Applied Psycholinguistics **24** (2003), 407–430
Printed in the United States of America
DOI: 10.1017.S0142716403000213

Specific relations between alphanumeric-naming speed and reading speeds of monosyllabic and multisyllabic words

KEES P. VAN DEN BOS and BONNE J. H. ZIJLSTRA
University of Groningen

WIM VAN DEN BROECK
University of Leiden

ADDRESS FOR CORRESPONDENCE
Dr. Kees P. van den Bos, University of Groningen, Department of Special Education, Grote Rozenstraat 38, 9712 TJ Groningen, The Netherlands. E-mail: k.p.van.den.bos@ppsw.rug.nl

ABSTRACT
The goals of this study are to investigate, at three elementary school grade levels, how word reading speed is related to rapidly naming series of numbers, letters, colors, and pictures, and to general processing speed (measured by nonnaming or visual matching tasks), and also to determine how these relationships vary with the reading task employed. The results indicate that, compared to color- and picture-naming speeds and nonnaming or visual matching speed, letter- and number-naming speeds are superior predictors of word reading speed. Furthermore, throughout the grade levels, associations between alphanumeric naming and monosyllabic word reading speeds are considerably stronger than for a widely used Dutch single-word reading test combining monosyllabic and multisyllabic words. It is suggested that, unlike multisyllabic words but similar to letters and numbers, monosyllabic words act as relatively holistic stimuli, which are recognized as sight words.

This study investigates how word reading speed (also referred to as decoding or word recognition speed) at three age levels is predicted by other frequently studied variables, namely, rapid naming and general processing (visual matching) speed.

The performance measures of all of our tasks will be speed measures and no accuracy measures. In random samples of Dutch elementary school children from Grade 2 (equivalent to 8-year-olds) and beyond, accuracy is almost perfect for the rapid naming and matching tasks that will be discussed and it is also high for word reading itself (van den Bos, Iutje Spelberg, Scheepstra, & de Vries, 1994). Like in other languages with a relatively regular orthography (e.g., German; see Wimmer, 1993; Wimmer & Mayringer, 2002; Wimmer, May-

© 2003 Cambridge University Press 0142-7164/03 $12.00

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

ringer, & Landerl, 1999), reading accuracy is a useful performance measure in beginning readers and in some reading-disabled children, but it is completely replaced by speed in older children.

Two sets of reading-related tasks will be studied. One set consists of continuous naming tasks, also referred to as serial or rapid naming tasks (Denckla & Rudel, 1974). The present study elaborates on our previous study in which the naming speeds of numbers, letters, pictures and colors were related to word reading speed (van den Bos, Zijlstra, & Iutje Spelberg, 2002).

The other set consists of tasks employed in the studies of Kail and Hall (1994) and Kail, Hall, and Caskey (1999). These authors consider these tasks as operationalizations of "general or global processing ability," and they claim that the reading–naming link is caused by shared *general* processing speed. However, we will argue, at least for the present age range and in contrast to the claims of Kail et al. (1999), that these tasks are weakly related to reading and naming speed and therefore cannot constitute a significant role in explaining the reading–naming link.

Finally, in this study the reading–naming–general processing link will be investigated with more than one word-recognition task. In our previous study (van den Bos et al., 2002), there was only one dependent variable of reading, namely, the Dutch One-Minute Test (OMT) of Brus and Voeten (1972). In the remainder of this article, this test will also be referred to as the standard test of word reading or the standard word reading list. In the present study, three more word reading tasks will be introduced and administered, tapping dimensions of semantic organization and congruency, stimulus repetitivity, and word length.

CONTINUOUS NAMING SPEED AND READING SPEED

In their seminal study on the naming–reading link, Wolf, Bally, and Morris (1986) followed "average" and impaired readers in the kindergarten through Grade 2 period. Following Denckla and Rudel (1974; 1976), Wolf et al. (1986) employed two "graphological" (i.e., with numbers and letters) and two "nongraphological" (i.e., with colors and pictured objects as stimuli) continuous or rapid naming tasks. There were three reading tests measuring silent reading comprehension, oral reading of graded and timed reading passages, and "single-word reading." On the basis of predictive and concurrent naming–reading correlations, Wolf et al. (1986, pp. 998–999, italics added) concluded that

> (1) At kindergarten age, all four rapid naming tasks ("regardless of graphological properties in the stimuli") are "capable of predicting both later higher-level and lower-level reading skills," and
>
> (2) "As continuous naming becomes fluent (by grade 2)" the data seem to be best described by a "double-differentiation" hypothesis. This means that number and letter naming become better predictors of reading than "nongraphological" naming stimuli, and that this differentiation "occurs in parallel with a differentiation in ability to predict different reading skills." In other words, "the relationships between automatized symbol speed and those forms of reading that emphasize lower-level processes—*word recognition and oral-reading*—remain stable; the

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

relationship to *comprehension* with its growing emphasis on higher-level processes is significant but minimal."

Focusing on word-recognition tasks and commenting on other prominent studies in those days (e.g., Spring & Davis, 1988; Walsh, Price, & Gillingham, 1988), Wolf (1991) further addressed the *developmental* aspect of the naming–reading link, and reasoned as follows. On the one hand, a developmentally "enduring" or "nontransitory" relation between continuous *alphanumeric* naming speed and word recognition was assumed, "given the *similar requirements* underlying both types of tasks (e.g., symbol recognition and identification, lexical access and retrieval, phonological processing, and the rapid integration of all sub processes)" (Wolf, 1991, p. 133, italics added). In the same paragraph, however, Wolf (1991, p. 133, italics added) speaks of a "*weakening of the relation with age.*" Although going less far than Walsh et al. (1988, p. 108), who considered the relationship to be of "transitory importance," Wolf (1991) states: "As *fluency in word recognition increases* over time (and with it the opportunity both for more direct-access routes and increased chunking), the load on word-recognition sub processes would be expected to *decrease*" (Wolf, 1991, p. 133, italics added).

More recent studies than Wolf (1991) were discussed in van den Bos et al. (2002). It was concluded that although many studies "embraced" naming speed as a new and promising variable in the explanation and subtyping of reading disabilities (Meyer, Wood, Hart, & Felton, 1998a, 1998b; Scarborough, 1998; Wimmer, 1993; Wimmer et al., 2000; Wolf & Bowers, 1999; see also Davies, Knopik, Olson, Wadsworth, & DeFries, 2001; Neuhaus, 2002), there seemed to be no expectations in the literature that further study of the reading–naming link in the *general population* could provide new insights in the development of word recognition (see, e.g., McBride–Chang & Manis, 1996; Kail & Hall, 1994; Kail et al., 1999; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997).

We also noted (van den Bos et al., 2002) that few of these studies had employed all *four* naming stimulus types, as suggested by Denckla and Rudel (1974) and used in Wolf et al. (1986) and Meyer et al. (1998a, 1998b). Additionally, the original focus of naming speed related to reading speed (as in Wolf et al., 1986) had infrequently been followed up in later studies, as the majority of (North American) studies in this field employed speed measures for the naming tasks but accuracy measures for the reading tasks (e.g., McBride–Chang & Manis, 1996; Meyer et al., 1998a, 1998b; Spring & Davis, 1988). Furthermore, the developmental question had been addressed in predominantly the early and middle elementary grades and had rarely been extended to populations beyond Grade 5. Finally, in the few studies that had used the original extensive rapid naming batteries and had investigated age levels older than Grade 5 (Meyer et al., 1998a, 1998b), interesting theoretical questions such as the validity of pooling (*irrespective of age*) letter- and number-naming scores and color, and picture-naming scores into two composite scores (Meyer et al., 1998a, 1998b)—graphological (or alphanumeric) and nongraphological (or nonalphanumeric)—had not been addressed.

Altogether, these observations motivated our life-span study (van den Bos et al., 2002). In this study we determined the reading *speed* of a Dutch standard

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

word reading task and naming speeds of letter-, number-, color-, and picture-naming tasks. These tasks were administered to random readers in Grades 2, 4, and 6 and to 16-year-olds and their parents (who had a mean age of 46 years). Four sets of results were reported.

First, comparisons of mean speeds with age indicated that word reading speed and naming speeds of colors and pictures continue to increase into mature adulthood. For letter and number naming, asymptotes were reached at around 16 years of age. The important point however is that all speed variables (of naming and reading) remain normally distributed and remain highly suitable for individual-differences and the study of interrelationships throughout the life span.

Second, with regard to the interrelationships of naming tasks, factor analyses indicated one color/picture-naming component throughout the age levels studied. For letter- and number-naming speeds, however, a single alphanumeric component was not obtained before Grade 6 (age 12). Third, reading–naming task correlations differed with the naming tasks. Number and letter naming (or the alphanumeric-naming component) had a much stronger correlation with word reading than the color/picture-naming component, which supported the original predictions of Wolf et al. (1986) and Wolf (1991). Fourth, instead of a *declining* association between alphanumeric-naming speed and word reading speed with age (Wolf 1991; Wolf et al., 1986) we found a different curve. That is, for the elementary age range (8-, 10-, and 12-year-olds) the percentages of common alphanumeric naming–reading speed variance were not very different (18, 12, and 18%, respectively). However, for the 16-year-olds and their 46-year-old parents (mean ages), these percentages increased to 34 and 28%, respectively. Apparently, during development alphanumeric-*naming* processes *interact* with processes of word *reading*, which is not the case with regard to nonalphanumeric-naming tasks and reading, where relationships were low and developmentally invariant.

However, the more precise nature of the interaction did not seem very clear yet, which led us to the question of which aspects of processes of reading and rapid naming tasks could explain the increase of the correlations of letter and number naming and of alphanumeric naming and the reading task with age. We followed a somewhat inductive approach to this question by examining differences in designs, tasks, and results of previous classic and modern studies of the naming–reading link.

First, at a general level, the naming-task battery in our previous study had been slightly unbalanced in that alphanumeric materials were overrepresented in a testing session. There were four alphanumeric tasks, two with letters and two with numbers, whereas there were only two nonalphanumeric naming tasks, with colors and with pictures. Second, there were differing degrees of item repetitivity in the various naming tasks. For example, in the capital letter and lowercase letter tasks, almost the full alphabet was used: 23 letters occurred 2.17 times in the set of 50 items, whereas the four colors occurred 12.5 times and the 10 pictures 5 times.

As will be clarified in the next paragraph, we did not think that this asymmetry could have had major effects on the intercorrelations of the naming tasks. Still, it seemed desirable (for international discussion) to eliminate as many

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

sources as possible that might decrease the compatibility of our study and various American studies. Hence, we decided to bring our naming materials in line with the Denckla-type rapid automatized naming (RAN) test (after Denckla & Rudel, 1974) and thereby also with studies of Wolf et al. (1986) and Meyer et al. (1998a, 1998b) in which the RAN test was also administered. The RAN test involves the rapid or continuous naming of sheets with 50 lowercase letters, 50 numbers, 50 colors, or 50 pictures of objects and with equal item repetitivity. That is, each sheet contains five unique stimuli of a given category and on each sheet the five stimuli are presented 10 times in random order.

With regard to the effect of item repetitivity in continuous-naming tasks, there are no recent studies on which predictions can be based. However, although directed at naming speed of *discretely* presented stimuli, the studies by Morin and Forrin (1965), and Morin, Konick, Troxell, and McPherson (1965) seem relevant for our purposes. Participants in these studies were first and third graders and undergraduate students. Employing nonalphanumeric stimuli (photographs of fraternity brothers, line drawings of animals, geometric forms, and colors) and alphanumeric ones (numbers and letters), the naming (reaction) times for sets containing 2, 4, and 6–8 different stimuli were measured. The results were that letter- and number-naming speeds were hardly affected as sets contained more different stimuli. However, for nonalphanumeric stimulus types, the naming times were considerably longer for sets containing more different stimuli, or in our terminology, if the degree of item repetitivity was relatively *low*. Because all stimulus types were highly overlearned, differential familiarity with the stimuli could not account for these findings. Rather, Morin et al. (1965) suggest that letters and numbers, compared to the other stimuli, are associated with strongly "*dominant or unambiguous*" responses, and therefore suffer less from response competition as a set contains more different stimuli. Thus, we do not expect substantial effects from the relatively small changes of item repetitivity in the means and interrelationships of the *naming tasks* of the present study and the previous one (van den Bos et al., 2002).

However, the issue of item repetitivity effects should also be discussed in the context of reading tasks and their relation to naming tasks. The reading task in our previous study (van den Bos et al., 2002), as well as in almost all other recent studies of the naming–reading link, consisted of *unique* words (i.e., the words were not repeated in the list), which contrasts with the designs of classic studies (Brown, 1915a, 1915b; Cattell, 1885, 1886; Ligon, 1932) in which naming and reading materials consisted of the *same referents* and therefore of identical degrees of item repetitivity. Consider, for example, the study of Ligon (1932) in which color patches were to be named and the same color names presented as written words were to be read. Ligon (1932) administered these tasks to subjects from ages 6 to 16 years (average group size = 57 subjects) and reported means and correlation coefficients. Comparing Ligon's (1932) correlations between color-naming and color–name reading speeds with the correlations in van den Bos et al. (2002) between color/picture-naming and word reading speed (unrepeated word list), then, averaged across similar age levels, a substantial difference between the 20% common variance in Ligon (1932) and the 9% in van den Bos et al. (2002) can be observed. We interpret this difference as caused

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

by the different *reading materials* in the two studies and not so much by the (only subtle) differences in the color/picture-naming tasks.

In order to more directly investigate this matter it was decided to extend the reading task battery with two *reading* tasks containing the same color and picture names as elicited in the color- and picture-*naming* tasks (see Method section) and to compare naming–reading relationships for these tasks with the standard word reading task previously used.

Two remaining issues must be addressed. First, with these two new reading tasks two additional dimensions are introduced, which may have possible relevance for the study of the naming–reading link. That is, compared to the reading task previously used, there are some complex *semantic* dimensions involved and the tasks also differ in *word length*. The semantic dimensions might be referred to as semantic organization and semantic congruency. By semantic organization we mean that color names come from one semantic category whereas the picture names do not. Semantic congruency refers to two types of circumstances: a more restricted type in which color- and picture-naming and reading speeds can be compared; and a more global type that refers to the circumstance that color- and picture-naming and reading tasks share identical referents, whereas the standard reading list and the naming tasks do not have common referents.

The question arises as to how these effects can be disentangled. If semantic organization and semantic congruency of the more restricted type are important (keeping item repetitivity constant), there should be differences between the naming–reading relationships of color- and picture-*naming* and color and picture–word *reading* tasks (color–color, picture–picture, color–picture, picture–color). If there are no significant differences between the correlations, semantic factors of the more restricted type play no role.

As was mentioned above, different degrees of item repetitivity and semantic identity and congruity are not the only contrasts between color and picture reading and naming tasks and the standard reading task. Whereas almost all items of the color- and picture-naming and reading tasks are monosyllabic words, the items of the standard word reading test (see Method section) show considerable length differences. Therefore, in order to be able to separate word length effects from those of item repetition and semantic factors, we decided to add a fourth reading task to the battery. This task should contain short monosyllabic content words (comparable to the color- and picture-word lists) with zero or low item repetitivity and semantic organization and congruency. This task was adapted from Aaron, Joshi, Ayotollah, Ellsberry, Henderson, and Lindsey (1999) and is further described in the Method section.

The final issue that we want to address in this section concerns the following. In order to investigate task-specific effects on the reading–naming link, we have imported several additional reading tasks from modern and classic studies (Aaron et al., 1999; Ligon, 1932). Our general expectation is that the more congruent (with regard to item repetition, semantic, and length dimensions) naming and reading tasks are, the higher the correlations will be. However, this should not obscure the previously developed notion (van den Bos et al., 2002; Wolf, 1991) of the domain-specific or *alphanumeric* nature of the reading–naming link. Thus, it is expected that, for example, color-*naming* speed correlates more strongly

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

with color name *reading* speed (cf., Ligon, 1932) than with reading speed on the standard reading task. However, regardless of the reading tasks used the correlations with alphanumeric naming tasks will remain superior to those with nonalphanumeric naming tasks. In the following we will extend our reasoning to *nonnaming* tasks, to which we will assign the same predictive status as for nonalphanumeric-naming tasks.

IS THE NAMING–READING LINK EXPLAINED BY THE DEVELOPMENT OF GENERAL PROCESSING SPEED?

Kail et al. (1999, p. 303, italics added) start their study with the observation that despite the finding of "naming speed being a potent predictor of reading skill, the meaning of the *link* remains unclear." Next, they refer to Spring and Davis (1988) and Wolf et al. (1986), who attribute the naming–reading link to the shared alphanumeric or "automatic" (Spring & Davis, 1988, p. 317) processing abilities required by reading and alphanumeric naming tasks. Kail et al. (1999) contrast this view with an alternative one, "that the link between naming speed and reading skill reflects more general cognitive processes, not those specific to processes required for skilled reading" (p. 304). Specific predictions are: "If naming times reflect automatic access to characters and words, reading relevant experience should predict naming time. If, instead, naming times reflect age-related change in processing speed, then measures of processing time should predict rapid naming" (p. 307). In order to test these predictions, Kail et al. administered two general processing tasks (the Cross-Out and Visual Matching tasks from the Woodcock–Johnson Tests of Cognitive Ability; Woodcock & Johnson, 1989) to 8- and 13-year-olds, along with the reading recognition and reading comprehension tasks of the Peabody Individual Achievement Test, an exposure to print task (measuring reading-related experience), and rapid naming tasks with digits and letters. Multiple regression analyses on naming speed with print exposure, general processing time, and age as independent variables indicated that general processing time was a superior predictor, "supporting the view that naming time reflects speed of processing" (Kail et al., 1999, p. 307).

We have a number of concerns about this conclusion. First, reading recognition was not included in the main set of predictors of naming speed. This is surprising because this "low-order" process variable can be considered as one of the most appropriate "partners" when talking about the reading–naming *link* (Wolf, 1991). Second, Kail et al. conclude their results section (pp. 310–311) with a regression analysis on reading recognition scores (with independent variables of age, processing time, naming time, and print exposure). Surprisingly, they leave the result of all variables showing significant beta weights, except for processing time, which is uncommented. In our opinion, this result is a very logical one, which is explained in the following.

In Kail et al. (1999), general processing speed (GPS) is operationalized by the cross-out and visual matching tasks from the Woodcock–Johnson Tests of Cognitive Ability (1989). An inspection of these tasks (also see the task descriptions in the Method section) shows that "cross-out" refers to circling or placing a line through identical figures (in the cross-out task) or numbers (in the visual

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

matching task). It can be assumed in both tasks that a visual matching operation is the central process whereas the more peripheral or output process is the cross-out action. We think that the concept of GPS is probably elusive and that it might be better to use the central process term (visual matching) instead.

The prediction of reading (and naming) can now be reconsidered. Some decades ago, Ellis and Miles (1978) and van den Bos (1984) employed the so-called Posner paradigm to alphabetic naming and visual letter matching performance to the reading performance of normal readers and poor readers. The main result was that letter naming, not visual matching, discriminated ability groups. The interpretation was, and this applies to the present discussion as well, that there seems to be much less process communality in visual matching tasks in which no explicit naming is required than in reading tasks and alphabetic-naming tasks. Thus, on this task-analytical basis, and not on the basis of differential assumptions concerning deep causal links between GPS and the mechanism of automatization with naming and reading (as theorized by Kail et al., 1999), we predict weak correlations between visual matching and reading or alphanumeric-naming speeds.

METHOD

Participants

The Dutch school system has a grade level notation different from that in the United States. In this report grade levels equivalent to the US system will be used. Experimental groups consisted of children at Grades 2, 4, and 6, or at 8, 10, or 12 years of age, from intact classes of three Dutch regular elementary schools in the medium-sized city of Groningen and from two neighboring towns. The children were predominantly of white middle class background. They were tested in April through June 2000. Mean ages in months of the three grade levels (samples from different classes or schools have been combined) were 98, 121, and 144 months, respectively, and the male/female ratios were 25/21, 39/39, and 32/27, respectively.

Tasks

Standard test of word reading. Similar to our previous experiments (van den Bos et al., 2002), testing for all participants started with the administration of the b-version of the Dutch OMT of Brus and Voeten (1972). This is a highly reliable speeded word reading test that is individually administered. The stimulus sheet consists of 116 unique (unrepeated) and semantically unrelated words of increasing length ordered in four columns of 29 words each. The instruction of the task introduces the stimulus sheet with the words "I want you to read aloud—as fast and as free of errors as you can—these columns of words." In the standard administration procedure the allotted reading time is 1 min. The raw score is the number of correctly read words in 1 min. For the age range of 7–13 years of age, the test was standardized by van den Bos et al. (1994) accord-

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

ing to the Wechsler scale with a standard score range of 1–19, a mean of 10, and a standard deviation of 3.

A disadvantage of the standard 1-min administration procedure is that individuals' average times per item (tpi) and error percentages are not necessarily based on the same items. Consequently, we decided to let all participants read at least the first 50 words and to base the tpi score, as well as the error percentage, on this *fixed* set of items. As noted before, this list is quite heterogeneous in word length. The first 50 items contain 16 monosyllabic words (11 of which appear among the first 15 items), 23 bisyllabic words, 9 words with three syllables, and 2 words with four syllables. Thus, the average syllable length of this list is 1.94. Experimental scores are the total reading time in seconds divided by 50 (tpi) and the error percentage. In the remainder of this article the tpi score on these 50 OMT items will be referred to as the standard test of word reading.

Color and picture–name reading. These individually administered tasks (same instruction as in the other reading tasks) consist of the written-word versions of the five color- and five picture-naming tasks (see below) in which the items are nonconsecutively repeated 9 times, which brings the item total to 50 items for each list. In both tasks, the 50 items are ordered in five columns of 10 words each and have to be read aloud. The five color names in Dutch, rood (red), geel (yellow), blauw (blue), zwart (black), groen (green), are all monosyllabic. Four picture names, bed (bed), boom (tree), vis (fish), and stoel (chair), are monosyllabic and one, emmer (bucket), has two syllables. The average phoneme and letter numbers in the items are 3.8 and 4.6 for the color–name reading task, and 3.4 and 4.0 for the picture–name reading task, respectively. The scores are the total reading times divided by 50 (tpi) and the error percentages.

Monosyllabic word reading. This individually administered task (same instruction as in the other word reading tasks) was derived from Aaron et al. (1999), who used, among others, a list with 20 unrelated, monosyllabic highly frequent content words that appeared twice in the list. In order to the match list length with the other tasks, we extended the list with 5 words. Consequently, our list contains 25 unique monosyllabic words that are nonconsecutively repeated once. The 50 items (in Dutch: 40 consonant–vowel–consonant [CVC], 4 VC, 4 CV, and 2 CCV words) with average phoneme and letter numbers of 2.84 and 3.32, respectively, are ordered in five columns of 10 words each and have to be read aloud. The scores are the total reading time divided by 50, which yields the tpi and the error percentage.

Table 1 provides a summary of the reading tasks (indicated by their variable names) and descriptions of the task-analytical dimensions that were previously discussed.

Continuous naming. The individually administered naming speed test battery contains eight tasks, two for each of four stimulus types: Numbers 1 (consisting of the digits 2, 4, 5, 8, and 9), Numbers 2 (consisting of the digits 2, 3, 6, 7, and 8), Letters 1 (consisting of the lowercase letters s, e, g, r, and k), Letters 2 (consisting of the lowercase letters d, o, a, s, and p, which are also used in

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

Table 1. *Description of items of reading tasks on the dimensions of word length, item repetitivity, and semantic congruency and organization*

	Dimension			
Reading Tasks	Word Length	Item Repetitivity	Semantic Congruency With Naming Tasks	Semantic Organization
STWR	Heterogeneous	Zero	No	Random
MSWR	Monosyllabic	Low	No	Random
CNR	Monosyllabic	High	Yes	From one category
PNR	Monosyllabic	High	Yes	Random

Note: STWR, standard test of word reading; MSWR, monosyllabic word reading; CNR, color name reading; PNR, picture name reading.

Denckla & Rudel, 1974), Colors 1 (consisting of rectangular color patches in black, yellow, green, red, and blue), Colors 2 (a repetition of the Colors 1 task), Pictures 1 (consisting of line drawings of five highly familiar objects: bed, tree, fish, bucket, and chair), and Pictures 2 (a repetition of the Pictures 1 task). The sizes of the stimulus fields and the visual angles of the separate stimuli are comparable for the number-, letter-, and picture-naming tasks, whereas the color patches are wider (1.5 cm) than the other stimuli. In each task, the five unique items are nonconsecutively repeated nine times, yielding a total number of 50 items for each task.

A general remark concerns the ordering of the items in *columns* in all our naming tasks. This deviates from the practice in almost all other studies based on Denckla and Rudel (1974) in which stimuli are horizontally presented in *rows*. Our argument to use columnwise ordering was simply that the tasks' between-item processing direction would be similar to that in the word reading tasks used. Of course, this similarity is only partial; as in word reading, within-item processing clearly occurs from left to right, being rowlike. We have no direct experimental evidence on the question of whether there will be differences between these orderings, but global comparisons with the means of, for example, Meyer et al. (1998a, 1998b) indicate high similarities.

The instruction of the naming speed tasks introduces the stimulus sheet with the words: "I want you to name aloud—as fast and as free of errors as you can—the numbers (or letters, colors, pictures) in these columns." In the instruction of the letter-naming tasks, it is stressed that alphabetic names, and not the sounds, have to be produced. Sometimes, and with some letters (especially at the youngest age level), phonetic letter names are produced. However, these are not counted as errors. Next, the first four columns are covered and participants practice with the fifth column of each task. Then the tester starts the stopwatch, records noncorrected misnamings and omissions as errors, and registers the time that the participant needed to name the whole page. Scores are the total naming times divided by 50 (tpi) and the error percentages.

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

General processing (visual matching). After Kail and Hall (1994) and Kail et al. (1999), the two measures of general or global processing were the visual matching and cross-out tasks, both from the Woodcock–Johnson Tests of Cognitive Ability (1989). In the visual matching task, each of 60 rows includes six digits, two of which are identical (e.g., 8, 3, 7, 0, 4, 8), and the participant places a line through the identical digits. In our administration, the scores are the total number of rows (including incorrect rows) completed in 3 min and the percentage of incorrect rows. In the cross-out task, each of 30 rows consists of a geometric figure at the left end of the row and 19 similar figures to the right. The participant places a line through 5 figures out of the 19 that are identical to the one at the left. Both tasks contain practice items that are filled out while the instruction proceeds. The scores are the total number of rows (including incorrect rows) completed in 3 min and the percentage of rows incorrectly processed. As noted in the introductory section, we prefer central-process addressed names for these tests. In the remainder of this article the visual matching task will be referred to as visual matching of numbers (VM numbers) and the Cross-Out task will be visual matching of figures (VM figures).

Procedure

The reading tasks and the eight continuous naming tasks were individually administered in the spring of 2000. Testing occurred in two sessions of about 20 min each in a quiet school room during school hours. The two test sessions mostly occurred within 1 week. Tasks were presented in the following constant order: Session 1: standard test of word reading, picture naming 1, color naming 1, number naming 1, and color–name reading; Session 2: monosyllabic word reading, number naming 2, letter naming 1, picture naming 2, letter naming 2, color naming 2, and picture name reading. After all children from a class had completed the reading and naming tasks in individual sessions, the two visual matching tasks (VM numbers and VM figures) were presented in group sessions to all children of a classroom. On these occasions, at least two extra supervisors assisted the instructor with the testing procedure. All tests were administered by trained university students of the Special Education Department of the University of Groningen.

RESULTS

Descriptives and preliminary analyses

Grade levels, gender distributions, and means and standard deviations of age in months, reading, naming, and visual matching ("general processing"; Kail et al., 1999) variables for each age level are presented in Table 2. Each age level's reading and naming tpi and the visual matching scores were logarithmically transformed. Normalities of distributions were inspected. If skewness and/or kurtosis statistics of a particular variable exceeded the critical value of twice the appropriate standard error, outliers were removed according to the Box plot

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

Table 2. *Descriptive statistics for three age levels of grade, age, and gender distributions and of reading, naming, and visual matching measures*

	Age (years)		
	8 ($n = 46$)	10 ($n = 78$)	12 ($n = 59$)
Grade	2	4	6
Age (months)	97.59 (4.74)	120.63 (4.96)	144.17 (4.34)
Gender (M/F)	25/21	39/39	32/27
Reading			
OMT, raw score	49.37 (14.23)	64.45 (11.15)	76.66 (11.51)
OMT, standard score	10.48 (3.16)	9.94 (2.67)	10.85 (2.56)
STWR, tpi (s)	1.41 (0.66)	.86 (.21)	.69 (.13)
MSWR, tpi (s)	.61 (.15)	.54 (.07)	.48 (.06)
CNR, tpi (s)	.59 (.10)	.53 (.06)	.46 (.06)
PNR, tpi (s)	.56 (.11)	.46 (.06)	.41 (.05)
Naming			
Numbers 1, tpi (s)	.62 (.12)	.53 (.08)	.45 (.07)
Numbers 2, tpi (s)	.62 (.12)	.52 (.08)	.44 (.07)
Letters 1, tpi (s)	.79 (.21)	.58 (.10)	.46 (.08)
Letters 2, tpi (s)	.67 (.12)	.52 (.10)	.42 (.06)
Colours 1, tpi (s)	1.13 (0.22)	.92 (.16)	.78 (.13)
Colours 2, tpi (s)	1.03 (0.21)	.81 (.16)	.70 (.10)
Pictures 1, tpi (s)	1.05 (0.22)	.89 (.13)	.78 (.10)
Pictures 2, tpi (s)	1.03 (0.27)	.86 (.15)	.73 (.11)
Visual matching (rows completed in 3 min)			
VM figures	17.83 (3.74)	21.30 (4.67)	25.22 (4.22)
VM numbers	34.57 (4.96)	40.04 (4.88)	45.71 (5.24)

Note: OMT, One Minute Test of Reading; STWR, standard test of word reading; MSWR, monosyllabic word reading; CNR, color name reading; PNR, picture name reading.

criterion. This occurred infrequently and resulted in small reductions of the original sample sizes. A subsequent check of the normalities of distribution did not indicate excessive deviations anymore.

In this cross-sectional study, three elementary age levels are compared. However, for the separate age levels we aimed at maximum homogeneity of age, so that ability assessments and correlations would not be inflated with age contributions. In order to establish whether the three age levels could be considered as having homogeneity of age, the correlations between age and the 14 experimental variables were investigated. At ages 12 and 10 there were zero and one significant correlations, respectively, and at age 8 there were five significant correlations at the 5% (one-tailed) confidence level. Thus, whereas the older age levels could be considered as having homogeneity of age, the youngest age level needed some further controlling of the age contribution to the variables. Whenever appropriate, this is indicated in the remainder of this section.

The error percentages were negligible (below 2%) for all variables and at

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

each age level, except for the 8-year-olds' performance on the standard test of word reading, on which they scored an error percentage of 4.43 (*SD* = 5.26). However, the speed–accuracy correlation was $r = .75$, which means that there was no sign of a speed–accuracy trade-off, in which case the speed analysis would have become less meaningful.

Mean processing speeds

Inspection of the mean processing speeds at the three age levels strongly suggests age level and task effects. In general, this means that each of the tasks is performed faster with age but the increases differ per task. For example, speeds by age are somewhat steeper for VM figures than for VM numbers. Concerning naming speeds, it can be seen (Table 2) that at each age level the color and picture naming take much longer than letter and number naming, a finding that is reported in numerous previous studies, beginning with Cattell (1885, 1886). Another interesting finding is that 8-year-olds, and to a slightly lesser extent, the 10-year-olds, take *longer* to continuously name 50 separate letters than to read an equal number of monosyllabic words that consist of at least three letters each. For the 12-year-olds, there are no longer any differences between letter-naming speed and the reading of monosyllabic words. In general, these findings replicate previously reported developmental trends (Aaron et al., 1999). Similarly, with regard to the reading tasks, it can be observed (see Table 2) that reading speeds of lists with short words differ much less among each other than from the speed of the standard word reading task, which contains longer words. In addition, the increases with age are most pronounced for the Standard Test of Word Reading at the transition of ages 8–10.

Although interesting, the analysis of means gives us little help in better understanding the naming–reading *link*. The latter being the primary research goal of this study, we now turn to the analysis of the interrelationships between the variables. For each age level, intercorrelations of the 14 experimental tasks (4 reading tasks, 8 naming tasks, and 2 visual matching or general processing tasks) are presented in Table 3, and they form the basis of further analyses.

Analysis of interrelationships

We first focus on the tasks that will be used later for prediction of reading, namely, naming and visual matching tasks. In order to reduce this predictive set of tasks to latent variables (components or factors) and to investigate whether underlying structures are obtained that are similar to the corresponding age levels in our previous study (van den Bos et al., 2002), a principal components analysis (PCA) with varimax rotation was performed. Table 4 contains the variables' loadings in the rotated component matrices, along with initial eigenvalues, rotation sums of squared loadings, and the cumulative percentage of variance explained.

As indicated in Table 4, rotations of three components at ages 10 and 12 and of four components at age 8 yield clearly interpretable orthogonal factors, that is, a color/picture-naming factor with strong loadings on color- and picture-

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

Table 3. *Pearson correlations per age level between log transformed speeds of four reading tasks, eight naming tasks, and two visual-matching tasks*

	STWR	MSWR	ColNR	PicNR	Num1	Num2	Let1	Let2	Col1	Col2	Pic1	Pic2	VMfig
8-Year-Olds													
MSWR	.86												
ColNR	.75	.83											
PicNR	.76	.86	.86										
Num1	.40	.56	.62	.65									
Num2	.43	.51	.58	.64	.85								
Let1	.58	.66	.61	.64	.55	.58							
Let2	.58	.63	.56	.72	.48	.49	.77						
Col1	.32	.38	.47	.50	.57	.58	.53	.33					
Col2	.40	.44	.48	.58	.61	.61	.54	.49	.87				
Pic1	.52	.60	.68	.61	.49	.44	.61	.51	.71	.70			
Pic2	.49	.59	.59	.63	.54	.52	.72	.57	.72	.74	.87		
VMfig	−.46	−.38	−.42	−.38	−.24*	−.38	−.39	−.44	−.22*	−.36	−.35	−.33	
VMnum	−.38	−.28*	−.28*	−.15*	−.24*	−.27*	−.33	−.20*	−.16*	−.23*	−.37	−.34	.54
10-Year-Olds													
MSWR	.74												
ColNR	.45	.68											
PicNR	.53	.71	.72										
Num1	.35	.58	.60	.60									
Num2	.47	.70	.62	.67	.75								
Let1	.49	.70	.64	.59	.53	.63							
Let2	.50	.65	.64	.66	.52	.62	.73						

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

Col1	.25	.28	.44	.36	.43	.39	.52	.42					
Col2	.37	.55	.57	.59	.59	.62	.66	.68	.69				
Pic1	.36	.42	.44	.54	.37	.46	.55	.51	.49	.68			
Pic2	.32	.50	.45	.51	.47	.56	.59	.59	.59	.73	.70		
VMfig	−.22*	−.21*	−.20*	−.22*	−.14*	−.45*	−.38	−.28	−.37	−.28	−.35	−.30	
VMnum	−.29	−.32	−.19*	−.17*	−.18*	−.33	−.34	−.35	−.36	−.37	−.26	−.29	.49
12-Year-Olds													
MSWR	.56												
ColNR	.41	.82											
PicNR	.42	.72	.80										
Num1	.38	.68	.81	.71									
Num2	.25*	.64	.75	.74	.76								
Let1	.42	.68	.71	.67	.68	.68							
Let2	.33	.65	.75	.79	.72	.70	.69						
Col1	.16*	.46	.54	.50	.53	.52	.53	.46					
Col2	.22*	.48	.51	.49	.45	.48	.48	.46	.72				
Pic1	.28	.46	.47	.46	.42	.49	.52	.42	.52	.53			
Pic2	.18*	.37	.41	.42	.38	.44	.49	.44	.55	.54	.76		
VMfig	−.18*	−.38	−.38	−.38	−.19*	−.27	−.25*	−.29	−.02*	−.09*	−.29	−.32	
VMnum	−.34	−.19*	−.22*	−.08*	−.23*	−.15*	−.16*	−.07*	−.16*	−.15*	−.16*	−.18*	.50

Note: STWR, standard test of word reading; MSWR, monosyllabic word reading; ColNR, color-name reading; PicNR, picture name reading; Num1, number naming 1; Num2, number naming 2; Let1, letter naming 1; Let2, letter naming 2; Col1, color naming 1; Col2, color naming 2; Pic1, picture naming 1; Pic2, picture naming 2; VMnum, visual matching of numbers; VMfig, visual matching of figures.
*nonsignificant correlations, $p > .05$.

Table 4. *Factor loadings of log transformed speeds of eight naming tasks and two visual matching tasks at three age levels*

	Rotated Component Matrix									
	8-Year-Olds				10-Year-Olds			12-Year-Olds		
Task	1	2	3	4	1	2	3	1	2	3
Numbers 1	.29	**.88**	.24	−.04	.24	**.87**	.03	**.87**	.23	−.11
Numbers 2	.28	**.85**	.27	−.20	.24	**.85**	−.30	**.83**	.31	−.12
Letters 1	.39	.29	**.77**	−.14	.51	**.60**	−.27	**.76**	.37	−.12
Letters 2	.20	.26	**.89**	−.12	.47	**.64**	−.20	**.85**	.24	−.09
Colors 1	**.87**	.35	.04	−.03	**.74**	.17	−.27	.39	**.75**	.09
Colors 2	**.82**	.42	.17	−.12	**.76**	.48	−.14	.33	**.76**	.05
Pictures 1	**.85**	.07	.31	−.13	**.81**	.20	−.15	.24	**.79**	−.22
Pictures 2	**.82**	.16	.41	−.07	**.80**	.34	−.12	.19	**.82**	−.25
VM figures	−.16	−.08	−.36	**.79**	−.17	−.14	**.85**	−.18	−.06	**.87**
VM numbers	−.05	−.10	−.05	**.91**	−.19	−.13	**.81**	−.04	−.11	**.81**
Initial eigenvalues	5.46	1.37	.99	.87	5.44	1.16	.87	5.01	1.39	1.11
Rotation sums of squared loadings	3.21	1.97	1.94	1.57	3.09	2.69	1.70	3.12	2.80	1.58
Cum. % variance	32	52	71	87	31	58	75	31	59	75

Note: The high loadings are in bold.

naming speeds, letter- and number-naming factors or a combined alphanumeric factor, and a visual matching factor with strong loadings on the two visual matching tasks. The emergence of a separate visual matching factor at each age level is not surprising in light of the relatively large number of nonsignificant correlations between visual matching and naming tasks reported in Table 3. This confirms our task analysis in which visual matching and naming operations were considered as independent processes.

Compared to the results of our previous study (van den Bos et al., 2002), the presently found color/picture- and alphanumeric-naming factors are identical for the 12-year-olds of the two studies. There is further similarity in regard to the separate alphabetic and numeric factors of the two studies for 8-year-olds. With regard to the 10-year-olds, a rotation of four factors was not feasible. However, as previously found, note that the factor structures of the 8- and 10-year-olds are more similar to each other than to the structure of the 12-year-olds. Also note the relatively low intercorrelations of number and letter naming at these age levels (Table 3). Moreover, although for the 12-year-olds the alphanumeric factor is dominant (first rotated factor), this is not so for the younger age levels.

Association between reading, naming, and visual matching speed

We will now focus on the interrelationships of the four reading tasks with the naming and matching tasks. With regard to the reading tasks, color name read-

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

ing and picture name reading, it was mentioned that these tasks differ in semantic organization and we wondered whether at this stage of the analyses, something could already be said about the effect of this subdimension. Hence, the correlations between color and picture *naming* and color and picture name–*reading* tasks were compared. Because the naming tasks colors 1 and colors 2 and pictures 1 and pictures 2 were highly associated (Table 3), these tasks were combined into the new variables color naming and picture naming. The correlations between these variables and color name reading and picture name reading were computed. At ages 10 and 12, no significant differences between these correlations were found. At age 8, one difference (r color naming − color name reading = .49; r picture naming − color name reading = .65) was significant ($t = -2.02$, $p = .025$, one-tailed). However, this difference was not in the expected direction, indicating an inferior instead of a superior naming–reading relationship for semantically identical stimuli. Thus, there seems to be no evidence for semantic organization effects in naming–reading relationships in tasks with equal item repetitivity. This conclusion, together with the finding of high correlations between the two color and picture name reading tasks (Table 3), warrants combining these tasks into one new reading variable of color–picture name reading. Thus, in the remainder of this section, we are left with three word reading variables whose relationships with naming and matching speeds will be compared at three age levels.

As in van den Bos et al. (2002), we will proceed in two steps. First, for a global impression, standard multiple regression (with a constant set of six predictor variables) was applied to each of the three reading variables and at each of the three age levels. The six predictor variables were number naming (Numbers 1 and 2 combined), letter naming (Letters 1 and 2 combined), color naming (Colors 1 and 2 combined), picture naming (Pictures 1 and 2 combined), and the two visual matching variables VM figures and VM numbers. Figure 1(a) presents the adjusted squared multiple correlations for each of the three word reading variables at the three age levels.

The data indicate that, at each of the age levels, the squared correlations (also referred to as common variance percentages) of the monosyllabic word reading and color–picture name reading measures and the predictor set of variables is about twice as high as for the standard test of word reading measure. Compared to this difference, differences between common variance percentages for monosyllabic word reading and color–picture name reading are small.

Second, in order to determine the separate contributions of *latent* naming and matching variables to the common reading–naming–matching variance for each age level, the correlations between *factor scores* (derived from the previously reported PCA in Table 4) and the three reading measures were computed. These correlations and their levels of significance are presented in Table 5.

At none of the three age levels does Table 5 indicate significant correlations between the color–picture naming factor scores and the standard test of word reading measure. According to expectations (e.g., Ligon, 1932), the color–picture naming factor scores correlated significantly with the color–picture name reading measure. Additionally, but at age 12 only, the color–picture naming factor scores correlated significantly with the monosyllabic word reading measure.

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

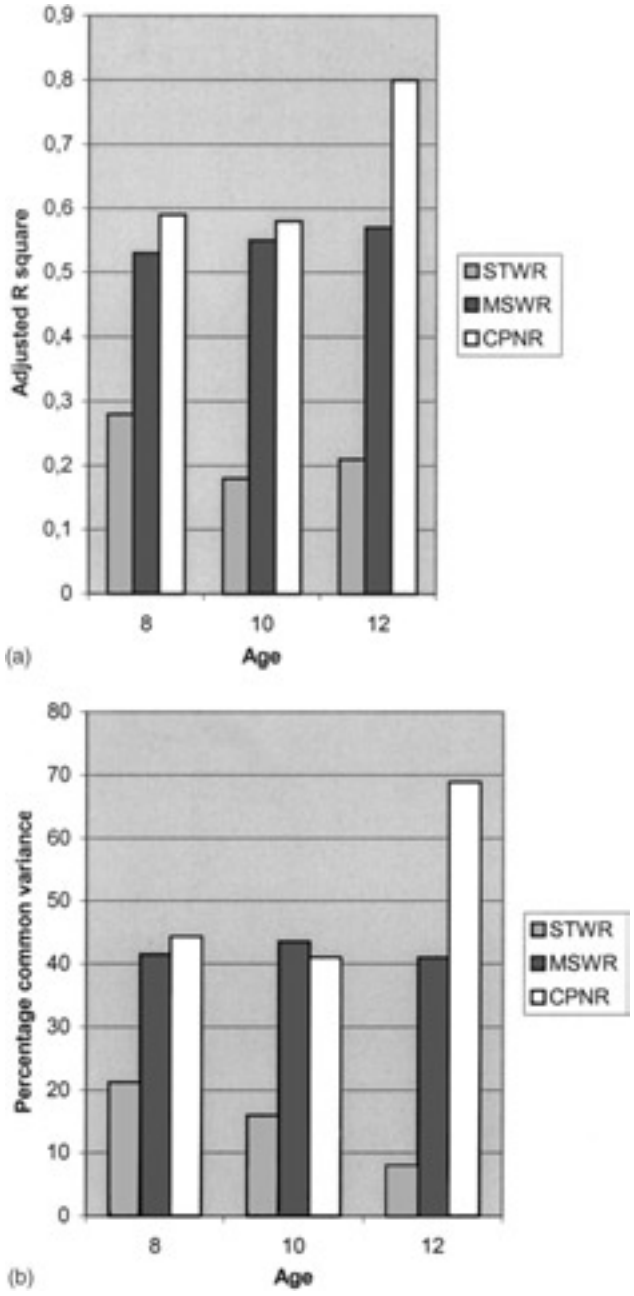


Figure 1. The three reading measures' common variance with (a) four naming and two visual matching variables and (b) alphanumeric-naming factor scores as a function of age. STWR, standard test of word reading; MSWR, monosyllabic word reading; CPNR, color–picture name reading.

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

Table 5. *Pearson correlations and two-tailed significance levels of three reading measures' reading speeds with naming and visual matching factor scores for three age levels*

		Reading Task					
Age	Factor	STWR	Sign.	MSWR	Sign.	CPNR	Sign.
8	COLPIC	.23[a]	.15	.31[a] (9.6)	.05	.35[a] (12.3)	.02
	NUM	.25[a]	.11	.38[a] (14.1)	.02	.45[a] (20.3)	.00
	LET	.46[a] (21.2)	.00	.52[a] (27.4)	.00	.49[a] (24.0)	.00
	VM	−.21[a]	.19	−.06[a]	.72	−.03[a]	.87
10	COLPIC	.16[a]	.20	.23	.07	.40 (16.0)	.00
	ALPHANUM	.40[a] (16.0)	.00	.66 (43.6)	.00	.64 (41.0)	.00
	VM	−.23[a]	.07	−.22	.09	−.07	.57
12	COLPIC	.23	.10	.39 (15.2)	.00	.33 (10.9)	.02
	ALPHANUM	.28 (8.0)	.04	.64 (41.0)	.00	.83 (68.9)	.00
	VM	−.36 (13.0)	.01	−.26	.06	−.21	.14

Note: The squared values are in parentheses, if $p < .05$. COLPIC, color–picture naming; NUM, number naming; LET, letter naming; VM, visual matching; ALPHANUM, alphanumeric naming; STWR, standard test of word reading; MSWR, monosyllabic word reading; CPNR, color–picture name reading.
[a]Controlled for age.

Similarly, the visual matching factor scores correlate significantly with one reading measure only (standard test of word reading) and only at age 12.

In contrast, the results in Table 5 make it clear that the most powerful source of common variance concerns alphanumeric naming speed contributions. A graphic representation of this finding is provided in Figure 1(b). Both parts of Figure 1 are highly similar, which is a strong indication of the supremacy of alphanumeric naming in explaining word reading variance. The data in Table 5 and Figure 1 show that, across age levels, the reading–alphanumeric naming links of monosyllabic word lists (monosyllabic word reading and color–picture name reading) are considerably stronger than for the standard test of word reading measure. Finally, comparing the link between alphanumeric naming and reading speed for different age levels, it can be seen that the link is relatively strong for the 12-year-olds' color–picture name reading performance. However, for the remaining reading variables the data in Figure 1 seem more suggestive of developmental constancy of the reading–naming link, rather than change. We will return to this issue in the Discussion.

DISCUSSION

Focusing on the elementary school age levels, one objective of the present study was to replicate and compare the developmental aspects of the factorial structures of a Denckla type of rapid naming battery and findings obtained in a previous study (van den Bos et al., 2002). The results indicate similarly developing factorial structures for the *naming* tasks in the two studies. That is, whereas

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

color- and picture-naming speeds load on the same factor throughout the elementary school age range, letter- and number-naming speeds initially (at age 8) form separate factors and do not combine into one single and stable alphanumeric factor until after age 10.

Previously, we concluded that there is "a gradual strengthening of initially loosely connected alphabetic and numeric access routes into an integrated alphanumeric network" (van den Bos et al., 2002, p. 43). However, this conclusion is more a tautology than an explanation, and the idea of a single integrated network might even prove elusive.

Currently, we think that the terminology in the studies of Morin et al. (1965), Morin and Forrin (1965), and Theios and Amrhein (1989) offers better perspectives. Morin et al. (1965) and Morin and Forrin (1965) showed that, in contrast to color and picture naming, for symbol naming (letters and numbers, specifically) the number of different stimuli in a set is of marginal influence on naming times, because letters and numbers elicit strongly dominant responses. In addition, Theios and Amrhein (1989) argued that, compared to number and letter naming, color and picture naming share the extra processing step of meaning determination. However, with regard to developmental patterns, we think that even the dominant-response assumption for letters and numbers should be differentiated in the sense that for young children letters have more response uncertainty than numbers. It can be assumed that the relatively greater response uncertainty for letters is induced by requiring the children to provide the alphabetic names whereas, because of the prevalent practice of providing early reading lessons in Dutch schools, the letter sounds are probably the more dominant responses. Our data suggest (see also the developments of letter- and number-naming speed means in Table 2) that it takes longer for children to comply with the instruction to provide the alphabetic names of the letters or to perform letter naming than for number naming.

The second major objective of this study was to investigate the nature of the naming–word recognition link by (a) hypothesizing and demonstrating that this link is relatively domain specific, that is, more determined by alphanumeric naming processes than by nonalphanumeric naming and nonnaming (visual matching) speeds, and (b) by investigating how the strength of the link varies with factors specific to naming and reading tasks.

We interpret the results of this study as offering little support for Kail et al.'s (1999) conclusion that the reading–naming *link* is determined by general processing speed. If this were so, nonnaming speed (visual matching) and nonalphanumeric-naming speed would be *related* to word reading speed at least as strongly as alphanumeric-naming speed. However, our results show that they are not, with one exception at age 12, when the visual matching speed was a relatively strong predictor of the standard test of word reading. Curiously, in our previous study (van den Bos et al., 2002) a similar peak was observed for the 12-year-olds' link between the standard test of word reading and nonalphanumeric naming. However, in that study this link was not demonstrated for 16-year-olds or adults, who showed an increased and consistently strong involvement of alphanumeric-naming speed instead.

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

With regard to task-specific effects on the naming–reading link, a central result seems to be that alphanumeric-naming speed is substantially stronger in relation to monosyllabic word reading and color–picture name reading than to the standard test of word reading. Which of the dimensions of item repetitivity, semantic organization and congruency, and word length seem most responsible for this finding? The results did not indicate significant differences between the correlations of the color- and picture-naming and color and picture reading tasks and the correlations of these naming tasks with the monosyllabic word reading measure, in which the items were semantically unrelated and only repeated once. Therefore, semantic organization and semantic congruency of (nonalphanumeric) naming tasks do not seem to add much to the explanatory dimension that is shared by all three "new" reading tasks (color name reading, picture name reading, and monosyllabic word reading), namely, the *monosyllabicity* of the words.

A similar conclusion probably also applies to the effects (within the class of monosyllabic words) of item repetitivity. Differences between the lists with low and high item repetitivity (i.e., the monosyllabic word reading and color–picture name reading lists, respectively) were either absent or developmentally uninterpretable. With the latter remark we mean that we have no explanation for the substantial reading–naming link *difference* between monosyllabic word reading and color–picture name reading at age 12. Assuming that for 12-year-olds, the lists with short words function as highly unambiguous sets of stimuli (Morin & Forrin, 1965), a substantial effect from differing degrees of item repetitivity was indeed not expected. Thus, the difference in reading–naming relationships between monosyllabic words (as contained in the monosyllabic word reading and color–picture name reading tasks) and the words in the standard test of word reading list seems to depend on the remaining variable of word length.

There are two remaining questions to address. First, which cognitive mechanism can be suggested to explain the robust differences in naming–reading speed *relationships* as a function of word length? Second, how can the developmental findings of the present study be integrated with those of our previous study (van den Bos et al., 2002)?

With regard to the first question, we focus on the observation that, from grade 2 onward, increasing numbers of words, starting with *monosyllabic* words, acquire the reading status of sight words (Ehri, 1997). This means that these words are "immediately or automatically activated in memory, without any sounding out or blending required" (Ehri, 1997, p. 166). This characterization comes very close to cognitive descriptions of letter and number naming. It is suggested, then, that the monosyllabic word lists contain words read by sight, which makes them functionally equivalent to alphanumeric stimuli that similarly elicit highly "dominant" (Morin & Forrin, 1965), "unambiguous" (Theios & Amrhein, 1989), or "automatic" or "routinized" (Wolf, 1991) naming responses. With regard to multisyllabic words, it can be assumed that these words, on average, are characterized by greater stimulus ambiguity than monosyllabic words. Therefore, it is predicted that the association between reading speed of multisyllabic words (of which there is a preponderance in the standard test of

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

word reading) and alphanumeric-naming speed will be weaker than for monosyllabic lists.

How do these naming–reading relationships develop? The results from both the present study and our previous study (van den Bos et al., 2002) suggest that these relationships are fairly *constant* for the elementary grade levels. However, compared to these age levels, the 16-year-olds and adults (Van den Bos et al., 2002) showed a substantial increase in the relationship between alphanumeric naming and the standard test of word reading. This could be explained by assuming that, as a result of prolonged domain-specific practice with reading, at least some of these longer words acquired the functional status of sight words (Ehri, 1997), a status that disambiguated letter names and monosyllabic words have for children of elementary age levels. However, at this stage of comparing age levels in various studies, we lack direct data on 16-year-olds' processing speeds on simpler lists (similar to the ones used in the present study) in comparison to the standard test of word reading measure. Will young adults *also* show stronger naming–reading links (compared to elementary grades) for lists with short words? If that proves to be the case, more general explanatory mechanisms than the growth of a sight word lexicon should be considered. We are presently investigating this issue and will report on it in the near future.

ACKNOWLEDGMENTS

We wish to thank the staff and students of three elementary schools in Aduard, Bedum, and Groningen, and former university students Marloes Roefs, Annemarie van der Lijn, and Kyra Meurs for collecting the data. We thank Dr. Charlotte Koster for correcting language errors. Finally, we wish to thank the editor and three anonymous reviewers of a previous version of this article. Their remarks were very stimulating for delivering an improved manuscript.

REFERENCES

Aaron, P. G., Joshi, R. M., Ayotollah, M., Ellsberry, A., Henderson, J., & Lindsley, K. (1999). Decoding and sight-word naming: Are they independent components of word recognition skill? *Reading and Writing, 11,* 89–127.

Brown, W. (1915a). Practice in associating color-names with colors. *Psychological Review, 22,* 45–55.

Brown, W. (1915b). Practice in associating number-names with number-symbols. *Psychological Review, 22,* 77–80.

Brus, B. T., & Voeten, M. J. M. (1972). *Een-minuut-test* [One-minute-test]. Nijmegen: Berkhout.

Cattell, J. M. (1885). Über die zeit der erkennung und benennung von schriftzeichen, bildern und farben [On the time it takes to recognize and name letters, pictures, and colors]. *Philosophische Studien, 2,* 635–650.

Cattell, J. M. (1886). The time it takes to see and name objects. *Mind, 11,* 63–65.

Davis, C. J., Knopik, V. S., Olson, R. K., Wadsworth, S. J., & DeFries, J. D. (2001). Genetic and environmental influences on rapid naming and reading ability: A twin study. *Annals of Dyslexia, 51,* 231–247.

Denckla, M. B., & Rudel, R. (1974). Rapid "automatized" naming of pictured objects, colors, letters, and numbers by normal children. *Cortex, 10,* 186–202.

Ehri, L. C. (1997). Sight word learning in normal readers and dyslexics. In B. Blachman (Ed.),

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

Foundations of reading acquisition and dyslexia. Implications for early intervention (pp. 163–189). Mahwah, NJ: Erlbaum.

Ellis, N. C., & Miles, T. R. (1978). Visual information processing in dyslexic children. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.), *Practical aspects of memory* (pp. 561–569). London: Academic Press.

Kail, R., & Hall, L. K. (1994). Procesisng speed, naming speed, and reading. *Developmental Psychology, 30,* 949–954.

Kail, R., Hall, L. K., & Caskey, B. J. (1999). Processing speed, exposure to print, and naming speed. *Applied Psycholinguistics, 20,* 303–314.

Ligon, E. M. (1932). A genetic study of color naming and word reading. *American Journal of Psychology, 44,* 103–110.

McBride–Chang, C., & Manis, F. R. (1996). Structural invariance in the associations of naming speed, phonological awareness, and verbal reasoning in good and poor readers: A test of the double deficit hypothesis. *Reading and Writing: An Interdisciplinary Journal, 8,* 323–339.

Meyer, M. S., Wood, F. B., Hart, L. A., & Felton, R. H. (1998a). Selective predictive value of rapid automatized naming in poor readers. *Journal of Learning Disabilities, 31,* 106–117.

Meyer, M. S., Wood, F. B., Hart, L. A., & Felton, R. H. (1998b). Longitudinal course of rapid naming in disabled and nondisabled readers. *Annals of Dyslexia, 48,* 91–114.

Morin, R. E., & Forrin, B. (1965). Information-processing: choice reaction times of first- and third-grade students for two types of associations. *Child Development, 36,* 713–720.

Morin, R. E., Konick, A., Troxell, N., & McPherson, S. (1965). Information and reaction time for "naming" responses. *Journal of Experimental Psychology, 70,* 309–314.

Neuhaus, G. F. (2002). What does it take to read a letter? *Perspectives, The International Dyslexia Association, 28,* 6–8.

Perfetti, C. A. (1985). *Reading ability.* New York: Oxford University Press.

Scarborough, H. S. (1998). Predicting the future achievement of second graders with reading disabilities: Contributions of phonemic awareness, verbal memory, rapid naming, and IQ. *Annals of Dyslexia, 48,* 115–136.

Spring, C., & Davis, J. M. (1988). Relations of digit naming speed with three components of reading. *Applied Psycholinguistics, 9,* 315–334.

Theios, J., & Amrhein, P. C. (1989). Theoretical analysis of the cognitive processing of lexical and pictorial stimuli: Reading, naming, and visual and conceptual comparisons. *Psychological Review, 96,* 5–24.

Torgesen, J. K., Wagner, R. K., Rashotte, C. A., Burgess, S., & Hecht, S. (1997). Contributions of phonological awareness and rapid automatic naming ability to the growth of word-reading skills in second- to fifth-grade children. *Scientific Studies of Reading, 1,* 161–185.

van den Bos, K. P. (1984). Letter processing in dyslexic subgroups. *Annals of Dyslexia, 34,* 179–193.

van den Bos, K. P. (1998). IQ, phonological awareness and continuous-naming speed related to Dutch poor decoding children's performance on two word identification tests. *Dyslexia, 4,* 73–89.

van den Bos, K. P., Lutje Spelberg, H. C., Scheepstra, A. J. M., & de Vries, J. R. (1994). *Handleiding de Klepel* [Manual pseudoword test 'the Clapper']. Nijmegen: Berkhout.

van den Bos, K. P., Zijlstra, B. J. H., & Lutje Spelberg, H. C. (2002). Life-span data on continuous-naming speeds of numbers, letters, colors, and pictured objects, and word-reading speed. *Scientific Studies of Reading, 6,* 25–49.

Walsh, D. J., Price, G. G., & Gillingham, M. G. (1988). The critical but transitory importance of letter naming. *Reading Research Quarterly, 23,* 108–122.

Wimmer, H. (1993). Characteristics of developmental dyslexia in a regular writing system. *Applied Psycholinguistics, 14,* 1–33.

Wimmer, H., & Mayringer, H. (2001). Is the reading-rate problem of German dyslexic children caused by slow visual processes? In M. Wolf (Ed.), *Dyslexia, fluency, and the brain* (pp. 93–102). London: York Press.

Wimmer, H., & Mayringer, H. (2002). Dysfluent reading in the absence of spelling difficulties: A specific disability in regular orthographies. *Journal of Educational Psychology, 94,* 272–277.

Wimmer, H., Mayringer, H., & Landerl, K. (2000). The double-deficit hypothesis and difficulties in learning to read a regular orthography. *Journal of Educational Psychology, 92,* 668–680.

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press

Wolf, M. (1991). Naming speed and reading: The contribution of the cognitive neurosciences. *Reading Research Quarterly, 26,* 123–141.
Wolf, M., Bally, H., & Morris, R. (1986). Automaticity, retrieval processes, and reading: A longitudinal study in average and impaired readers. *Child Development, 57,* 988–1000.
Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology, 91,* 415–438.
Woodcock, R. W., & Johnson, M. B. (1989). *Tests of cognitive ability.* Chicago: Riverside Publishing.

https://doi.org/10.1017/S0142716403000213 Published online by Cambridge University Press