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Research Article

Rapid Naming and Phonemic Awareness in Children With Reading Disabilities and/or Specific Language Impairment: Differentiating Processes?

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Purpose: The objective of this study was to assess and compare the predictive values of group membership for rapid automatized naming (RAN) and phonemic awareness (PA) in Dutch school children with and without reading disabilities (RD) or specific language impairment (SLI).
Method: A composite word reading index and a formal SLI diagnosis were used to classify a total of 1,267 children aged 8 to 13 years old either as RD-only (*n* = 126), SLI-only (*n* = 21), comorbid (RD+SLI; *n* = 30), or typically developing (*n* = 1,090). RAN and PA were assessed with 4 standardized subtests. The clinical subgroups were compared to each other and contrasted with the control group.
Results: For each subgroup, results indicate substantial effect sizes of RAN and PA. However, the RD-only group seems to be more affected by poor RAN than the SLI-only group, whereas the 2 groups perform equally poorly on PA. The comorbid group was revealed as most severely impaired on all measurements.
Conclusions: In studying RD and SLI, this research indicates that it is important to distinguish between RD-only, SLI-only, and comorbid groups. The comorbid group shows additive effects of both disorders.

This study focuses on the issue of comorbidity of *specific language impairment* (SLI) with (specific) *reading disability* (RD). SLI has been defined as a failure of normal oral language development despite normal intelligence, adequate learning environment, and no apparent sensory or emotional problems (Bishop, 1992). RD has been similarly defined as persistent difficulties with word reading, with reading comprehension mentioned as a possibly secondary risk (Lyon, Shaywitz, & Shaywitz, 2003). The problem that generated the present research is that the literature frequently reports RD in children with SLI (De Bree, Rispens, & Gerrits, 2007; Vandewalle, Boets, Ghesquiere, & Zink, 2012). Although the comorbidity rate in clinical samples is likely to be inflated (Catts, Adlof, Hogan, & Weismer, 2005), even conservative estimates warrant further study of reading-related processes in the groups involved (Bishop & Snowling, 2004; McArthur, Hogben, Edwards, Heath, & Mengler, 2000; Scuccimarra et al., 2008).

A further and obviously more content-related motive for studying comorbidity is that it remains unclear how the two disorders are related at the level of decoding and/or reading comprehension. This study specifically involves the decoding and word recognition part of the question, leaving comprehension for future research. To be specific, the question is raised as to whether word reading–related cognitive processing is different in children with or without SLI and/or impaired single word reading fluency (RD). In the remainder of this introduction we will briefly discuss two word reading–related cognitive processes deemed as obvious candidates for comparative research with these groups: *phonemic awareness* (PA) and *rapid automatized naming* (RAN).

Phonemic Awareness

A deficit in PA—that is, the ability to recognize and manipulate the sound constituents of oral language, and to apply this insight to alphabetic knowledge and knowledge of written sublexical units of words (Ehri, 2005)—is regarded by many researchers as a core deficit of dyslexia

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(De Groot, Van den Bos, Minnaert, & Van der Meulen, 2015; Kirby, Desrochers, Roth, & Lai, 2008; Rack, 1994; Ramus, White, & Frith, 2006; Van den Bos, 2008; Wagner et al., 1997; Wimmer, Mayringer, & Landerl, 1998, 2000; Wolf & Bowers, 1999). There is substantial evidence indicating that PA plays an important role in the prediction of single word reading ability (WR), at least in the early grades of primary education (Van den Bos & De Groot, 2012), and in poor readers in particular (De Groot et al., 2015).

In addition, children with SLI have frequently been reported to demonstrate specific problems with PA tasks (e.g., McArthur et al., 2000; Nathan, Stackhouse, Goulandris, & Snowling, 2004; Scuccimarra et al., 2008). A point of interest is that studies distinguishing between SLI-only and comorbid groups (Baird, Slonims, Simonoff, & Dworzynski, 2011; Catts et al., 2005; Eisenmajer, Ross, & Pratt, 2005) have typically reported relatively better PA in children with SLI-only relative to comorbid groups. This suggests that PA impairments are primarily related to RD and to a lesser extent to SLI. Another line of research that might clarify the link between SLI and poor PA performance is formed by studies that have investigated the connection with phonological short-term memory (STM; Catts et al., 2005; Edwards & Lahey, 1998; Snowling, Bishop, & Stothard, 2000). These studies demonstrated considerable evidence of STM deficits in SLI, and this might partially explain PA deficits in those groups. The link between SLI and STM is further emphasized by poor performance on nonword repetition tasks, which are considered good phenotypic indicators of SLI (Conti-Ramsden & Durkin, 2007; De Bree et al., 2007; Edwards & Lahey, 1998). However, most of the studies mentioned did not assess reading abilities. Thus, it seems likely that a substantial proportion of children had RD as well, which may have biased the results.

Having established that PA and, by implication, STM, have been central issues for research on RD as well as SLI, the question now arises as to predictions for the comorbid group, which is characterized by RD as well as oral language difficulties. A recent longitudinal study by Vandewalle et al. (2012) reported PA impairments in kindergartners and first graders with SLI and/or RD, with the comorbid group showing the poorest performances. This latter finding is repeated for third graders. For the children with SLI-only, the PA effect seems to have diminished at this grade level. In concordance with earlier results (Bishop, McDonald, Bird, & Hayiou-Thomas, 2009; Catts et al., 2005), Vandewalle et al. (2012) concluded that with age, PA deficits become more closely linked to RD, as opposed to SLI. However, this conclusion seems to be modified by the discovery of persistent problems with more demanding PA tasks in children with SLI-only. Moreover, using a relatively difficult PA task, Brizzolara et al. (2006) reported PA problems for older language-delayed dyslexic children.

In the context of comorbidity, Catts et al. (2005) considered three different explanatory models. According to the first model, RD and SLI are different manifestations of the same underlying phonological processing deficit—as operationalized by PA—and differ primarily in the severity of this deficit. That is, SLI accompanied by a severe PA deficit could lead to RD and oral language difficulties, whereas a less severe deficit would lead to RD only. The second model assumes that SLI and dyslexia are partially similar but distinct disorders. Therefore, both groups would experience similar problems with PA and WR. The difference with Model 1 is that children with SLI would experience additional cognitive problems operating on oral language abilities relatively independent of phonological processing, which may or may not manifest as—or contribute to—RD at the behavioral level. According to Bishop and Snowling (2004), "…more severe basic language impairments do not necessarily map to more severe literacy problems because of the division of labor between resources shared by language and literacy" (p. 878). The third model assumes that RD and SLI are distinct developmental disorders that result from different cognitive deficits—that is, RD is primarily linked to phonological processing deficits—whereas SLI is better described as resulting from a collection of higher order linguistic deficits that are not phonologically based. According to this model, overlap between the two disorders is due to comorbidity in the literal sense—that is, the disorders are related but distinct and sometimes just happen to co-occur in the same individual. In summary, whereas Model 3 seems to preclude phonological involvement in children with SLI, the first two models imply such involvement in both RD and SLI. These models, then, seem more closely aligned with the findings of the aforementioned studies on PA. That is, PA impairments are expected in children with SLI as well as those with RD, and the largest negative PA effects occur in comorbid groups.

Rapid Automatized Naming

As implied by the double deficit hypothesis (DDH; Wolf & Bowers, 1999), a large number of studies have made clear that, in addition to—or even instead of—difficulties in sublexical processing, many individuals with RD typically demonstrate impaired RAN skills (Bowers, 1995; Kirby et al., 2008; Logan, Schatschneider, & Wagner, 2011; Torgesen et al., 1999; Torppa, Georgiou, Salmi, Eklund, & Lyytinen, 2012; Van den Bos, 2008; Wimmer, 1993). The general notion of the link between RAN and WR speed should, however, be refined by the following note on RAN subtasks. Batteries of RAN tasks (Denckla & Rudel, 1974) typically consist of RAN_{colors}, $RAN_{pictures}$, RAN_{digits}, and $RAN_{letters}$. Factor analysis has repeatedly demonstrated that colors and pictures load on a nonalphanumeric RAN factor, whereas RAN_{digits} and $RAN_{letters}$ form the alphanumeric RAN category (Van den Bos, Zijlstra, & Lutje Spelberg, 2002). This distinction is relevant because it has consistently been demonstrated that alphanumeric stimuli are more strongly related to WR than their nonalphanumeric counterparts (Van den Bos & Lutje Spelberg, 2010; Van den Bos et al., 2002; Wagner, Torgesen, Rashotte, & Pearson, 2013), and this applies to broad age ranges of typically developing (TD) children as well as those with RD. Because of their more substantial relationship to reading, in the present study, RAN data will be restricted to alphanumeric stimuli (see the Method section for further details).

Bishop et al. (2009) proposed two possible explanations for links between RAN and RD or SLI. First, reading and RAN have overlapping neural networks (Dehaene, 2005; Geschwind, 1965). It has been demonstrated that these networks are impaired in dyslexic adults (McCrory, Mechelli, Frith, & Price, 2005). This may cause problems accessing lexical–phonological representations (Boets et al., 2013; Logan et al., 2011; McCrory et al., 2005), which in turn affects fast and accurate word recognition. In any case, this reasoning predicts poor RAN performance in RD children. Second, Bishop et al. (2009) considered RAN as a correlate of oral language development. As oral language development is the primary problem of children with SLI, this line of thought predicts RAN deficits in most children with SLI, regardless of WR proficiency. Moreover, this would imply that RAN would be impaired only in cases of dyslexia with comorbid oral language impairments. However, for this implication, the research literature offers no support, as several studies of children with RD-only indicate poor RAN skills in the absence of oral language difficulties (Bishop et al., 2009; Brizzolara et al., 2006; Gough & Tunmer, 1986; Wolf & Bowers, 1999). Also, with regard to the general prediction of a RAN–language relation, there are various studies in which children with SLI-only demonstrate normal RAN skills (Bishop et al., 2009; Vandewalle et al., 2012). It should be noted, however, that many earlier studies (e.g., Katz, Curtiss, & Tallal, 1992; Lahey & Edwards, 1996) used nonalphanumeric RAN only, and that they did not distinguish between SLI-only and RD+SLI. The latter confounding may also explain why RAN was found to be markedly poorer in these studies. On the other hand, low RAN performance might be suggestive of vocabulary deficits or word-finding problems being expressed in the naming of nonlinguistic or nonalphanumeric stimuli (pictures) by language-impaired children (e.g., Kail & Leonard, 1986; Leonard & Deevy, 2004; Sheng & McGregor, 2010). However, as noted earlier, nonalphanumeric stimuli have a relatively low bearing on WR and RD. To conclude, the few studies that did involve alphanumeric RAN suggest a specific link to RD, either in a relatively pure form (RD-only) or as part of comorbid problems. With regard to SLI-only groups' oral language problems, no link with alphanumeric RAN has been reported.

Summarizing, this study will investigate the effects of PA and alphanumeric RAN in children with SLI and/or RD. With regard to PA, effects are anticipated for children with RD, but possibly for those with SLI as well. The comorbid group is expected to show the most severe impairments on PA. Regarding RAN, we hypothesize a specific link to RD, either in a relatively pure form (RD-only) or as part of comorbid problems. The SLI-only group is not expected to show impaired RAN performance.

Method

Participants

This study involves a total of 1,267 Dutch school children. The sample contains children with RD-only, SLI-only, children with both RD and SLI (RD+SLI), and a large control group of TD children. Below, the sampling procedure, classification criteria, and the resulting subgroups are described in more detail.

General Sampling Procedure

General inclusion criteria were as follows: 8–13 years old, IQ > 80, no uncorrected hearing or vision problems, and no apparent clinical-neurological disorders additional to RD and/or SLI, as indicated by school records. It is important to note that the Dutch educational system with schools for regular and special education conveniently acted as a pre-selection filter for recruitment in this study. The large majority of the population of regular elementary schools can be considered to consist of TD children. However, policy changes of the past 30 years have resulted in more varied admittance and educational approaches to children with atypical development than before, so that children with RD-only are no longer referred to schools for special education, whereas children with SLI are. Therefore, controls and children with RD-only were sampled from regular elementary schools, and children with SLI were sampled from schools specializing in speech, language, hearing, and communication disorders. Further procedural remarks are that for children younger than 12 years of age, informed consent was required from their parents. Participants older than 12 years were also required to provide consent on their own behalf. Data collection was carried out by the first author and undergraduate students either at a university research facility or at the school or special care institute of the participant.

Group Assignments

Children were classified as RD if reading performance (for measurement details see the Instruments section below) was more than 1.5 *SD* below the population mean. Assignment to either SLI group was based upon concomitant clinical-diagnostic assessments (see below) according to formal Dutch criteria for enrollment in special educational programs. These criteria include: (a) significant language impairments—indicated by test performances of at least 1.5 *SD* below average on two standardized tests—for at least two of four areas (i.e., lexical-semantic processing, syntactic processing, speech production, and auditory perception); (b) these impairments are not attributable to general cognitive dysfunction; (c) speech therapy in regular educational contexts, with a duration of at least 6 months, has not yielded significant improvements; and (d) evidence of impoverished social-educational participation, which is due to limited communication skills that are not adequately accommodated by regular educational and support systems. The present study further narrows its focus to receptive language impairments, as indicated by lexical-semantic and syntactic processing tasks—see criterion (a)—while excluding those children with impairments in speech production and/or significant hearing loss (i.e., an uncorrected loss > 35 dB, as diagnosed by independent audiologists). Application of these criteria yielded group frequencies as specified in Table 1, which also includes age and gender characteristics of each group. For external validity purposes, IQ and vocabulary tests (see below) were administered by our research team. Table 1 shows these means as well.

RD-Only and Controls

The RD-only group (*n* = 126) and the control group (*n* = 1,090) consist of children attending regular Dutch elementary schools. Although the participating schools (*n* = 52) were approached through personal networks, and thus were not selected entirely at random, they span all major regions of the Netherlands. As such, these groups can be considered representative of the Dutch population for this age range. The criterion for RD was provided above. Children not meeting this criterion were considered controls. In order to establish the validity of the term RD-only, the children, school boards, and their teachers were questioned for any additional disabilities that could have led to exclusion. For the present study, such exclusions were minimal. The RD-only group also encompassed clinical referrals (*n* = 25) from specialized dyslexia care centers that were participating in more elaborate clinical trials taking place at a university research facility. To ensure that reading-related problems were not attributable to deficits in general cognitive functioning (IQ) or oral language abilities, these children were assessed with four subtests from the Dutch version of the Wechsler Intelligence Scale for Children (WISC-III-NL; Wechsler, 2005) and a Dutch version of the Peabody Picture Vocabulary Test–III (PPVT-III-NL; Dunn & Dunn, 2005), respectively (see Table 1). The IQ assessment consisted of the subtests of Vocabulary, Similarities, Object Assembly, and Block Design. The average of the standard scores of these selected subtests can be considered a reliable estimate of IQ (Legerstee, van der Reijden-Lakeman, Lechner-van der Noort, & Ferdinand, 2004). As indicated by Table 1, the clinically referred RD-only subgroup shows normal IQ and passive vocabulary test (PPVT) scores. These results support the assumption of specific RD in this group. It should be noted, however, that as these measurements were unavailable for the non-clinically referred children with RD-only and the control group, precise group comparability on IQ and vocabulary cannot be guaranteed. This issue is further considered in the limitations paragraph of the Discussion section.

Table 1. Group frequencies plus means (and standard deviations) for age (in months) and measurements of language and general intelligence.

	Frequencies					
Group	*n*	Girls	Boys	Age	Oral language	IQ
RD-only	126	57	69	127.4 (18.3)	98.9 (10.5)	97.5 (8.1)
SLI-only	21	13	8	128.5 (13.5)	82.6 (11.1)	92.2 (12.3)
RD+SLI	30	15	15	122.7 (13.2)	85.3 (11.5)	93.4 (10.4)
Control	1,090	566	524	124.5 (16.4)	—	—
Total	1,267	651	616	124.6 (16.3)	—	—

Note. Oral language (ability) was assessed with a Dutch version of the Peabody Picture Vocabulary Test (Dunn & Dunn, 2005), and IQ was measured with four subtests (Vocabulary, Similarities, Object Assembly, and Block Design) from the Dutch version of the Wechsler Intelligence Scale for Children (Wechsler, 2005). Oral language and IQ scores are both standardized with *M* = 100, *SD* = 15. Dashes signify data not available. RD = reading disability; SLI = specific language impairment.

SLI-Only and SLI+RD

At the time of recruitment, all children with SLI were enrolled in schools for special education, and they all had received speech-language services for at least 5 years. The large majority of the children were from schools in the northern region of the Netherlands. The remaining participants were recruited by miscellaneous means of advertisement. With regard to speech-language services provided at the schools, special attention was given to language comprehension, vocabulary, grammar, oral fluency, communicative assertiveness, phonological processing, STM, storytelling, and phonics training. The majority had Dutch as their native language (92%), with few exceptions of second-language home environments (*n* = 4; English, Persian, Polish, and Chinese).

As part of the SLI group assignments, recent test results (i.e., not older than one year) of a Dutch version of the Clinical Evaluation of Language Fundamentals (CELF-4-NL; Kort, Schittekatte, & Compaan, 2008), and the Dutch Language Test for Children (Van Bon, 1982), were retrieved from diagnostic test records in the special education school archives. These records provided two standardized indexes (*z* scores are mandatory) of syntactic and lexical-semantic processing. The SLI-only group showed indexed scores of −2.4 and −1.9 *SD*, respectively. Quite similarly, the RD+SLI group showed indexed scores of −2.5 and −1.8 *SD*, respectively. These results indicate that the language abilities of either SLI group, on average, are more than 2 *SD*s below the population mean. In addition, as an external validity check, children with SLI were assessed by the investigators with a Dutch standardized version of the PPVT-III-NL (Dunn & Dunn, 2005). As expected, results for the SLI-only and the RD+SLI groups indicate that these children perform well below the population mean of 100, whereas the RD-only scored within the normal range (see Table 1). Last, general cognitive functioning was assessed with a Dutch version of the Wechsler Non Verbal Scale of Ability (WNV-NL; Wechsler & Naglieri, 2008), the Dutch Snijders-Oomen Non Verbal Test of Intelligence (SON-R; Snijders, Tellegen, & Laros, 1988), or the WISC-III-NL (Wechsler, 2005). IQ scores for the SLI-only and RD+SLI groups indicate that both groups on average perform somewhat lower than the population mean, but well within the normal range (see also Table 1).

Instruments

WR, or fluency, was operationalized by averaged mean performance of two commonly used standardized Dutch tests for word recognition and pseudoword reading. Word recognition was measured with Monosyl and Multisyl

(Van den Bos & Lutje Spelberg, 2010). Pseudoword reading was measured with The Klepel (Van den Bos, Lutje Spelberg, Scheepstra, & De Vries, 1994).

Monosyl is a timed WR test, which consists of 50 unique meaningful and frequent monosyllabic words that are ordered in five columns on a standard A4-size sheet. The raw score is the total time needed, in seconds, to read all words (including words read incorrectly), which is converted to a standardized score (Wechsler scale; $M = 10$, $SD = 3$). Test–retest and split-half reliabilities are .92 and .91, respectively.

Multisyl is the multisyllabic counterpart of the Monosyl. This test is an adaptation of the One Minute Test (OMT; Brus & Voeten, 1979). In the adaptation only the first 50 words of the original list of 116 words are read, and the raw score is the total time (seconds) to read these 50 words, including words read incorrectly. The raw time score is converted to a standardized score (Wechsler scale; $M = 10$, $SD = 3$). Averaged parallel test and retest reliabilities are .90 (Van den Bos & Lutje Spelberg, 2010).

The Klepel is a timed test of pseudoword reading that consists of 116 pronounceable pseudowords presented to the participant in four columns on a standard A4-size sheet. The participant is required to read for the duration of 2 min, as quickly and accurately as possible. The raw score is the number of items read correctly, which is converted to a standardized score (Wechsler scale; $M = 10$, $SD = 3$). The test manual reports a median parallel test reliability of .92.

In order to obtain a reliable index of general WR efficiency or fluency, Torgesen, Wagner, and Rashotte (2011) combined scores from real word and pseudoword tests. High intercorrelations have been reported for these reading tests, as well as an absence of differential links of pseudoword and real-word reading with RAN and PA (De Groot, Van den Bos, & Van der Meulen, 2014; Moll, Fussenegger, Willburger, & Landerl, 2009; Warmington & Hulme, 2011). Thus, in the present study, the standard scores of the tests mentioned were averaged to one standardized composite score (Wechsler scale; $M = 10$, $SD = 3$), which, in the remainder of this article, is referred to as the WR fluency index.

RAN was assessed by two commonly used alphanumeric RAN subtests of a standardized Dutch testing battery (Van den Bos & Lutje Spelberg, 2010). Participants are required to sequentially state, as quickly and accurately as possible, the alphabetic names of letters (d, o, a, s, p) or digits (2, 4, 5, 8, 9), which occur 10 times each and are presented to them in columns (5 × 10) on a standard A4-size sheet. The times to complete each series are converted to separate standardized scores (Wechsler; $M = 10$, $SD = 3$). Averaged test–retest and split-half reliabilities for the subtests are .84, .86, .87, and .83, respectively.

PA was assessed by an auditory computer-assisted Dutch standardized test consisting of an elision ($PA_{elision}$) and a substitution ($PA_{substitution}$) task (2 × 12 trials; De Groot et al., 2014). Examples are "Say *streek* without the /r/" or "Substitute the first letter sounds of the first- and surnames *Kees Bos* and state the result," respectively. Response times and accuracies were recorded and combined by means of a standardized scoring rule that imposes an age-dependent time penalty when an erroneous answer is given by the participant. This resulted in separate standardized scores for the subtests and a standardized composite index of PA (PA_{com}), scaled as *t* scores ($M = 50$, $SD = 10$). Averaged item intercorrelations for $PA_{elision}$, $PA_{substitution}$, and PA_{com}, are .82, .91, and .92, respectively. Test–retest reliabilities are .68, .76, and .78. Last, averaged parallel test reliabilities are .81, .90, and .89, respectively.

Statistical Analysis

To avoid confounding the results, principal component analysis with varimax rotation and Kaiser normalization was performed on the RAN and PA subtasks. This procedure resulted in two orthogonal components that clearly bear on RAN and PA, and these components are referred to as RANFAC versus PAFAC (see Table 2 for factor loadings and the online supplemental materials [see Supplemental Appendix] for additional information on the principal component analysis, such as component eigenvalues), which together explain 85% of total variance. Furthermore, the linear combination of alphanumeric RAN and PA (RANPA) was computed.

To facilitate the interpretability of the results, all measures were transformed into *z* scores. As the relatively small sample sizes for the SLI groups do not allow for age differentiation, all analyses are based on age-collapsed data. Last, multivariate analysis of variance (MANOVA) was performed with RANFAC and PAFAC as dependent variables and RD versus non-RD and SLI versus non-SLI as classification factors. Moreover, the model was corrected for age effects by including age as a covariate. Effect sizes are presented as *d*, with values of 0.2, 0.5, and 0.8 being considered as small, medium, or large effect sizes, respectively, or as eta squared, with values of .01, .06, and .14 being considered as small, medium, or large effect sizes, respectively (Cohen, 1988).

Results

Descriptive Statistics

A first observation on the standardized means (see Table 3) is that there are clear differences in terms of the

Table 2. Rotated factor loadings on RANFAC and PAFAC.

Input variable	Component	
	RANFAC	PAFAC
RAN_{digits}	.93	.14
$RAN_{letters}$	.90	.24
$PA_{elision}$	.26	.86
$PA_{substitution}$	.12	.91

Note. Depicted values represent the correlations between the input variables and the components. RANFAC = RAN factor; PAFAC = PA factor; RAN_{digits} = rapid naming of digits; $RAN_{letters}$ = rapid naming of letters; $PA_{elision}$ = phoneme elision; $PA_{substitution}$ = phoneme substitution.

Table 3. Group sizes and summary test scores (*z* scores).

Group	WR	$PA_{elision}$	$PA_{substitution}$	PA_{com}	RAN_{digits}	$RAN_{letters}$	RAN_{an}	RANFAC	PAFAC
RD-only (*n* = 126)									
M	−2.05	−1.38	−1.45	−1.60	−1.23	−1.45	−1.37	−1.03	−1.19
SD	0.41	1.14	1.22	1.13	0.87	0.88	0.78	0.77	1.08
Median	−1.92	−1.35	−1.30	−1.60	−1.33	−1.33	−1.33	−1.13	−1.27
Min.	−3.00	−3.00	−4.00	−3.20	−3.00	−3.00	−3.00	−2.60	−3.33
Max.	−1.51	1.40	0.80	1.20	1.33	0.67	0.67	0.99	1.35
SLI-only (*n* = 21)									
M	−0.43	−1.22	−1.57	−1.60	−0.84	−1.46	−1.16	−0.81	−1.24
SD	0.76	0.82	1.01	0.83	0.90	1.13	0.95	0.89	.76
Median	−0.67	−1.10	−1.30	−1.60	−0.67	−1.67	−1.33	−0.98	−1.36
Min.	−1.50	−3.00	−3.00	−3.00	−2.33	−3.00	−2.67	−2.33	−2.64
Max.	1.33	−0.20	−0.10	−0.40	1.00	0.67	0.67	0.69	.06
RD+SLI (*n* = 30)									
M	−2.33	−2.49	−2.47	−2.66	−1.67	−2.03	−1.90	−1.32	−2.23
SD	0.49	0.70	0.77	0.52	0.60	0.75	0.64	0.61	.63
Median	−2.43	−3.00	−3.00	−3.00	−1.67	−2.17	−2.00	−1.42	−2.44
Min.	−3.00	−3.00	−3.00	−3.00	−3.00	−3.00	−3.00	−2.49	−2.98
Max.	−1.67	−0.70	−0.60	−1.20	−0.33	0.00	−0.17	0.29	−.79
Control (*n* = 1,090)									
M	0.07	0.08	0.04	0.04	0.03	−0.01	0.02	0.05	.08
SD	0.73	0.87	0.94	0.92	0.99	0.93	0.91	0.93	.86
Median	0.07	0.10	0.20	0.20	0.00	0.00	0.00	0.05	.17
Min.	−1.49	−3.00	−3.00	−3.00	−3.00	−2.67	−2.67	−2.87	−3.36
Max.	1.49	2.20	1.80	2.10	2.67	2.33	2.67	2.71	1.99

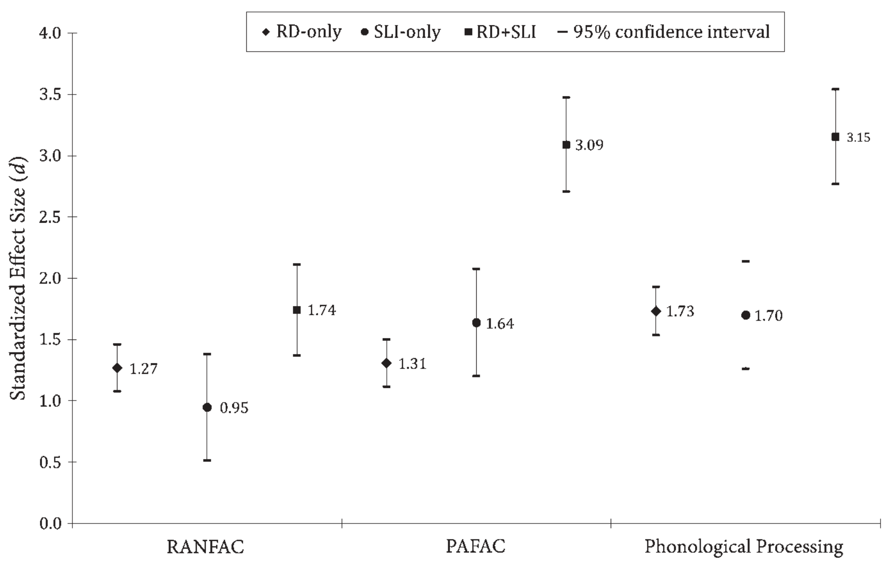
Note. WR = word reading; $PA_{elision}$ = phoneme elision; $PA_{substitution}$ = phoneme substitution; PA_{com} = composite score phonemic awareness; RAN_{digits} = rapid naming of digits; $RAN_{letters}$ = rapid naming of letters; RAN_{an} = composite score alphanumeric RAN; RANFAC = RAN factor; PAFAC = PA factor.

severity of phonological impairment between the comorbid group and the control group, as well as the RD-only and SLI-only groups. As hypothesized, the comorbid group performed markedly more poorly than all others on all measures. The means for the control group are very close to zero, indicating that this group is representative of the general population of TD children. Regarding the RD-only group, Table 3 shows that RAN and PA are both quite severely impaired in this group, with a small negative tilt toward PA. As for the SLI-only group, WR performance is slightly below average. PA, however, is quite severely impaired (cf. RD-only). There appears to be an effect of subtask, as the SLI-only group performed markedly poorer on the $PA_{substitution}$ task as compared to $PA_{elision}$. Regarding RAN, all groups showed substantial differences between mean performances for RAN_{digits} and $RAN_{letters}$, with RAN_{digits} yielding better results. RANFAC seems to reflect this finding as it appears relatively unaffected by the poor $RAN_{letters}$ performance in the SLI-only group. In general, compared to the RD-only group, the SLI-only group shows a slightly inversed pattern in terms of less severely impaired RAN(FAC) performances whereas PA(FAC) performances are poorer. Together, these results are in line with the hypothesized specific link of RAN impairments with RD, and the expectation that RAN is relatively unimpaired in the SLI-only group. A supplementary result that becomes apparent from the proportion of children with RD of the total group of children with SLI (see Table 3) is that the presently used RD criterion yields a comorbidity rate of 59% with SLI.

Effect Sizes for Mean Differences

Figure 1 depicts the clustered standardized effect sizes of RANFAC, PAFAC, and RANPA per group. First, Figure 1 shows that the effects of group membership are generally large to very large. Second, as hypothesized, the overall effects are largest in the comorbid group. Moreover, this group shows the additive effects of RD and SLI, for PAFAC in particular. Third, the earlier mentioned reversal of RANFAC and PAFAC between RD-only and SLI-only is also apparent from the effect sizes in Figure 1. RD-only appears to be slightly more affected on RANFAC relative to the SLI-only group. In contrast, the SLI-only group seems slightly more impaired on PAFAC relative to the RD-only group. This discrepancy between RANFAC and PAFAC in the SLI-only group is notable, although considering the present confidence intervals, these differences remain tentative. Regarding the remaining comparisons, RANFAC did not differ significantly for RD-only versus RD+SLI, $t(53) = 1.81$, $p = .077$, whereas SLI-only versus RD+SLI was significant, $t(33) = 2.24$, $p = .032$, $d = 0.67$. With regard to PAFAC, we found large effects for both the contrasts of RD-only versus RD+SLI, $t(47) = 4.67$, $p < .001$, $d = 1.19$, and SLI-only versus RD+SLI, $t(38) = 5.13$, $p < .001$, $d = 1.49$. As for RANPA, similarly large effects were found for RD-only versus RD+SLI, $t(49) = 4.89$, $p < .001$, $d = 1.25$, and SLI-only versus RD+SLI, $t(36) = 5.44$, $p < .001$, $d = 1.60$. Last, there were large significant differences between RAN_{digits} and $PA_{substitution}$ in

Figure 1. Standardized mean difference effect sizes (Cohen's *d*) for RANFAC, PAFAC, and (combined) phonological processing per group compared to controls.



the SLI-only group, $t(39) = 2.47$, $p = .02$, $d = 0.76$, and the RD+SLI group, $t(55) = 6.17$, $p < .001$, $d = 1.14$.

Analysis of Variance

Two separate analyses were performed to ascertain (a) the main and interactive effects of RD and SLI, and (b) those of group membership in terms of explained variance (η^2). To start with, a MANOVA was performed with RANFAC, PAFAC, and RANPA as dependent variables and RD versus non-RD and SLI versus non-SLI as classification factors. Table 4 summarizes the results of the first MANOVA, listing the main and interaction effects.

The first analysis revealed considerable main effects of both RD and SLI (see Table 4). In general, the effect of RD seems somewhat stronger compared to that of SLI. In particular, RANFAC seems more affected by RD than SLI, explaining 16% and 10% of variance, respectively. PAFAC, on the other hand, seems equally affected by either condition. However, the interactions are not significant. Regarding group comparisons, a second MANOVA was performed with group as the independent variable. Figure 2 depicts the explained variances (η^2) of each measure clustered by clinical group (as compared to controls) on the horizontal axis. As substantiated by large proportions of explained variance, it is shown that PA, and to a certain extent also RAN, is significantly affected in all three clinical groups. However, similar to the results of the first MANOVA, RAN generally seems to bear more relevance to RD than SLI, as the proportion of variance explained by RANFAC is lowest in the SLI-only group. Figure 2 further adds to the previously mentioned notion of additivity of RD and SLI for the comorbid group.

Table 4. Main and interactive effects of SLI and RD for RAN and PA measurements.

Factor	Measurement	*F*(1, 107)	*p*	η^2
SLI	RANFAC	15.05	<.001	.10
	PAFAC	40.52	<.001	.20
	RANPA	62.98	<.001	.23
RD	RANFAC	25.65	<.001	.16
	PAFAC	41.78	<.001	.21
	RANPA	79.42	<.001	.30
RD × SLI	RANFAC	3.46	.066	.02
	PAFAC	0.22	.643	.00
	RANPA	3.15	.079	.01

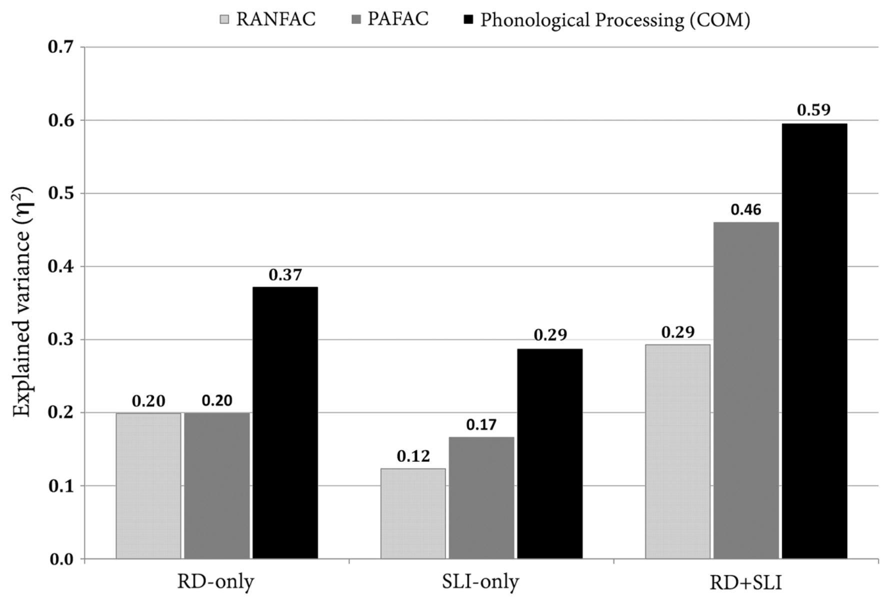
Note: SLI = SLI versus non-SLI; RANFAC = RAN factor; PAFAC = PA factor; RANPA = composite score of RAN_{an} and PA; RD = RD versus non-RD; RD × SLI = interaction term.

Discussion

In this study the reading-related processes of RAN and PA were investigated in Dutch children with and without RD and/or SLI. The discussion of the findings is organized as follows. Going from details to more general perspectives, we first try to unravel some of the complexities in the findings on the groups' task performances on RAN and PA. Next, the focus will be on relationships with WR, and specifically on the RD criterion used. Last, comorbidity models previously mentioned will be discussed, as well as limitations of the present study.

We found the combination of RAN and PA to be severely impaired in the RD-only group as well as in both groups with SLI. However, there were notable differences between the groups when evaluating RAN and PA separately. Regarding RAN, we found significant overall impairments

Figure 2. Explained variances (η^2) of RANFAC, PAFAC, and (combined) phonological processing per group.



for all clinical groups, with larger negative effects for the comorbid group. At a more detailed level, there was an intriguing discrepancy between the alphanumeric RAN subcomponents in the SLI-only group, whereas this did not apply to the RD-only group. For SLI-only, RAN_{digits} performance—although still in the low-average range—was significantly higher than $RAN_{letters}$. Average RAN_{digits} performance for 9- to 10-year-old children with SLI-only was also reported in Bishop et al. (2009). However, this study did not investigate $RAN_{letters}$. In another recent study (Vandewalle et al., 2012) both alphanumeric subtests were used, but these authors neither found significant main effects nor a $RAN_{letter–digit}$ discrepancy in third graders with SLI-only. However, the subject sample of the latter study was quite small. Therefore, an interpretation of the finding of a letter-digit discrepancy in children with SLI must remain tentative. Our reasoning is as follows. $RAN_{letter–digit}$ discrepancies are a rather normal phenomenon for young TD readers (Van den Bos et al., 2002). This can be interpreted as due to interference or ambiguity on account of the availability of both phonetic and alphabetic names of letters, which does not apply to digits. This may result in longer naming times of letters than digits (cf. Kail & Leonard, 1986; Sheng & McGregor, 2010). In TD children this discrepancy quickly resolves with age and reading experience. Therefore, the discrepancy we found in children with SLI may be interpreted as reflecting a developmental delay, possibly in combination with lower reading exposure rates.

Turning to the findings on PA, we found severe impairments in the SLI-only group. Although Bishop et al. (2009) did find PA deficits in an SLI-only group of 4- and 6-year-olds, these authors found PA to be only mildly impaired in 9-year-olds. In another study, however, it was found that older children with SLI still experienced difficulties with more complex PA tasks (Vandewalle et al., 2012). To be specific, the present $PA_{substitution}$ task can be considered as quite demanding, in the sense that the STM load is substantial (Landerl & Wimmer, 2000). Considering that children with SLI are particularly prone to STM problems, this may have contributed to their deficient PA performance. Obviously, as STM was not directly measured in the present study, this explanation must be considered as tentative. Another dimension of future research on PA in these groups could incorporate the finding that children with SLI experience basic auditory perceptual deficits (Kuppen, Huss, Fosker, Fegan, & Goswami, 2011). As indicated by these authors, these deficits might influence a wide range of higher order linguistic processes, such as PA and reading tasks.

Remaining questions are why the SLI-only group's deficient $RAN_{letters}$ and PA performances did not seem to profoundly affect their word reading performance, and, second, how the RD criterion used might have influenced the comorbidity rate and the nature of its underlying mechanisms. In line with Bishop et al. (2009), it was established that there evidently are children with SLI demonstrating adequate WR skills. It is possible that at this age-level, children with SLI have learned to compensate previous weaknesses in single-letter amalgamation with orthographic strategies at a higher analytic and synthetic level (Bishop & Snowling, 2004; Van der Leij, 2003). It is clear that these suppositions of early reading problems and compensatory reading strategies require further study.

A more general point of discussion concerns the present—rather strict—RD criterion, and its effect on the comorbidity rate. With this strict criterion to define RD and SLI—that is, 1.5 *SD* below average—a quite substantial comorbidity rate (59%) was found. This rate is in agreement with other studies reporting SLI and RD as frequently co-occurring phenomena (De Bree et al., 2007; McArthur et al., 2000; Vandewalle et al., 2012). As the present study used clinical samples of children with SLI, this estimate might be inflated compared to epidemiological studies that probably would also contain less severe cases (Catts et al., 2005). However, as there are no Dutch epidemiological studies on SLI available, and the present study was primarily intended as a comparative study, we will refrain from further comments on this matter.

A related question arises as to the effects of different criteria for RD. Although the presently studied SLI-only group by definition did not meet the strict RD criterion, their WR performance was significantly below average. It seems likely, therefore, that a more lenient RD criterion, such as the commonly used 1.3 *SD* below average, would have raised the comorbidity rate in these groups beyond the reported 59%. What would this mean in terms of explanatory mechanisms? In this context, it is worth noting that, for the general population, recent research (De Groot et al., 2015) demonstrates that the effect sizes for RAN and PA are dependent on the severity of RD. More specifically, the study by De Groot et al. shows that using more lenient RD criteria leads to a decrease of the negative effects of RAN and PA. Considering the present finding of RAN being a candidate to differentiate between RD and SLI, the implication for these groups is that the employment of a lenient criterion might attenuate the discriminative power of RAN for RD and SLI. It seems, therefore, a good option for future research to extend the present analyses to variable criteria for RD.

As a further point of this discussion, we want to consider the theoretical models provided by Catts et al. (2005) that explains the relationship between SLI and RD. A severity-based one-dimensional phonological deficit model (Model 1) relates poorly to current definitions of (specific) RD and SLI and raises questions regarding differential-diagnostic procedures. This model notably predicts that all children with SLI are expected to demonstrate significant RD. Hence, the model does not allow for an SLI-only group, suggesting that SLI is comorbid intrinsically, and it predicts that children with RD have a less severe phonological deficit. These assumptions clearly do not fit with the present results. According to Model 3, RD and SLI are considered as independent disorders and SLI as a non-phonological condition. In particular, the latter statement is in disagreement with our data, as the presently studied SLI-only group, as well as the children with RD+SLI, typically do exhibit impaired PA skills. Therefore, Model 3 does not apply either. In general, the present results fit best with a two-dimensional model such as the one proposed by Bishop and Snowling (2004)—that is, Model 2. This model assumes that RD and SLI are similar but distinct phonologically linked disorders, which are primarily differentiated by additional oral language deficits that may or may not lead to manifest comorbid RD at the behavioral level. This model can certainly account for the quite substantial overlap we found. A weakness, however, is that the model fails to accommodate the additive phonological problems that were found for the present comorbid group. Hence, as acknowledged by Bishop and Snowling (2004), the model should be refined by including more dimensions. A plausible candidate for an additional dimension would be reading skill itself. Children with SLI-only will be found at the positive end of the WR dimension, whereas children with comorbidity will be on the negative side. This extension would accommodate for the near additive effects of RD and SLI that were found for the comorbid group on all three measurements (RANFAC, PAFAC, and RANPA).

Last, before formulating an overall conclusion, some limitations of the present study should be discussed. First, it should be noted that, although the large majority of the presently involved children with SLI are Dutch monolingual native speakers, four have one bilingual parent. However, as analyses excluding these children yielded highly similar results, it was decided to maintain the original sample. Second, not all study participants received uniform assessments of oral language abilities and IQ, which may have affected the external validity of the present study. For controls and nonclinically referred children with RD, these abilities were not formally assessed at all. However, considering the overall quality of their academic work (as indicated by school records and teacher assessments), these children were in all likelihood within the normal ranges of intelligence and oral language abilities. Moreover, the sample sizes of these groups can be considered to have attenuated the possible effects of undetected low IQs and poor language abilities. On the other hand, there can be no question about the severity of the oral language impairments of the present SLI groups. Inherent to the Dutch special education school system, which only accepts referrals that have been thoroughly diagnosed, it is clear that the groups selected represent the most severe end of the SLI continuum ($M = 1.5$ *SD*). As stated earlier in the context of RD criteria, further research is needed to indicate whether the present findings and conclusions can be generalized to samples studied under less strict criteria.

In conclusion, this study emphasizes the relevance of RAN, and PA in particular, for the prediction of severe oral language impairments and reading deficits. The combination of RAN and PA proved most effective in terms of predictability for all three deficit groups studied, and the comorbid group in particular. With regard to the separate predictors, alphanumeric RAN seems to be the most likely candidate to differentiate between these two disorders. Specifically, the contrasts of RAN_{digits} versus $PA_{substitution}$ for the SLI-only and comorbid groups were found to be substantial, whereas this contrast was absent for RD-only. Other contrasts are, however, difficult to understand. For example, why are poor performances on $RAN_{letters}$ and PA clear characteristics in the RD-only group, whereas similarly poor performances in children with SLI-only do not lead to RD? We have made suggestions as to compensatory reading mechanisms. Future research should focus on these mechanisms and find out how the mechanisms interact with age, reading curricula, and remedial settings.

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