sounds that the reader or listener is attempting to decode. A nonword repetition task is an example of phonological working memory. In this task, an individual is instructed to listen to a "nonsense" word and repeat it. Rapid automatic naming (RAN) is the ability to visually scan, recall, and name items verbally. Items of interest include specific objects, letters, and numbers (Stappen & Reybroeck, 2018). An example of this task is asking an individual to rapidly name different objects or numbers which requires retrieval of phonological information from long-term storage or permanent memory (Wagner, Torgesen, Rashotte, & Pearson, 2013). Performance in RAN depends upon being able to name items both quickly and accurately.

Phonological Awareness

In order to determine how young children develop phonological awareness skills, Yopp examined kindergarten children. In this study, the purpose of the research was to determine how young children develop phonemic awareness skills and how important it is for children to develop these skills (Yopp, 1992). The subjects in this research consisted of kindergarten children from ages five to six years. The children were administered phonological awareness

tasks to complete such as breaking words down into their specific sounds and removing certain sounds from words. The results demonstrated that many kindergarten children lacked phonological awareness considering their performance on a reading measure, and that it is very important for children to develop these skills. Especially in young children, phonological awareness has a great impact on reading abilities (Yopp, 1992). Being able to manipulate sounds and syllables determines how well the child can manipulate written words in context.

Another research study examined the significance of emergent phonological awareness skills as predictors for both later literacy skills and reading (Lonigan, Burgess, & Anthony, 2000). The subjects in this study were two groups of preschoolers. One group consisted of 96 children who were followed from early to late preschool, ages four to age five years. The other group consisted of 97 children who were followed from preschool to kindergarten, ages five to six years. The researchers assessed phonological skills and reading skills at two different times during early and late preschool in one group, and during late preschool and early kindergarten in the other group. This study demonstrated that phonological awareness, when compared to other predictors, was the most stable and robust indicator of later reading skills for both groups of preschool children (Lonigan et al., 2000).

Phonological Memory

Phonological memory affects a person's ability to store phonological information in order to decode words and can be a predictive measure of reading comprehension. Likewise, deficits in phonological memory adversely affect reading comprehension. One research study aimed to investigate possible correlations between reading comprehension and phonological memory (Carvalho, Kida, Capellini, & Avila, 2014). The subjects in this study consisted of two groups of

children who had either average reading abilities or dyslexia. The researchers in this study evaluated both groups based on reading comprehension and phonological working memory. The results indicated that when comparing the two groups, the group of children who had dyslexia showed significantly poorer performance in phonological memory. This research has shown that the role of phonological memory on the comprehension of written text is crucial in young children (Carvalho et al., 2014).

Rapid Automatic Naming

Rapid naming ability has been shown to predict the ability to read words correctly and fluently. Likewise, deficits in rapid naming are predictive of difficulty with reading, decoding, and fluency. In a longitudinal study, researchers tested the hypothesis that individual differences in RAN skills make a unique contribution to the growth of orthographic reading skills (Torgesen, Wagner, Rashotte, Burgess, & Hect, 2009). The researchers in this study examined two groups of children during two overlapping periods of development which were from second to fourth grade, ages seven to 10 years, and from third to fifth grade, ages eight to 11 years. Separate analyses were done on the entire sample of children's performance to assess for impairment in word-reading development. The researchers concluded that RAN skills were strongly predictive of individual differences in reading two years later, as well as indicative of positive reading development among the two groups of children (Torgesen et al., 2009).

In another study, researchers examined the influence of RAN intervention on a group of second graders (Stappen & Reybroeck, 2018). The researchers provided RAN intervention to the children at school twice a week over the course of two months. The researchers then compared the initial level of reading ability to the level of reading ability after RAN intervention. The

results indicated that intervention in RAN enhanced reading speed and thus was considered to have a significant correlation with reading abilities among the second grade children. In this study, rapidly naming with speed was more predictive of average reading abilities than was naming with accuracy (Stappen & Reybroeck, 2018). Thus, RAN is associated with positive reading development in early childhood, especially reading fluency.

Other Factors Predicting Reading Skills

In a longitudinal study of children ages three to nine years, phonological processing skills and later reading skills were compared to determine if cognitive ability had any effect on developing language or reading skills (Durand, Loe, Yeatman, & Feldman, 2013). The researchers in this study analyzed phonological skills and cognition in relation to reading ability in a group of children at age three years and again at age nine years. The researchers analyzed vocabulary, syntax, speech maturity, and cognition in relation to decoding, comprehension, and oral reading fluency. The results of this study indicated that variation in cognitive ability was not significantly related to reading ability. Thus, the researchers determined that the strongest predictor of later reading skills were developing phonological processing skills during the preschool years and throughout early childhood (Durand et al., 2013).

First grade reading ability is best predicted by phonological processing skills measured during preschool in children from middle class income families (Swank & Catts, 1994). Those who do not have these skills tend to have reading deficits at the beginning of first grade. In one research study, phonological processing measures were investigated as predictors of first-grade broad reading ability in children from low socioeconomic status families (Gilbertson & Bramlett, 1998). The subjects in this study consisted of 91 Headstart students. The researchers in this study

administered standardized assessments of cognitive ability and informal phonological processing tasks during kindergarten and early first grade. The results indicated that phonological processing tasks (such as spelling, categorization, and blending) correctly identified at-risk students with 92% accuracy. This research study showed that phonological processing tasks were the most predictive of standardardized reading measures obtained at the end of first grade (Gilbertson & Bramlett, 1998). Regardless of socioeconomic status, preschooler's phonological processing abilities accurately predicted their reading levels during first grade. This study, although not relevant to the participants in my study, did highlight that phonological processing skills are good predictive measures of obtaining average reading skills regardless of socioeconomic status

Phonological Processing and Later Reading Ability

Research indicates that 74% of children with a reading disorder who are not diagnosed by the second grade will continue to have a reading deficit (Dyslexia Center of Utah, 2014). In one study, researchers discussed the importance of identifying children with reading disabilities at a young age (Otaiba, Connor, Foorman, Schatschneider, Greulich, & Sidler, 2009). The researchers found that when early difficulties persisted in phonological processing such as learning about sounds, letters, and rhymes, these difficulties predicted which children were likely to develop difficulties in reading. This study recognized the relationship between phonological processing abilities and reading skills for young children, but stated that less is known about the impact and relationship between phonological processing abilities on reading skills for older students and young adults (Otaiba et al., 2009).

Phonological processing skills which include phonological awareness, phonological memory, and rapid automatic naming are present at a young age and are predictive of average

reading abilities in early childhood. Reading skills that are predicted by phonological processing abilities include decoding, fluency, and comprehension. One literature review aimed to determine the predictive ability of phonological processing skills on later reading level (Ekins & Schneider, 2006). The researchers critically reviewed the literature to determine which phonological skills predict lower reading level versus higher reading level. The researchers found that children with deficits in RAN and phonological awareness had a lower reading level in relation to standardized measures of expressive and receptive language. The results in this study showed that there is a strong relationship between phonological processing abilities and reading ability in early childhood, such that phonological processing abilities ultimately determines reading level and success in young children (Ekins & Schneider, 2006). Although there is a substantial amount of research regarding phonological processing abilities and its impact on reading skills for children, less is known about this relationship in young adults.

In young adults, many different factors play a role in being able to read fluently and accurately. In one study, variations in phonological processing abilities were assessed to determine the role they play in reading in a group of young adults (Watson & Miller, 1993). The subjects in this study consisted of 94 college undergraduates, 24 of whom had a reading disability. The purpose of the study was to determine how individual differences in phonological processing abilities affect reading level. The results indicated that young adults who had a reading disability showed individual differences in phonological processing abilities. It was concluded that speech perception, which was measured by speech repetition and degraded speech tasks, contributed significantly to these individual differences in phonological abilities necessary for skilled reading (Watson & Miller, 1993). Thus, more research is needed to identify

commonalities among young adults' phonological processing skills to understand their relationship to reading ability.

Defining Reading Abilities

Reading abilities include word recognition, word decoding, fluency, and comprehension. Word recognition is the ability to quickly recognize familiar words. Word decoding is one's ability to recognize letter-sound relationships and sound-out or pronounce written words correctly (Kang & Shin, 2019). Decoding also includes pseudo-word decoding ability. Fluency is a reader's ability to read words accurately, quickly, and expressively (Kang & Shin, 2019). This includes being able to read written text with speed while correctly pronouncing the words as well. Reading comprehension is one's ability to read written words and understand what has been read (Elleman & Oslund, 2019). This includes being able to make conclusions, inferences, comparisons, and summarizations of written material. Reading comprehension is one of the more difficult skills to master because it involves using context clues to make inferences about information that may not be explicit within the text. Comprehension is significantly influenced by both reading fluency and decoding (Elleman & Oslund, 2019).

One research study aimed to discuss the contributions of reading fluency and decoding to reading comprehension. The subjects in this study consisted of fourth grade students who had reading difficulties or disabilities. The researchers in this study used standardized assessments to measure reading comprehension and decoding levels. The researchers found that deficits in decoding accounted for 43.3% of deficits in reading comprehension (Kang & Shin, 2019). These results indicated that children must have the foundational knowledge in reading fluency and decoding in order to become efficient in reading comprehension as a result (Kang & Shin, 2019).

Defining Reading Disorders

The U.S. Department of Health and Human Services (2020) defines a reading disorder as "having difficulty reading words or understanding what has been read." A reading disorder is not an intellectual or developmental disorder, but rather a deficit in the way one processes written words or text in the brain. People with reading disorders often have problems recognizing printed words that are within their spoken vocabulary and understanding the words they read (U.S. Department of Health and Human Services, 2020). Typically, people with reading disorders have problems with word decoding, fluency, and/or comprehension at a young age. Individuals may often have deficits in multiple areas such as co-occurring deficits in comprehension and decoding (ASHA, 2009). Word decoding deficits involve difficulty with sounding out written words and syllables and matching letters and letter sequences to their corresponding sounds. Reading fluency deficits are characterized as difficulty with decoding quickly, difficulty with recognizing printed words, and/or lack of expression in oral reading. Reading comprehension deficits involve difficulty with understanding and remembering what has been read. People with reading disorders normally have these problems present at a young age, and these problems can often continue to affect reading abilities later on in life (U.S. Department of Health and Human Services, 2020).

Reading Abilities of College Students and Young Adults

As many as one in five college students suffer from a reading disability (Burton, 2018). In fact, many young adults struggle with reading and do not perform well in school as a result. One research study aimed to discover why young adults struggle with reading and writing skills. This study also aimed to promote useful strategies to benefit reading skills for college students.

The researchers provided techniques to enhance reading comprehension and metacomprehension. The results demonstrated that many college students did not already utilize these comprehension techniques. Therefore, the researchers concluded that many college students did not possess high level reading skills and struggled with literacy skills that are needed to be successful in higher education (Gruenbaum, 2012). The nature of these literacy deficits in young adults include problems with decoding, fluency, and comprehension. Since phonological processing abilities can directly affect reading skills in early childhood, those who struggle with phonological awareness, memory, or RAN skills may subsequently struggle with reading ability in young adulthood as a result.

Conclusions

Reading is among one of the most important foundational skills a person can develop. Being able to read successfully determines how well an individual can develop knowledge of other skills such as speaking effectively and writing clearly. In order for children and even young adults to expand their knowledge base, they must develop the necessary skills required to read successfully. Those children who have acquired predictor phonological processing skills are children who have at least average reading skills at the beginning of first-grade (Durand et al., 2013). These skills are determined largely by phonological processing abilities that are present early in life including phonological awareness, phonological memory, and RAN. In particular, RAN has been shown to be the best predictor of decoding ability, and RAN intervention has been shown to increase reading speed. Poor phonological memory has been associated with diagnoses of dyslexia. Speech perception tasks are predictors of reading ability in young adults. In young

adults, more research is needed to identify commonalities among young adults' phonological processing skills to understand their relationship to reading ability.

The primary purpose of this study was to determine if phonological processing deficits were present in young adults with histories of diagnosed reading, writing, and/or processing disorders. Standardized tests were used to determine their performance on measures of reading fluency, decoding, comprehension, and phonological processing. A pass/fail screening of auditory processing was also administered to determine if degraded signal testing could add to any identified relationship between phonological processing abilities and reading performance.

Method

Participants

The participants in this study were recruited using announcements through the Arkansas Newswire, which is an online school newspaper for the University of Arkansas, and emails. Each participant gave written informed consent as approved by the University of Arkansas Institutional Review Board (see Appendices A and B). The participants consisted of three college students who reported a diagnosed reading, writing, or processing impairment during school age and who also attended the University of Arkansas. All three participants reported continued concerns about reading, writing, and spelling skills despite good grades in college. None of the participants reported direct intervention services to target reading or processing skills during their school age years. Both Participant 1 and Participant 3 reported using accommodations for classes while attending the University of Arkansas. Participant 1, who was 21 years old, reported diagnoses of dyslexia and central auditory processing disorder (CAPD). Participant 2, who was 19 years old, reported diagnoses of dyslexia, dysgraphia, and CAPD. Participant 3, who was 20

years old, reported a diagnosis of dysgraphia. All participants passed a hearing screening and the SCAN-3 measure that assessed auditory processing. The participants then completed the other standardized assessments.

	Participant 1	Participant 2	Participant 3
Age	21 years old	19 years old	20 years old
History	Dyslexia and CAPD	CAPD, Dyslexia, and Dysgraphia	Dysgraphia

Table 1: Participant's Age and Histories

Materials and Assessments

The principal researcher administered the assessments for all of the participants. The assessments, which included the SCAN-3 screening, The Decoding Subtest of the Phonological Awareness Test (PAT-2), the Comprehensive Test of Phonological Processing (CTOPP-2), and the Gray Oral Reading Test (GORT-5).

The SCAN-3 screening measure consisted of subtests that were used to assess auditory processing. Three tests are included in the screening. The test was administered using a CD player according to directions in the manual. Gap Detection was assessed by instructing the participant to indicate how many tones he or she heard. The Auditory Figure Ground subtest assessed each participant's ability to repeat spoken words in both the left and the right ear in the presence of background noise. The Competing Words free recall subtest assessed each participant's ability to repeat spoken words that were presented in both ears at the same time.

The PAT-2 decoding subtest was used to measure decoding skills using novel syllable patterns. Printed novel words were read aloud by the participants. Because this test is normed only through age 9:11 years, the number of correct responses out of 80 possible was used for

scoring. Results from this assessment were informally examined for mastery of pronunciation and spelling rules that influence reading, writing, and spelling.

The CTOPP-2 was used to assess phonological awareness, phonological memory, and RAN. This assessment measures skills that are strong predictors of academic success, particularly reading and writing. Some of the phonological awareness skills measured in this assessment include the student's ability to omit a sound in a word, to blend words and nonwords, to isolate a sound, to repeat nonwords, and to segment nonwords. The rapid naming portion of this assessment required the student to name numbers or letters as quickly as possible from left to right. Some phonological memory tasks included repeating spoken digits and multisyllabic nonsense words.

The majority of subtests for the CTOPP-2 assessment used auditory cues which were administered orally by the examiner as well as via a CD player with no visual cues. These subtests included the phonological awareness, the phonological memory, and the supplemental subtests. One subtest used visual cues only which was the rapid naming portion of this assessment. Standard scores normed with age peers were obtained for the CTOPP-2.

Finally, the GORT-5 was used to assess reading rate, accuracy, fluency, and comprehension. The GORT-5 also provided an oral reading quotient for each participant that was used to assess each participant's overall reading abilities. In this assessment, the reader was asked to read stories aloud while being timed. Following each story, the reader answered five comprehension questions about that story. The number of errors made while reading were counted as well as the time it took to complete the entire story. These two measures combined to obtain a reading fluency standard score.

Procedures

Data were individually collected from all three participants. Each participant met individually for a one-time, two-hour session in a quiet room located in the Epley Center for Health Professions. Each participant completed and passed a standard pure-tone hearing screening at 20 dB for 1000, 2000, and 4000 Hz in each ear (ASHA, 2019). The participant then began the other standardized assessments. The order of assessments administered to each participant was as follows: the SCAN-3, the PAT-2, the CTOPP-2, and the GORT-5. Once all the assessments were administered and scored, the data were compiled and compared to identify any relationships.

Results

All three participants passed the SCAN-3 screening measures that assessed auditory processing. All raw scores exceeded the criterion scores for passing. Results for all three participants on the GORT-5, CTOPP-2, and PAT-2 are shown below in Tables 2-10. As seen in the results, all participants performed within average to high average limits on the standardized measures of oral reading (GORT-5) and phonological processing (CTOPP-2). Performance for the decoding subtest of the PAT-2 showed mastery of decoding novel syllable shapes for Participant 3 who had a history of dysgraphia, whereas, the other two participants with diagnoses of dyslexia and CAPD struggled with many of these tasks. The majority of reading errors were due to mispronunciation of vowel sounds as seen in Tables 5 and 6.

Participant 1's Results:			
GORT-5 Test/Quotient	Index Score	Percentile Rank	Scaled Score
Oral Reading Quotient	**107**	**68th**	**11**
Reading Rate		88th	13
Reading Accuracy		91st	14
Reading Fluency		84th	13
Comprehension		63rd	11

Table 2: Participant 1's GORT-5 Results

Participant 2's Results:			
GORT-5 Test/Quotient	Index Score	Percentile Rank	Scaled Score
Oral Reading Quotient	**100**	**50th**	**10**
Reading Rate		50th	10
Reading Accuracy		50th	10
Reading Fluency		50th	10
Comprehension		50th	10

Table 3: Participant 2's GORT-5 Results

Participant 3's Results:			
GORT-5 Test/Quotient	Index Score	Percentile Rank	Scaled Score
Oral Reading Quotient	**102**	**55th**	**10**
Reading Rate		63rd	11
Reading Accuracy		50th	10
Reading Fluency		55th	10
Comprehension		63rd	11

Table 4: Participant 3's GORT-5 Results

Participant 1's Results:					
Subtest	Pronunciation/Spelling	% Correct	Printed Word	Production Target	Production Error
DECODING Total	Raw score = 67/80 ***Age Equivalent = 8:10***	**84%**			
Vowel-Consonant (VC) Words	Short vowel sounds	70	"ob, um, og"	/ɑb, ʌm, ɑg/	/ob, um, og/
Consonant-Vowel-Consonant (CVC) Words	Short vowel sounds	80	"rop, fum"	/rɑp, fʌm/	/rop, fum/
Consonant Digraphs (CCVC, CVCC, CCVCC)	2 consonants = one sound	80	"nuch, shom"	/nʌʃ, ʃɑm/	/nuʃ, ʃæm/
Consonant Blends (CCVC, CVCC)	2 consonants = two sounds	90	"drob"	/drɑb/	/drob/
Vowel Digraphs (CVVC)	2 vowels = one long vowel sound	70	"faim, coan, jeax"	/fem, kon, ʤiks/	/faɪm, koæn, ʤo/
R-Controlled Vowels (CVrC)	Vowel + vocalic "r" (ar, or, eer, etc.)	100			
CVCe Words	Long vowel sound via silent "e"	80	"mave, sipe"	/mev, saɪp/	/mauv, sIp/
Diphthongs (CVVC, CVV)	2 adjacent vowel sounds	100			

Table 5: Participant 1's PAT-2 Results

Participant 2's Results:					
Subtest	Pronunciation/Spelling	% Correct	Printed Syllable	Production Target	Production Error
DECODING Total	Raw Score = 65/80 ***Age Equivalent = 8:7***	**81%**			
Vowel-Consonant (VC) Words	Short vowel sounds	60	"ep, ob, im, og"	/ɛp, ɑb, ɪm, ɑg/	/ip, ob, aɪm, og/
Consonant-Vowel-Consonant (CVC) Words	Short vowel sounds	100			
Consonant Digraphs (CCVC, CVCC, CCVCC)	2 consonants = one sound	90	"shom"	/ʃɑm/	/ʃom/
Consonant Blends (CCVC, CVCC)	2 consonants = two sounds	90	"smesk"	/smɛsk/	/smIsk/
Vowel Digraphs (CVVC)	2 vowels = one long vowel sound	80	"sead, jeax"	/sid, ʤiks/	/sɛd, ʤo/
R-Controlled Vowels (CVrC)	Vowel + vocalic "r" (ar, or, eer, etc.)	100			
CVCe Words	Long vowel sound via silent "e"	60	"pote, lere, sipe, puze"	/pot, lɪr, saɪp, puz/	/pɑt, laɪr, sɪp, pʌz/
Diphthongs (CVVC, CVV)	2 adjacent vowel sounds	70	"poil, touse, voust"	/poɪl, taus, vaust/	/pol, tus, vust/

Table 6: Participant 2's PAT-2 Results

Participant 3's Results:					
Subtest	Pronunciation/Spelling	% Correct	Printed Syllable	Production Target	Production Error
DECODING Total	Raw Score = 77/80 ***Age Equivalent = <10:0***	**96%**			
Vowel-Consonant (VC) Words	Short vowel sounds	100			
Consonant-Vowel-Consonant (CVC) Words	Short vowel sounds	100			
Consonant Digraphs (CCVC, CVCC, CCVCC)	2 consonants = one sound	100			
Consonant Blends (CCVC, CVCC)	2 consonants = two sounds	100			
Vowel Digraphs (CVVC)	2 vowels = one long vowel sound	90	"jeax"	/ʤiks/	/ʤo/
R-Controlled Vowels (CVrC)	Vowel + vocalic "r" (ar, or, eer, etc.)	100			
CVCe Words	Long vowel sound via silent "e"	100			
Diphthongs (CVVC, CVV)	2 adjacent vowel sounds	80	"touse, voust"	/taus, vaust/	/tus, vust/

Table 7: Participant 3's PAT-2 Results

Participant 1's Results:				
Composite/Test Task	*Ability*	Standard Score	Scaled Score	Percentile Rank
Phonological Awareness	*Knowledge of word's sound structure*	**116**	13	86th
Elision	Removing specified spoken sounds		11	63rd
Blending Words	Combining spoken sounds into words		13	84th
Phoneme Isolation	Identifying the ordinal position of a sound		13	84th
Phonological Memory	*Short-term memory temporary storage*	**120**	13	90th
Digits	Repeating spoken digits		12	75th
Nonwords	Repeating multisyllabic nonsense words		12	75th
Rapid Naming	*Retrieval of names for visual stimuli scanned left to right*	**98**	10	45th
Digits	Naming single digits fluently		10	50th
Letters	Naming letters fluently		10	50th
Supplemental Tests		**104**	11	61st
Blending Nonwords	Combining spoken sounds into nonsense words		11	63rd
Segmenting Nonwords	Pronouncing spoken nonsense words as individual sounds		10	50th

Table 8: Participant 1's CTOPP-2 Results

Participant 2's Results:				
Composite/Test	*Ability* Task	Standard Score	Scaled Score	Percentile Rank
Phonological Awareness	*Knowledge of word's sound structure*	**96**	9	39th
Elision	Removing specified spoken sounds		10	50th
Blending Words	Combining spoken sounds into words		10	50th
Phoneme Isolation	Identifying the ordinal position of a sound		8	25th
Phonological Memory	*Short-term memory temporary storage*	**107**	11	68th
Digits	Repeating spoken digits		10	50th
Nonwords	Repeating multisyllabic nonsense words		12	75th
Rapid Naming	*Retrieval of names for visual stimuli scanned left to right*	**88**	8	21st
Digits	Naming single digits fluently		9	37th
Letters	Naming letters fluently		8	25th
Supplemental Tests		**98**	10	45th
Blending Nonwords	Combining spoken sounds into nonsense words		11	63rd
Segmenting Nonwords	Pronouncing spoken nonsense words as individual sounds		8	25th

Table 9: Participant 2's CTOPP-2 Results

Participant 3's Results:				
Composite/Test	*Ability* Task	Standard Score	Scaled Score	Percentile Rank
Phonological Awareness	*Knowledge of word's sound structure*	**105**	11	63rd
Elision	Removing specified spoken sounds		11	63rd
Blending Words	Combining spoken sounds into words		10	50th
Phoneme Isolation	Identifying the ordinal position of a sound		11	63rd
Phonological Memory	*Short-term memory temporary storage*	**101**	10	53rd
Digits	Repeating spoken digits		10	50th
Nonwords	Repeating multisyllabic nonsense words		11	63rd
Rapid Naming	*Retrieval of names for visual stimuli scanned left to right*	**101**	10	53rd
Digits	Naming single digits fluently		11	63rd
Letters	Naming letters fluently		10	50th
Supplemental Tests		**107**	11	68th
Blending Nonwords	Combining spoken sounds into nonsense words		10	50th
Segmenting Nonwords	Pronouncing spoken nonsense words as individual sounds		12	75th

Table 10: Participant 3's CTOPP-2 Results

Oral Reading Ability

All three participants performed at least average (at the 50th percentile or above) in each measure (rate, accuracy, fluency, and comprehension) of the GORT-5 assessment. Each participant's oral reading quotient was also average. Participant 1's performance was high average in reading accuracy (91st percentile) and reading rate (88th percentile). Performance for Participants 2 and 3 was in the average range on all subtests of the GORT-5. Despite having a history and formal diagnosis of a reading, writing, or processing impairment, all three participants had overall average performance on reading measures.

Auditory Phonological Processing

All scores on the auditory processing components of the CTOPP-2 assessment were in the average to high average range. The phonological memory, phonological awareness, and the supplemental subtests of the CTOPP-2 assessed the participant's ability to process auditory information. Participant 1 performed in the high average range in phonological awareness (86th percentile) and in phonological memory (90th percentile). Scores for Participant 2 and 3 indicated average performance in all auditory phonological processing subtests. As seen below in Figures 1 and 2, Participants 1 and 2 had relative strengths in phonological memory, whereas Participant 3's performance was consistent across all three auditory assessments. Overall, all three participants performed in the average to high average range for auditory phonological processing.

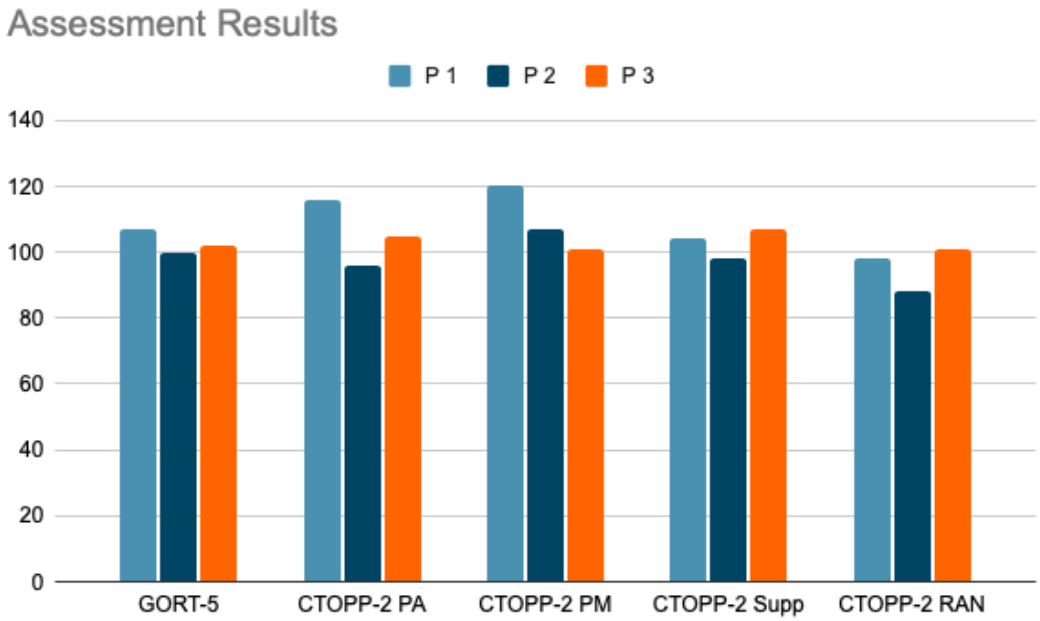

Figure 1: Oral Reading Results Compared to Phonological Processing Results

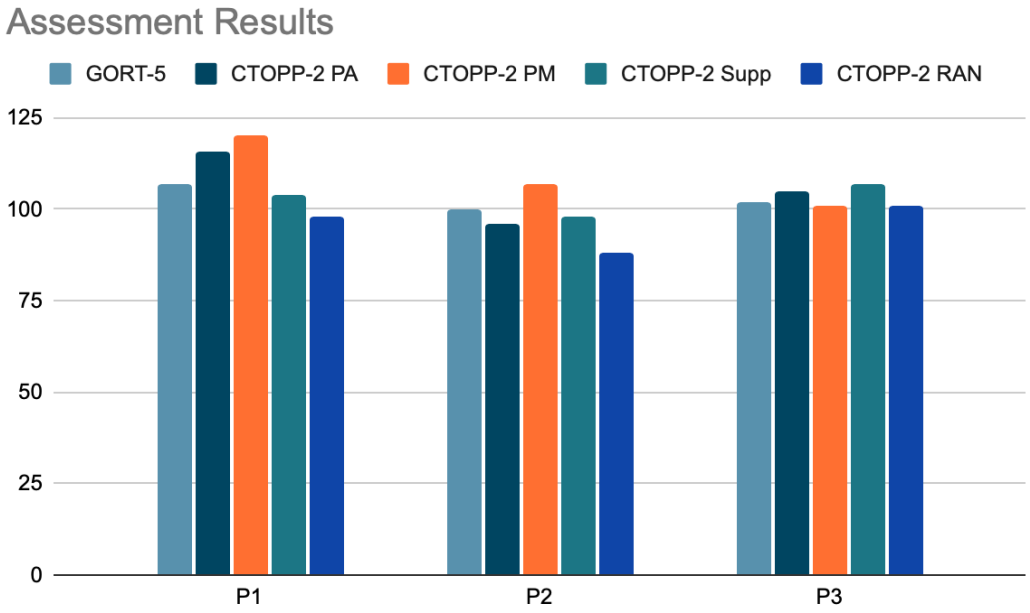

Figure 2: Individual Performance by Participant

Visual Phonological Processing

Rapid Automatic Naming

This task required each participant to visually scan a set of letters or numbers from right to left while naming them as quickly as possible. As seen in Figures 1 and 2, performance on the RAN component of the CTOPP-2 assessment yielded scores in the average to low average range. Performance of Participants 1 and 3 was average in rapid naming. Participant 2 performed in the low average range in rapid naming (21st percentile). Although all participants were within average limits on this assessment, standard scores were the lowest in rapid automatic naming considering all four components.

Decoding

Decoding required each participant to look at a nonsense word and read it aloud. The raw scores on the PAT-2 assessment indicated decoding struggles for both Participants 1 and 2. Recall that standard scores beyond age 9:11 were not available for this measure. Therefore, age equivalent scores were derived for each participant and were as follows: Participant 1 = 8:10; Participant 2 = 8:7; and Participant 3 = greater than 10:0. The average raw score for children aged 9:11 years was 70/80 or 88%.

As seen below in Figure 3, Participants 1 and 2 specifically struggled with decoding novel syllables. Participant 1 scored 84% correct responses in syllable decoding. Participant 2 scored 81% correct responses in syllable decoding. Participant 3 scored 96% correct responses in syllable decoding, indicating adequate decoding abilities. Decoding performance for Participants 1 and 2 was commensurate with that expected for second to third grade students, whereas their performance for auditory phonological processing measures was average for age peers.

Participant 1 performed average to high average on all auditory processing subtests, whereas on the visual processing subtests, Participant 1 performed in the average to low average range. Participant 2 performed in the average range in auditory phonological processing, whereas their performance for the visual processing tasks was the lowest.

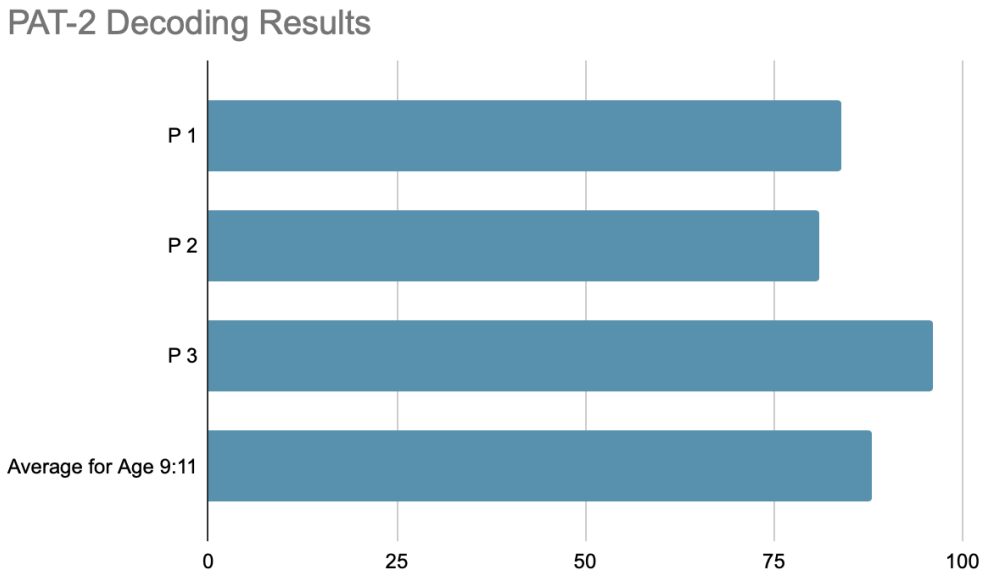

Figure 3: Percentage Correct Decoding for Participants Compared to the Average for Age 9:11

Discussion

Because all three participants performed at least average on all measures of the GORT-5 assessment, it can be concluded that there was no remaining evidence of significant reading impairment. The results from the CTOPP-2 assessment likewise indicated that there was no phonological processing deficits on this standardized measure. Scores for these participants were the lowest in visual phonological processing/RAN compared to the auditory processing subtests of the CTOPP-2 assessment. Both Participants 1 and 2, who had histories of dyslexia and CAPD, struggled with novel syllable decoding. Participant 1 specifically demonstrated struggles with vowel-consonant words and vowel digraphs. Participant 2 specifically demonstrated struggles

with vowel-consonant words and CVCe words. Individuals who are older than 9:11 would be expected to have all categories mastered on the PAT-2 assessment. All errors made by the participants were due to mispronunciation of vowels, and the majority of these errors were due to lack of mastery of long and short vowel rules. Recall that for young children, RAN is a strong predictor of decoding ability. It is interesting to note that for these two college students, RAN was a relative weakness. Auditory phonological processing skills were a relative strength for all three participants.

Future Directions

Future research with a larger number of subjects should explore the relationship between early diagnosis of reading impairment and later persistence of decoding weaknesses in college students. Recall that intervention in RAN with children has been shown to have positive effects. A future direction for this research could be to determine how successful visual phonological processing intervention for decoding or RAN could be for young adults with histories of reading impairments. For example, a future study could explore how teaching decoding and spelling rules could impact RAN and/or reading ability in individuals who have histories of CAPD or dyslexia, and who continue to show decoding errors. It is also interesting to note that all three participants in this case study were recruited from the Communication Sciences and Disorders department, and they all possessed high grade point averages. Future studies may want to incorporate participants who have different majors, grade point averages, or backgrounds.

Limitations

There are a few limitations with the present study that need to be addressed. First, there were only three participants in this case study with diagnosed histories of reading and/or

processing disorders. Having a larger sample of young adults with and without diagnosed histories of reading impairments would produce results more representative of this population. Another limitation was that standard scores could not be obtained from the PAT-2 assessment. This meant that the participant's scores could not be compared to a large sample of age peers. Thus, we could only derive age equivalent scores. Future research should also include more measures of decoding with standard scores for age peers available.

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Appendix A

Phonological Processing Abilities and Reading Skills in Young Adults
Consent to Participate in a Research Study
Principal Researcher: Sarah Thompson
Faculty Advisor: Dr. Margie Gilbertson

INVITATION TO PARTICIPATE

You were invited to participate in a research study about Phonological Processing Abilities and Reading Skills in Young Adults. You were asked to participate in this study because you showed interest, and you met the requirements to be a participant.

WHAT YOU SHOULD KNOW ABOUT THE RESEARCH STUDY

Who is the Principal Researcher?
Sarah Thompson (set022@uark.edu)

Who is the Faculty Advisor?
Dr. Margie Gilbertson (mlg023@uark.edu)

What is the purpose of this research study?
The purpose of this study is to determine if phonological processing abilities predict performance on measures of reading fluency, decoding, and comprehension in young adults.

Who will participate in this study?
The participants of this study will be college students, ages 18-23 years, who have either average reading abilities or have been diagnosed with a reading disorder or auditory processing disorder.

What am I being asked to do?
Your participation will require the following:

- Complete the following assessments
  - Hearing screening
    - For the hearing screening, earphones will be placed on the participant's ears and they will be asked to raise their hand when they hear a series of pure tones at 1000, 2000, and 4000 Hz.
  - Comprehensive Test of Phonological Processing-2
  - Phonological Awareness Test 2-NU
  - Gray Oral Reading Test-5
  - SCAN-3A Test for Auditory Processing Disorder

What are the possible risks or discomforts?
There are no anticipated risks by participating in this study. You might experience some fatigue associated with completing assessments.

What are the possible benefits of this study?
You will be able to determine your strengths and weaknesses in phonological processing and reading abilities.

IRB #1909219750
Approved: 12/17/2019
Expires: 11/17/2020

How long will the study last?
This study will consist of one meeting that will last approximately 3 hours total. If the participant cannot meet for this long at one meeting, it can be broken down into two separate meetings for convenience. These meetings will take place in the Speech and Hearing Clinic at the Epley Center in room 156.

Will I receive compensation for my time and inconvenience if I choose to participate in this study?
No, there is no compensation for time spent participating in this study.

Will I have to pay for anything?
No, there will be no cost associated with your participation.

What are the options if I do not want to be in the study?
If you do not want to be in this study, you may refuse to participate. Also, you may refuse to participate at any time during the study. Your job, your grade, your relationship with the University, etc. will not be affected in any way if you refuse to participate.

How will my confidentiality be protected?
All information will be kept confidential to the extent allowed by law and University policy. No identifying information will be used in any publications or reports resulting from this research.

Will I know the results of the study?
At the conclusion of the study you will have the right to request feedback about the results. You may contact the faculty advisor, Dr. Margie Gilbertson (mlg023@uark.edu) or Principal Researcher, Sarah Thompson (set022@uark.edu). You will receive a copy of this consent form for your files.

What do I do if I have questions about the research study?
You have the right to contact the Principal Researcher or Faculty Advisor as listed below for any concerns that you may have.

Sarah Thompson (set022@uark.edu)

Dr. Margie Gilbertson (mlg023@uark.edu)

You may also contact the University of Arkansas Research Compliance office listed below if you have questions about your rights as a participant, or to discuss any concerns about, or problems with the research.

Ro Windwalker, CIP
Institutional Review Board Coordinator
Research Compliance
University of Arkansas
109 MLKG Building
Fayetteville, AR 72701-1201
479-575-2208
irb@uark.edu

I have read the above statement and have been able to ask questions and express concerns, which have been satisfactorily responded to by the investigator. I understand the purpose of the study as well as the potential benefits and risks that are involved. I understand that participation is voluntary. I understand that significant new findings developed during this research will be shared with the participant. I understand that no rights have been waived by signing the consent form. I have been given a copy of the consent form.

_____

Signature Date

IRB #1909219750
Approved: 12/17/2019
Expires: 11/17/2020

Appendix B

UNIVERSITY OF ARKANSAS

To:	Sarah Elizabeth Thompson
From:	Douglas James Adams, Chair IRB Committee
Date:	12/17/2019
Action:	**Expedited Approval**
Action Date:	12/17/2019
Protocol #:	1909219750
Study Title:	Phonological Processing Abilities and Reading Skills in Young Adults
Expiration Date:	11/17/2020
Last Approval Date:	

The above-referenced protocol has been approved following expedited review by the IRB Committee that oversees research with human subjects.

If the research involves collaboration with another institution then the research cannot commence until the Committee receives written notification of approval from the collaborating institution's IRB.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date.

Protocols are approved for a maximum period of one year. You may not continue any research activity beyond the expiration date without Committee approval. Please submit continuation requests early enough to allow sufficient time for review. Failure to receive approval for continuation before the expiration date will result in the automatic suspension of the approval of this protocol. Information collected following suspension is unapproved research and cannot be reported or published as research data. If you do not wish continued approval, please notify the Committee of the study closure.

Adverse Events: Any serious or unexpected adverse event must be reported to the IRB Committee within 48 hours. All other adverse events should be reported within 10 working days.

Amendments: If you wish to change any aspect of this study, such as the procedures, the consent forms, study personnel, or number of participants, please submit an amendment to the IRB. All changes must be approved by the IRB Committee before they can be initiated.

You must maintain a research file for at least 3 years after completion of the study. This file should include all correspondence with the IRB Committee, original signed consent forms, and study data.

cc: Margie L Gilbertson, Investigator