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Rapid serial naming and reading ability: the role of lexical access

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Abstract

Rapid serial naming tasks are frequently used to explain variance in reading skill. However, the construct being measured by rapid naming is yet undetermined. The Phonological Processing theory suggests that rapid naming relates to reading because of similar demands of access to long-term stored phonological representations of visual stimuli. Some researchers have argued that isolated or discrete-trial naming is a more precise measure of lexical access than serial naming, thus it is likely that any shared variance between these two formats can be attributed to similar lexical access demands. The present study examined whether there remained any variance in reading ability that could be uniquely explained by the rapid naming task while controlling for isolated naming. Structural equation modeling was used to examine these relations within the context of the phonological processing model. Results indicated that serial naming uniquely predicted reading, and the relation was stronger with isolated naming controlled for, suggesting that isolated naming functioned as a suppressor variable in the relation of serial naming with reading.

Keywords

Rapid serial naming; Isolated naming; Reading; Structural equation modeling

Introduction

There is a substantial body of evidence demonstrating a significant relation between rapid serial naming tasks and reading performance (e.g., Aarnoutse, van Leeuwe, & Verhoeven, 2005; Bowers, 1989; Clarke, Hulme, & Snowling, 2005; Compton, 2003; Neuhaus, Foorman, Francis, & Carlson, 2001; Plaza, 2003; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004; Simpson & Everatt, 2005; Spring & Davis, 1988; Swanson, Trainin, Necochea, & Hammill, 2003; Uhry, 2002; Wagner, Torgesen, & Rashotte, 1994; Wolf, 1991). The most commonly used measure of rapid serial naming is the rapid automatized naming (RAN) task, in which participants are asked to name five different stimuli (letters, digits, colors, or objects) repeated at random in a grid of 10 columns and 5 rows (Denckla & Rudel, 1974). There are several proposed theories regarding the underlying relation of these tasks to reading outcomes. In the present study, the theories of phonological access, automaticity, global processing speed, and multiple processes will be discussed as exemplars of the different ways in which the relation of rapid serial naming and reading has been conceptualized.

Although all four theories discussed in the present study posit a relation between rapid serial naming and reading, each proposes a different critical cognitive component (or components) as underlying this relation. However, all theories are consistent in the basic information processing steps required for performing the rapid serial naming task, collectively termed *lexical access*. Namely, lexical access during rapid naming requires that the participant rapidly transfer presented visual symbols to phonological codes retrieved from long term memory store (Denckla & Rudel, 1974; Wagner & Torgesen, 1987; Wolf, Bally, & Morris, 1986). At issue, however, is just how much variability in reading is attributed to the lexical access process. While lexical access is considered to play a significant role in the phonological access theory of rapid serial naming performance, its role in other theories is less central.

Phonological processing—Because serial naming speed requires the transfer of visual stimuli to phonological codes, many believe the task to be tapping a phonological process. Specifically, this theory highlights the importance of phonological lexical access (also called phonological or phonemic recoding), and suggests that the rapid serial naming task is measuring individual differences in the efficiency with which visual symbols are recoded into their phonological representations. This theory was put forth as part of the phonological processing theory by Wagner and Torgesen (1987) who were the first to propose that phonological awareness, phonological memory, and phonological lexical access were causally related to reading ability. It was this paper that first brought awareness to the major, and causal, role that phonological processing played in learning to read. As the phonological nature of the reading process became well established, the belief in the phonological view of serial naming speed became one of the most widely accepted theories of what serial naming is measuring.

Following the phonological processing theory; Wagner, Torgesen, Laughon, Simmons, and Rashotte (1993) compared a number of confirmatory factor models to explain the observed covariation between several measures of phonological processing. Their results supported the phonological processing theory, with the best fit for the data being three distinct but significantly correlated factors: (1) Phonological awareness (blending and segmenting sounds from words), (2) Phonological memory (digit span), and (3) lexical access (naming speed). Several other studies have also found evidence consistent with this theory, citing significant correlations between serial naming speed and phonological awareness (e.g., Perfetti, 1992). Specifically, two meta-analyses conducted on studies including both rapid naming and reading found that naming speed correlates moderately (.30–.40) with phonological awareness outcomes (Swanson et al., 2003; Vukovic & Siegel, 2006).

One major line of evidence cited to argue against the phonological processing theory of rapid serial naming is that serial naming is often found to be uniquely predictive of reading after controlling for phonological awareness. However, this argument ignores the fact that phonological awareness does not encompass all of phonological processing. The three phonological processing constructs were proposed to be separable but correlated (Wagner & Torgesen, 1987). Therefore, the fact that serial naming adds uniquely to the prediction of reading ability is not sufficient evidence that the process is not phonological. The phonological processing theory would predict this as well.

However, it may be argued that if the relationship between rapid serial naming and reading is due to the speed and efficiency with which lexical codes are accessed in long term store, then the type of stimulus should not make a difference in the predictive utility of the task; letters, numbers, objects, and colors all must be translated from their visual representations into their correct phonological codes. However, contrary to this prediction, several studies have found that colors and objects do not predict reading ability as well as do letters or digits

(Denckla & Rudel, 1974; McBride-Chang, 1996; Schatschneider et al., 2004; Walsh, Price, & Gillingham, 1988). This suggests that there may be other cognitive skills being tapped by serial naming that are also shared by reading other than the efficient retrieval of phonological codes.

Automaticity—One construct that has also been hypothesized to play a role in rapid serial naming speed is the general automaticity with which tasks are performed. This theory acknowledges that lexical access is required for rapid naming performance, but attributes the variance to the automaticity of the process rather than the phonological aspects of the process. Basically, this theory suggests that the more familiar or rehearsed a child is with letter names, the more automatic the process of naming them becomes, and so the faster children perform when naming them (Bowers, 1995; Spring & Davis, 1988). This idea was first proposed by Eakin and Douglas (1971) who called “automatization” a kind of rapid retrieval function, and was cited by Denckla and Rudel (1974) in the work that first attempted to distinguish dyslexic from non-dyslexic children, and was later included in a model of information processing in reading put forth by LaBerge and Samuels (1974).

Evidence for this theory comes from developmental research suggesting that when learning to read, the lower-level processes involved in reading (i.e., letter sound identification) are effortful and require cognitive processing, but as reading is practiced these processes become less effortful and more automatic (Walsh et al., 1988). Evidence for this theory as it relates to learning disabilities comes from Sternberg and Wagner (1982) in which they found that tasks normally developing children perform automatically are still performed consciously and methodically in their peers with learning disabilities. Additionally, Spring and Davis (1988) suggested that word recognition of exception words is a measure of word-level automaticity, as the pronunciation of exception words cannot be decoded and must be memorized. They showed evidence that naming speed was more highly correlated with automaticity measured in this way than with the higher-level process of reading comprehension, concluding that this pattern of relations supports the role of automaticity in naming speed. However, a meta-analysis of serial naming conducted by Swanson et al. (2003) suggested that the correlation of word reading with serial naming is very similar to that of reading comprehension with reading (.41 and .45, respectively). Therefore the role of automaticity in the naming task remains unclear.

Global processing speed—An alternative explanation for why children get faster at the rapid naming task as they age is that the increase in speed is just one of the many manifestations of a more global processing speed mechanism caused by age-related growth and development (Kail & Hall, 1994). This theory also acknowledges that lexical access is required for the task, but that the individual differences in performance are related to global processing speed rather than the phonological process. This theory is based in the observation that all cognitive processes increase in speed as children age (Kail & Hall, 1994). Theoretically, as information processing speed increases, so will the speed with which letters are named, and so will reading ability. This theory therefore posits that the shared variance between rapid serial naming and reading ability lies in this more global mechanism. Global processing is often measured by simple cognitive tasks not related to memory, such as visual matching or cross-out tasks. Findings suggest that these tasks are correlated strongly ($r = .66$; Kail & Hall, 1994) to moderately (r ranging from .41 to .47) with serial naming (Bowey, McGuigan, & Ruschena, 2005).

Theoretically, if global processing speed was the critical component of serial naming speed, serial naming should be highly related to all other tasks that require this same global speed mechanism. One such task is simple reaction time. However, research examining both simple and choice reaction time has found no reliable differences between dyslexic and

normal readers (Nicolson & Fawcett, 1994; see Wolf, Bowers, & Biddle, 2000 for a review). Further, Powell, Stainthorp, Stuart, Garwood, and Quinlan (2007) directly tested the global processing theory of rapid serial naming, and found that after controlling for global processing measures, rapid naming still significantly contributed to the prediction of reading ability. These results suggest that while the two may be related, even strongly related, global processing speed does not account for all of the variance in serial naming speed as it relates to reading.

Multiple constructs—Another popular theory of rapid naming speed accounts for several potential non-phonological processes involved in serial naming. Discussed in Wolf and Bowers (1999), this model includes the three constructs previously discussed (lexical access, automaticity, and global processing speed), as well as attentional, visual, and articulatory processes, with an emphasis on the processing speed requirements within each of these components. In this theory, the critical variance in the relation of serial naming with reading relates to the efficiency with which these multiple processes are integrated through precise timing mechanisms. Also key to this integration is the fact that these processes require cross-hemispheric connections and the transfer of orthographic symbols to phonological codes. This theory also suggests that the transfer of visual stimuli to phonological codes is a phonological process, but that this is not the primary source of explanatory variance in serial naming.

In sum, it is certainly true that, as suggested by Wolf and Bowers (1999), serial naming is a cognitively complex task in which a number of important skills must be coordinated; it is the relative importance of the different cognitive components that remains unclear. Interestingly, each of the aforementioned theories has acknowledged that lexical access does occur during the rapid naming task, but attributes varying degrees of the shared variance between reading and naming speed to this particular skill. While Wagner et al. (1993) have stressed the importance of lexical access, Wolf and Bowers (1999) have discounted this component of their model, suggesting that it plays only a minor role in the actual variance of the serial naming task as it relates to reading. The debate continues because any observed variability in the task could be attributed to either the full set of cognitive processes or to the one component of lexical access alone.

The present study sought to examine this inherent problem by controlling for lexical access in the relations of rapid naming with reading ability. If lexical access alone is responsible for the relation of rapid naming with reading, then controlling for lexical access should eliminate any unique contribution of rapid serial naming to variance in reading. As such, if controlling for lexical access eliminates the relation of rapid naming with reading, then lexical access could be argued to be the underlying critical component relating rapid naming to reading ability. If this does not occur, it could be argued that other components are also important in this relation. In the present study, the construct of lexical access was tapped by the isolated naming task.

Isolated naming

Although the rapid serial naming task is very commonly used in studies of reading ability, some researchers have also measured naming speed in a discrete-trial (or isolated) format. In this format, stimuli are individually presented, usually on a computer screen, for a set amount of time. In between each presentation, a blank screen is shown, also for a set amount of time (i.e., inter-stimulus interval). The stimuli are usually colors, objects, digits, or letters. Also, like the serial task, the metric for the isolated task is speed, typically measured by the average time it takes the participant to name a letter after it is first presented.

In general, research using the isolated naming task has found a moderate relationship between isolated naming speed and reading outcomes, but the results are still inconsistent with those of serial naming. For example, while the rapid serial naming task has been used consistently to classify good and poor readers, the isolated task often fails to do so (Perfetti, Finger, & Hogaboam, 1978; Stanovich, 1981). Also, Walsh et al. (1988) found that isolated naming is predictive in first grade, but is no longer significantly related to reading by third grade. Additionally, studies that included both isolated and serial naming suggest that serial naming correlates more strongly with reading than isolated naming (Bowers & Swanson, 1991; Pennington, Cardoso-Martins, Green, & Lefly, 2001; Wagner et al., 1993, 1994).

Research that has employed this task often relied on the argument that the isolated naming task is a more precise estimate of true naming speed or lexical access speed than is the serial naming task (Bowers & Swanson, 1991; Pennington et al., 2001; Stanovich, Feeman, & Cunningham, 1983; Walsh et al., 1988). For example, Stanovich et al. (1983, p. 202) when arguing the importance of using the isolated naming task, suggested “the relationship between rapid name retrieval ability and reading skill is overestimated by continuous-list tasks that tap many other cognitive processes in addition to name retrieval”. Further, it is generally acknowledged in the literature that serial naming is a more complex task than isolated naming. Wolf and Bowers (1999) argued that the isolated task has nothing to offer to the prediction of reading not accounted for in serial naming. However, the observed difference in the correlations between isolated naming, serial naming, and reading has broader implications than these studies suggested. Specifically, it indicates that there may be some important differences between the isolated and serial naming tasks that are indicative of serial naming’s unique relation with reading.

Based on this idea, the present study explicitly examined the differences between isolated and serial naming performance and their relations with reading ability. The study had three main goals. Because the isolated naming task has been considered to be a less contaminated measure of lexical access than serial naming, the first goal of the present study was to examine how performance on the two formats differs. This was done by examining mean performance differences between the two tasks, and differences in the correlations of each task with reading ability. The second goal builds on this idea, using mediation models to determine whether lexical access, as measured by isolated naming, can account for all of the shared variance between serial naming and reading. Finally, the same mediation models were tested within the context of the Phonological Processing theory, to determine if the relation of rapid naming with reading can be accounted for by other shared phonological skills.

Method

The present study is a re-analysis of the original data used in Wagner et al. (1994), which employed an autoregressive model to test the causal implications of the phonological processing model proposed in Wagner et al. (1993). As the goal of the present study was to examine the unique contribution of rapid serial naming to reading performance above and beyond lexical access (as measured by isolated naming), these data were examined concurrently without controlling for reading performance from the previous year.

Participants

Two hundred and eighty-eight English-speaking children (53% female) were randomly selected from kindergarten classrooms. Of those, 244 were retained through the course of the project. Ages of the children at first data collection time point ranged from 5:0 to 6:9, with a mean age of 5:8. The participants were 75% white. The remaining 25% were primarily African-American. The sample of children in this study is the same as those

reported in several previous studies (Torgesen, Wagner, & Rashotte, 1994; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997; Wagner et al., 1994; Wagner, Torgesen, Rashotte, & Hecht, 1997).

Measures

The following measures were included in the longitudinal sample, and will be reexamined as part of this study. They are listed here in the classifications that resulted from the Wagner et al. (1993) confirmatory factor analysis; specifically five latent variables, each defined by several observed variables. Reliabilities are reported for each measure in each grade.

Phonological analysis—The construct of phonological analysis was measured by three latent variables, elision, sound categorization, and first sound comparison. Each phonological awareness measures consisted of several practice trials and 15 test items. In the elision task, children were asked to say a word, and then say the word with a given letter sound removed. All sounds to be removed were consonants, and the phoneme position varied across beginning, middle, or end of the word. ($\alpha = .90, .92$, and $.90$ in kindergarten, first, and second grade). In the sound categorization task, children were asked to determine which of a set of four words was different than the others. Three presented words typically shared a phoneme that was absent in a fourth word. The phoneme varied in position in the different words ($\alpha = .91, .90, .89$). Finally, in the first sound comparison task, children were presented with four pictures and the names of the objects in each picture, and were asked to select the picture that had the same first sound as the first picture ($\alpha = .95, .92, .88$).

Phonological synthesis—The phonological synthesis construct consisted of three tasks that required children to add or blend sounds together. In the blending onset and rime task, children were required to blend the initial consent sound(s) with a vowel and coda of words. Stimuli consisted of one- and two-syllable words ($\alpha = .95, .95, .93$). The second task, blending phonemes into words, was similar to the onset and rime task, except that children were asked to combine phonemes to create a word ($\alpha = .90, .90, .86$). Finally, blending non-words was the same as the blending words subtest, except with non-words ($\alpha = .86, .86, .82$).

Phonological memory—The third latent construct, phonological memory, consisted of two latent constructs, sentence memory, wherein children were scored on how accurately they repeated 19 recorded sentences ($\alpha = .81, .72, .72$), and an oral digit-span task, requiring children to accurately recall a series of recorded digits immediately after presentation (split-half = $.84, .88, .86$).

Isolated naming—The observed variables for the Isolated Naming construct were results of three different sets of stimuli, letters (A, B, E, H, K, R, S, T), digits (1, 2, 3, 4, 5, 6, 8, 9), or a combination of digits and letters. Regardless of the stimuli used, each stimulus was presented individually in the center of a computer screen, with a short blank screen between presentations. Stimuli were presented in a random order, and each was presented twice for a total of 16 trials. Before testing, children were presented with the stimuli included in the task to make certain they were familiar with them. The time between the presentation of each stimulus and the onset of the vocal response was measured, and the average latency was calculated across all 16 presentations ($\alpha(\text{letters}) = .79, .78, .91$; $\alpha(\text{digits}) = .82, .84, .89$; $\alpha(\text{digits and letters}) = .74, .87, .91$).

Serial naming—In the serial naming tasks, 36 letters were presented in a block of 9 letters per row and 4 letters per column. In the letters version of the task, a sequence of six different capital letters (A, D, S, L, R, M) was repeated randomly 6 times to create a block of 36

letters. Children were first tested to make certain that they knew all of the letters included in the task. Two different forms of each version of the task were presented to the children. Scores on the task are the average time it took to finish each of the two trials (split half = .91, .95, .93). The same format was followed for the digits (split half = .90, .94, .95) and combined digits and letters (split half = .90, .92, .96) versions of the task.

Reading ability—The latent construct of reading ability was measured with two observed variables. First, the word identification untimed subtest of the Woodcock reading mastery test (Woodcock, 1987), which required children to accurately name individually presented words ($\alpha = .98, .98, .97$). Secondly, the untimed word analysis subtest of the Woodcock reading mastery test (Woodcock, 1987) required children to name individually presented non-words ($\alpha = .96, .93, .96$).

Assessment procedure

These tasks were administered in random order to children in the fall of kindergarten, first, and second grade. Testing took place in four individual sessions within a 2-week period and was conducted by trained research assistants.

Analytic procedure

The present study was divided into three parts. In the first part of the study, mean performance differences across the isolated and serial naming tasks were compared, as were differences in the correlations of each task with reading ability. In the second part of the study, a mediation analysis was conducted, which was designed to examine whether lexical access mediates the relation of rapid serial naming with reading ability. In the third part of the study, the mediation analyses were revisited within the context of the phonological processing model proposed by Wagner et al. (1993).

Mean differences and correlations

Results

If isolated and serial naming were measuring identical constructs, they should correlate very highly with one another. However, the correlations reported in Wagner et al. (1994) showed that isolated and serial naming correlate between .48 and .57 across the grades and stimuli, indicating that the tasks do have some differences in cognitive demands (see Table 1). Further, the two naming tasks appear to be differently correlated with the two reading outcomes (Table 1).

The differences between the two naming speed tasks' correlations with reading were statistically compared using a z transformation formula developed to statistically test the correlations of two different independent variables with the same dependent variable (see Meng, Rosenthal, & Rubin, 1992). Results of these analyses are presented in Table 1. For example, the correlation of isolated naming of letters with word identification in kindergarten was .19, serial naming of letters with word identification in kindergarten was .50, and those correlations were significantly different ($p < .01$). The overall results of these analyses suggested that serial naming was more strongly related to reading outcomes than isolated naming (significant differences are reported in Table 1). This held for all modifications of the task, grade levels, and outcomes, with the exception of second grade predictions of word analysis, which showed no differences in correlations between the two tasks.

To better understand the relationship of these two tasks with each other, scatterplots of isolated and serial naming were created for each grade with a reference line added to

indicate the points at which isolated and serial naming speed would be equal (Fig. 1). Examining the kindergarten scatterplot, the majority (86%) of points are above the reference line. This indicates that these children were faster (named more letters per second) on the isolated task than the serial task. However, this difference in speed changes as the children grow older. In first grade the difference decreases, with 65% still being faster at isolated naming. By second grade, the children's speeds have shifted, with the majority (56%) below the line; indicating that they are now faster at the serial task than the isolated task. Analyses of the difference scores between isolated and serial naming confirm that children were faster at naming stimuli in isolation in kindergarten, $t(242) = 15.27, p < .01$, and first grade, $t(242) = 6.10, p < .01$, and were faster at serial naming than isolated naming in second grade, $t(242) = -3.75, p < .01$.

Discussion

The initial analyses of the two naming variables resulted in two main findings. First, across the three grades, serial naming was found to be more strongly related to reading outcomes than isolated naming, and most of these differences were found to be significant. This finding was expected, and is in line with similar findings in the literature (Bowers & Swanson, 1991; Pennington et al., 2001; Wagner et al., 1993). Secondly, the speed with which each naming task is performed increases from kindergarten through second grade. This finding has also been reported in other studies in the literature (i.e. Bowers & Swanson, 1991). However, the present study provides a new perspective on this relation; the speeds of the two tasks *differentially* changed across the three grades. Each task increased in speed as the children aged, but the speed of serial naming increased at a faster rate, such that rapid serial naming was faster than isolated naming by second grade. If lexical access is the critical component relating each task to reading, then the speeds of the two tasks should increase at a similar rate; the efficiency with which letters are accessed should be the same regardless of the format. Thus, this would seem to indicate that there are other important cognitive components in this task besides lexical access to phonological codes.

To explicitly test whether other factors are important in the relation of rapid naming with reading, the next step of the analysis used latent variable modeling to test mediation models, with isolated naming as a mediator variable in the relation of rapid naming with reading. If there are other constructs that are involved beyond lexical access, then rapid naming should continue to explain unique variance in reading ability once isolated naming is controlled for.

Latent variable modeling

Analytic procedure

Using the procedures from Wagner et al. (1994), latent variables for reading ability, isolated naming, and serial naming, were created for each grade. These variables were then entered into a series of SEMs in mediation models designed to estimate each construct's unique contribution to reading ability. Latent variable modeling is advantageous because it allows the use of only the shared variance between these three observed variables, resulting in a more accurate representation of the true construct underlying the tasks. In this case, content sampling error was controlled for because three different versions of the task were conducted. The tests were also given to students in random order, thus controlling for order effects.

All models were estimated using AMOS 5.0 (Arbuckle, 2003). For each model estimated, four tests of model fit were reported; the root mean square error of approximation (RMSEA) indicates good or adequate fit if the value is less than .08, a non-significant value suggests good model fit for the Chi-square index, and The goodness of fit index (GFI) and

comparative fit index (CFI) range from 0 to 1, with values of .9 or greater indicating good fit.

Mediation—To test if the relation of rapid serial naming and reading can be attributed to lexical access, isolated naming was entered into a mediation analysis of the relation of rapid naming with reading ability. This analysis follows a four step procedure as outlined by Baron and Kenny (1986). Step 1 identifies that there is an effect to mediate, by determining whether a relation exists between the initial variable (which in this case will be rapid naming) with the outcome variable (reading). In step 2, the relation of the initial variable (rapid naming) and the mediator variable (isolated naming) is examined. Once these relations are established, both independent variables (serial naming and isolated naming) are simultaneously entered into the model explaining the outcome (reading). If the mediator (isolated naming) is related to the outcome measure when the initial variable (serial naming) is partialled out, then there is some type of mediation occurring. The fourth, and final, step in the analysis focuses on the relation of the initial variable with the outcome. In this case, if isolated naming completely mediates the relation of rapid naming and reading, then rapid serial naming will contribute nothing to the variance in reading ability once isolated naming is controlled for.

Results

The first step of the mediation process has already been established; the correlations of rapid serial naming with reading were examined extensively in the first stage of the analysis. Standardized beta weights were used to examine the next three steps of the mediation analysis, and presented in Table 2, with graphical depictions of the full models for kindergarten, first, and second grades are presented in Figs. 2, 3, and 4 respectively.

In kindergarten, the results of the single-predictor analyses found that isolated naming significantly contributed to variance in reading (.19), and serial naming was also significantly related to reading (.51). Interestingly, when both naming variables were included, rather than diminish, as would be expected if mediation were occurring, the rapid serial naming contribution actually increased to .69. Further, the sign of the isolated naming beta weight changed in the full model (−.27). Results also showed that the explained variance in the latent reading ability variable was the largest for the model including both variables ($R^2 = .30$).

The results of the first grade model were very similar to the kindergarten model (see Table 2; Fig. 3). The isolated naming beta weight was again moderately positively related to reading performance when it was the only variable provided to explain the variance in reading (.36), but when both naming variables were included, the sign again flipped, resulting in a moderately negative relation with reading (−.24). Just as with the kindergarten model, the beta weight for serial naming was smaller when it was the only predictor (.68) and increased when isolated naming was added to the model (.85). The variance in reading explained was again largest for the full model ($R^2 = .50$).

A different pattern of results emerged for the second grade model. The single-variable relations of reading with isolated and serial naming were quite large compared to the previous two grades (.49 and .71, respectively). When both variables were included in the model, a more typical multiple-variable model emerged; the beta weight for isolated naming decreased substantially (.05), while that of serial naming decreased only slightly (.67).

Discussion

Though the SEMs conducted were designed to test for mediation effects of isolated naming on the relation of serial naming with reading, the observed patterns were not consistent with this theory. If mediation were present, and rapid serial naming task was measuring lexical access, then controlling for isolated naming should have left no variability in reading to be explained by rapid serial naming. Notably, the opposite pattern was found in second grade. Isolated naming, which was a strong indicator of reading skill when measured alone, became insignificant once rapid serial naming was controlled for. This indicates that, in second grade, the variance in isolated naming is completely taken up by serial naming. This is likely a result of the more complex nature of serial naming compared to isolated naming, a theory cited by many in the extant literature (i.e., Wolf et al., 2000). At least in second grade, it appears that these results confirm the hypothesis put forth by Wolf and Bowers (1999) that with rapid serial naming controlled for isolated naming contributes little to the explanation of the variance in reading ability.

However, the mediation result was not observed in the kindergarten and first grade models. Instead, in full models, isolated naming contributed negatively to the variance in reading, allowing the contribution of serial naming to increase. This pattern of results observed in kindergarten and first grade indicates that isolated naming may act as a suppressor variable in the relation of serial naming and reading ability. Suppression is defined by one variable's suppression of variance through other independent variables; allowing the independent variable to be a more "pure" indicator of the dependent variable. In this case, it seems that isolated naming is suppressing some of the variance in serial naming that is unrelated to reading ability, allowing serial naming to account for more variability in reading skill. At present, there is not a statistical test to determine whether suppression is occurring (Tabachnick & Fidell, 2001). However, when the sign of an independent variable's regression weight is the opposite of what would be expected based on bivariate correlations; it is called "negative" or "net" suppression (Tabachnick & Fidell, 2001, p. 148). The suppressive effect will be discussed in greater detail in the general discussion.

One potential problem with this interpretation is that it is possible to see suppressive-like effects when multicollinearity is observed between two variables. Multicollinearity occurs when two variables are highly correlated (between 0.8 and 0.9 or higher), and is an indication that the two variables involved are actually measuring the same construct. However, as previously mentioned, the correlations between the individual naming variables ranged from .48 to .57 across the three grades, indicating that there were significant differences between the two tasks (see Table 1). Further, the correlations between the two latent constructs was not much larger, ranging from .65 to .67 in the three grades, thus indicating that multicollinearity was not an issue with the data in the present study.

A second possible alternative explanation of these results could involve only accounting for variance associated with naming speed in the model of reading ability. It is possible that other variables associated with reading ability would, if added to the model, change these naming-speed relationships. Specifically, any remaining shared variance between rapid naming and reading ability may be due to other shared phonological skills, which may be accounted for in the other phonological processing constructs of phonological awareness and phonological memory.

Phonological processing theory

Procedure

Models were constructed following the phonological processing model reported in Wagner et al. (1993); two latent variables for phonological awareness (analysis and synthesis), one

for phonological memory, and two for naming speed (isolated and serial). This measurement model was used as a base to create a structural equation model explaining the variance in reading ability. As with the smaller models, these models were tested for a mediation effect. If the critical relation of serial naming with reading were due to lexical access, then the relation of rapid naming with reading should be completely mediated (be reduced to near 0) by controlling for isolated naming and the other phonological processing variables.

To test this hypothesis, a series of four structural equation models was estimated following procedures outlined in Baron and Kenny (1986). To begin, a model was fitted with no naming variables, to see how much variance in reading ability was explained by the other phonological processes alone. In the second step, two models were estimated, one with each naming task as the only measure of lexical access. With these paths estimated, a full model was estimated including both isolated and serial naming. The paths of interest are reported in Table 3. In this table, the row labeled “no naming variables” contains parameter estimates from a model containing only the phonological processing variables, no rapid naming tasks. The “isolated only” column contains all three of the other reading predictors plus isolated naming, “serial only” contains the same three predictors and serial naming, and “both” indicates the full models. These full models, for kindergarten, first, and second grades, including model fit indices, are presented graphically in Figs. 5, 6, and 7 respectively.

Results

In kindergarten, serial naming was moderately related to reading ability with the other phonological processes controlled for (.27). However, isolated naming is no longer significantly related to reading in this model (.05). When both naming variables were entered together (Fig. 5), the same pattern was observed as with the earlier models; isolated naming was significantly negatively related to reading (−.28), and serial naming increased its unique contribution (.46). The variance explained also increases in the full model ($R^2 = .38$).

A similar result was observed in first grade, with the other phonological processes controlled for, serial naming was again moderately related to reading ability (.38), and isolated naming was not (.01). In the full models (see Fig. 6), isolated naming again contributed significantly negatively to reading (−.25), and serial naming increased its unique contribution to .55. The variance explained also increases in the full model ($R^2 = .65$).

Although a similar pattern was observed for second grade, both serial and isolated naming contributed significantly to the variability in reading (.42 and .12, respectively), the results of the full model were slightly different. Although the beta weight for isolated naming was negative, it was not significantly different from zero (−.09). Thus, although the serial naming beta weight increases in the full model (to .47), the variance in reading explained does not change from that of the model including only serial naming speed.

Discussion

The results of the individual naming variable models (isolated only and serial only) suggest that controlling for the phonological processes of phonological awareness and memory resulted in smaller beta weights for both naming variables. While the serial naming weights remained significant in all three grades, isolated naming was only significant in second grade; the isolated only models showed non-significant relations of isolated naming with reading in kindergarten and first grade. This minimal relation suggests that the significant relations between isolated naming and reading observed in the previous analyses were accounted for by other shared phonological skill, either phonological awareness or memory.

Just as with the previous set of models, the full SEMs were designed to test for a possible mediation effect of isolated naming on the relation of serial naming with reading, this time while controlling for the other phonological processes. However, also as with the previous analyses, the observed patterns were not consistent with this theory. Results of the second grade model again suggested that isolated naming did not contribute significantly to the variability in reading ability beyond the variance controlled for in serial naming speed (i.e., Wolf & Bowers, 1999).

The results of the kindergarten and first grade full models were very similar to that of the previous analyses, and again indicated that isolated naming may act as a suppressor variable in the relation of serial naming and reading ability. Comparing the current results to those with only the naming variables as predictors, the magnitude of the negative relation of isolated naming with reading was the same in both models. However, unique contribution of serial naming to variance in reading was smaller with the phonological processes controlled for, thus suggesting that some of the variance in serial naming as it relates to reading was accounted for by the constructs of blending, elision, and memory. Even so, serial naming remained a significant predictor, and was the variable with the largest factor beta weight in first and second grades. This indicates that even when accounting for other predictors of reading skill, isolated naming acted as a suppressor for some portion of the variance associated with the relation of serial naming with reading. The suppressive effect will be explained in more detail in the following section.

General discussion

Because the isolated naming task has been considered to be a less confounded measure of lexical access than serial naming, the first goal of the present study was to examine how the two formats differ from one another. Overall, serial naming was found to be more strongly related to reading outcomes than isolated naming, and the speed with which the two naming tasks are performed differentially changes from kindergarten through second grade.

The increase in serial naming speed is well documented, and is often attributed to children's increasing familiarity with letter names, which is believed to make the process more automatic (Bowers, 1995; Moll, Fussenegger, Willburger, & Landerl, 2009; Spring & Davis, 1988). However, if this is the case, then there should be no differential change in speed for the isolated and serial tasks; the speed with which letters are recognized should be the same regardless of the format. The fact that this differential change takes place is a good indicator that these two tasks are measuring more than just how automatically letters can be named. A similar conclusion can be drawn for the Global Processing Theory also mentioned in the introduction. If the shared variance in rapid naming and reading ability is due to a global processing mechanism, the speed with which the two tasks are completed should grow at a similar rate, not differentially as was observed in the present study.

The second goal of the present study was to examine the role of lexical access in the relation of rapid serial naming with reading ability. The latent variable mediation analyses did not show the expected mediation effect of reducing the relation of rapid naming speed with reading. Contrarily, in second grade, the mediation effect worked in the opposite way; serial naming absorbed all of the variance that could be attributed to isolated naming. In kindergarten and first grades, however, the SEMs revealed a suppressive effect, isolated naming contributed negatively to variability in reading, which resulted in an increased relation of serial naming with reading. These results were mirrored in the testing of the third goal of the study, controlling for the phonological processes of blending, elision, and memory.

Suppression

The negative relations of isolated naming with reading in the kindergarten and first grade models suggest that suppression was observed. Suppression has two characteristic traits, and thus the suppressive finding has two main implications for the relations of rapid serial naming with reading, and the role of lexical access in this relation. First, there is some shared variance between isolated and serial naming speed that is unrelated to reading; and second, that there must remain at least one cognitive component of rapid serial naming, unique from the skills required for isolated naming, that is strongly related to reading performance.

To illustrate, the typical example of suppression is one involving a written test of a physical skill (such as dancing) as one dependent variable, and a test of writing skill as the second dependent variable, or suppressive variable. When both variables are used to predict physically measured dancing ability, the writing test suppresses some variance in the writing-based dancing ability test that is unrelated to the actual construct of dancing. The first hallmark of suppression is that the relation of suppressive variable (writing test) with the outcome becomes negative. The second characteristic is that the negative variance allows for the first independent variable (written dancing test) to become more strongly related to the outcome. This is precisely what was observed in the present study. It is not simply the case that serial naming is more predictive than isolated naming. Isolated naming is removing, or taking up, some variance in serial naming that is unrelated to reading ability.

For the first hallmark, the shared variance between the two independent variables causes the sign to flip. In the dancing example, this variance can be attributed to writing skill; the variance that is not necessary for explaining the outcome. In the present application, this would correspond to the shared variance in isolated and serial naming that is unrelated to the outcome of reading ability. While there may be several constructs that exist in this space, the most obvious candidate for this variance is lexical access. The speed with which visual symbols are recognized and transferred to phonological codes should be identical for both the rapid serial naming and isolated naming tasks. Further, the isolated naming task has been cited as a direct measure of lexical access, not confounded by other processes (i.e., Stanovich et al., 1983). Thus, it is logical to think that this is the shared variance that is being suppressed. Ironically, the present study was designed to measure the role of lexical access in the relation of rapid serial naming with reading ability, and this finding seems to suggest that the construct of lexical access is not part of these relations in kindergarten and first grade.

For the second hallmark of suppression, there is some aspect of the independent variable that is allowed to shine through when the suppressive variable is controlled for, resulting in stronger relations between the independent variable and the outcome. In the dancing example, the removal of writing variance allows for dancing ability to be more accurately measured, thus increasing the relations with the outcome. This leads to the question of what aspect of the serial naming task remains once isolated naming is controlled for; the aspect that contains the underlying relation of rapid naming with reading ability. This must be a construct or skill required in serial naming, but not in isolated naming (just as dancing ability is required of the written dancing test, but not of the writing test).

Though it is possible that several constructs fit this description, one possibility was previously discussed in the multiple constructs theories, such as the model suggested by Bowers and Wolf (1993). Like reading, the rapid serial naming task requires the integration of several constructs. As not all of these skills are required in isolated naming, it could be this integration that is shared between rapid naming and reading that is allowed to be more fully expressed with the variance in lexical access or letter naming accounted for.

Two other candidates for the skills that are not necessary in isolated naming but are aspects of the serial task that are required of reading are eye-movements and the ability to obtain information outside of the direct focal point. For the first construct, eye-movements are required in both reading and the rapid naming task. Specifically, the eyes have to follow the same motions that they would in reading. Participants must move their eyes from left to right, jump to the next line, and repeat the process. Therefore, it seems logical that children who are better readers would be faster at the task that requires this same skill. While eye-movement control has been implicated as being potentially important in the relations of rapid naming speed and reading ability (i.e., Jones, Obregon, Kelly, & Pranigan, 2008), examinations of the role of eye-movements in both tasks has yet to be explicitly tested in the reading literature. However, in the eye-tracking literature, a study by Hawelka and Wimmer (2005) found a strong relation between eye-movements (measured as the number of saccades per item in a word-reading task) and rapid serial naming speed.

Another reading-like aspect of this task is that there are several letters visible at once. This could possibly allow participants to pre-process the letters not directly in the fovea, or center of their field of vision. Because the processing of parafoveal information is important in the reading process, it seems logical that better readers will be better at processing the information outside their fovea. This assertion has also been made by Staller and Sekuler in a 1975 paper exploring the naming speeds of a traditional serial task and one with mirror-image letters. They found that good and poor readers differed on the standard but not mirror-image versions, and suggested that the enhanced speed of the standard task could be due to the different amount of information able to be processed in preview by good readers. This advantage would not be available for the less familiar mirror-image letters as they would require more cognitive processing to correctly identify. In fact, a recent study by Jones et al. (2008) found that when visually or phonologically confusable letters followed a target letter in the rapid naming task, fixation times on the target letter were slowed, thus indicating that readers are able to process letters outside of their focal point in the rapid naming task.

Limitations and future directions

One alternative explanation for the reported results is that the formats of the isolated and serial naming tasks were different. First, the specific letters and digits used in the isolated task were different from those used in the serial task. Also, the set size was larger in the isolated task; there were eight different letters in the isolated task and only six in the serial task. Finally, the isolated task was presented on a computer, while the serial task was presented on a card laid on the table or floor in front of the participant. Any of these differences could have had an impact on the naming speeds measured in this study, and thus the subsequent SEMs. As such, follow up studies should be conducted wherein these differences are minimized. Although it is not anticipated that these differences would have an impact on the results presented in the present study, they should be ruled out through additional study. In addition, only accuracy-based reading outcomes were used in the present study. As both naming tasks have a speeded component, the suppressive results may have been different were fluency-based reading outcome measures used, and this is an interesting direction for future study. Future studies could explicitly examine the constructs implicated by the suppressive effect as being likely candidates for the increase in reading variance explained by serial naming; eye-movements and parafoveal processing. Either of these candidates could account for the suppressive effect observed in the present study, and should be examined in future studies.

Conclusions

In sum, the results of the present study are inconsistent with the theories of automaticity and global processing speed, and make a strong case that lexical access does not account for an

important portion of the variance relating serial naming with reading ability. Rather, these results provide empirical support for arguments that serial naming is more strongly associated with reading than isolated naming because it is a closer approximation of the reading process. This suggests that the unique contribution of rapid serial naming to reading ability is unrelated to the cognitive processes required in naming letters, and is instead related to the demands associated with the format in which these letters are presented.

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Fig. 1.
Scatterplot of isolated and serial naming; tasks are measured in letters per second

Fig. 2. Isolated and serial naming as predictors of reading in kindergarten. $\chi^2(17) = 30.62, p = .02$, RMSEA = .06, CFI = .99, GFI = .97. *Word ID* word identification, *Word AN* word analysis. * $p < .05$, ** $p < .01$

Fig. 3. Isolated and serial naming as predictors of reading in first grade. $\chi^2(17) = 24.5$, $p = .10$, RMSEA = .04, CFI = .99, GFI = .98. *Word ID* word identification, *Word AN* word analysis. * $p < .05$, ** $p < .01$

Fig. 4.

Isolated and serial naming as predictors of reading in second grade. $\chi^2(17) = 29.59, p = .03$, RMSEA = .06, CFI = .99, GFI = .97. *Word ID* word identification, *Word AN* word analysis.

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

Fig. 5.

Five phonological abilities as predictors of reading in kindergarten. Correlations between latent factors were included in this analysis. They are listed in the table for clarity. $\chi^2(89) = 120.34, p = .02, RMSEA = .04, CFI = .99, GFI = .94$. *Word ID* word identification, *Word AN* word analysis. * $p < .05$, ** $p < .01$

Fig. 6.

Five phonological abilities as predictors of reading in first grade. Correlations between latent factors were included in this analysis. They are listed in the table for clarity. $\chi^2(89) = 173.95, p = .00, RMSEA = .06, CFI = .97, GFI = .92$. *Word ID* word identification, *Word AN* word analysis. * $p < .05$, ** $p < .01$

Fig. 7. Five phonological abilities as predictors of reading in second grade. Correlations between latent factors were included in this analysis, but are listed in the table for clarity. $\chi^2(89) = 197.89, p = .00$, RMSEA = .07, CFI = .96, GFI = .91. *Word ID* word identification, *Word AN* word analysis. * $p < .05$, ** $p < .01$

Correlations of isolated with serial naming, and significance tests for differences between the two naming variables' correlations with two reading outcomes ($n = 244$)

Table 1

Stimuli	Isolated/serial	Word identification		Word analysis	
		Isolated	Serial	Isolated	Serial
Kindergarten					
Letters	.49	.19	.50	.15	.37
Digits	.5	.08	.45	.06	.36
Both	.51	.19	.44	.13	.33
First grade					
Letters	.56	.32	.67	.25	.54
Digits	.62	.29	.6	.22	.45
Both	.57	.33	.65	.32	.51
Second grade					
Letters	.48	.42	.68	.37	.37
Digits	.55	.42	.6	.37	.43
Both	.5	.44	.66	.38	.51

Standardized beta weights predicting reading (and reading variance explained) from isolated and serial naming latent variables for three different models in each grade

Table 2

Model description	β (Isolated-reading)		β (Serial-reading)		R^2 (Reading)	
	K	1	2	K	1	2
Isolated only	.19	.36	.49	–	–	.04 .13 .24
Serial only	–	–	–	.51	.68	.71 .26 .47 .50
Both (Figs. 2, 3, and 4)	–.27	–.24	.05	.69	.85	.67 .30 .50 .50

Table 3

Standardized beta weights of isolated and serial naming with reading (and reading variance explained) after controlling for analysis, synthesis, and phonological memory in four different models for each grade

Model description	β (Isolated-reading)		β (Serial-reading)		R^2 (Reading)	
	K	1	K	1	K	1
No naming variables	–	–	–	–	.29	.58
Isolated only	.05	.01	.12	–	.29	.57
Serial only	–	–	.27	.38	.34	.62
Both (Figs. 5, 6, and 7)	–.28	–.25	.46	.55	.47	.65