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Children Develop Initial Orthographic Knowledge During Storybook Reading

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We examined whether young children acquire orthographic knowledge during structured adult-led storybook reading even though minimal viewing time is devoted to print. Sixty-two kindergarten children were read 12 storybook "chapters" while their eye movements were tracked. Results indicated that the children quickly acquired initial mental graphemic representations of target nonwords. This learning occurred even though they focused on the target nonwords approximately one fourth of the total time while viewing the pages. Their ability to acquire the initial orthographic representations of the target nonwords and their viewing time was affected by the linguistic statistical regularities of the words. The results provide evidence of orthographic learning during structured storybook reading and for the use of implicit linguistic statistical regularities for learning new orthographic word forms in the early stages of reading development.

Experts have suggested that adult-led storybook reading enhances young children's oral language, emergent literacy, and literacy skills (e.g., Bus, van IJzendoorn, & Pellegrini, 1995; Scarborough & Dobrich, 1994). However, based on young children's minimal viewing time devoted to the written words on a page, researchers also have suggested that storybook reading is not conducive to the development of knowledge for orthographic patterns and/or specific orthographic word forms (e.g., Evans, Williamson, & Pursoo, 2008; Justice, Pullen, & Pence, 2008). However, across a series of studies, Apel and colleagues have documented young children's ability to quickly acquire initial mental graphemic representations (MGRs), that is,

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the specific, stored mental orthographic representations of written words, with relatively few exposures to novel written words within storybook reading contexts (e.g., Apel, 2010; Apel, Thomas-Tate, Wilson-Fowler, & Brimo, 2011; Apel, Wolter, & Masterson, 2006; Wolter & Apel, 2010). The present investigation addressed a gap in the literature by examining children's eye gaze during an experimental, structured storybook reading task designed to assess children's initial acquisition of MGRs.

ACQUISITION OF INITIAL MENTAL GRAPHEMIC REPRESENTATIONS

In an effort to document pre- and beginning readers' acquisition of initial MGRs, Apel and colleagues have conducted a series of studies examining young children's implicit initial MGR learning (Apel, 2010; Apel et al., 2011; Apel et al., 2006; Wolter & Apel, 2010). In these studies, preschool or kindergarten-age children were exposed to novel spoken and written nonwords during an adult-led storybook reading context. In each study, the children were read 12 short stories, each containing a novel nonword that was read four times and appeared four times in print. These nonwords varied in their phonotactic (i.e., the frequency with which the phonemes and biphones in the spoken form of the word occur) and orthotactic (i.e., frequency with which the graphemes and bigrams in the written word occur) probabilities. After reading each story, the children spelled the target nonword and then identified it from among three to four choices: the target nonword, two foils, and a real word.

Across these investigations, children with typical language skills demonstrated initial MGR acquisition; that is, most children spelled and/or identified target nonwords well above chance level (e.g., Apel, 2010; Apel et al., 2006). The children's ability to quickly develop initial MGR information was related to or explained unique variance on measures of reading and/or spelling above other known contributors (e.g., phonemic awareness, vocabulary). Further, the children's ability to spell the target words correctly was affected by the nonwords' linguistic statistical regularities; nonwords with high orthotactic probability were spelled accurately more often than words with low orthotactic probability. Kindergarten children with language impairment or from low-income homes, both groups considered to be at risk for literacy difficulties, also demonstrated some initial MGR acquisition but to a lesser extent than children not considered to be at risk for literacy difficulties (Apel et al., 2011; Wolter & Apel, 2010). However, these at-risk groups' MGR acquisition abilities were related to their reading and/or spelling skills, and the statistical regularities of the words affected their MGR learning.

The finding that young children in the early stages of literacy learning acquire initial MGRs after minimal exposure and no overt attempts at decoding suggests that MGRs can be acquired in less direct ways than through active decoding attempts (e.g., Share, 1995) and that the MGR acquisition is aided by children's tacit knowledge of orthographic statistical regularities. Of interest, this implicit knowledge likely is developed through exposure to print, given that children are not provided instruction in orthographic probabilities. However, researchers investigating the effects of adult-led storybook reading on children's literacy development have suggested that there are minimal opportunities to acquire specific orthographic information during shared storybook reading.

EYE MOVEMENTS DURING STORYBOOK READING

Decades ago, researchers suggested that adult-led storybook reading affected young children's developing ability to comprehend text more than their knowledge of print (e.g., Yaden, Smolkin, & Conlon, 1989). In more recent years, a number of investigators have used eye-tracking measures to determine the amount of time children devote to looking at print during storybook reading and whether their viewing time relates to their literacy abilities (e.g., Evans, Saint-Aubin, & Landry, 2009; Evans et al., 2008; Justice & Lankford, 2002; Justice et al., 2008; Roy-Charland, Saint-Aubin, & Evans, 2007). Generally, these investigators have found that young children devote a short amount of time focused on print during storybook reading. For example, Justice et al. (2008) found that their preschool children ($M = 54$ months) spent minimal time looking at print when read stories via a computerized storybook; 6% of their fixations were on print and 4% of the total viewing time was on print. As part of their cross-sectional study of elementary school age, Roy-Charland et al. (2007) reported similar findings for six kindergarten children ($M = 65$ months) whose parents read them stories; 5% and 9% of eye gaze was devoted to print for difficult (above grade level) and easy texts (about grade level), respectively. Evans et al. (2009) reported that their kindergarten children (ages ranged 59–71 months) spent 14% of their gaze time focused on a target word. The findings regarding the relation between eye gaze and literacy skills have been equivocal. Evans et al. (2009) reported that alphabetic knowledge predicted the length of children's viewing time of target words. Justice et al. (2008) found that their participants' eye gaze was not significantly related to any of their measures of literacy ability. Consequently, these researchers have suggested that young children likely learn minimal information about orthography in the context of adult-led storybook reading.

These conclusions do not square well with the results of investigations into young children's acquisition of initial MGRs in several ways. First, in the eye-tracking studies, no measures of orthographic knowledge development, such as MGR learning, were obtained. It may be that even with relatively small proportions of exposure, young children acquire some orthographic knowledge. Second, in the MGR learning studies, no eye movement data were collected. Thus, it is not clear whether age or the tasks employed, although similar to other storybook reading investigations (e.g., Justice et al., 2008), led to viewing times that were different than past reports.

A third potential difference between the two lines of research centers on words' linguistic properties. For example, it may be that viewing times during storybook reading are allocated differentially to printed words depending on the words' linguistic statistical regularities. Apel and colleagues demonstrated that preschool and kindergarten-age children acquire more initial MGRs for words with higher levels of orthographic statistical regularity than those with lower orthographic statistical regularity (e.g., Apel, 2010; Apel et al., 2006). There is no doubt that eye movement behavior in middle- to upper-elementary age children and adult readers shows influences of word-level linguistic properties of the text (e.g., Feng, Miller, Shu, & Zhang, 2009; Huestegge, Radach, Corbic & Huestegge, 2009; Inhoff, Connine, Eiter, Radach, & Heller, 2004; Radach, Inhoff, & Heller, 2004; Radach & Kennedy, 2004; Rayner, 1998; Staub, Grant, Clifton, & Rayner, 2009; White, 2008); however, to date, little is known about how these effects come into existence in developing readers (see Radach, Schmitten, Glover, & Huestegge, 2009, for a review) and whether young children's eye movement behavior during storybook reading is affected by or related to words' linguistic statistical regularities.

The purpose of this study was to combine the two lines of research to gain additional information about what young children might learn about orthography in storybook reading contexts. To do this, we investigated kindergarten children's ability to acquire initial MGRs within a structured adult-led storybook reading context while monitoring their eye movements. Specifically, we examined whether the children demonstrated acquisition of initial MGRs and whether that acquisition was influenced by the phonotactic and orthotactic probabilities of the target nonwords. We hypothesized, based on former studies (e.g., Apel, 2010), that our participants would demonstrate evidence of initial MGR acquisition and that the linguistic statistical regularities of the target nonwords would influence that development. Further, we sought to determine the proportion of the children's fixations and total viewing time that was devoted to the target nonwords and what the duration of those target fixations were. Given the literature on eye gaze during storybook reading (e.g., Evans et al., 2009; Justice et al., 2008), we anticipated that the percentage of children's eye gaze devoted to print would be markedly less than to other aspects of the page. Finally, because findings regarding the relation between eye gaze and language and literacy skills have been equivocal (i.e., Evans et al., 2009; Justice et al., 2008), we examined the association of children's concurrent literacy and literacy-related abilities, including their tacit knowledge of the statistical regularities of words, and eye gaze parameters.

METHOD

Participants

Kindergarten children ($N = 62$; M age = 5;9, $SD = 0;4$) were recruited from community centers and private schools located in a U.S. southeastern state. Participation was based on signed parental consent approved by the university Institutional Review Board. Of the 63 children, 32 (52%) were male, 35 (57%) were African American, 16 (26%) were Caucasian, 3 (5%) were Hispanic, and 8 (12%) were not reported or listed as "other ethnicity." The Hollingshead four-factor socioeconomic (SES) scale was computed for each child (Hollingshead, 1975). Sixty-eight percent of the children were considered to be upper middle to high SES, and 32% were considered to be lower to lower middle SES. All of the children's nonverbal cognitive skills were within typical limits ($M = 98.1$, $SD = 12.5$) as measured by the Matrices subtest of the Kaufman Brief Intelligence Test–2 (Kaufman & Kaufman, 2004).

Measures

Experimental MGR learning task. Twelve target nonwords were presented across 12 "chapters" of a story about an alien from outer space. The target nonwords were used in previous investigations of initial MGR learning (e.g., Apel, 2010). Three nonwords represented each of the following four categories: high phonotactic and high orthotactic probability, high phonotactic and low orthotactic probability, low phonotactic and high orthotactic probability, and low phonotactic and low orthotactic probability.[1]

[1]As reported in Apel et al. (2006), orthotactic probability was calculated by totaling the number of real words in the Hoosier Mental Lexicon, an online version of Webster's Pocket Dictionary (Pisoni, Nusbaum, Luce, & Slowiaczek,

Each chapter was presented on a computer monitor using the ExperimentBuilder software (SR-Research, http://www.eyelinkinfo.com). Within the chapter, each target nonword was presented once within a printed sentence on each of four slides (10 s per page; total chapter time was 40 s). All sentences were in black, 32 regular Arial font except for the target nonwords, which were in red, bold letters in 36 regular Arial font (see Evans et al., 2008, for similar approach to stimuli). An audio-recorded reading of each sentence was synchronized with the onset of each slide. In addition, the target nonword was represented with an illustration on each page (see example in the appendix). The illustration representing the target nonword was a nondescript drawing of the novel word previously determined to be unidentifiable by adults (Apel et al., 2006).

The target nonwords were counterbalanced across chapters to ensure that order did not affect results. To ensure understanding of the task, all children were read one practice chapter within the story that contained a novel nonword that was not one of the 12 targets. Within this practice chapter, the examiner highlighted the expectations of the task (e.g., to sit in the chair, look at the screen, follow directions) and made adjustments if the child did not understand the directions.

After the presentation of the each chapter, the story was paused and the children were instructed to perform two tasks: the *production task* and the *recognition task*. The production task was always presented first. For this task, a picture of the target nonword was presented on the computer screen while the audio recording prompted the children to spell the target nonword using a pencil on a blank sheet of paper by saying, "Write what this thing is called." For the recognition task, the audio recording prompted the children to point to the target nonword from a choice of four written words presented on the computer screen by saying, "Which one of these is what this thing is called?" The four words consisted of the target nonword (e.g., 'chan'), a foil that varied on one letter by changing the manner or voice of the sound (e.g., 'shan'), a foil that varied on two or more letters that were cognates (e.g., 'grak'), and a real word (e.g., 'the'). For both the production and recognition tasks, all items were scored as correct or incorrect. Past investigations (e.g., Apel, 2010) have reported adequate internal consistency reliability for the production task (α =.89) and recognition task (α = .82).

Receptive vocabulary. Receptive vocabulary was assessed with the Peabody Picture Vocabulary Test–IV (Dunn & Dunn, 2007). The children were required to point to one of four pictures that matched a word spoken by the examiner. Standard administration and scoring procedures were followed. The test has a split-half internal consistency of .93 to .95 and a test–retest reliability coefficient of .92.

Phonemic awareness. Phonemic awareness was assessed with the elision subtest of the Comprehension Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999). This task required the children to repeat an orally presented word and then repeat the word again after eliminating either a part of the word or a single sound. Test–retest reliability is reported to be .77.

Letter knowledge. Letter knowledge was assessed with the letter identification subtest of the Woodcock Reading Mastery Test–Revised (WRMT–R; Woodcock, 1998). The children were

1985), that contained the three digraph sequence in a target nonword and dividing that number by the total number of digraph sequences in the four-letter words in the Hoosier Mental Lexicon. The target nonword's orthotactic probability then was determined as the log of the product of probabilities of the three digraphs composing it.

required to name a letter presented in uppercase or lowercase forms. Split-half reliability is reported to be .94.

Print and orthographic pattern knowledge. Print and orthographic pattern knowledge was assessed with a criterion-referenced visual/orthographic knowledge task developed by Levy, Gong, Hessels, Evan, and Jared (2006). This task is a two-alternative, forced-choice task. The children were presented with 130 items with two "word" alternatives—one correct representation of a word and one that violated a print convention in the English language. The print conventions consisted of word shape (e.g., variations involving scribbles, letter-like characters, and pictures), linearity (e.g., variations on allowable spacing and multiple letters), word elements (e.g., variations in letter–number combinations, variety in letters, and upside-down or backward letters), and spelling (i.e., variations in allowable vowel and consonant patterns, and pseudo-homophones). For each word-pair, the children were presented with a card and were asked to point to the one item of the pair that looked more "like something Mommy or Daddy would read." Items were scored as correct or incorrect. Adequate internal consistency reliability for this task was obtained ($\alpha = .87$).

Rapid automatized naming. We used the RAN Letters subtest from the Comprehension Test of Phonological Processing (Wagner et al., 1999) to measure our participants' ability to rapidly name letters presented in five rows of a test plate. Standard administrative procedures were followed. The reported reliability coefficient for this subtest is .82.

Reading. Reading ability was assessed with the Nonsense Word Fluency subtest from the Dynamic Indicators of Basic Early Literacy Skills 6th edition (Good & Kaminski, 2001) and the word identification subtest of the WRMT–R (Woodcock, 1998). On the Dynamic Indicators of Basic Early Literacy Skills nonsense word fluency measure, the children were given 1 min to decode as many nonsense words as possible. Test–retest reliability is reported to be .90. The Word Identification subtest from the WRMT–R measured children's ability to read words. Split-half reliability is reported to be .98.

Spelling. Spelling ability was assessed using a 10-word spelling dictation task used in previous investigations (e.g., Wolter & Apel, 2010). The words were *fan, pet, dig, mop, rope, wait, chunk, slip, stick,* and *shine*. Each word was presented to a child in isolation, then in a sentence, and then in isolation again, and the child was asked to write the word. Wolter and Apel's 8-point rating scale was used. This scoring system gives an increasing amount of credit for spelling attempts that conform more to the actual orthographic representation of the target word (see Wolter & Apel for rating system). This spelling task was given to ensure commensurate spelling measures across studies of initial MGR acquisition and to prevent floor effects that can occur with young children when given norm-referenced spelling measures. Internal consistency reliability was .82.

Apparatus

Eye movements were recorded using a desk mounted EyeLink1000 in the heads-free (remote option) operating mode (SR Research Ltd., http://www.eyelinkinfo.com), running with a 500Hz sampling rate. This recording system has a relative spatial resolution on the order of a few minutes of arc and its absolute accuracy is better than $\frac{1}{3}^{\circ}$, depending on calibration. Participants were seated comfortably in front of a 22-in. CRT monitor using a screen resolution of 1024 × 768 and a refresh rate of 160Hz for stimulus presentation. Due to the age of our participants, we used a chinrest in addition to the heads-free mode to achieve the best possible data quality. Viewing was binocular, but eye movements were recorded from the right eye only. A 9-point calibration was performed at the beginning of each chapter, and mean average position error in an accuracy validation routine was not to exceed 0.5°. In addition, a drift correction was performed before each page. If participants looked away from the screen or moved excessively during reading a page, a new calibration was performed instead of the drift correction for the following trial. An additional purpose of the practice chapter just mentioned was to allow the children to become accustomed to the calibration and drift correction routines of the eye tracker. The online saccade parser of the eye tracking system was set to detect saccades with an amplitude of 0.15° or greater, using an acceleration threshold of $8000°/sec^2$ and a velocity threshold of 30°/sec.

Procedures

All tasks were administered individually, and raw scores from all measures were used in the analyses. The experimental MGR learning task was conducted first. All other tasks were administered in a randomized order to each child. Trained graduate and undergraduate students in communication science and disorders administered all of the tasks. The complete assessment battery was conducted over two sessions within 2 weeks. The entire battery took approximately 3 hr.

Reliability

Interrater scoring reliability was calculated on 15% (10 children) of the responses on all tasks. Agreement was calculated separately for each task. For the MGR learning procedure task, the interrater scoring reliability was 99.9%. For all other tasks, the interrater scoring reliability was 99.2 to 100%.

RESULTS

The children in our study varied in their SES level: 68% of the children came from upper middle to high SES homes and 32% came from lower to lower middle SES. As an initial step, we examined whether there were any differences between these two SES groups on the experimental MGR learning, eye gaze, or the other language and literacy measures. An initial MGR learning composite score was calculated by adding together the raw scores from the production and recognition tasks. The two groups did not differ significantly on the composite initial MGR learning score or on any of the eye movement parameters (all $ps > .05$). The lower SES group had significantly longer RAN times than the upper SES group ($t = 2.30$, $p = .025$) and significantly lower vocabulary scores ($t = -3.815$, $p < .001$). No other significant differences were found between the groups. Thus, the scores for all the children were used in all analyses. Descriptive statistics for all measures for the entire group are provided in Table 1.

TABLE 1
Means and Standard Deviations Initial Word Learning and Literacy Measures

	Total Group	*Low SES*	*High SES*
Experimental MGR learning measures			
Production (12 possible)	5.90 (3.43)	5.30 (3.66)	6.19 (3.33)
Recognition (12 possible)	10.42 (2.24)	9.55 (2.96)	10.83 (1.68)
Composite score (24 possible)	16.32 (4.88)	14.85 (5.69)	17.02 (4.35)
Receptive vocabulary (PPVT–IV)	107.00 (18.5)	95.25 (14.61)	112.60 (17.63)
Phonemic awareness (CTOPP Ellison)	6.87 (3.99)	5.70 (4.35)	7.43 (3.73)
Letter identification (WRMT–R)	35.39 (3.28)	34.95 (2.80)	35.60 (3.50)
Print/Orthographic pattern knowledge (130 possible)	104.97 (21.15)	104.15 (18.67)	105.36 (22.44)
RAN	97.44 (32.75)	111.63 (36.22)	91.55 (29.97)
Reading			
Word Identification (WRMT–R)	24.90 (16.84)	20.85 (14.77)	26.83 (17.59)
Word Attack (DIBLES NWF)	38.94 (30.46)	37.35 (31.29)	39.69 (30.42)
Composite	63.84 (44.95)	58.20 (43.17)	66.52 (46.04)
Spelling (10 possible)	62.52 (15.19)	60.65 (13.39)	63.40 (16.06)

Note. Mean raw scores are reported for all measures. SES = socioeconomic status; MGR = mental graphemic representation; PPVT–IV = Peabody Picture Vocabulary Test, 4th Edition; CTOPP = Comprehension Test of Phonological Processes; WRMT–R = Woodcock Reading Mastery Test–Revised; RAN = Rapid Automatic Naming DIBELS = Dynamic Indicators of Basic Early Literacy Skills; NWF = nonword fluency.

Initial MGR Learning Ability

We first examined whether the children demonstrated some initial MGR learning. On the production task, the children spelled roughly half of the target nonwords correctly ($M = 5.9$, $SD = 3.4$). On the recognition task, all but one child performed above chance level (i.e., correctly identified more than 4 of the 12 target nonwords; $M = 10.42$, $SD = 2.2$). Thus, our results indicated that all of the participants acquired some initial MGRs after minimal exposure to the target nonwords.

We then investigated whether the linguistic statistical regularities of the target nonwords affected the children's MGR learning. We conducted two 2 × 2 repeated measures analyses of variance (ANOVAs), with the within-subject variables of phonotactic probability (high vs. low) and orthotactic probability (high vs. low), for the production and recognition tasks. A Bonferroni correction, with alpha level set at .025, was applied to correct for possible Type 1 errors.

On the production task, there was a significant main effect for phonotactic probability, $F = 16.29$, $p < .001$, $\eta^2 = .21$, and orthotactic probability, $F = 17.43$, $p < .001$, $\eta^2 = .22$. More target nonwords were spelled correctly representing the high phonotactic ($M = 1.6$, $SD = .13$) and high orthotactic probability conditions ($M = 1.6$, $SD = .12$) than the low phonotactic ($M = 1.3$, $SD = .12$) and low orthotactic probability conditions ($M = 1.3$, $SD = .12$), respectively. The interaction between phonotactic and orthotactic probabilities was not significant. There were no significant main effects or interactions on the *recognition task* (all *p*s > .05).

Percentage of Total Viewing Time Devoted to Target Nonwords

We examined the children's total viewing time, number of fixations, and mean fixation durations devoted to the target nonwords compared to other areas of the page (other print, pictures, or other

TABLE 2
Means of Eye Movement Measures for Different Areas on Page

Task	*Total Viewing Time*[a]	*No. of Fixations*	*M Fixation Duration*[a]
Target nonword	9.36	19.2	.16
Other print	4.34	13.3	.11
Picture	17.40	51.9	.11
Other	3.89	13.8	.09

Note. Other print = words on the screen that were not target words; Other = nonprint, nonpicture aspects of the page.
[a]Measured in seconds.

space). The total viewing time was defined as the sum of all fixation durations in a particular area and can be taken as an indicator of the overall processing effort. The number of fixations was the count of fixations in a given area. The mean fixation duration reflected the average duration of these fixations per region (see Radach & Kennedy, 2004, for definitions of oculomotor measures). Results are presented in Table 2. On average, the children spent 50% of the total viewing time looking at the pictures on the page, 27% looking at the target nonwords, 12% looking at other print, and 11% looking at other space on the page. Thus, slightly more than one fourth of their total viewing time was devoted to the target nonwords, resulting in approximately 10.8 s, or 2.7s per exposure, devoted to looking at each target nonword. A one-way, repeated measures ANOVA revealed significant differences in the average total viewing time devoted to the target nonwords versus other aspects of the page, $F = 71.79$, $p < .001$, $\eta^2 = .74$. The average total viewing time devoted to the target nonwords was significantly less than that devoted to the pictures but significantly more than the viewing time devoted to other print or other aspects of the pages (all ps $< .001$).

Fifty-three percent of the children's fixations fell on the pictures, 19% on the target nonwords, 14% on other print, and 14% on other spaces on the page not involving print or pictures. Again, results of a one-way, repeated measures ANOVA revealed significant differences in the average number of fixations on the target nonwords versus other aspects of the page, $F = 193.981$, $p < .001$, $\eta^2 = .76$. The average number of fixations on the novel words was significantly less than those on the pictures ($p < .001$) but significantly more than those fixations on the other print or other portions of the pages (ps $< .001$ and .002, respectively). Of interest, the duration of fixations was significantly longer on the target nonwords than any other aspects of the page, $F = 57.95$, $p < .001$, $\eta^2 = .49$ (all ps for pairwise comparisons $< .001$) . Thus, although the children fixated less on the target nonwords than other aspects of the page, the duration of their fixations on the target nonwords was substantially longer than on the other print, pictures, or other areas of the page.

Association of Concurrent Literacy and Linguistic Knowledge With Eye Movement Parameters

Finally, we calculated Pearson product moment correlations to examine the relation between receptive vocabulary, phonemic awareness skills, letter knowledge, print and orthographic pattern knowledge, RAN, and reading and spelling skills with total viewing time, number of fixations, and mean length of fixation on the target nonwords. As can be seen in Table 3, few of the eye gaze

TABLE 3
Relations Among Eye Movement Measures and Literacy and Literacy-Related Tasks

Task	*Total Viewing Time*	*No. of Fixations*	*M Fixation Time*
Receptive Vocabulary	−.255*	−.222	−.096
Phonemic Awareness	−.160	−.090	−.120
Letter Knowledge	−.176	−.039	−.324*
Print/Orthographic Pattern Knowledge	.011	.057	−.081
RAN	−.006	−.024	−.035
Reading			
Word Identification	−.213	.033	−.340**
Word Attack	−.209	.000	−.299*
Spelling	−.059	.141	−.189

Note. RAN = Rapid Automatic Naming.
*$p < .05$. **$p < .001$.

parameters were associated with the children's literacy and literacy-related skills. For example, none of the literacy and literacy-related skills were associated with the number of fixations on the target nonwords and total viewing time was only significantly and negatively associated with receptive vocabulary ($r = –.26$). Mean fixation duration was significantly and negatively related to letter knowledge ($r = –.32$) and real ($r = –.40$) and nonsense word reading ($r = –.30$).

We also examined whether the statistical regularities of the target nonwords affected children's eye gaze parameters to determine whether the children's tacit knowledge of linguistic regularities influenced where children focused their eye gaze during the structured storybook context. We used total viewing time as our eye gaze parameter because it served as a general measure of visual processing load per region and was significantly associated with the other two measures (rs = .79 and .61 for number and duration of fixations, respectively). Thus, we conducted a 2 × 2 repeated measures ANOVA, with the within subject variables of phonotactic probability (high vs. low) and orthotactic probability (high vs. low). There was a significant main effect for phonotactic and orthotactic probability. The children devoted more total viewing time for the target nonwords representing high phonotactic probabilities ($M = 29.26$, $SD = 2.34$) than low phonotactic probabilities ($M = 26.88$, $SD = 1.72$), $F = 5.046$, $p = .028$, $\eta^2 = .078$. They also devoted more total viewing time to the target nonwords representing low orthotactic probabilities ($M = 28.99$, $SD = 2.05$) than high orthotactic probabilities ($M = 27.14$, $SD = 2.05$), $F = 4.374$, $p = .041$, $\eta^2 = .068$. The interaction was nonsignificant.

DISCUSSION

There were three major findings in our study. First, the kindergarten children quickly acquired initial MGRs of target nonwords presented in a storybook reading context, and MGR acquisition was influenced by the phonological and orthographic statistical regularities of the target nonwords. Second, viewing time on the target nonwords was approximately one fourth of the total viewing time, and the number of fixations on the target nonwords was 20% of the total number of fixations. Critically, the duration of those fixations on target nonwords was longer than those for other print, pictures, or other aspects of the story pages. Finally, similar to Justice et al. (2008), there were minimal significant associations between eye gaze and typical measures of literacy ability; however, total viewing time on the target nonwords was affected by the linguistic statistical regularities of those words. This has not been previously examined in previous studies. The results reveal that the children spent more time looking at target nonwords with high phonotatic probabilities than low phonotactic probabilities and target nonwords with low orthotactic probabilities than high orthotactic probabilities. The implications of these major findings are discussed next.

Initial MGR Learning Ability

Our findings of rapid initial MGR learning corroborated results from previous investigations of young children's orthographic knowledge acquisition (e.g., Apel, 2010; Apel et al., 2006). Further, as in previous studies, the linguistic statistical regularities of the words affected that learning. Words that represented high phonotactic probabilities and high orthotactic probabilities were spelled correctly more than words that represented low phonotactic probabilities and low orthotactic probabilities. The finding that the orthotactic probabilities of words influenced initial MGR learning is consistent with all previous investigations of initial MGR learning with children who were typically developing, at risk for literacy difficulties, and language impaired. This growing body of evidence suggests that young children acquire at least tacit knowledge of the statistical regularities of orthography before they typically have fully developed their reading abilities. What remains to be determined is when this tacit knowledge develops.

The children in our study spelled more target nonwords correctly when those nonwords represented high phonotactic probabilities. The same result occurred in Apel et al. (2006) but not in other initial MGR learning studies (Apel, 2010; Apel et al., 2011). The children in our study and in Apel et al. (2006) were younger than the children in the other investigations. Thus, it may be that younger children rely implicitly on their phonological knowledge as well as their orthographic knowledge but, in time and with presumably additional exposure to text, the influence of phonology diminishes or lessens in the MGR acquisition process.

Percentage of Viewing Time Devoted to Target Nonwords

Our participants devoted 27% of their viewing time, or a cumulative average viewing time of 10.8 s, toward each target nonword. This average viewing time was longer than found in most reports of preschool (6%; Justice et al., 2008) and kindergarten (14%; Evans et al., 2009) children's viewing time during storybook reading but similar to reports for first-grade children (30%; Roy-Charland et al., 2007). As others have suggested (Evans et al., 2008; Roy-Charland et al., 2007), it may be that higher viewing time represents a developmental progression in the allocation of eye gaze time devoted to print, with older or more language- and literacy-experienced children spending greater time viewing print than younger children. Our findings on the relation between language and literacy skills and eye movement parameters, however, provide little support for this contention as concurrent language and literacy skills were minimally associated with total viewing time. We return to this discussion of the possible effect of linguistic knowledge on eye movements in the next section. At the least, our results suggest that young children are quite facile at storing initial MGR information with, in absolute terms, relatively modest viewing time spent on the word, suggesting that, at least for simple orthographic representations, initial MGR learning occurs quickly and without overt decoding of the word.

We also examined the number of fixations, and the duration of those fixations, on the target nonwords. The children fixated on the target nonwords less than 20% of the total number of fixations. This percentage is higher than past reports of younger children's number of fixations on print (e.g., 6% reported by Justice et al., 2008, for their preschool children). Looking at the frequency of fixations, the respective percentage for the target nonword is somewhat lower in comparison to the viewing time, which is to be expected, given the much longer fixation durations. The fact that fixation durations on the target nonwords are increased by a factor of 1.5 relative to viewing pictures or other words suggest that the linguistic information necessary for the acquisition of an MGR is not just scanned more often but processed quite selectively.

Taken as a whole, our findings suggest that the kindergarten children spent considerable time (yet not the majority of their time) looking at our target nonwords and quickly establish initial MGRs. The differences in our findings from previous studies may be due to a number of factors. First, the ages of the children involved in previous investigations have ranged notably, from preschool through elementary grades, with several studies including children from a wide range of ages (e.g., Evans et al., 2008; Evans et al., 2009). The one study examining kindergarten children specifically involved only six participants (Roy-Charland et al., 2007). Thus, it is difficult to compare our results against theirs. Further research involving more kindergarten children would provide a better picture of their eye gaze devoted to print during storybook reading. Second, the type of story material may have affected the outcomes. Roy-Charland et al. (2007) reported longer gaze time for texts considered to be easy for kindergarten children (such as the material we used in our study) than those considered to be more difficult. Further, our stories contained similar amounts of language as some previous studies and were relatively simple in nature (e.g., Evans & Saint-Aubin, 2005; Justice et al., 2008; Roy-Charland et al., 2007); however, our stimuli contained novel objects. Some previous investigations used popular commercial books that contained more and likely familiar illustrations (e.g., Evans et al., 2008; Justice et al., 2008). Perhaps the novelty of the object and/or its name drew increased attention to the written word form. This possibility could be empirically examined in the future.

Two final factors that may have resulted in the longer eye gaze times we found in our study compared to previous investigations was the nature of our structured storybook reading and the target nonword print style. In our task, we questioned the children about the target nonword after each chapter. Although some investigators have instructed children that they would be asked questions about words after a reading (e.g., Evans et al., 2008), no research team questioned children in between readings of different stories. Thus, although there was no order effect, our procedure may have led children to increase the amount of time they spent on viewing our novel words as a whole. In addition, the target nonwords were larger, bold, and in a different color than other words. Although other investigators also have used bold, larger, and varying stylized fonts when measuring eye gaze toward print (e.g., Evans et al., 2009; Evans et al., 2008; Justice et al., 2008), our stylized target nonwords may have led to additional visual attention. There is some evidence from previous investigations that when adults draw attention to a written word (often by pointing), children's eye gaze increases (e.g., Evans et al., 2008; Justice et al., 2008). In Evans et al., for example, 5-year-old children focused on the target words for approximately 25% of the total viewing time when an adult pointed at words during reading. Although we did not provide any gestures during the storybook reading task, it may be that our questions after each chapter and/or stylized font were, in essence, a verbal equivalent of pointing. Nevertheless, our findings suggest that young children can acquire initial MGRs with minimal exposure within a structured storybook reading context during which they devote less viewing time to specific words than they do other aspects of the pages.

Influence of Concurrent Literacy and Linguistic Knowledge and Eye Movement Parameters

Other than a small, negative correlation with receptive vocabulary, the children's performance on norm-referenced measures of language and literacy was not related to our eye movement parameters during storybook reading. These findings are more similar to those of Justice et al. (2008), who found no significant association between language and literacy skills and eye movements, than to Evans et al. (2009), who, in contrast, reported significant relations between letter knowledge and eye movement. One possible explanation for the different results between our study and those of Evans et al. is that the children in Evans et al. read the stories versus having adults read stories to them, as occurred in our study. It may be that the children's performance on the letter knowledge task served as a proxy for reading ability, which was borne out via eye gaze while reading the stories. Future studies could examine the influence of child versus adult reading on eye gaze within a storybook reading context.

When we examined the effect of children's tacit knowledge of linguistic statistical regularities on eye movement parameters, a different picture emerged. The children devoted significantly more viewing time to target nonwords with high phonotactic probability than they did to target nonwords with low phonotactic probability. Conversely, the children devoted significantly more viewing time to words with low orthotactic probability than they did to words with high orthotactic probability. Although the findings for phonotactic probability mirrored the results for the effects of phonotactic probabilities on initial MGR learning (production task), the findings for orthotactic probability did not. The somewhat unexpected and seemingly contradictory findings may be explained using Storkel's (2009) theory of spoken word learning. Storkel (2009) suggested that the lexical and sublexical phonological characteristics of spoken words influence word learning. Phonological neighborhood density, a lexical characterization of the number of words that share all but one sound, aids storage of new words that are highly similar in lexical structure. Phonological neighborhood density is highly correlated, but not identical, to sublexical characteristics of spoken words (i.e., phonotactic probabilities). The sublexical features of words, according to Storkel, trigger initial learning when those characteristics are novel compared to previously stored representations.

It may be that words' lexical and sublexical orthographic characteristics also influence initial MGR learning (Apel, 2010). Our findings that more viewing time was devoted to low orthotactic probability target nonwords may have occurred because those words also represented low orthographic neighborhood density words. As such, additional viewing time may have been devoted to them because of their less familiar sublexical representations. Similarly, more target nonwords that represented high orthotactic probability words may have been spelled correctly in the experimental initial MGR learning production task because those target nonwords also represented high orthographic neighborhood density words, leading to quicker and more efficient lexical storage. The findings that high phonotactic probability target nonwords were spelled better and viewed more than low phonotactic probability target nonwords suggest that, perhaps because of the children's lengthier experience with phonology and its lexical and sublexical features, the children were using their knowledge of the lexical phonological characteristics when viewing and learning the target nonwords. In this investigation, we did not manipulate the lexical and sublexical characteristics of the target nonwords to allow us to confirm these possibilities; thus, these potential explanations are speculative. Future investigations that examine words' lexical and sublexical characteristics will shed further light on the factors that influence initial MGR acquisition.

The influence of words' linguistic statistical regularities on eye movement parameters is important in two ways. First, these findings substantiated the facilitative effect of preexisting linguistic knowledge on initial MGR learning at a very young age. That is, the children seemed to have developed a tacit knowledge of the orthographic statistical regularities of words, and this implicit knowledge influenced viewing times and their ability to quickly store new orthographic knowledge. Second, the findings suggest young children's eye movements are linguistically motivated, at least in storybook reading situations involving print. Using eye movement technology, researchers have documented that for middle to upper-elementary school level readers and adults, processing skills and prior linguistic knowledge impacts reading behavior (e.g., Feng et al., 2009; Huestegge et al., 2009; Inhoff et al. , 2004; Radach et al., 2004). Our investigation is one of the first to demonstrate that implicit phonological and orthographic knowledge affects kindergarten children's eye movements toward print.

Limitations

We address several limitations to this investigation. First, the story was presented via a Microsoft PowerPoint presentation. Although past investigations have used a similar medium (e.g., Evans et al., 2008; Justice et al., 2008), the presentation may not have simulated well the subtle, natural interactions that occur between a reader and listener. Future research might examine ways to measure eye gaze during storybook reading in more naturalistic reading conditions. Second, we had six exemplars per linguistic probability condition. Our findings should be considered within the context of this limited data set. Third, our target words represented one grammatical aspect of speech (i.e., nouns). Studies of spoken language acquisition (e.g., Rice & Woodsmall, 1988) indicate that words from other parts of speech (e.g., verbs) may be more challenging to learn. Future research could include words from other grammatical categories to examine whether initial learning of the orthographic form of written words varies according to the grammatical class of the word. Fourth, we examined MGR learning shortly after exposure to the target words in the story. Further investigations could examine the longer term influences of linguistic regularities on word learning after time and/or additional exposures to target words. Finally, because of the nature of the task, our study demonstrates the amount of orthographic information kindergarten children acquire, and the viewing time afforded to that learning, in a structured storybook task that may not represent the adult–child interactions that typically occur in natural settings.

Theoretical Implications

According to Gombert's (1992) proposed theory of metalinguistic development, children first develop implicit knowledge of the statistical regularities of orthography and use that knowledge in a tacit manner to read new words. With time and experience, this knowledge rises to a more explicit level of awareness and children use that more explicit awareness actively. The results of our investigation, coupled with those of our past investigations (e.g., Apel, 2010; Apel et al., 2006; Wolter & Apel, 2010), provide some evidence of this first phase of development when children appear to rely implicitly on an understanding of orthographic regularities; their reliance on this knowledge appears to aid initial MGR learning.

The possibility that children as young as 5½ years of age may be tapping into their implicit knowledge of linguistic statistical regularities is not new. Indeed, multiple researchers have demonstrated that very young children, some as young as 9 months of age, demonstrate a sensitivity to the phonological statistical regularities of spoken words (e.g., Jusczyk, Cutler, & Redanz, 1993; Storkel, 2001, 2003). That young children apply this early-developing statistical knowledge in written word learning is nonetheless remarkable. Our findings provide evidence of early use of orthographic regularity knowledge in written language learning. With more subtle measures of that learning, such as through eye movement measurements, it may be possible to determine the earliest age at which children tap into that orthographic regularity knowledge to learn new written words.

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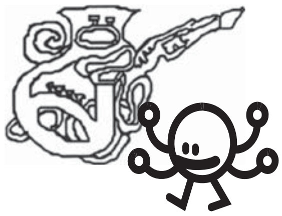
APPENDIX

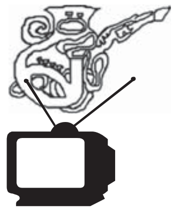
Sample Story from Experimental Initial Mental Graphemic Representations Learning Task

This is about Jak's **chan**.

A **chan** is hard.



Jak pushes a **chan**.



A **chan** is on a TV.