Associations Between Key Language-Related Measures in Typically Developing School-Age Children

Lisa M.D. Archibald, Marc F. Joanisse, and Melany Shepherd

University of Western Ontario, London, Ontario, Canada

Abstract. Three measures have been found to be predictive of developmental language impairment: nonword repetition, the production of English past tense, and categorical speech perception. Despite this, direct comparisons of these tasks have been limited. The present study explored the associations between these measures and other language and cognitive skills in an unselected group of 100 children aged 6 to 11 years. The children completed standardized tests of nonverbal ability, receptive language, and reading, as well as nonword repetition, past tense production, and categorical speech perception tasks. Nonword repetition and past tense were highly correlated. Variance in nonword repetition was explained additionally by digit recall, whereas receptive language, age, and digit recall accounted for significant portions of variance in past tense production. Categorical speech perception was not associated with any of the measures in the study. The extent to which common and distinct facts underlie the key language-related measures is discussed.

Keywords: nonword repetition, past tense, speech perception, specific language impairment

In recent years, three measures have consistently been found to be predictive of developmental language impairment: nonword repetition – the ability to repeat novel phonological forms such as *fowmoychee*; the production of morphologically complex words such as English past tense; and the perception of acoustic cues necessary to categorize or discriminate speech sounds. Children with specific language impairment – an unexpected failure to develop language skills at a typical rate – tend to perform poorly on all of these tasks (Dollaghan & Campbell, 1998; Rice & Wexler, 1996; Tallal & Stark, 1981). These findings have sparked considerable debate as to what underlying deficits may account for low scores on these tasks, with some arguing that they tap distinct cognitive processes (e.g., Bishop, Adams, & Norbury, 2006; Bishop et al., 1999) and others suggesting that they are different measures of a single, language processing construct (e.g., MacDonald & Christiansen, 2002). One problem hampering this debate is that most studies include just one or two of these measures and, thus, a clear picture of how performance on these tasks may be related has yet to emerge. Leonard (2003) has called for the inclusion of these three measures in all studies of specific language impairment (SLI) in order to allow comparison across groups. However, it is important also to gain an understanding of how these tasks are related in typical development. The purpose of the present study was to investigate the relationships between nonword repetition, past tense production, speech perception, and other measures of language and cognitive skill in a representative sample of school-age children.

The research literature pertaining to SLI is replete with attempts to identify consistent areas of deficit in these children. Both nonword repetition (Bishop, North, & Donlan, 1996; Conti-Ramsden, 2003***[not in refs]***; Conti-Ramsden, Botting, & Faragher, 2001) and grammatical tense marking (Rice, 2003; Rice & Wexler, 1996) have been suggested as clinical markers of the disorder. The finding by Tallal and colleagues (Tallal & Piercy, 1973; Tallal & Stark, 1981) of an impairment in auditory temporal processing has been highly influential also. Few studies have attempted to compare these measures directly, however. A notable exception is a study by Bishop and colleagues, who used a twin study methodology to examine the joint heritability of these different difficulties in SLI. They found that nonword repetition and auditory temporal processing deficits in SLI were genetically independent (Bishop, et al., 1999), as were the nonword repetition and verb tense marking impairments (Bishop et al., 2006). These data suggest that even though auditory temporal processing, nonword repetition, and grammatical difficulties are all poor in language impaired children, they are not caused by a single underlying neurobiological factor.

One impediment to studying individual differences in these three abilities in SLI is the notoriously small sample sizes of children with SLI available to participate in studies, resulting in power issues for statistical analyses such as

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regression. This problem is avoided by studying the relationship among different language variables in samples of children representing the full range of abilities, who can be identified and recruited in sufficient numbers. The relevance of information drawn from such a sample to SLI was established in a study involving a latent class analysis of the language skills of a large sample of 3-year-old and 4-year-old children (Dollaghan, 2004). The results of this study revealed a dimensional distribution of language skills with no indication that a subgroup of children with SLI formed a qualitatively distinct group for three clinical indicators, receptive vocabulary, mean length of utterance, and mean number of different words. The present study builds on this by including an unselected group of school-age children and exploring relationships between the three key language-related measures of interest. The literature pertaining to each of these measures, including their possible relationship to language development, is summarized below.

Nonword Repetition

Nonword repetition is a deceptively simple task that mimics new word learning in that one way by which we may learn novel words is repeating their phonological form. Consistent with this, nonword repetition is highly associated with vocabulary knowledge of both native language (e.g., Gathercole & Baddeley, 1989; Gupta, 2003) and foreign language (e.g., Cheung, 1996; Masoura & Gathercole, 1999). In experimental studies, poor nonword repetition has been linked with slower or less accurate new word learning (Gathercole, Hitch, Service, & Martin, 1997; Papagno & Vallar, 1995), and difficulties acquiring foreign vocabulary (Palladino & Cornoldi, 2004). In addition to vocabulary acquisition, there has been some suggestion that the ability to repeat phonological forms may be related to the learning of grammatical forms, either because the necessary accumulation of word forms for rule abstraction is delayed (Baddeley, Gathercole, & Papagno, 1998) or grammatical markers are preferentially lost due to their frequent appearance in nonsalient, final positions (Leonard, 1989, 1998). Consistent with this suggestion, some studies have demonstrated associations between nonword repetition and language skills more broadly such as spoken narrative skills (Adams & Gathercole, 1996), utterance length, and range of syntactic constructions used (Adams & Gathercole, 1995, 2000).

Nonword repetition was originally proposed as a relatively pure index of phonological short-term memory – the ability to hold phonological information in mind for brief periods of time (Gathercole & Baddeley, 1993). There is now considerable evidence in support of this. For example, it is more difficult to recall longer than shorter nonwords, consistent with temporal forgetting from a limited storage mechanism (e.g., Baddelely, Thomson, & Buchanan, 1975). Also, repetition is less accurate for nonwords that are particularly unlike known words, reflecting a greater reliance on short-term memory when recall cannot be supported by existing lexical knowledge (e.g., Hulme et al., 1997). High correlations between nonword repetition and performance on more conventional short-term memory measures, such as digit recall, provide additional corroborative evidence (e.g., Gupta, MacWhinney, Feldman, & Sacco, 2003).

It must be acknowledged, however, that the act of repeating a nonword involves several steps, including hearing, perceiving, and segmenting the phonological form; encoding and retaining the phonological representation; and planning, programming, and executing the output. Alternative accounts suggest that nonword repetition taps other cognitive processes, including lexical knowledge (Snowling, Chiat, & Hulme, 1991), phonological sensitivity (e.g., Bowey, 1996), and output phonology (Wells, 1995). It is apparent, though, that the extent to which other cognitive processes influence nonword repetition depends on the nature of the nonwords. Wordlikeness (e.g., Hulme et al., 1997), phonotactic frequency (e.g., Munson, 2001), and prosodic pattern (Roy & Chiat, 2004) have all been found to influence nonword repetition. Even patterns of group differences between children with SLI and typically developing children vary when two tests of nonword repetition that differ in nonword length, wordlikeness, and articulatory complexity are compared (Archibald & Gathercole, 2006a).

Past Tense Production

Past tense forms in English are typically marked by adding the *-ed* suffix to a verb stem (e.g., *bake-baked*). However, like many morphological systems, this process is only partly regular, such that many exceptional cases also exist (e.g., irregulars such as *take-took*). Past tense productions typically emerge in the second year of life. The appearance of such relational structures is widely held to reflect the ability of the human cognitive apparatus to abstract categories and schemas (Tomasello, 2001) or linguistic rules (Pinker, 1991) from the amassed lexicon. Children with SLI are both delayed and less consistent in the use of inflectional verb morphology such as past tense (e.g., Leonard, Bortolini, Caselli, McGregor, & Sabbadini, 1992; Oetting & Horohov, 1997; Rice & Wexler, 1996; Rice, Wexler, & Cleave, 1995), and fail to achieve mastery in later years (e.g., Marchman, Wulfeck, & Ellis Weismer, 1999; Rice, Wexler, & Hershberger, 1998).

It has been suggested that there is a close link between phonological processing and the ability to learn past tense forms (Joanisse, 2004). This view appeals to the observation that there is typically a strong degree of phonological similarity between a present and past tense form (e.g., *walk-walked*), as well as overlap among past tenses of dif-

ferent verbs (e.g., *ripped, walked,* and *typed* are all formed by adding the same alveolar consonant to the end of the stem). Finally, the regular past tense ending is phonologically realized in one of three ways, depending on the phonological characteristics of the stem, as observed in the cases of *walked*, *sailed*, and tasted (/*-t*/, /*-d*/, and /*-Id*/). In all these cases, learning to generate past tenses involves close analysis of the phonological form of both inflected and uninflected forms to acquire an adequate generalization to new forms. This observation is also not restricted to regulars; subregularities are also observed in irregular forms such as *sing-sang, ring-rang*, and across regular and irregular forms such as hugg*ed* versus hel*d*.

A key test of rule-like representations in morphology is the so-called *wug* task (Berko, 1958), in which a speaker is asked to produce the past tense of a novel form (e.g., *He likes to wug everyday. Just like today, yesterday, he . . .*). Typically developing children and adults tend to productively apply the regular past tense ending to novel forms, although this tends to lag the development of familiar verbs to some extent (Berko, 1958). In contrast, children with SLI have greater difficulty with these types of forms, suggesting they have poorly-developed representations of the past tense morpheme (van der Lely & Ullman, 2001).

Speech Perception

In addition to nonword repetition and past tense production, a third key language-related measure involves speech perception. In some respects the relationship between the perception of speech sounds and the development of robust phonological representations may be considered reciprocal in nature. It is well known that although infants can discriminate most speech contrasts during the first few months of life, phonetic categories specific to a child's language environment are acquired during the first few years of development (Werker & Tees, 1999). It is assumed from these findings that exposure to the native language improves phonological representations that in turn shape the perception of speech sounds. The importance of speech perception, on the other hand, is reflected by two lines of converging evidence: Improvements in speech perception via perceptual identification training leads to better speech production (Bradlow, Pisoni, Akahane-Yamada, & Tohkura, 1997; Bradlow, Akahane-Yamada, Pisoni, & Tohkura, 1999), and poor speech perception is often associated with difficulties in language and/or reading acquisition (e.g., Chiappe, Chiappe, & Siegel, 2001; Tallal & Stark, 1981).

Speech perception deficits have been raised as a potential causal factor in the phonological impairments observed in dyslexia and SLI (Joanisse, Manis, Keating, & Seidenberg, 2000). Using a connectionist model, Joanisse and Seidenberg (2003) demonstrated that a phonological deficit could give rise to a sentence processing deficit similar to that observed in SLI. It must be acknowledged, however, that phonological impairments can have causes other than a speech perception deficit and, thus, poor speech perception may be present in only a subset of those affected with language disabilities. In a study of children with either phonological dyslexia only, dyslexia plus language impairment, or a global reading delay, only the group with a concomitant language deficit demonstrated impairments on speech perception tasks (Joanisse et al., 2000). The suggestion that developmental language and reading difficulties may have multiple origins is certainly not a new one (e.g., Aram & Nation, 1975; Conti-Ramsden, Crutchely, & Botting, 1997; Nation, 2001; Tomblin & Zhang, 1999).

One of the most commonly employed speech perception tasks involves the categorization of speech sounds. The acoustic change associated with minimal speech sound contrasts of voicing (e.g., /p/ – /b/) or place of articulation (e.g., /b/ – /d/) can be represented along a continuum. For example, small changes in onset frequency of the second formant can gradually make the syllable /da/ sound more like /ba/. In spite of this continuity, children and adults tend to produce a nonmonotonic response curve marked by similarly consistent responses for both endpoint and midpoint stimuli (Liberman, Harris, Hoffman, & Griffith, 1957). Weak or distorted categorization has been reported in some studies of dyslexia (e.g., Werker & Tees, 1987) and SLI (e.g., Sussman, 1993), typically characterized by less consistent responses for midpoint and occasionally endpoint stimuli.

As discussed above, there is some disagreement as to the extent of such difficulties both in dyslexia and SLI (Rosen, 2003). One possible reason for the lack of consistent findings related to speech perception in language-disabled groups is task sensitivity. Synthetic speech, for example, is more difficult to categorize than naturally spoken syllables (Coady, Evans, Mainela-Arnold, & Kluender, 2007) while a voicing continuum may be less demanding than a continuum based on place of articulation (Joanisse et al., 2000). It has been suggested also that children may recover from early speech perception deficits that cause long-term phonological impairments (Fitch & Tallal, 2003). If this is the case, children with early difficulties perceiving speech sounds may be indistinguishable from same-age peers on speech perception tasks in their school-age years.

Overview of Present Study

The purpose of the present study was to investigate the relationships between nonword repetition, past tense production, and speech perception, and to explore broader associations with other measures of language and cognitive skill. One aim was to examine the extent to which scores across tasks share common variance. Strong associations between these measures would reflect a common factor influencing performance. A second goal was to examine the

influence of other cognitive processes on the key tasks. A pattern of differential associations with short-term memory, receptive language, or the remaining measures would point to the importance of distinct underlying cognitive mechanisms.

Phonology is, on at least some accounts, the common factor among the three measures that we have described above; it provides the information for retention in nonword repetition, a probabilistic influence in past tense production, and influences recognition in categorical speech perception. The three measures, then, should show some degree of association that may be explained by a common phonological processing factor. Nevertheless, there are important additional influences for at least two of the tasks: the capacity for retention in nonword repetition and the role of prior knowledge (semantics) in past tense production. It follows from this that different patterns of association may be expected between these three language-related tasks and other measures. Nonword repetition may exhibit a greater association with memory-based tests such as immediate recall, whereas past tense production may be more related to knowledge-based measures. The case for categorical speech perception is more difficult to predict. Associations with all language-related measures would provide strong evidence of the role of speech perception in language development. It may be, however, that the importance of speech perception diminishes as the phonological system develops. If this is the case, an overall weak relationship between categorical speech perception and other language-related measures may be observed in children with well-developed language skills.

Method

Participants

A total of 97 children in grades 2 to 5 ranging in age from 6.9 to 11.1 years (see Table 1) were recruited from two primary schools in the city of London, Ontario. All were native English speakers, and were considered to be displaying typical development generally by teachers and parents. Only children with diagnosed neurological, cognitive, or developmental impairments (assessed by parent report) were excluded from the study.

Procedure

All participants were tested in a quiet room in their school over two individual sessions not longer than half an hour each. Each child completed tests tapping the following areas in the order indicated: Session 1, word and nonword reading, receptive grammar, and nonverbal cognitive ability; Session 2, nonword repetition, past tense production, categorical speech perception, and digit recall.

Nonword Repetition

The Nonword Repetition Test (NRT; Dollaghan & Campbell, 1998) consisted of 16 nonwords, four stimuli each containing one, two, three, and four syllables. The nonwords were constructed from a limited set of phonemes (11 consonants, 9 vowels) excluding late developing sounds. The nonwords followed an alternating consonant-vowel structure, and none of the syllables correspond to English lexical items. Only tense vowels were used, and therefore the stress patterns of the nonwords were unlike typical English words in that they had no weak syllables. A detailed description of the criteria guiding the development of the NRT is provided in Dollaghan and Campbell (1998). The nonwords were presented auditorily in fixed random order via a digital audio recording of an adult female speaker following the phonetic transcription and pronunciation guidelines described by Dollaghan and Campbell (1998). Responses were digitally recorded and scored offline by computing the number of phonemes correct for each nonword, and the percent phonemes correct at each nonword length and overall.

Speech rate was measured from all fluent productions of 3- and 4-syllable nonwords on the NRT. Nonwords were judged by the first author as fluent if the item was produced without perceptible pauses between syllables, hesitations, or phoneme duplications. On average, participants produced 6.51 (SD = 1.30) out of 8 possible trials fluently. Measurements were taken from the initial burst or aperiodicity of the first consonant to the end of aperiodicity of the final consonant. Average speech rate across fluent trials in syllables per second (syl/s) was calculated for each participant.

Past Tense Production

In this task the child was asked to complete phrases of the form "They print letters. Yesterday, they . . ." The test included 48 items, 24 real words and 24 nonwords. Twelve of the real words were irregular verbs (e.g., *dig-dug*), and 12 were regular verbs with 6 realized phonologically as a final /t/ (e.g., *pass-passed*), 2 as a final /d/ (e.g., *play-played*), and 4 as a final /Id/ (e.g., *want-wanted*). For the nonwords, trials in which participants produced the regular endings were scored as "correct," with 8 realized phonologically with a final /t/ (e.g., *goss-gossed*), 8 with a final /d/ (*murn-murned*), and 8 with a final /Id/ (*mund-munded*). The number of correct responses for words, nonwords, and overall, were computed for each participant.

Speech perception

The *categorical speech perception task* contrasted sounds differing in place of articulation, */b/* and */d/*. An eight-member *ba-da* series was created using a digital implementation

of the Klatt (1980) cascade/parallel speech synthesizer, recorded as 16-bit, 22.05-kHz digital sound files. Place of articulation was manipulated by varying the onset frequency of the second formant (F2) between 900 and 1600 Hz, while keeping all other parameters constant (F1 onset: 200 Hz; F3 onset: 2550 Hz; F4 onset: 3300; F0 was initially 120 Hz, falling to 100 Hz mid-vowel; see Joanisse, Robertson, & Newman [2007] for details of the synthesis procedure). Each syllable was presented six times for a total of 48 trials presented in fixed random order. On each trial, the child was asked to identify the syllable as either */ba/* or */da/*. Response profiles were quantified by computing the proportion */da/* identifications for each item in the continuum, yielding a response curve for each participant. This curve was then fitted subject-wise to a logistic function using a curvefitting procedure in SPSS 14. The slope of this curve was used as the participant's score on this task.

Short-Term Memory

The Digit Recall subtest of the Wechsler Intelligence Scale for Children – IV (WISC-IV; Wechsler, 2003) involved the presentation of a sequence of digits that the child was required to recall in correct serial order. Two lists were provided at each length to a maximum of eight digits. Testing commenced with a list length of two, and continued until both lists of a particular length were recalled incorrectly. The raw score equalled the number of lists correctly recalled.

Receptive language

The Test for Reception of Grammar (TROG; Bishop, 1982) is a multiple choice comprehension test. The child was required to select a picture to match a sentence spoken by the tester. All items used simple vocabulary; grammatical complexity increased as the test proceeded, and understanding of 20 sentence types was tested. Four items were administered per sentence type and correct responses were required for all four items in order for the block to be considered correct. The raw score equalled the number of blocks completed correctly.

Reading

In the Word Identification of the Woodcock Reading Mastery Test (Woodcock, 1989), the child was asked to read aloud each real word presented on a page. The test began with simple words and continued until six consecutive failed responses occurred. For the Word Attack subtest, the child was required to read aloud a nonword presented in written format. Testing commenced with two-phoneme nonwords and continued with increasingly longer and more complex nonwords until six consecutive errors occurred. It should be noted that both word attack and word identification skills are known to be highly correlated with traditional measures of phonological awareness (e.g., Saunders & DeFulio, 2007).

Nonverbal Cognition

Both the Block Design and Matrix Reasoning subtests of the WISC-IV (Wechsler, 2003) were administered. These subtests comprise part of the core performance measure of the WISC-IV and were intended to measure general nonverbal ability in children. Block design involved arranging colored blocks in shapes based on a model; matrix reasoning involved completing a visual pattern.

Results

Descriptive statistics for all standardized measures are provided in Table 1. Standard scores within grades and for the entire group were in the average range for all tests. The data

Table 1. Descriptive statistics for all standardized measures by grade

				Block design		Matrix reasoning		TROG		Word identification		Word attack	
Grade	*N*		Age	RS	SS	RS	SS	RS	SS	RS	SS	RS	SS
2	28	*M*	7.52	18.50	9.14	13.43	9.57	14.46	97.89	52.79	106.04	20.32	108.00
		SD	0.28	13.99	2.92	5.22	3.43	2.85	13.25	11.15	9.96	8.17	9.29
3	37	*M*	8.46	27.94	11.19	18.14	10.81	16.44	101.86	59.72	101.86	23.86	105.50
		SD	0.32	10.07	2.64	4.37	2.64	2.74	12.54	10.87	10.34	8.02	9.92
4	23	*M*	9.62	31.57	10.91	22.26	11.70	17.17	104.22	69.30	105.43	27.35	107.48
		SD	0.33	9.85	2.58	3.06	1.94	1.58	14.10	8.83	10.24	8.57	10.14
5[a]	9	*M*	10.49	27.11	8.33	20.56	9.78	16.44	93.11	73.89	101.67	31.33	105.67
		SD	0.39	9.84	2.87	3.94	2.54	2.30	13.45	8.61	11.35	5.96	10.72
All	97	*M*	8.65	25.81	10.22	17.92	10.54	15.99	100.21	61.14	103.75	24.29	106.62
		SD	1.01	12.26	2.91	5.43	2.83	2.72	13.57	12.55	10.40	8.61	9.78

[a]includes one child in grade 6.

Table 2. Descriptive statistics for nonstandardized measures by grade

			Past tense production				Digit recall	Categorical	Speech rate
Grade	*N*		Regular	Irregular	Nonwords	Overall			
2	28	*M*	9.75	4.68	15.64	30.07	6.89	0.29	2.01
		SD	2.44	3.59	3.92	8.12	1.34	0.13	0.27
3	37	*M*	11.00	8.14	16.06	35.19	7.44	0.29	2.08
		SD	1.79	3.58	5.04	8.33	2.02	0.01	0.30
4	23	*M*	11.50	8.73	17.43	37.73	8.09	0.28	2.05
		SD	0.93	2.55	3.93	6.27	1.66	0.20	0.23
5[a]	9	*M*	11.44	7.56	18.33	37.33	8.00	0.36	2.05
		SD	1.01	2.65	3.87	7.07	2.24	0.29	0.25
All	97	*M*	10.77	7.11	16.44	34.33	7.45	0.30	2.05
		SD	1.93	3.67	4.39	8.17	1.81	0.16	0.27

[a]includes one child in grade 6.

are representative of the typical range of abilities observed in school age children. Raw scores tended to increase with grade level reflecting the developmental nature of these tasks.

Preliminary Analyses of Individual Measures

Mean phoneme accuracy scores for each nonword length and overall score on the NRT are summarized for each grade group in Figure 1. Accuracy was highest for the 2-syllable nonword length, and lowest for the 4-syllable nonwords for all groups. A one-way ANOVA completed on the accuracy data as a function of nonword length was significant, $F(3, 288) = 91.88$, $p < .001$, $\eta_p^2 = 0.49$. Pairwise comparisons with Bonferroni correction for multiple comparisons revealed that accuracy for 2-syllable words was significantly higher than all of the other nonword lengths (1-syl: $p = .02$; 3- & 4-syl: $p < .001$), and significantly lower for the 4-syllable nonwords than any of the other nonword lengths ($p < .001$, all cases). It should be noted that accuracy on both the 1- and 2-syllable nonwords approached ceiling levels.

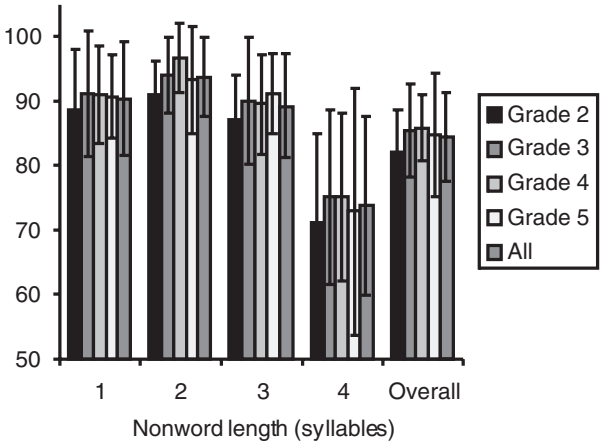

Figure 1. Percent phonemes correct on NRT at each syllable length and overall for each grade.

Descriptive statistics for the remaining experimental measures are presented in Table 2. Similar to the standardized measures, a developmental trend was apparent in both the past tense production and digit recall tasks. In contrast, all groups performed at similar levels on the categorical perception and speech rate tasks. Performance on past tense production for regular verbs approached ceiling for all groups except the youngest (2nd grade). It should be noted that the categorical speech perception data were highly skewed due to the nonlinear nature of how curve slopes change in response to small changes in response rates, and, thus, a log transformation of the data was employed for all statistical analyses.

Associations Between Measures

In order to explore associations between the key experimental measures and all remaining measures, a correlation matrix was computed. Both zero and partial correlations controlling for age are summarized in Table 3. Nonword repetition and past tense production were significantly correlated even after effects due to age were partialled out, whereas categorical speech perception was not correlated with these, or any of the measures. Additional significant correlations persisted for nonword repetition after adjustments for age with digit recall and speech rate, and for past tense production, with digit recall and word identification. None of the experimental measures were significantly correlated with the two measures of nonverbal ability (block design, matrix reasoning), the TROG, or word identification.

A further correlation matrix was computed to examine whether the relationships between digit recall, past tense production, nonword repetition, and speech rate vary as a function of nonword length or past tense type (Table 4).

Table 3. Zero order (upper; *df* = 96) and partial correlations controlling for age (lower; *df* = 92) for all measures

	BD	MR	TROG	WID	WA	DR	CSP	Rate	PTtot	NRTtot
Block design		.49**	.33**	.30**	.18	.19	.04	–.08	.24**	.14
Matrix reasoning	.41**		.60**	.62**	.46**	.23*	.08	.09	.15	.18
TROG	.25*	.56*		.37**	.26**	.05	–.03	.08	.20	–.03
Word identification	.16	.45**	.26*		.80**	.23*	.001	.08	.33**	.16
Word attack	.06	.33**	.17	.76**		.14	.15	.15	.20*	.09
Digit recall	.13	.15	–.03	.15	.06		–.10	.22*	.41**	.55**
Categorization slope	.08	.14	.02	.05	.20	–.07		.14	–.15	–.03
Speech rate	–.10	.07	.05	.06	.14	.21*	.14		.17	.255*
Past tense (total)	.18	.03	.12	.24**	.12	.38**	–.14	.15		.42**
Nonword rep (total)	.11	.15	–.07	.11	.05	.55**	–.04	.24*	.40**	

*$p < .05$, **$p < .01$.

Table 4. Zero order (upper; *df* = 97) and partial correlations controlling for age (lower; *df* = 92) for selected measures

	Rate	DR	PTreg	PTirreg	PTnwd	PTtot	nrt1	nrt2	nrt3	nrt4	NRTtot
Speech rate		.22*	.05	.19	.14	.17	.01	–.003	.19	.25*	.255*
Digit recall	.21*		.17	.39**	.36**	.41**	.06	–.003	.36**	.55**	.55**
Past tense (regular)	.01	.14		.57**	.49**	.75**	.07	.23*	.11	.15	.20*
Past tense (irregular)	.16	.36**	.53**		.44*	.82**	.27**	.20	.23*	.39*	.46**
Past tense (nonwords)	.14	.34**	.49**	.43**		.85*	.08	.11	.14	.29**	.30**
Past tense (total)	.15	.38**	.74**	.80**	.86**		.18	.20*	.21*	.37**	.42**
Nonword rep (1-syllable)	.003	.06	.05	.27*	.08	.18		–.02	.16	.11	.30**
Nonword rep (2-syllables)	–.01	–.05	.20	.15	.09	.16	.09		–.06	.07	.22*
Nonword rep (3-syllables)	.18	.34**	.09	.21*	.12	.18	.16	–.09		.36**	.63**
Nonword rep (4-syllables)	.24*	.57**	.12	.39**	.29*	.36**	.10	.06	.36**		.91**
Nonword rep (total)	.24*	.55**	.17	.44**	.29*	.40**	.29*	.20	.63**	.92**	

*$p < .05$, **$p < .01$.

Ceiling effects may have influenced the data for the 1- and 2-syllable lengths in nonword repetition resulting in low *r*-values for these subscores across the board, and the production of regular past tense yielding poor correlations with all but the other past tense tasks. Both the repetition of 4-syllable nonwords and digit recall were significantly correlated with all of the remaining measures including speech rate, 3-syllable nonword repetition, past tense production for irregulars and nonwords, and with each other. None of the past tense measures were associated with speech rate.

Three stepwise regression analyses were completed in order to investigate the extent to which variance in each of the key language-related measures (nonword repetition, past tense production, speech perception) may be explained either by each other (shared variance) or by different relationships with other variables. For each analysis, one of these tasks was entered as the dependent measure and the remaining two were entered as possible predictor variables together with age (months), measures of nonverbal ability (block design, matrix reasoning), phonological awareness (word attack), receptive language (TROG), digit recall, and speech rate. The regression performed on the categorical speech perception task yielded no significant predictor variables. The outcome of the regression analyses on nonword repetition and past tense production are summarized in Table 5. In the analysis on nonword repetition, a large proportion of the variance was explained by digit recall (32%), with an additional 4% accounted for by past tense

Table 5. Summary of stepwise regressions with unique variance explained by each significant predictor variable for respective analyses of nonword repetition and past tense production

Step	Predictor variable	ΔR^2
	Nonword Repetition Test (NRT) total score	
1	Digit recall	0.318**
2	PT overall	0.42**
	Past tense (PT) production (overall score)	
1	NRT	0.172**
2	Digit recall	0.042*
3	TROG	0.034*

*$p < .05$, **$p < .01$.

production (overall). For past tense production, nonword repetition explained the greatest portion of variance among the variables entered (17%) with an additional 4% and 3% accounted for by digit recall and TROG, respectively.

In order to ensure that ceiling effects (in nonword repetition of 1- and 2-syllable nonwords, and regular past tense production) were not influencing these analyses, corresponding regression analyses were completed on

1) Nonword repetition collapsed across the 3- and 4-syllable nonwords only,
2) Past tense production of irregulars, and
3) Past tense production for nonwords.

The results of the analysis on the 3- and 4-syllable nonwords were unchanged from the overall nonword repetition score. For past tense irregulars, 21% of the variance was explained by nonword repetition and an additional 6% by age. For past tense on nonwords, digit span accounted for 12% of the variance and the TROG, an additional 4%.

Discussion

Recent studies have suggested that nonword repetition, past tense production, and speech perception predict typical and impaired language development in children. The present study explored associations among these tasks, and also how they are related to broader measures of language, and cognition. School-age children completed measures of nonword repetition, past tense production, categorical speech perception, short-term memory, receptive language, reading, and nonverbal ability. The results indicated that nonword repetition and past tense production were highly correlated, with each explaining a significant portion of variance in performance on the other measure. This relationship was driven largely by the longest nonwords in the nonword repetition task and the production of irregulars in the past tense test. Distinct associations were noted also. A large amount of variance in nonword repetition was accounted for by digit recall whereas past tense production was explained also by digit recall and receptive language. More specifically, this latter finding was qualified by the observation that nonword past tenses were specifically predicted by TROG scores, whereas variance in irregular past tenses were instead explained by age. In contrast, performance on the categorical speech perception task was not associated with any of the measures included in the study.

The present findings provide evidence for a common factor influencing performance on both the nonword repetition and past tense tasks. Given that this relationship was strongest among the longest nonwords and irregular past tenses, it is tempting to conclude that the unifying feature tapped by these two tasks is related to memory skills. There are indications, though, that this is not the case. First, the association between nonword repetition and past tense was present even when variance due to short-term memory as measured by digit recall was taken into account. Second, only the past tense task was linked to the measure of long-term knowledge-based receptive language (TROG), and this association was present only for the production of past tense for nonwords, and not irregulars. It may be, too, that performance was most variable for four-syllable nonwords and irregular past tenses, and as such these subtasks were the most likely to show significant correlations.

That said, nonword repetition and past tense production generally appear to tap a common cognitive process separate from short-term or long-term memory skills. What additional cognitive demands might be shared among these two skills? Unfortunately, there are few hints in the present data to answer this question. One suggestion is that they both tap more basic phonological processing skills related to analyzing the phonological structure of words and nonwords. While the present lack of an association between these measures and categorical speech perception does not provide support for this hypothesis, it does not rule it out either. There is good evidence that speech perception abilities are not always the best predictor of phonological processing, in that many children with phonological problems are unimpaired on speech perception tasks (Joanisse et al., 2000). Nevertheless, there was a strong correlation between past tense production and word identification. Given the strong role that phonological processing plays in reading (Saunders & DeFulio, 2007), this seems to support the idea of a link between phonology and past tense skills in the present data.

The role that age plays in nonword repetition and past tense production merits some consideration here. Developmental factors explained variance in irregular past tense production – consistent with the later acquisition of these forms (Brown, 1973; Bybee & Slobin, 1982), which in turn accounted for variance in repetition of longer nonwords. It may be that the lexicon becomes better equipped to deal with atypical forms as the system develops.

Results of this study also reflect different relationships with other language and cognitive measures for at least two of the three key measures. Consistent with many previous findings, nonword repetition was highly correlated with a conventional measure of short-term memory, digit recall (see Baddeley et al., 1998, for a review). It has been suggested that the repetition of novel word forms facilitates lexical learning by generating a brief phonological representation, thereby mediating the creation of a phonological entry within the long-term lexical store (Baddeley et al., 1998; Gathercole, 2006). Not all of the variance in nonword repetition performance was explained by digit recall, however.

There were differences also in the pattern of associations for digit recall and repetition of the longest nonwords, indicating that digit recall and nonword repetition are not just mirror measures. The suggestion that nonword repetition may tap additional cognitive processes other than short-term memory is supported by findings that nonword repetition is more sensitive to SLI than conventional serial re-

call measures such as digit recall (Archibald & Gathercole, 2006b). It may be that long-term phonological knowledge is tapped to a greater extent by the unfamiliar sequences in nonword repetition than the automatic, over-learned items in digit recall. The unique associations between past tense production and both the receptive language measure (TROG) and age suggests also that past tense production relies on some underlying cognitive and linguistic processes separate from that tapped by nonword repetition.

While not entirely unexpected, the findings regarding categorical speech perception were disappointing. In this group of school-age children, categorical speech perception was unrelated to any of the other study measures. One of the most likely but uninteresting explanations for this result is that the measure employed was not sensitive enough to capture the variability in performance of this age range. Another possibility is that while speech perception tasks of this type are able to detect gross differences between language impaired children and typically developing age-mates, they do not appear to capture potentially graded differences in speech abilities across all speakers. Consequently, we observed very good categorical perception skills across nearly all children in the study, regardless of age.

Conclusions

In this study, school-age children's performance on nonword repetition and past tense production tasks were highly correlated, but each also exhibited unique associations with other language, memory, and cognitive measures. Categorical speech perception was unrelated to any of the study measures. The results indicate that a common factor may be tapped by both nonword repetition and past tense production. While the present results provide little information as to the nature of this process, theories relevant to each of these tasks converge on the role of phonology. The findings also provide support for the notion that nonword repetition is an index of short-term memory, consistent with many previous findings (Baddeley et al., 1998). The lack of a relationship of any of the language or language-related measures with categorical speech perception in a school-age group may reflect a diminished role of speech perception on language in older children, or a general insensitivity of the task in capturing variability in most typically-developing children. The results do suggest that both common and distinct mechanisms underlie nonword repetition, past tense production, and categorical speech perception – three measures that have been found to be highly sensitive to language and reading impairments in children. It would seem important, then, that more studies of children with SLI and dyslexia employ all three of these tasks in order to facilitate understanding of the cognitive processes implicated and comparisons across studies.

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Lisa Archibald

Department of Psychology
University of Western Ontario
[full address, please]
London, Ontario
N6A 5C2
Canada
Tel. +1 519 661-2067
Fax. +1 519 661-3961
E-mail larchiba@uwo.ca

