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The Contribution of Graphophonological-Semantic Flexibility to Reading Comprehension in College Students: Implications for a Less Simple View of Reading

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Reading is complex and requires that individuals process many types of information concurrently. Contemporary perspectives on cognitive development focus on the ability to process cognitively complex stimuli, indicate cognitive development is domain-specific, and suggest cognitive development occurs across the lifespan. Yet little work has examined reading-specific cognitive developmental variation and its contribution to skilled reading. This study investigated the contribution of a measure of reading-specific cognitive development, graphophonological-semantic flexibility (the ability to process concurrently phonological and semantic information associated with print), to reading comprehension in college students. Graphophonological-semantic flexibility made a unique contribution to adults' reading comprehension over phonological and semantic processing assessed independently, even when general cognitive ability was controlled. Implications for the simple view of reading are discussed.

Over two decades ago, Royer (1983, p. 205) asserted that reading is "the natural interface between developmental and educational psychology." Naturally, research in the development of individuals' thinking has the capacity to inform understanding of skilled reading in both children and adults. Yet the fields of educational and developmental psychology remain largely independent (Sternberg,

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2000; Sternberg & Lyon, 2002). As reading is primarily a cognitive process, theories of cognitive development provide a logical point of intersection for application of developmental psychology to educational concerns. In fact, after the introduction of Piaget's work in the United States, several researchers demonstrated significant relations between general measures of cognitive development and reading skill (Althouse, 1985; Arlin, 1981; Briggs & Elkind, 1973; Canter, 1975; Cohen, Hyman, & Battistini, 1983; Elkind, Larson, & Van Doornick, 1965), but the precise nature of this relation was not determined.

COGNITIVE DEVELOPMENT AND FLEXIBILITY

Recent conceptualizations of cognitive development have focused in particular on individuals' capacity to handle cognitively complex tasks, or tasks that involve multiple features, and flexibly use these features while engaging in the tasks (e.g., Deák, 2003; Frye, Zelazo, & Burack, 1998; Jacques & Zelazo, 2005; Zelazo & Frye, 1998; also see Andrews & Halford, 2002, for a discussion of cognitive complexity across the life span). Classification tasks that require individuals to sort objects along multiple dimensions, either successively or simultaneously, are typically used to assess individuals' ability to consider flexibly and concurrently multiple features of stimuli (see recent work on the development of cognitive flexibility in children, Bialystok, 1999; Frye, Zelazo, & Palfai, 1995; and adults, Diamond & Kirkham, 2005). The multiple classification task, for example, is a general task that requires individuals to sort pictures of objects simultaneously along multiple dimensions (e.g., shape and color) and indicates the flexibility with which individuals can consider concurrently multiple features of stimuli (Inhelder & Piaget, 1964). This task has been successfully adapted to assess and train domain-specific flexibility with social stimuli (Bigler, 1995; Bigler & Liben, 1992), and is easily adapted for use in other domains, like reading (Cartwright, 2002, 2006).

Because readers must process, or mentally represent, many features of text at the same time, contemporary cognitive developmental perspectives have much to offer for better understanding skilled reading. Finally, it should be noted that reading-related mental representations may be automatic and below the level of conscious awareness (as is typical with skilled readers) or effortful and above the level of conscious awareness. In fact, in their review of work on representational development, Forguson and Gopnik (1988) asserted,

> We typically do not allege that those to whom we ascribe mental representations consciously experience the representations we attribute to them. Indeed, even we language-using adults typically do not experience our own mental representations as such; they are psychologically transparent, not noticed (or perhaps better, beneath notice). (p. 229)

FLEXIBILITY IN READING

There is wide agreement that reading requires individuals to handle concurrently many kinds of information (Adams, 1990; Beck & Carpenter, 1986; Clay, 2001). Perfetti (1985, 1992) and Ehri (1992, 1993), for example, both point to the importance of phonological, lexical, orthographic, and semantic representations in the reading process, arguing that skilled reading involves the processing of, and links between, these features of print. Furthermore, less skilled readers frequently exhibit inflexibility in reading processes (Pressley, 2006). Clay (1985, p. 13) described the "rigid and inflexible viewpoint" of these readers, who focus on few features of print when engaged in reading tasks. Similarly, Gaskins and Gaskins (1997) reported that the struggling readers at Benchmark School often focus primarily on decoding processes, or phonological information, to the exclusion of semantic information and thus exhibit difficulties with comprehension.

Even the "simple view" of reading suggests skilled reading requires multiple processes. Gough and colleagues argued that the "complexities [of the reading process] can be divided into two parts" (Hoover & Gough, 1990, p. 128). Their simple view of reading holds that skilled reading comprehension is the product of decoding skill and (spoken) language comprehension ($R = D \times C$; Gough, Hoover, & Peterson, 1996; Gough & Tunmer, 1986; Gough & Walsh, 1991; Hoover & Gough, 1990), which correspond roughly to the phonological and semantic aspects of print, respectively. Although recent cognitive developmental work suggests the flexibility with which individuals can consider simultaneously these kinds of information should also contribute to skilled reading, this kind of flexibility is not captured in the simple view (Pressley et al., in press).

In support of this notion, some researchers have argued that phonological and semantic processes operate concurrently and interact in skilled readers (Adams, 1990; Nation & Snowling, 1998; Plaut, McClelland, Seidenberg, & Patterson, 1996). In fact, these processes interact in both children and adults, even when they occur automatically (Crain-Thoreson, 1996; Luo, Johnson, & Gallo, 1998; McCutchen & Crain-Thoreson, 1994; McCutchen, Dibble, & Blount, 1994; Van Orden, 1987). The simple view would seem to suggest that individuals with demonstrated proficiency in phonological and semantic processing would also demonstrate skilled reading comprehension. However, if a reader cannot flexibly engage in phonological and semantic processes simultaneously, he or she is effectively limited to one or the other of these processes at any given time, despite demonstrated proficiency when these processes are assessed independently.

Consistent with these observations, recent work showed that the flexibility with which children can process simultaneously phonological and semantic features of printed words, *graphophonological–semantic flexibility* (GSF), made a unique contribution to reading comprehension, over the contributions of phonological and semantic processing assessed independently (Cartwright, 2002). That is, flexibility contributed additional variance to comprehension, over the variables traditionally associated with the simple view of reading. This work adapted the classic multiple classification task to produce a reading-specific task that required children to sort printed words along phonological and semantic dimensions simultaneously, providing an index of the ability to consider concurrently two kinds of information that are processed while reading (Cartwright, 2002). Classification along a single dimension, either phonological or semantic, has been associated with skilled reading (Chabot, Petros, & McCord, 1983; Gattuso, Smith, & Treiman, 1991; Lovrich, Cheng, & Velting, 1996). However, Cartwright (2002) extended this work, finding that the concurrent classification of words on phonological and semantic dimensions made a unique contribution to children's reading comprehension beyond the contributions of phonological processing, semantic processing, and general flexibility. This finding held even when age was controlled. More important, an experimental intervention showed training in GSF produced significant improvements in children's reading comprehension, whereas training in general flexibility did not. These findings suggest cognitive flexibility plays an important role in skilled reading, but no work has examined this kind of flexibility in adults.

ADULT COGNITIVE DEVELOPMENT AND FLEXIBILITY IN READING

Although original theoretical accounts of cognitive development implied relative uniformity in adult cognitive processing (Piaget & Inhelder, 1966/1969), in later years Piaget (1972) recognized that variability within and between individuals' levels of cognitive development might be associated with individual, domain-specific experiences. These ideas paved the way for contemporary theories of cognitive development, which suggest that cognitive development occurs gradually (not necessarily in a stage-like fashion), throughout the life span, and varies with individual experience in a domain (Case, 1992; Case & Okamoto, 1996; Karmiloff-Smith, 1991), even in adults (Bidell & Fischer, 1992; Labouvie-Vief, 1990, 1992; Sinnott, 1998). According to Sinnott, for example, adults may exhibit varying levels of thinking, ranging from rudimentary, sensorimotor thinking (as in learning to drive a stick shift car) to more complex thinking in other domains with which they have more experience.

It stands to reason, then, that although most adults are experienced readers, adults' reading experiences vary, and thus adults should also vary on reading-specific measures of cognitive development, such as GSF. Further, these perspectives suggest that adults' experience with print should be related to their levels of GSF. Stanovich and colleagues have demonstrated that literacy experiences do, in fact, influence individuals' cognitive processes (Stanovich, Cunningham, & West, 1998; Stanovich, West, Cunningham, Cipielewski, & Siddiqui, 1996), and they developed measures such as the Magazine Recognition Test (MRT) to assess individuals' exposure to print (Stanovich & Cunningham, 1992; Stanovich & West, 1989). Consistent with this notion, time spent reading contributes significant variance to reading fluency (see Kuhn & Stahl, 2003, for a review). However, no research has assessed reading-specific cognitive flexibility in adults or the relation of reading experience to adults' reading-specific cognitive flexibility.

CURRENT HYPOTHESES

This study was designed to examine three hypotheses. First, consistent with prior work with children (Cartwright, 2002), it was expected that GSF would make a unique contribution to adults' reading comprehension over the contributions of phonological processing (decoding skill) and semantic processing (assessed with a standardized measure of verbal ability), even when controlling for general cognitive ability. Second, the study was designed to assess the relation of reading experience to adults' GSF, as recent perspectives in cognitive development suggest reading experience should produce reading-specific cognitive developmental variation. Finally, this study was designed to examine the predictions of the simple view of reading in light of new work on GSF. As noted previously, even if readers demonstrate proficiency on independent assessments of phonological and semantic processing (and obtain high scores on the simple view's product of decoding and linguistic comprehension, $D \times C$), these readers may be limited to one or the other of these processes at any given time if they cannot flexibly engage in both processes simultaneously. Therefore, it was expected that GSF would contribute significant, unique variance to reading comprehension over the product of decoding and language comprehension.

METHOD

Participants

Forty-eight undergraduate students (24 women and 24 men) who attended a small, private Northeastern liberal arts college participated in this study. The sample was homogeneous (97% European American), and participants ranged in age from 18 years, 2 months to 22 years, 3 months ($M = 19$ years, 5 months). Participants volunteered to be part of the study in response to an announcement distributed in psychology courses and received extra credit in those courses for participation.

Procedure

Participants were tested individually and completed three researcher-administered tasks in a counterbalanced order: the Woodcock Reading Mastery Tests-Revised (WRMT-R), the Kaufman Brief Intelligence Test (K-BIT), and the GSF task. Participants completed the self-administered MRT after they had completed the three researcher-administered tasks. Each of the tasks is described briefly below.

WRMT-R. Decoding skill was assessed with raw scores from the Word Attack subtest of the WRMT-R (Woodcock, 1987), which required participants to produce accurate pronunciations of nonwords. Because nonword reading measures of decoding are not highly associated with adults' comprehension (Gough et al., 1996), raw scores from the Word Identification subtest of the WRMT-R were collected as a second measure of adults' decoding skill. This task required participants to produce fluent readings of real words within 5 seconds. Reading comprehension was assessed with raw scores from the Passage Comprehension subtest of the WRMT-R; this subtest required participants to supply missing words for prose passages.

K-BIT. This test has two subscales, Verbal and Matrices, that yield standardized estimates of verbal and nonverbal intelligence, respectively. Standardized measures of verbal ability have been used to assess linguistic comprehension, or semantic processing, in prior research (see Gough & Tunmer, 1986). Therefore, the Verbal Subscale of the K-BIT (Kaufman & Kaufman, 1990) was used to assess semantic processing in this study. The Matrices subscale provided an index of participants' general matrix reasoning (in contrast to the reading-specific matrix reasoning required by the graphophonological-semantic multiple classification task). General matrix reasoning is also correlated with working memory (Colom, Flores-Mendoza, & Rebollo, 2003; Salthouse, 1993; Unsworth & Engle, 2005; Verguts & De Boeck, 2002). Thus, this measure was included to control for these kinds of domain-general cognitive abilities.

Graphophonological-semantic multiple classification task. Participants completed a graphophonological-semantic multiple classification task to assess GSF (i.e., they sorted printed words by initial phoneme and by meaning into a 2×2 matrix). This task was originally developed for use with elementary children (Cartwright, 2002) and was based on a classic cognitive developmental task that assessed cognitive flexibility (the multiple classification task; Inhelder & Piaget, 1964), thus providing face validity. Five sets of 12 cards, each with one printed word, were used for this task (see Appendix). The researcher demonstrated a correct sort with one set of cards and provided a verbal explanation for the sort, following Cartwright (2002). See Figure 1 for an example of a correct

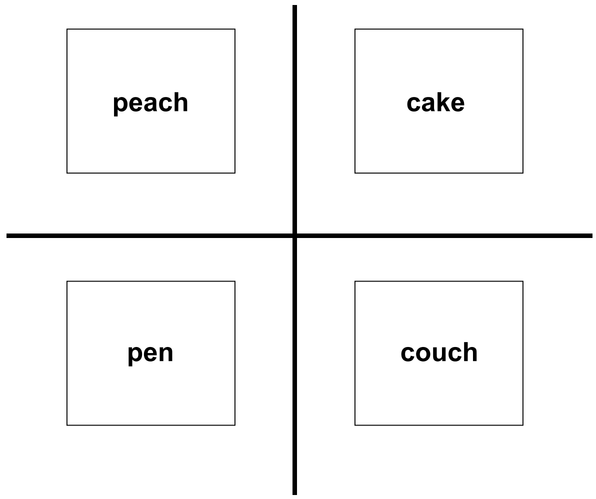

FIGURE 1 Example of a correct sort on the graphophonological-semantic multiple classification task. Cards are sorted semantically (foods and nonfoods) and by initial phoneme.

sort. The researcher told participants, "I have some cards for you to sort. You can sort these two ways at the same time, by how they sound and what they mean." After sorting the cards, the researcher described the arrangement of the sort by saying, "See, these are all foods, these are all nonfoods, these are all /k/ words, and these are all /p/ words" (while pointing to the appropriate columns and rows in the 2×2 matrix; diagonal sorts were not permitted). The remaining four card sets were presented in a random order and participants were told, "Sort these two ways at the same time just like I showed you, by how they sound and what they mean. I am going to time you, just to see how long it takes." Participants sorted each card set by initial phoneme and word meaning, one set at a time, into a 2×2 matrix, and sorting time in seconds was recorded for each set of cards. If the participant sorted correctly, he or she was asked to provide a verbal justification for the sort. The researcher corrected incorrect sorts and then requested a verbal justification for the corrected sort from the participant.

As in prior work, GSF scores were based on both accuracy and speed of sorting (Cartwright, 2002; Cartwright, Isaac, & Dandy, 2006). GSF accuracy was calculated following prior work (Bigler, 1995; Bigler & Liben, 1992; Cartwright, 2002; Golbeck, 1983). For each card set, three points were awarded when both the sort and justification were correct. Two points were awarded when the sort was incorrect, but the participant provided a correct justification for the researcher-corrected sort. One point was awarded for a correct sort followed by an incorrect justification, and no points were awarded when both the sort and justification were incorrect. This scoring scheme is consistent with what is known about cognitive development, as individuals often demonstrate skills implicitly before they can access and explain them explicitly (Flavell, Miller, & Miller, 2002; Inhelder & Piaget, 1964; Karmiloff-Smith, 1991). In sum, participants' GSF sorting accuracy could range from 0 to 12 total points across the four card sets, with higher numbers indicating greater flexibility. Cartwright et al. (2006) examined this measure across the 44 children in the original study (Cartwright, 2002) and the 48 adults in the current sample and found high reliability for sorting accuracy across the four card sets (Cronbach's $\alpha = .85$).

Because the phonological distinctions and semantic categorizations were relatively simple, it was expected that adult participants would perform close to ceiling on sorting accuracy. Thus, following prior work with children (Cartwright, 2002), sorting speed in seconds was also recorded for each card set. This is consistent with other work investigating adults' cognitive flexibility, which showed sorting time was a sensitive measure of variation in flexibility for adults (Diamond & Kirkham, 2005). Cartwright et al. (2006) reported that sorting speeds were highly reliable across the four card sets (Cronbach's $\alpha = .87$).

Following prior work (Cartwright, 2002; Cartwright et al., 2006), a comprehensive GSF score was calculated for each participant, based on both speed and accuracy of sorting, by dividing participants' sorting accuracy by their mean sorting speed. Because participants with the greatest degree of flexibility achieved the highest accuracy and the lowest (fastest) sorting speeds, the highest GSF scores (i.e., high accuracy/low speed) indicated the greatest degree of GSF. Furthermore, participants who were the least flexible demonstrated lower accuracy and higher (slower) speed, achieving the lowest GSF scores (i.e., low accuracy/high speed). These GSF ratios ranged from .08 to .72 for this study; and they were multiplied by 100 to facilitate practical interpretation, yielding scores that ranged from 8.09 to 71.52 (see Table 1).

MRT. Finally, participants completed the MRT to assess exposure to print. This questionnaire was comprised of 40 actual magazine titles (Stanovich & Cunningham, 1992) and 40 foils (Stanovich & West, 1989). Participants checked the titles they recognized as authentic magazine titles. The number of incorrectly identified titles (i.e., foils that were checked) was subtracted from the number of correctly identified titles to yield a total score for each participant that could range from −40 to +40 titles correct. The utility of this measure of print exposure has been questioned in prior work because most individuals have access to magazines in everyday experience such as in doctors' offices (Stanovich & West, 1989); however, subsequent work has demonstrated the validity of the MRT as a measure of reading frequency (Stanovich & Cunningham, 1992; Stanovich et al., 1998). Even if the MRT is a less sensitive measure of print exposure than

TABLE 1
Descriptive Statistics for K-BIT, WRMT-R, GSF, and MRT Scores

Measure	*M*	*SD*	*Minimum*	*Maximum*
K-BIT Verbal	102.77	9.01	78	127
K-BIT Matrices	101.02	11.03	74	132
WRMT-R				
Word Attack	33.46	5.45	19	41
Word Identification	92.75	4.63	79	104
Passage Comprehension	54.27	6.08	41	67
GSF	46.90	15.98	8.09	71.52
MRT	13.79	4.99	1	22

Note. $N = 48$; K-BIT = Kaufman Brief Intelligence Test; WRMT-R = Woodcock Reading Mastery Tests-Revised; GSF = graphophonological-semantic flexibility score; MRT = Magazine Recognition Test. K-BIT Verbal and Matrices scores are standard scores with $M = 100$ and $SD = 15$. WRMT-R Word Attack, Word Identification, and Passage Comprehension scores could range from 0 to 45, 0 to 106, and 0 to 68 correct, respectively. GSF scores are the GSF accuracy divided by mean sorting speed and multiplied by 100. Participants were allowed as much time as necessary to complete each sort. Thus, no ceiling exists on the range for these scores. However, minimum and maximum scores for participants in this study are reported. MRT scores could range from −40 to +40 titles correctly recognized.

other measures (such as author or title recognition), this feature actually provides a more stringent test of the current hypothesis, as uniformity in familiarity with magazine titles across participants would bias against finding a significant relation of print exposure to reading-specific flexibility in this sample.

RESULTS

Descriptive Statistics

Means, standard deviations, minimum values, and maximum values for participants' K-BIT Verbal and Matrices scores, WRMT-R Word Attack, Word Identification, and Passage Comprehension scores, GSF scores, and MRT scores are reported in Table 1.

To determine whether participants' scores differed by sex or task order, 2 (Sex) × 6 (Task Order) analyses of variance were conducted with K-BIT Verbal and Matrices scores, WRMT-R Word Attack, Word Identification, and Passage Comprehension Scores, GSF scores, and MRT scores as dependent measures.

TABLE 2
Intercorrelations Between Participants' K-BIT, WRMT-R, GSF, and MRT Scores

	1	*2*	*3*	*4*	*5*	*6*	*7*
K-BIT Verbal	—	.20	.24	.54**	.63**	.53**	.50**
K-BIT Matrices		—	.14	.31*	.35*	.16	−.10
WRMT-R Word Attack			—	.68**	.16	.13	.06
WRMT-R Word Identification				—	.57**	.47**	.25
WRMT-R Passage Comprehension					—	.58**	.36*
GSF						—	.31*
MRT							—

Note. $N = 48$; K-BIT = Kaufman Brief Intelligence Test; WRMT-R = Woodcock Reading Mastery Tests-Revised; GSF = graphophonological-semantic flexibility score; MRT = Magazine Recognition Test.

$^{*}p < .05$. $^{**}p < .01$.

No significant effects of task order were found. However, significant main effects of sex were found for K-BIT Verbal scores, $F(1, 36) = 7.42$, $p < .05$, and GSF scores, $F(1, 36) = 6.29$, $p < .05$, indicating that women ($M = 105.75$, $SD = 7.71$, and $M = 52.58$, $SD = 12.02$, respectively) scored higher than men ($M = 99.79$, $SD = 9.39$, and $M = 41.21$, $SD = 17.61$, respectively) on these tasks. The correlations between participants' scores on all measures are reported in Table 2.

Hypothesis 1: The Contribution of GSF to Adults' Comprehension

To determine whether GSF made a unique contribution to adults' reading comprehension over the contributions of phonological and semantic processing assessed independently, two hierarchical linear regression analyses were conducted, one for each measure of decoding: WRMT-R Word Attack and WRMT-R Word Identification. In addition, to control for general cognitive ability, participants' K-BIT Matrices scores were included in these analyses.

Each regression was conducted in two steps, with WRMT-R Passage Comprehension scores as the criterion measure. Participants' K-BIT Verbal scores (semantic processing), decoding scores, and K-BIT Matrices scores were entered on Step 1, and GSF scores were entered on Step 2. Regardless of the measure of decoding used, GSF accounted for significant, unique variance in participants' reading comprehension over and above semantic processing, decoding, and general cognitive ability, as predicted (see Table 3). These results remained, even when reading experience (MRT scores) and sex were controlled.

TABLE 3
Summary of Hierarchical Regression Analyses Predicting Reading Comprehension While Controlling for Semantic Processing, Decoding,[a] and General Cognitive Ability

Variable Entered	*B*	*SE B*	β
Analysis 1, using Word Attack to assess decoding skill			
Step 1			
K-BIT Standard Verbal Scores	0.40	0.08	.59**
WRMT-R Word Attack Scores	−0.01	0.13	−.01
K-BIT Matrices (general cognitive ability)	0.13	0.06	.23
Step 2			
GSF Scores	0.12	0.05	.32*
Analysis 2, using Word Identification to assess decoding skill			
Step 1			
K-BIT Standard Verbal Scores	0.31	0.09	.46**
WRMT-R Word Identification Scores	0.35	0.17	.27*
K-BIT Matrices (general cognitive ability)	0.10	0.06	.17
Step 2			
GSF Scores	0.11	0.05	.28*

Note. $N = 48$; K-BIT = Kaufman Brief Intelligence Test; WRMT-R = Woodcock Reading Mastery Tests-Revised; GSF = graphophonological-semantic flexibility score. Analysis 1: $R^2 = .45$ for Step 1; $\Delta R^2 = .08$ for Step 2 ($ps < .001$); Analysis 2: $R^2 = .50$ for Step 1; $\Delta R^2 = .05$ for Step 2 ($ps < .001$).

[a] Word Attack in Analysis 1 and Word Identification in Analysis 2

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

Hypothesis 2: The Relation of Reading Experience to Adults' GSF

As predicted, a significant correlation emerged between participants' reading experience, assessed with MRT scores, and GSF scores, $r(48) = .31$, $p < .05$. To determine whether reading experience made a unique contribution to participants' GSF over the contribution of general matrix reasoning, a hierarchical regression analysis was performed with GSF scores as the criterion. Participants' K-BIT Matrices scores were entered on Step 1 to control for the contribution of general matrix reasoning, and MRT scores were entered on Step 2. Reading experience accounted for a significant, unique amount of variance in GSF, over general matrix reasoning (see Table 4).

Hypothesis 3: Flexibility and the Simple View

Hierarchical regression analyses were conducted to test predictions of the simple view of reading and to determine whether GSF would account for additional variance in reading comprehension over that accounted for by the simple view

TABLE 4
Summary of Hierarchical Regression Analysis Predicting GSF While Controlling for General Matrix Reasoning ($N = 48$)

Variable Entered	*B*	*SE B*	β
Step 1			
K-BIT Matrices	0.24	0.21	.16
Step 2			
MRT Scores	1.06	0.45	.33*

Note. $N = 48$; K-BIT = Kaufman Brief Intelligence Test; GSF = graphophonological-semantic flexibility score; MRT = Magazine Recognition Test. $R^2 = .03$ for Step 1; $\Delta R^2 = .10$ for Step 2 ($p = ns$ for Step 1, $p < .05$ for Step 2).
$^*p < .05$.

model. These analyses were conducted for each of the measures of decoding, WRMT-R Word Attack and WRMT-R Word Identification, and each analysis was done in three steps with WRMT-R Passage Comprehension scores as the criterion variable. Recall that the simple view holds that the product of decoding and comprehension (D × C) will account for more variance in reading comprehension than the linear contribution of these scores (Gough et al., 1996; Gough & Tunmer, 1986; Gough & Walsh, 1991; Hoover & Gough, 1990). Thus, participants' decoding scores and language comprehension scores (K-BIT Verbal scores) were entered on Step 1 of each analysis, D × C was entered on Step 2 of each analysis, and GSF scores were entered on Step 3 of each analysis. In both analyses, D × C did not account for significant variance in comprehension over D + C (as would be predicted by the simple view). Further, regardless of the measure of decoding (WRMT-R Word Attack or WRMT-R Word Identification), GSF accounted for significant unique variance in comprehension over the simple view model (see Table 5). Finally, when GSF scores were entered on Step 2 and D × C was entered on Step 3 in these analyses, D × C did not account for significant variance over that accounted for by D + C and GSF scores.

DISCUSSION

This study was designed to examine adults' reading skill in light of recent advances in the field of cognitive development. Specifically, I hypothesized that GSF would contribute significant variance to adults' reading comprehension, over the independent contributions of phonological processing, semantic pro-

TABLE 5
Summary of Hierarchical Regression Analyses Predicting Reading Comprehension to Test the Predictions of the Simple View, Controlling for Semantic Processing, Decoding,[a] and D × C

Variables Entered	*B*	*SE B*	*β*
Analysis 1, using Word Attack to assess decoding skill			
Step 1			
K-BIT Standard Verbal Scores	0.43	0.08	.63**
WRMT-R Word Attack Scores	0.01	0.13	.01
Step 2			
D × C	0.01	0.01	1.20
Step 3			
GSF Scores	0.15	0.05	.38**
Analysis 2, using Word Identification to assess decoding skill			
Step 1			
K-BIT Standard Verbal Scores	0.31	0.09	.46**
WRMT-R Word Identification Scores	0.41	0.17	.31*
Step 2			
D × C	0.01	0.01	1.16
Step 3			
GSF Scores	0.12	0.05	.35*

Note. $N = 48$. K-BIT = Kaufman Brief Intelligence Test; WRMT-R = Woodcock Reading Mastery Tests-Revised; GSF = graphophonological-semantic flexibility score. Analysis 1: $R^2 = .40$ for Step 1; $\Delta R^2 = .01$ for Step 2; $\Delta R^2 = .10$ for Step 3 ($ps < .001$); Analysis 2: $R^2 = .47$ for Step 1; $\Delta R^2 = .00$ for Step 2; $\Delta R^2 = .07$ for Step 3 ($ps < .001$).

[a] Word Attack in Analysis 1 and Word Identification in Analysis 2.

$^*p < .05$. $^{**}p < .01$.

cessing, and general cognitive ability. This hypothesis was supported with two different measures of adults' phonological processing (i.e., WRMT-R Word Attack and Word Identification). As predicted, GSF contributed significant, unique variance to adults' reading comprehension over the contributions of semantic processing and phonological processing alone, even when general matrix reasoning was controlled. These findings are consistent with recent work with elementary-age children (Cartwright, 2002) and are also consistent with recent theory and research in cognitive development, as the contribution of cognitive flexibility to reading comprehension appears to be domain-specific and not mediated by general cognitive ability or participants' levels of general verbal ability.

Recent perspectives in cognitive development also suggested domain-specific experience would be related to cognitive advances in a particular domain. Therefore, this study assessed the relation of reading experience to GSF, finding that reading experience was significantly related to reading-specific flexibility even when general matrix reasoning was controlled.

Finally, this study was designed to test the predictions of the simple view of reading in light of contemporary cognitive developmental perspectives. The simple view suggests reading comprehension is the product of decoding and linguistic comprehension. Thus, according to this view, individuals high on both of these skills should also be high on reading comprehension. Contemporary cognitive developmental theory, however, suggests a third cognitive skill may impact individuals' reading comprehension: individuals' flexibility in handling concurrently multiple features of print. Consistent with this perspective, GSF contributed significant unique variance to adults' reading comprehension over the independent contributions of decoding and linguistic comprehension and over the product of these variables ($D \times C$). These findings held, regardless of the measure of decoding used in the analyses: nonword reading or word identification.

Implications

This study, along with Cartwright (2002), demonstrated that skilled reading requires more than just decoding skill and linguistic comprehension as suggested by the simple view of reading (Gough et al., 1996; Gough & Tunmer, 1986; Gough & Walsh, 1991; Hoover & Gough, 1990). Skilled reading comprehension in children and adults also involves GSF, a cognitive function over and above the abilities traditionally associated with skilled reading and independent of general cognitive ability and verbal ability. Individuals who lack flexibility, for example, may be skilled at both decoding and linguistic comprehension when these abilities are assessed in isolation. The simple view would predict that such individuals would also be skilled at reading comprehension (because $D \times C$ would be high). However, if these readers cannot consider flexibly and simultaneously phonological and semantic information while reading, they may effectively be limited to either decoding or linguistic comprehension (despite demonstrated proficiency in each skill assessed independently), thus limiting reading comprehension. Furthermore, the unique contribution of reading-specific flexibility has been demonstrated for skilled readers (in this research) as well as for individuals who are learning to read (Cartwright, 2002). Hence, GSF appears to be important to reading comprehension at varying levels of reading proficiency.

One contribution that GSF may make to proficient reading is in reading fluency. As skilled reading develops, Chall (1996) argued that fluency emerges when readers "unglue" from print and can thus turn attention from decoding to language comprehension processes. Although some fluency theorists argue that automaticity of decoding occurs prior to prosody and the connection to spoken language (Dowhower, 1991; Kuhn & Stahl, 2003; Stanovich, 1996), implying a sequential developmental progression in which decoding processes dominate reading behavior initially after which linguistic comprehension is the dominant process, other work shows that these processes occur concurrently during skilled reading, even when they are automatic (Crain-Thoreson, 1996; Luo et al., 1998; McCutchen & Crain-Thoreson, 1994; McCutchen et al., 1994; Van Orden, 1987). These perspectives suggest fluent reading should occur when an individual can successfully (and flexibly) coordinate the processes necessary for skilled reading, including at least phonological and semantic processes. Fluidity in an oral reading of text should be enhanced when a reader can process flexibly and concurrently the various representations associated with text. That is, readers may have difficulty producing a fluent reading of text if representational inflexibility prevents the fluid, concurrent operation of phonological and semantic processes. Consistent with this view, these data indicate a significant, positive correlation between GSF and word reading fluency (assessed with the WRMT-R Word Identification subtest, which required fluent readings of individual words within 5 seconds), $r(48) = .47$, $p < .01$. The contribution of GSF to fluency is speculative and requires empirical validation. If this speculation is confirmed, GSF may offer insight to aid in the integration of the automaticity and prosody perspectives on fluency (see Kuhn & Stahl, 2003, for a discussion of these perspectives).

Limitations and Future Work

Although this study is correlational and causal conclusions should not be drawn from these data, correlational research provides the basis necessary for designing experimental tests of hypotheses and revising extant theories. Underwood (1975, p. 128) argued that correlational research is the "crucible for theory construction;" and Pressley (2002) recently extended this argument to the field of literacy research specifically, suggesting that correlational work is valuable and necessary to building a complete understanding of the reading process. Certainly, more research is needed to ascertain the precise contribution of GSF to reading processes with additional and more heterogeneous samples of participants. However, this study makes an important contribution to the research literature in that it extends prior work with elementary school age children (Cartwright, 2002) to a young adult sample and establishes the unique contribution of reading-specific cognitive developmental variation to adults' reading comprehension, over several variables that could mediate the relation.

More broadly, this work adds to the existing empirical foundation for the design of future quasi-experimental and experimental work to assess the causal relation of GSF to skilled reading and to determine the efficacy of reading-specific flexibility interventions for improving flexibility and reading skill. Although experimental work has demonstrated facilitative effects of GSF training for a limited sample of elementary students (Cartwright, 2002), this work needs to be replicated and extended to other samples such as struggling readers, English language learners, and adult education students.

Furthermore, future work needs to address the development of reading-specific flexibility, with an eye for determining the origins of such flexibility, as well as the precise contributions of reading-specific flexibility to the reading process across the life span. These data suggest reading experience contributes to flexibility, but the MRT is not without its limitations. Although statistically significant, from a practical standpoint the amount of variance in GSF accounted for by MRT scores over general cognitive ability was relatively small. This could be due to the potential insensitivity of the MRT to variation in reading experience or to fatigue, as participants completed the MRT after the researcher-administered measures. More work is clearly necessary to examine the role of reading experience in the development of reading-specific flexibility. In addition, because only one measure of reading comprehension was used in this study (the cloze passage format, WRMT Passage Comprehension subtest), future work on the role of GSF in skilled reading should use more diverse measures of comprehension.

Finally, this work is limited in that it examined flexibility in processing only two features of print: phonological and semantic. As reading is such a complex enterprise, there are many potential avenues for application of contemporary cognitive developmental ideas to the reading process. For example, future investigations may focus on flexibility in the use of syntactic or orthographic representations or in the implementation of multiple reading comprehension strategies. A more comprehensive view of reading requires that we understand how individuals successfully coordinate the many processes required for skilled reading (Pressley et al., in press), and such a view is necessary for us to move beyond the relatively simple view of reading favored in the current national climate (Allington, 2002; Pressley, Duke, & Boling, 2004).

Horowitz (2000) argued that complete conceptualizations of human development must forge connections between multiple bodies of literature. However, the insular nature of fields of study often prevents such cross-fertilization, as suggested by Sternberg (2000; Sternberg & Lyon, 2002) with regard to developmental and educational research. This study is an attempt to create such a bridge by employing cognitive developmental theory to further explicate an important issue in educational psychology: the nature of the process of skilled reading and the potential for improving reading instructional practice.

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APPENDIX

Word Stimuli Used for the Graphophonological–Semantic Multiple Classification Task

Card Set	*Words Classified by Initial Phoneme and Meaning*			
Training Set	*Foods*		*Nonfoods*	
	Cake Corn Cream	Peach Peas Plum	Car Clip Couch	Paint Pen Plug
Test Set 1	*Body Parts*		*Objects*	
	Cheek Chest Chin	Hair Hand Head	Chair Chain Chalk	Harp Hook House
Test Set 2	*Foods*		*Clothing*	
	Banana Beans Bread	Salad Spinach Soup	Belt Bonnet Boot	Skirt Sock Sweater
Test Set 3	*Vehicles*		*Animals*	
	Bike Boat Bus	Tractor Train Truck	Baboon Bear Bird	Tiger Toad Turkey
Test Set 4	*Animals*		*People*	
	Deer Dog Donkey	Panda Pig Puppy	Dancer Dentist Doctor	Pilot Pirate President

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