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# What Do Children Know Before Spelling Phonologically? Prephonological Spellers' Knowledge of Writing

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ABSTRACT OF THE THESIS

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Most theories of literacy development have focused on children's knowledge of the phonological aspect of writing. Relatively few studies have investigated children's writing-related knowledge before they acquire alphabetic knowledge. The constructivist theory provides insights into what and how children know about other aspects of writing such as its graphic properties and symbolic function. The present study examined different aspects of the constructivist perspective. Preschool children with a mean age of 4 years and 4 months completed a spelling task and a recognition task. Participants who had not grasped conventional phoneme-grapheme correspondences in English were of primary interest. Consistent with the constructivist view that children use writing to directly represent meaning, prephonological spellers produced more written elements for words representing long objects than those representing short objects. The present findings do not support several other aspects of the constructivist theory, however. For example, contrary to the constructivist idea that children learn about universal features of writing before language-specific ones, prephonological spellers produced features that are conventional in their writing system (e.g., horizontal arrangement of lines of writing) much more often than features conventional in other systems (e.g., vertical arrangement). Some of the present findings

are more consistent with the view that children use their statistical learning skills to understand aspects of writing such as its visual properties.

## Introduction

In order to use an alphabetic writing system, children need to understand different aspects of the system. One important aspect is called the *alphabetic principle*, or the appreciation of how printed words relate to spoken words (Treiman, 2000). Many theories of literacy acquisition focus on how children learn to map phonemes onto phonetically appropriate graphemes as they get more experience with alphabetic writing systems like English (e.g., Ehri, 2005; Frith, 1985; Gentry, 1982). Children need to understand other aspects of writing in addition to the alphabetic principle and specific phoneme-grapheme correspondences. For example, it is important to understand what writing looks like and what writing represents. Most previous studies of literacy development did not examine such knowledge of writing. However, some researchers (e.g., Ferreiro & Teberosky, 1982; Lavine, 1977; Levy, Gong, Hessels, Evans, & Jared, 2006) reported that even children who could not yet read understood certain graphic properties of writing. The present study was designed to examine what children know about writing before they understand the alphabetic principle and conventional phoneme-grapheme correspondences.

One influential theory, which may be called the *constructivist* perspective (Ferreiro, 1985; Ferreiro & Teberosky, 1982), provides alternative views to theories focusing on the phonological domain. Researchers in the constructivist tradition argue that children possess some writing-related knowledge even before they understand the relation between sounds and letters. Children are said to actively explore print in their environment and develop their own ideas about writing. The constructivist view will be discussed in more detail in the following sections.

In what follows, I first consider some aspects of writing that children need to know in addition to the alphabetic principle and phoneme–grapheme correspondences. Four aspects of the constructivist framework of literacy development will be reviewed and discussed. For each

aspect, I first present the constructivist view and then review the literature concerning that idea, highlighting possible theoretical and methodological gaps in previous research.

**What Do Children Need to Know About Writing?**

One important aspect of writing that children need to learn about is the relationship between writing and language. Writing is a second-order symbolism (Vygotsky, 1978): Writing represents spoken language which in turn represents concepts. This indirect symbolic system is different from other representational systems that are familiar to young children. For example, photographs and realistic drawings directly represent meaning. A picture of an object resembles the real object in physical characteristics of the object. It is hard for young children to conceive of language as something that can be represented like physical objects, given the quick dissipation of spoken language (Treiman & Kessler, 2007). Moreover, words are arbitrarily assigned to represent concepts. There is little or no resemblance between spoken or written words and their denoted objects.

Writing systems have conventions that govern the visual aspect of writing. Children have to learn about the graphic properties of their writing system. For example, writing is sequential, consisting of units that are arranged along straight lines. In English, the lines of print are horizontal. Users of a writing system follow a conventional direction in which they read and write. In English, words are read and written from left to right. Moreover, although written units are drawn from a finite set of symbols, symbols do not repeat multiple times within each unit. Given their relatively frequent exposure to text such as signs, storybooks and commercial print, young children in literate societies could have gained sensitivity to certain graphic characteristics of writing on a purely visual basis.

## The Constructivist Perspective of Literacy Development

The constructivist perspective of literacy development is particularly prominent in non-English speaking countries such as those speaking Spanish (Ferreiro & Teberosky, 1982) and Portuguese (Martins & Silva, 2001). Some researchers have applied the constructivist perspective to understand written language acquisition among English-speaking children (e.g., Kamii, Long, Manning and Manning, 1990; Vernon, 1993). Research in the constructivist tradition is heavily influenced by Piaget's work. Based on insights gleaned from his method of clinical observation, Piaget theorized that children learn through their actions on external objects and pass through developmental stages in which they construct different ideas about the world. Advocates of constructivism applied the Piagetian method and thinking to study written language acquisition (Ferreiro, 1985, 1990; Ferreiro & Teberosky, 1982). Constructivists argued that young children possess some knowledge of their writing system even before receiving formal literacy instruction or acquiring any alphabetic knowledge. Actively attempting to understand written language, young children formulate and test their own hypotheses about characteristics of writing. They are therefore said to construct their knowledge about writing through active exploration of print in their environment. Such knowledge represents their original ideas and may be different from what adults know about writing. Constructivists also contended that children's own beliefs about writing are abstract and similar in children growing up in different cultures (Ferreiro, Pontecorvo, & Zucchermaglio, 1996). An important strength of the constructivist view is that these theorists acknowledged children's understanding of writing before acquiring phoneme-to-grapheme correspondences and postulated specific patterns that young children accept and produce as writing.

**Knowledge of the Symbolic Function of Writing**

Ferreiro and colleagues (Ferreiro, 1985; Ferreiro & Teberosky, 1982) proposed that young children construct the hypothesis that writing directly represents meaning and that features of written words should be consistent with features of the denoted objects. Ferreiro (1985) reported case studies of Spanish-speaking children who could not yet read and used more letters for words representing greater quantities of objects or for words denoting larger objects. For example, in one interview, the experimenter presented a 4-year-old child with the written word ‹GALLO› 'rooster', and asked the child to write the words *gallina* 'hen' and *pollito* 'little chicken'. The child wrote ‹GALL› for *gallina* and ‹GAL› for *pollito*, and explained his responses in terms of the relative animal sizes. Such evidence is consistent with the view that children's writing is guided by the semantic content of words. Although Ferreiro and colleagues presented some interesting examples supporting their idea, their data were largely observational and their conclusion lacked support from rigorous statistical analysis.

Evidence for the idea that children rely on semantic content to interpret words also comes from studies that used a different type of task, a recognition task (e.g., Bialystok, 1991; Levin & Landsmann, 1989; Lundberg and Tornéus, 1978; Papandropoulou & Sinclair, 1974). In Bialystok's (1991) study, the experimenter showed children two pictures each depicting an object and two printed words each representing one of the two objects on the pictures. The experimenter then asked the children to place each word under the picture that it went with. In corresponding pairs such as *ball* vs. *ballerina*, words representing a large object were spelled with more letters than words representing a small object. In noncorresponding pairs such as *cat* vs. *caterpillar*, words representing a large object were spelled with fewer letters than words representing a small object. English-speaking children who could not read performed better on

corresponding pairs than noncorresponding pairs, suggesting that they used the relative sizes of objects as a cue to decide what written words should be like.

Using a slightly different procedure, Lundberg and Tornéus (1978) presented Swedish-speaking children with word pairs both aurally and visually and asked children to indicate which printed word went with each spoken word. The 4- to 7-year-old prereaders produced more correct responses when word length was consistent with referent size than when word length did not correspond to referent size. Similar findings have been reported for English-speaking children (Rozin, Bressman, & Taft, 1974) and Hebrew-speaking children (Levin & Landsmann, 1989). Together, such evidence supports the constructivist notion that prereaders use writing as iconic representation of objects.

Previous researchers have typically examined children's responses in recognition tasks. While this approach is useful for gauging young children's implicit understanding of writing, it is unclear whether similar beliefs about writing can be inferred from children's writing productions. Moreover, some features of the previous studies might have biased children to use the properties of denoted objects to make decisions. Given that pictures contain rich semantic information, Bialystok's (1991) presentation of pictures could have heightened the accessibility of the semantic attributes of the words. In some other studies, the simultaneous presentation of words denoting objects of contrasting sizes might have made the dimension of size particularly salient, consequently influencing children's responses. Examining children's writing produced one word at a time could help alleviate potential concerns with the stimulus presentation of previous studies.

**Syllabic Spelling**

Constructivists proposed that another belief children hold before they use letters to represent phonemes is the syllabic hypothesis. That is, each written symbol corresponds to one syllable. Attempting to relate writing to speech, children use this hypothesis to decide how many written symbols they need to spell different words. Ferreiro and Teberosky (1982) reported instances of syllabic spelling from their interviews with Spanish-speaking children. For example, one 5-year-old child wrote two characters resembling the letters ‹OO› for the two-syllable word *oso* ‘bear’, and wrote three characters resembling the letters ‹CUO› for the three-syllable word *patito* ‘duckling’. Ferreiro and Teberosky (1982) further argued that children’s formulation of the syllabic hypothesis is independent of understanding of other aspects of writing such as conventional symbol shapes and consistent sound-letter mappings. Children who could not yet produce conventional letter shapes used symbols like circles and dots to match the number of syllables in spoken words. A letter string may be used to spell words with different sounds; the critical criterion is that the string has as many letters as syllables of those words.

Evidence supporting syllabic spelling comes from studies that examined spellings of children who spoke Romance languages (e.g., Martins & Silva, 2001, for Portuguese; Rego, 1999, for Brazilian Portuguese; Sirois, Boisclair, & Giasson, 2008, for Canadian French). For example, Martins and Silva (2006) reported that more than half of the Portuguese-speaking children in their study produced spellings that contained the same number of letters as syllables in words, suggesting that children pass through a syllabic stage. Other researchers, however, have argued against the presence of a syllabic stage even in Romance language speakers (Cardoso-Martins, Corrêa, Lemos, & Napoleão, 2006; Treiman, Pollo, Cardoso-Martins, & Kessler, 2013). In a longitudinal study, Cardoso-Martins et al. (2006) periodically tested 4½ - to

6½ -year-old Brazilian children's spelling. Only 35% of the children consistently demonstrated syllabic spelling at some point of the study; the rest of the children did not seem to spell syllabically. Moreover, the few syllabic spellers identified in Cardoso-Martins et al.'s (2006) and Treiman et al.'s (2013) studies almost always produced phonetically appropriate letters to represent some phonemes of the words. These researchers therefore argued that syllabic spelling does not result from children's belief that writing should represent syllables, but from their beginning ability to map letters to phonemes.

Mixed findings have also been reported for syllabic spelling in speakers of non-Romance languages. While some researchers reported relatively high proportions of syllabic spellings (e.g., Tolchinsky & Teberosky, 1998, for Hebrew; Vernon, 1993, for English), others have casted doubt on the existence of a syllabic stage at least in English-speaking children. Kamii et al. (1990) reported that children did not consistently match letters to syllables, but attempted to represent consonant sounds in their spellings. In a more recent study (Pollo, Kessler, & Treiman, 2009), English-speaking children were asked to spell words containing different number of syllables. Instead of looking for exact correspondences between syllable length and graphemic length of written productions, Pollo et al. (2009) examined whether children produced more letters to spell two-syllable words than one-syllable words. No evidence of syllabic spelling was found: Similar number of letters was used for both one-syllable and two-syllable words.

One potential limitation of Pollo et al.'s study is that only one-syllable and two-syllable words were included in the spelling task. The small variability in syllable length might have obscured possible effects of syllable length. Using a relatively large range of syllable length, Cardoso-Martins et al. (2006) did not find evidence of syllabic spelling in Brazilian Portuguese-speaking children. In the present study, words with a similar range of syllable length (1 syllable

to 4 syllables) were used to test whether Cardoso-Martins et al.'s (2006) finding could be replicated among English-speaking children. The present study focused on data from children who had not acquired conventional sound-letter correspondences to test the constructivist idea. This focus would also allow one to better ascertain the nature of syllabic spellings. If children's syllabic hypothesis is independent of their knowledge about writing such as conventional graphic patterns and sound-letter correspondences, children who have not acquired alphabetic knowledge are likely to demonstrate syllabic spellings. If, on the other hand, syllabic spellings are incidental results of attempts at mapping letters to sounds, prephonological spellers are unlikely to produce more symbols for words with more syllables.

**Knowledge About Within-word Variation**

According to the constructivist perspective, another belief that young children hold pertains to the visual aspect of writing and is called *within-word variation*. That is, the letters in a word should be different from one another. In their interviews with Spanish-speaking children, Ferreiro and Teberosky (1982) presented children with cards each containing a letter string (e.g., ‹MMMMMM› and ‹MANTECA›) and asked them whether the text was something to read or not something to read. Slightly more than half of the four-year-olds and two thirds of the five-year-olds rejected the cards with repeated letters and stated that reading could take place only when the letters were varied. Again, Ferreiro and colleagues' observational approach is not sufficient to draw any definitive conclusion.

Other researchers have more systematically examined what young children know about the fact that letters do not usually repeat in sequence within a word. Levy, Gong, Hessels, Evans, and Jared (2006) presented 4-, 5- and 6-year-old children with cards each showing a correctly spelled word and a nonword consisting of repeated letters (e.g., ‹SWAMP› vs. ‹SSSSS›) and

asked them which one was a better word to read. By age 4 years and 4 months, children who could not yet read were significantly more likely to choose words with varied letters than strings with repeated letters as better words for reading. Lavine (1977) presented 3-, 4- and 5-year-old children with nonword displays with different graphic characteristics, one display at a time (e.g., ‹TOODLE› and ‹TTTTTT› were displays presented on two different trials). Children of all age groups accepted displays with varied letters as writing more often than displays with repeated letters. These researchers therefore concluded that young children demonstrated understanding of at least this graphic pattern of writing well before receiving formal instruction and learning to read.

Although Levy et al.'s (2006) and Lavine's (1977) studies were methodologically more rigorous than Ferreiro and Teberosky's study, there are also concerns with the former studies. One potential methodological limitation has to do with the stimulus selection. For items with varied letters, Levy et al. (2006) used real words, half of which were high-frequency words. This design could have inflated children's preference for displays with varied letters, because children might simply pick the displays they had seen before. Lavine (1977) used nonword displays to reduce possible influence of familiarity with words. However, even this control might not be sufficient. Children who do not yet understand the correspondences between sounds and letters are sensitive to how common individual letters or letter groups are in their environment (Kessler, Pollo, Treiman, & Cardoso-Martins, 2013; Pollo, Kessler, & Treiman, 2009). Controlling for letter frequency and bigram frequency of the two displays on each trial would allow researchers to better examine whether children hold the within-word variation hypothesis.

Previous researchers interpreted children's preference for displays with varied letter shapes as supporting the idea that children demonstrate some understanding of writing. This

conclusion may be premature. Displays with varied letter shapes are not only consistent with what writing looks like but may also be interesting to look at especially for young children. It is unclear whether children's responses in previous studies reflect their understanding of writing-specific features or their general perceptual preferences. One way to tease apart the two possibilities is to also examine whether children privilege variability in dimensions other than symbol shape. In any spoken language, sounds do not repeat in sequence multiple times within a word. Writing represents spoken language and therefore generally consists of different letters in a word. Variability in other dimensions like color is not related to this symbolic nature of writing; letters do not usually vary in color.

**Development of Knowledge of Writing**

Advocates of the constructivist perspective have proposed a developmental sequence in which children acquire certain properties of writing. According to Tolchinsky (2003), young children learn about characteristics universal to all writing systems before characteristics specific to a particular writing system. This proposal is called the *differentiation hypothesis*. One graphic feature that is common to all writing systems is that words are arranged along straight lines. This linear arrangement may be seen as a way to preserve the temporal order of the spoken language (Brenneman, Massey, Machado, & Gelman, 1996). All writing systems represent spoken language and therefore follow this convention of linear arrangement. Other graphic properties do not stem directly from the symbolic nature of writing and may not be the same in all scripts. For example, the orientation of lines of print is a script-specific property. While in writing systems such as English and Hebrew, lines are arranged horizontally, in writing systems such as Japanese and Mongolian, lines are written vertically. The direction in which words are written may also differ across writing systems. In English, words are written from left to right; in Hebrew, words

are written from right to left. The differentiation hypothesis predicts that children acquire the linear arrangement of writing before the orientation of print and directionality specific to their writing system.

Most previous studies have examined whether different types of graphic features are present in young children's writing productions (e.g., Brenneman et al., 1996; Chan & Louie, 1992; Puranik & Lonigan, 2011; Tolchinsky-Landsmann & Levin, 1985). For example, in Tokchinsky-Landsmann and Levin's study (1985), while 78% of the 4-year-old learners of Hebrew consistently produced characters that were arranged along straight lines, only 29% of the same children followed the conventional direction of writing in Hebrew (i.e., right-to-left directionality). Similar findings were reported for English-speaking children (Brenneman et al., 1996). Puranik and Lonigan (2011) more directly explored the sequence in which English-speaking children demonstrated different features of writing such as linearity and left-to-right directionality. Their data from several writing tasks were consistent with a developmental sequence in which universal features (e.g., linearity and segmentation) appeared earlier than script-specific features (e.g., directionality and symbol shapes).

However, studies using recognition tasks did not find evidence supporting the differentiation hypothesis. When presented with the letters of their name which were arranged in different orientations, 3- and 4-year-old children were more likely to accept the horizontal arrangement, which is conventional in English, as writing than the vertical arrangement, which is conventional in other writing systems (Treiman, Cohen, Mulqueeny, Kessler, & Schechtman, 2007). In a study that tapped more general knowledge about print orientation (Treiman, Mulqueeny, & Kessler, 2014), 4-year-old children were more likely to pick horizontally arranged lines of letters as writing than vertically arranged lines of letters. Because orientation of writing

is a script-specific convention, according to the differentiation hypothesis, young children are unlikely to have acquired the conventional orientation of their writing system and should be equally likely to accept horizontally and vertically arranged lines of print as writing. Treiman and colleagues' findings did not support this idea.

The discrepant findings reviewed above could have resulted from the types of features researchers were interested in. While Treiman and colleagues focused on children's knowledge of orientation of print, other researchers (e.g., Puranik & Lonigan, 2011) did not report whether children's linear writing productions were horizontally or vertically arranged. Orientation of print is an arbitrary convention that varies across writing systems. Focusing on orientation of writing would allow researchers to test whether even young children demonstrate some understanding of properties specific to their writing system. Moreover, different types of tasks (production tasks vs. recognition tasks) may have tapped different components of children's abilities and led to discrepant conclusions. While production tasks like the ones Brenneman et al. (1996) and Puranik and Lonigan (2011) used require detailed memory representations and good mechanical skills, recognition tasks like the ones Treiman and colleagues used tap children's implicit conceptual knowledge of writing. As Treiman et al. (2014) suggested, it would be important to test whether children's understanding of language-specific features such as orientation of print could also be observed in production tasks.

**Overview of the Present Study**

The present study attempted to address remaining questions regarding the different aspects of the constructivist perspective reviewed above. To preview, preschool children were asked to spell words that represented objects of different lengths and contained different number of syllables. Number of written elements was coded to be the dependent variable. Evidence for

children's belief that writing directly represents meaning has come from studies that typically used a recognition task; it was of interest to ascertain whether similar evidence could be found in production tasks like the present spelling task. If children believe that characteristics of writing should resemble those of the denoted objects, they are expected to use more elements to spell words representing long objects than those representing short objects. Moreover, words to be spelled were presented one at a time in a straightforward manner. This procedure could circumvent potential problems caused by the presentation of accompanying stimuli like pictures (e.g., Bialystok, 1991).

To examine whether children produced patterns of syllabic spelling, words with a relatively wide range of syllable length were used in the present study. If children consider writing as representing speech at the syllable level, they should use more elements for words with many syllables than those with few syllables.

Another question of the present study pertained to how children learned about properties of writing. To answer this question, the orientation of each writing production was coded; the direction in which children wrote the elements of each production was also recorded. If, as the differentiation hypothesis (Tolchinsky, 2003) predicts, children acquire characteristics common to all writing systems before characteristics specific to their own writing system, children who have not grasped alphabetic knowledge should be equally likely to write along horizontal lines and along vertical lines. They are also expected to write in the left-to-right direction as often as in the right-to-left direction.

In the second part of the present study, children completed a graphotactic task in which they were shown nonword pairs and were asked to pick the display that was better for reading. For each pair, one display consisted of letters that varied in one dimension while the other

display had letters that did not vary in that dimension. Critically, stimuli with two types of variability, variability in letter shape and variability in letter color, were included. The present study therefore extended findings from previous studies by asking whether children's preference for displays with varied letters truly reflect writing-specific knowledge. If young children are indeed knowledgeable about graphic properties of writing, they should prefer displays with varied letters over those with repeated letters, and prefer displays with letters in one color over those with letters in different colors.

One important feature of the present study is that responses from children who had not acquired conventional phoneme-to-grapheme correspondences in English (i.e., prephonological spellers) were of primary interest. In previous studies, prephonological spellers were often identified based on the researchers' intuition. In the present study, a statistically rigorous approach was used to ensure that children's responses were not guided by phonological knowledge. It would then be possible to ask whether young children could learn about characteristics specific to writing on a purely visual basis. Also, this focus could help verify whether syllabic spellings found in previous studies reflect children's partial ability to represent phonemes with corresponding graphemes.

To summarize, the first goal of the present study was to examine whether prephonological spellers use writing to directly represent meaning, producing more written elements to spell words referring to long objects than those referring to short objects. The second research question was whether children spell words with more syllables using more written marks. The third research question concerned whether prephonological spellers produced conventional language-specific features such as horizontal arrangement and left-to-right

directionality. The final question of the present study was whether prephonological spellers privilege writing-related characteristics like symbol shape over other characteristics like color.

## Method

### Participants

The participants were 75 children (45 boys, 30 girls) with a mean age of 4 years and 4 months and a range of 3;3 (years;months) to 6;1. All the children attended preschools in the St. Louis area with English as the medium of communication and teaching. All the children were frequently exposed to storybooks and other print in their classrooms.

### Stimuli

**Reading task.** The same materials as those in Treiman and Rodriguez (1999) were used for the reading task. The materials included 14 cm × 21.5 cm cards each containing 2 words and 1 colored picture. The words were printed in uppercase letters which were 2.6 cm high. The words were thought to be easy for novice readers. The pictures were included to make the task less frustrating for children who could not read any words. The words used in the reading task were *book*, *come*, *dog*, *eat*, *go*, *green*, *in*, *is*, *it*, *jump*, *look*, *no*, *play*, *red*, *see*, *stop*, *the*, *up*, *yellow*, *yes*, *you*, and *we*.

**Spelling task.** Twenty-four words were used for the spelling task. All the words were thought to be familiar to young children in the spoken language. Actual height or length of the object represented by each word was used as a measure of the object size. Average length (horizontal extent) of the object represented by each word was obtained from the internet. For example, the average distance across the shoulders of a grown female was used for teacher; the average length of trimmed asparagus was used for asparagus. The stimuli also varied in number

of syllables, ranging from 1-syllable words to 4-syllable words. Appendix 1 presents the means of the two characteristics of words. For each word, a sentence with that word in it was created to make sure that children could understand the word they were asked to spell. All of the sentences contained 7 words. This control was done to ensure that the length of each sentence would not influence children's writing production. A 21.5 cm by 21.5 cm booklet containing 48 empty pages was prepared for each child to produce their spellings on. Each booklet was made to be in a square shape, such that it would be possible to determine where a writing production was relative to the edges of the booklet. An oversized beginner pencil was provided for the children to write with.

**Graphotactic task.** The graphotactic task tapped children's knowledge about one visual aspect of writing, variation within words. The displays were printed on the facing pages (10.5 cm by 14.9 cm) of a booklet made of white paper. Each child saw 20 pairs of stimuli and 5 pairs of fillers. Two types of nonword pairs were devised. In the first pair type, "shape vary" type, one display consisted of letters that were different from one another in shape (e.g., ‹DWP›), while the other display contained letters that were identical in shape (e.g., ‹DDD›). The first letter of the two displays was always identical. The displays with shape variation were composed of less common letters and bigrams than the displays without shape variation (e.g., ‹DW› is much less frequent than ‹DD›). This control was done to ensure that children's potential preferences for items with variation were not because of more frequent exposure to letters and letter sequences in the displays with variation than those in the displays without variation. The letter frequency and bigram frequency were computed based on a corpus of 6232 words which are found in books targeted at preschoolers and first graders (Zeno, Ivenz, Millard, & Duvvuri, 1995). Both displays of the "shape vary" type were printed in black. In the second pair type, "color vary" type, both

displays contained same letters that were identical in shape. The first display was composed of letters that differed from one another in color (e.g., ‹D› in scarlet, ‹D› in green, and ‹D› in blue); the other display was composed of letters that were all in the same color (e.g., ‹D› in scarlet, ‹D› in scarlet, and ‹D› in scarlet). The color of the first letter in both displays was always the same. The print colors for the "color vary" pairs included scarlet (cyan (C): 0, magenta (M): 100, yellow (Y): 100, key (K): 0), green (C: 100, M: 0, Y: 100, K: 20), blue (C: 100, M: 50, Y: 0, K: 20), tenné (C: 0, M: 50, Y: 100, K: 20), fuchsia (C: 20, M: 100, Y: 0, K: 0), turquoise (C:100, M: 0, Y: 25, K: 20), magenta (C: 0, M: 100, Y: 31, K: 16), lime (C: 25, M: 0, Y: 100, K: 20), Prussian blue (C: 100, M: 33, Y: 0, K: 40), cerise (C: 0, M: 100, Y: 50, K: 20), red (C: 0, M: 100, Y: 100, K: 20), orange red (C: 0, M: 80, Y: 100, K: 0), electric indigo (C: 60, M: 100, Y: 0, K: 0), mustard (C: 0, M: 25, Y: 100, K: 20), avocado (C: 33, M: 0, Y: 100, K: 40), Pakistan green (C: 100, M; 0, Y: 100, K: 50), and tangerine (C: 0, M: 40, Y: 100, K: 0). All colors had the same level of brightness. There were ten pairs of each pair type. Within each pair type, half of the pairs consisted of three-letter displays and the other half consisted of four-letter displays.

All displays of the two pair types were printed in lowercase letters which were consistent with what children were exposed to in storybooks. The letters were printed in 56-point calibri and ranged from 0.9 cm to 1.3 cm in height. All pairs of displays appeared at the center of each facing page, with one display positioned above the other. Displays with variation in shape or color appeared on the top for half of the trials and on the bottom for the other half of the trials.

Each child was presented with a different booklet, which contained 20 critical display pairs and 5 filler pairs. For the filler pairs, each page contained two images, each representing a common object. Children were asked to make simple judgments about the objects. For example, in one filler pair, children were presented with an image of a dog and that of a car, and were

asked which of the two was better for driving. The filler items were made interesting and easy. Indeed, the children almost always produced the correct responses for the filler pairs. Within each booklet, the display pairs were randomly ordered; filler items occurred after every four display pairs.

**Procedure**

The children were tested individually at a quiet location at their school in three sessions. Each session lasted approximately 15 to 20 minutes. On the first day of testing, the children completed the reading task and spelled half of the words in the spelling task. On the second day of testing, they spelled the remaining words in the spelling tasks. On the third day of testing, the children completed the graphotactic task.

**Reading task.** Children were shown 11 cards, one card at a time, and were asked to identify any items that they could recognize. If a child did not identify any of the items, the experimenter pointed to each item and asked the child if he or she knew the item. The experimenter praised all responses the children made. Each child had a different randomized order of presentation of the cards. Only the number of correctly identified words was scored.

**Spelling task.** The spelling task was presented with the aid of a dinosaur puppet and a rabbit puppet. The dinosaur puppet was used for dictating the first half of the word list and the rabbit puppet was used for the second half. During each spelling session, the experimenter first introduced the children to a puppet and explained that the puppet did not know how to spell some words and wanted to see how children spell those words. For the dictation of each word, the experimenter said the word, and the puppet then said a sentence containing the word. The children were asked to repeat the word before spelling it. They were asked to spell each word on a facing page of the booklet with the pencil provided. The children were not given any

instructions as to the specific location of their writing and could choose to write anywhere on the page. They were told that they should not worry about the accuracy of their spellings and that the puppet just wanted them to try their best. The direction in which children wrote (e.g., left to right) was recorded during each trial. After the children finished spelling each word, the experimenter asked them to identify the letters they used to spell the word. In cases where the children's identified letters were not identical to those they wrote, what they said to be the letters was used as their spelling response. The order of presentation of the words was randomized for each child.

**Graphotactic task.** The experimenter first talked to the children about reading and words and used storybook reading, grocery list writing, and children's own name writing as examples of writing and words. The children were then presented with display pairs in a booklet, one pair at the time. For the test pairs, they were asked to point to the display that was a better word and was better for reading. For the filler pairs, they were asked to choose the object that was better for a particular purpose (e.g., eating, sleeping, and driving).

## Results

In this section, I first present the procedure used to identify prephonological spellers, that is, children who did not yet apply conventional sound-to-letter correspondences. I then report analyses that helped address questions regarding each of the four aspects of the constructivist perspective. The first analysis tested whether length of object represented by a word and number of syllables in the word influenced number of written marks in children's productions. The second set of analyses was conducted to see whether prephonological spellers understood the conventional orientation and directionality of writing in English. The last set of analyses concerned children's knowledge of the fact that words consist of varied letter shapes.

**Identification of Prephonological Spellers**

A technique used by Pollo et al. (2009) was adopted to classify children into groups of different spelling abilities. To identify prephonological spellers among children who orally reported some or all symbols in their written productions, each of their spelling responses was compared to phonologically plausible spellings of each target word. The phonologically plausible spellings of a target word included the correct spelling and spellings containing letters or letter groups that often correspond to the sounds of the target word in other words. The list of conventional phoneme-grapheme correspondences developed by Treiman and Kessler (2004, i.e., the AMPR scheme) was used to determine which spellings were phonologically plausible. The correspondence between the sound /i/ and the letter *i* was also included, given that *i* is an acceptable spelling of the sound in words like *macaroni* and *mosquito* (see Appendix 3 for the complete list of phoneme-grapheme correspondences used in the study). To name a few examples of phonologically plausible spellings, because *e*, *i*, and *y* are often used to represent the sound /i/, *betle*, *bitle*, and *bytle* are all phonologically plausible spellings of the word *beetle*. To gauge the extent of phonological plausibility of each spelling, the Levenshtein distance was computed between the spelling and each of the phonologically plausible spellings. The best distance was then used as the phonological plausibility score of each spelling. The Levenshtein metric kept track of all changes required to transform each spelling to a phonologically plausible one, ignoring extraneously inserted letters and counting1 unit of distance for each letter deletion, and 1 unit for each letter substitution. Letters were not required to be in the correct sequence. Higher Levenshtein distances indicate greater deviations from plausible spellings. For each child, the distance scores of all 24 spellings were summed. Because children could have produced a plausible spelling simply by guessing, their spellings were compared to chance-level

performance. In a Monte Carlo test (Good, 1994), the pairings between target words and each child's spellings were rearranged for 10,000 times and the fraction of the rearrangements that had a score as good as or better than each child's summed score was computed. If no less than 5% of the rearranged scores were as good as or better than a child's score, the child was considered to perform at a level expected by chance. Prephonological spellers were identified as children whose spelling scores were neither significantly better than chance nor more than 1% better than the average of rearranged scores. In addition, children who were not able to identify any of the letters they produced were also considered as prephonological spellers. Using these criteria, 34 prephonological spellers were identified. Data from these prephonological spellers were the focus of the present study. Table 1 shows the characteristics of the prephonological spellers.

**Scoring of Data**

Number of written elements in each production was used as the dependent variable for analysis on the effects of object length and syllable length. If a child did not correctly identify the letters he or she produced or did not produce conventional letters, number of written elements was counted as the number of marks that did not connect to any other marks within the same production. If a child was able to identify the letters he or she wrote and the letters were recognizable by judges, number of written elements was coded as the number of letters used to spell each word. Marks that the child explicitly identified as drawings were excluded from the coding of number of written elements. A second judge coded 25% of all the writing productions made by the prephonological spellers. The reliability between the two judges was high (ICC (2, 1) = .976, $p < .001$).

The orientation of each writing production was classified into one of the following four categories: horizontal, vertical, diagonal, or other. If a production was arranged along an

approximately horizontal line or approximately horizontal lines, the writing was coded as having a horizontal orientation. Similarly, if a production was along an approximately vertical line or approximately vertical lines, the production was coded as having a vertical orientation; productions with a diagonal orientation were those that were arranged along an approximately diagonal line or approximately diagonal lines. Productions that did not fall under any of the above three categories were coded as "other". Common examples of writing in this category were productions that were randomly scattered over the page and productions that consisted of only one letter or character. A second judge coded 25% of all the writing productions made by the prephonological spellers. Cohen's kappa was calculated to determine the inter-rater reliability. The reliability was high ($\kappa = .968$, $p < .001$).

For all writing that was produced along horizontal and vertical lines, the specific direction in which children produced the writing was coded, based on observations made during the spelling task. Specifically, horizontally arranged productions were coded as following a left-to-right, right-to-left, or inconsistent directionality; vertically arranged productions were coded as following a top-to-bottom, bottom-to-top, or inconsistent directionality.

**Knowledge of the Symbolic Function of Writing and Syllabic Spelling**

Preliminary analysis showed that there was a trend to use more elements to spell words representing long objects than those representing short objects. This trend approached statistical significance. With a relatively small number of prephonological spellers identified in the present study, it is possible that the analysis did not have sufficient power to detect possible effect of object length. To address this concern, spelling data from a previous study were combined with the present data to carry out the main analysis.

In the previous study, all the words used in the reading and spelling tasks were identical to those of the present study. While the procedures of the two studies were similar, two aspects of the previous study were different. First, during each trial of the previous study, children were presented with a simple picture with a girl and several objects and were told a sentence about what the girl was doing (e.g., "The girl is eating some delicious watermelon."). Children were then asked to repeat and spell the word representing one of the objects in the picture (e.g., the word *watermelon*). Second, instead of writing down their responses, children in the previous study were asked to spell using magnetic letters. During each trial, all 26 letters of the alphabet in the form of black magnetic letters were placed in a scrambled order in two rows. Children were asked to pick whichever letters that they thought were in each word. Following the same procedure outlined above, prephonological spellers from the previous study were identified based on magnetic spelling responses. Number of elements was simply number of magnetic letters used to spell each word.

All continuous variables (i.e., object length, syllable length, and number of elements for each of the two studies) were checked for normality of distribution using the Shapiro–Wilk test. The log-transformed values of object length ($W = .92$, $p < .001$) were more normally distributed than the raw values ($W = .24$, $p < .001$) and were therefore used for the analysis. Syllable length and number of elements did not show improvement in normality after the logarithmic transformation; the original values of syllable length and number of elements were used for the analysis.

Multilevel model analysis was conducted using the R software package lme4 (Bates, Maechler, Bolker, Walker, Christensen, & Singmann, 2014), with a linear mixed effects regression model. The model included separate intercepts for each participant and each item.

Object length and syllable length were included in the model as fixed factors. Because exploratory analyses showed that several other variables were likely to influence the number of elements children used to spell, these variables were also included as fixed factors in the model. These variables were day of testing (day 1 vs. day 2), order of word presentation (ranged from 1 to 12), and study (writing study vs. magnetic spelling study). The inclusion of the additional variables allowed one to examine whether effects of object length and syllable length would be found after controlling for other variables. To compute *p*-values for each of the fixed factors, the parametric bootstrap method implemented in the package pbkrtest (Halecoh & Højsgaard, 2013) was used. The parametric bootstrap approach samples data from fitted model under the hypothesis. Specifically, to obtain the *p*-value for a fixed factor, the full model was compared with a smaller model including all fixed factors but the particular factor of interest. For example, to compute the *p*-value for object length, the full model with participant and item as random effects and object length, syllable length, day of testing, order of word presentation, and study as fixed effects was compared with a model with participant and item as random effects and syllable length, day of testing, order of word presentation, and study as fixed effects.

Object length was found to have a significant effect on number of elements ($\beta = .03$, SE = .01, $p = .021$, see Figure 1), such that prephonological spellers used more elements to spell words representing long objects than those representing short objects. Syllable length had no effect on number of elements ($p = .850$); prephonological spellers used similar number of elements for words with different number of syllables. Day of testing was also significantly associated with number of elements ($\beta = -.46$, SE = .09, $p < .001$), such that children tended to use more elements on the first day ($M = 4.64$) than the second day ($M = 4.16$) of the spelling task. Similarly, there was an effect of order of presentation ($\beta = -.06$, SE = .01, $p < .001$); words

presented during the early trials were spelled with more elements than those presented during the late trials (see Figure 2). Moreover, children in the magnetic spelling study ($M$ = 5.51) used significantly more elements to spell words than those in the writing study ($M$ = 3.13, $\beta$ = 2.34, SE = .48, $p$ = .001), suggesting that spelling was not as taxing when letter shapes were readily available.

**Knowledge of Orientation and Directionality of Writing**

Table 2 presents the frequency and percentage of writing productions that were classified under each of the four writing orientations (i.e., horizontal, vertical, diagonal, and other). About half (49.76%) of the prephonological spellers' writing productions were along horizontal or vertical lines, both of which are conventional in some writing systems. A binomial test was conducted on the number of horizontally and vertically arranged productions to examine whether children were equally likely to arrange writing in these two manners. According to the binomial test, prephonological spellers produced horizontal lines of writing at a level significantly higher than the chance level of 50% ($M$ = .975, $p < .001$).

Table 3 shows the number and percentage of writing productions falling under each of category of directionality (i.e., left-to-right, right-to-left, top-to-bottom, bottom-to-top, and inconsistent). Given the rare occurrences of productions along vertical lines, the analysis focused on the directionality of horizontally arranged productions. A binomial test was conducted to investigate whether children followed the left-to-right directionality as often as right-to-left directionality. The mean proportion of productions written from left to right ($M$ = .924) was significantly higher than the chance level ($p < .001$), suggesting that the prephonological spellers had learned about the conventional directionality of the English writing system.

### Knowledge About Within-word Variation

The next part of the analysis was run to test whether prephonological spellers' preference for displays in the graphotactic task was related to type of variation (shape vary vs. color vary). For each display pair, children's response was coded as whether or not choosing the item with variation as acceptable writing. Table 4 shows the proportion of choosing displays with variation for both variation types. In the R package lme4 (Bates et al., 2014), a generalized linear mixed-effects model with a logit link function was selected for this analysis, because the dependent variable was binary. The model included participant and item as random effects, and type of variation (shape vary vs. color vary) as a fixed effect. The effect of pair type was not significant ($p = .220$), such that prephonological spellers were equally likely to accept displays with shape variation and displays with color variation as writing. A binomial test was conducted on all responses collapsing across the two variation types to test whether children's tendency to choose displays with variation was higher than the chance level of 50%. The test showed that prephonological spellers chose displays with variation at a level significantly higher than the chance level ($M = .612$, $p < .001$).

## Discussion

According to the constructivist perspective, young children formulate and test their own hypotheses about the nature of writing long before they learn to read and write. The present study was designed to address the following questions that grew out of the constructivist views on what young children know about writing: 1) Do children use writing to directly represent meaning, such that they use more written elements to spell words denoting long objects than those denoting short objects? 2) Do children believe that writing corresponds to speech at the level of syllables and spell words with more syllables using more written characters? 3) Do

children understand such language-specific properties as orientation and directionality of print? 4) Do children privilege variability in symbol shape, a writing-specific characteristic, over variability in other dimensions like color? Children who had not grasped phoneme-to-grapheme mappings (i.e., prephonological spellers) were the focus of the present study.

**Knowledge of the Symbolic Function of Writing**

Prephonological spellers in the present study produced more marks to spell words representing long objects than those representing short objects. With a different type of task (i.e., production task), the present study found evidence consistent with that of previous studies using recognition tasks (e.g., Bialystok, 1991; Lundberg and Tornéus, 1978; Papandropoulou & Sinclair, 1974). The present finding provides additional support for the constructivist notion that children conceive of writing as direct representation of meaning. Unlike previous studies, words were aurally presented one at a time without accompanying stimulus. This design ruled out the possibility that the presentation of pictures or words referring to objects of contrasting sizes made semantic attributes especially accessible to children. Children's reliance on semantic content of words, therefore, appeared to be an internal and automatic process.

The relation between writing and meaning is indirect: Writing represents spoken language, which, in turn, represents meaning (Vygotsky, 1978). Grasping this indirect relation is hard for young children. Children may not consider spoken language as something that can be represented. Moreover, the relation between words and meaning is arbitrary; there is little or no resemblance between characteristics of objects and those of spoken or written words. On the other hand, realistic pictures resemble objects they represent. Given their frequent exposure to realistic pictures and drawings, young children may assume that all types of symbols are iconic representation of objects. Children have to abandon this early idea, in order to acquire the

symbolic function of writing. In the present study, the effect of object length on number of written marks is relatively small, suggesting that children may not consistently rely on the meanings of words when they spell. Indeed, written words rarely look like the denoted objects; children are frequently exposed to examples of writing that are inconsistent with their own belief. Children may gradually alter their belief after encountering accumulated discrepant evidence.

**Syllabic Spelling**

Contrary to the constructivist view that young children use writing to represent language at the level of syllables, no evidence of syllabic spelling was found in the present study. Contrary to the finding that English-speaking children passed through a syllabic stage (Vernon, 1993), the prephonological spellers in this study produced no more marks to spell words with more syllables than those with fewer syllables. This finding is in line with results from previous studies focusing on English-speaking children's spelling (Kamii et al., 1990; Pollo et al., 2009). Ferreiro and Teberosky (1982) argued that the symbols children assign to syllables may neither have conventional letter shapes nor represent plausible spellings of a word. In the present study, all written marks including nonconventional letter shapes were coded and analyzed. If young children who do not yet have good letter knowledge use unconventional characters to represent syllables, participants in this study would be expected to produce more written elements for words with more syllables. However, even with a coding system that captured all types of written marks, no evidence of syllabic spelling was found. Arguing against the presence of a syllabic stage, Cardoso-Martins et al. (2006) proposed that previous evidence for syllabic spelling resulted from children's partial ability to represent phonemes with corresponding graphemes. The present finding is in line with Cardoso-Martins et al.'s proposed nature of syllabic spelling. Children who were identified as prephonological spellers, by definition, had

not acquired conventional phoneme-to-grapheme correspondences. Indeed, these prephonological spellers' use of written elements did not vary as a function of syllable length.

**Knowledge of Orientation and Directionality of Print**

Focusing on children's knowledge of orientation and directionality of writing, the present study also attempted to test predictions regarding how children acquire characteristics of their writing system. According to the differentiation hypothesis proposed by adherents of the constructivist perspective (e.g., Tolchinsky, 2003), universal properties of writing (e.g., linear arrangement) stem from the representational nature of writing and are relatively easy for children to learn. Characteristics specific to a particular writing system are arbitrary and take a relatively long time for children to acquire (Brenneman et al., 1996; Puranik & Lonigan, 2011). Orientation of print is a script-specific property; young children who have not acquired this property are expected to arrange writing horizontally as often as vertically. However, results from this study did not support this hypothesis: Prephonological spellers were significantly more likely to produce writing with horizontal arrangement, which is characteristic of the English writing system, than writing with vertical arrangement, which is conventional in some other writing systems. Similarly, prephonological spellers wrote in the left-to-right direction much more often than in the right-to-left direction. Such evidence demonstrates that even young children have acquired some characteristics specific to their writing system. The present study extended previous results from recognition studies (Treiman et al., 2007; Treiman et al., 2014) using a production task. Young children showed some understanding of their writing system, even when their ability was tested with a cognitively taxing production task.

The present findings regarding children's understanding of the orientation and directionality of the English writing system are consistent with another perspective of literacy

development, the statistical learning view. The statistical learning perspective emphasizes children's implicit learning of common and co-occurring patterns in their environment. In the domain of spoken language, even infants and young children are able to abstract certain patterns and use them under similar circumstances in the future (e.g., Saffran, Asin, & Newport, 1996). Young children also use this general learning mechanism to learn about graphic properties of wring (Pollo et al., 2009; Pollo, Treiman, & Kessler, 2008). Attending to common features in the print to which they are frequently exposed, young children gradually internalize and reproduce such features in their own writing. Consistent with this idea is the finding that the largest amount of print (about 80% of storybook pages contained all horizontal arrangement, Treiman et al., 2014) that U.S. preschoolers encounter is horizontally arranged. Vertical lines of print are extremely rare in books for children. To learn about graphic properties such as orientation and directionality of writing, children do not seem to rely on their knowledge of the symbolic function of writing, but use their statistical learning ability to pick up patterns in their environment.

**Knowledge about Within-word Variation**

Turning to results from the graphotactic task, when presented with two nonword displays and asked which of the two was better for reading, the prephonological spellers were significantly more likely to pick the display containing varied letters (e.g., ‹DWP›) than the one containing repeated letters (e.g., ‹DDD›). In this light, with more tightly controlled stimuli and a statistically rigorous method of classifying children's alphabetic knowledge, the present study replicated previous finding that children considered nonword items with varied letters as acceptable writing (Lavine, 1977; Levy et al., 2006).

One additional goal of the present study was to test whether children's preference for items with variation reflect their knowledge specific to writing. In some trials, displays consisting of identical letters in different colors were pitted against displays consisting of the same identical letters all in one color. Interestingly, children were more likely to choose displays with varied colors than those with a same color. Moreover, children were equally likely to pick items with variation for both "shape vary" trials and "color vary" trials. While variability in letter shape has to do with the symbolic nature of writing and is an intrinsic property of writing, variability in color is not normally observed in writing. If young children have some knowledge about writing, they would be expected to prefer displays with shape variation over those with color variation. The present finding suggests that, in this case, young children may not truly possess writing-specific knowledge. Their tendency to pick displays that vary in some dimension as writing could have resulted from their general perceptual preference. It is also possible that prephonological spellers have picked up certain characteristics of writing on a visual basis and therefore believe that there needs to be some kind of variability in writing. However, because these children have not grasped the idea that writing represents language, they do not understand why variability in a specific dimension (i.e., shape) is important for writing, therefore failing to distinguish between different types of variability.

Potential follow-up questions to ask are whether and how attractiveness of nonword displays perceived by children might influence their choices in the graphotactic task. Researchers who used forced-choice tasks to examine children's understanding of writing (e.g., Lavine, 1977; Levy et al., 2006) have typically assumed that both displays on each trial are equally likely to be chosen. However, although children are asked to pick the display that is more acceptable as writing, their choices might be biased by the physical appearance of the displays. For example,

the high proportion of choosing items with color variation may partially be due to the attractiveness of such items. One way to verify this possibility is to present children with the very same stimuli and ask them to pick the item that looks pretty. It is possible that children would be much more likely to pick items with color variation in this physical appearance condition than in the writing condition. Such evidence would suggest that young children do have some writing-specific knowledge, despite their tendency to be biased by features not inherently related to writing. This speculation awaits future investigation.

**What Does the Constructivist Perspective Tell and Not Tell Us?**

The present study examined three aspects of the constructivist view of early literacy development. Constructivists postulated that even young children's writing is patterned and guided by children's own beliefs about the nature of writing (Ferreiro & Teberosky, 1982). While constructivists' recognition of children's early knowledge of writing deserves merit, some aspects of their proposal may lack sound empirical support. For example, children who have not grasped alphabetic knowledge may not produce spellings that represent spoken words at the syllable level. Previous evidence of syllabic spelling may be attributed to young children's partial ability to map some sounds to corresponding letters. Children do not appear to learn about universal properties of writing before language-specific ones; instead, they are sensitive to the patterns in their environment. Moreover, constructivists have interpreted children's preference for displays with varied letters as evidence for children's understanding of writing. Children's tendency to accept displays with varied colors as writing seems to speak against constructivists' interpretation. Children's preference for items with some kind of variation may result from non-writing-related features such as physical attractiveness.

Another potential issue with the constructivist perspective has to do with the proposal that children construct their own hypotheses about writing and that the formulation of such hypotheses largely depends on children's own thinking and input. Indeed, even young children hold beliefs and expectations about writing. Such expectations could be inferred from children's invented spellings or responses to recognition tasks like the present graphotactic task. However, children's formation of beliefs is likely to be determined by the environment to which they are exposed and their domain-general learning mechanisms such as statistical learning. Relating the statistical learning perspective to the present findings, young children's idea that writing directly represents meaning could have resulted from their frequent exposure to another symbolic system, photography. Having abstracted the pattern that symbols directly represent concept from their exposure to realistic pictures, young children generalize this relation to writing. As they gain more experience with writing, they would learn patterns that are important for writing and finally grasp the symbolic function of writing. Children also use their statistical learning to explore graphic properties of writing before they grasp the alphabetic principle. For example, even young children are sensitive to features such as orientation and directionality of print. Statistical learning therefore plays an important role in children's understanding of different aspects of writing. Of course, statistical learning is influenced by characteristics of specific patterns in children's environment. For example, the horizontal arrangement of words is a particularly salient feature that facilitates children's statistical learning. The pattern that letter shapes do not repeat within a word may require relatively close attention and take longer for children to acquire.

One limitation of the present study is that children's spellings were examined at only one time point. It is possible that some children had demonstrated syllabic spellings prior to the time of this study or would go on to show syllabic spellings after this study. Future studies could use a

longitudinal approach (e.g., Treiman et al., 2013) to better track the development of possible syllabic spellings among English-speaking children.

The constructivist perspective acknowledges children's incipient understanding of writing. Indeed, even at early ages, children appear to understand different properties such as orientation and directionality of their writing system. Such early knowledge may serve as important foundation for literacy development. Prephonological spellers' early sensitivity to graphic patterns of writing (e.g., letter frequency and bigram frequency) was found to predict their later spelling performance (Kessler et al., 2013). Children's early understanding of other aspects of writing may also have some predictive power. Insights into children's early beliefs about writing therefore not only allows better understanding of how children gradually acquire literacy skills, but could also have implications for early detection of children who may have difficulties learning to read and spell.

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Table 1

*Information about Prephonological Spellers in the Writing and Magnetic Spelling Studies*

| | Writing production study (n = 34) | | Magnetic spelling study (n = 41) | |
|---|---|---|---|---|
| | Mean (range) | SD | Mean (range) | SD |
| Age | 4;1 (3;4 – 5;4) | 0;6 | 4;7 (3;3 – 5;8) | 0;6 |
| Number of words read (maximum = 20) | 0.44 (0 – 13) | 2.23 | 0.27 (0 – 4) | 0.71 |
| Number of written elements | 3.13 (1 – 21) | 2.41 | 5.49 (1 – 17) | 3.16 |

Table 2

*Frequency Count and Percentage of Writing Productions in Each Category of Orientation*

| Orientation | Frequency count | Percentage (%) |
|---|---|---|
| Horizontal | 395 | 48.41 |
| Vertical | 11 | 1.35 |
| Diagonal | 70 | 8.58 |
| Others | 340 | 41.66 |

Table 3

*Frequency Count and Percentage of Writing Productions in Each Category of Directionality*

| Directionality | Frequency count | Percentage (%) |
|---|---|---|
| Left-to-right | 351 | 86.45 |
| Right-to-left | 28 | 6.90 |
| Top-to-bottom | 2 | 0.49 |
| Bottom-to-top | 5 | 1.23 |
| Inconsistent | 20 | 4.93 |

Table 4

*Proportion of Selections of Display with Variation in the Graphotactic Task*

| Type of variation | Mean | SD |
|---|---|---|
| Shape variation | .59 | .49 |
| Color variation | .64 | .48 |

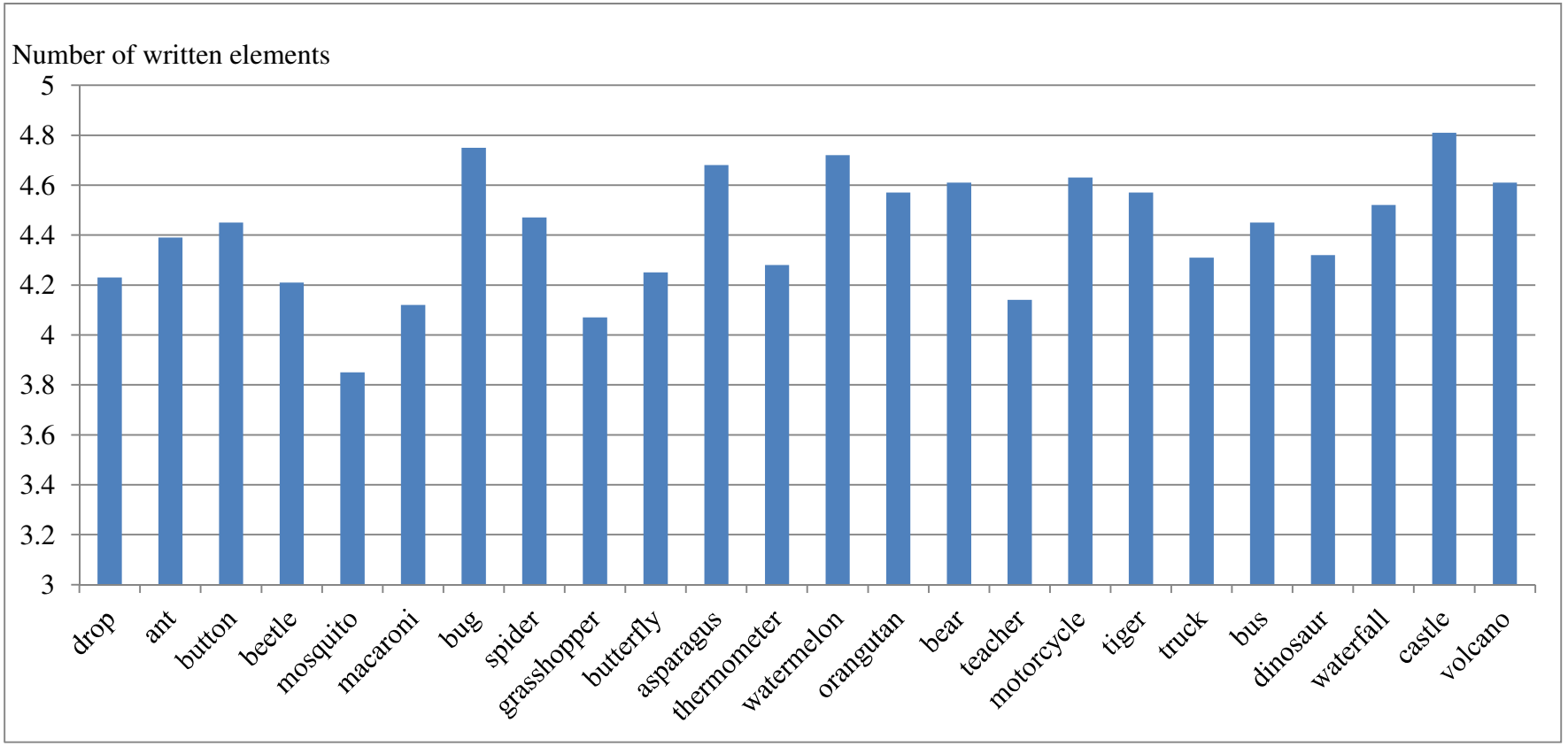


*Figure 1*. Number of written elements as a function of object length.

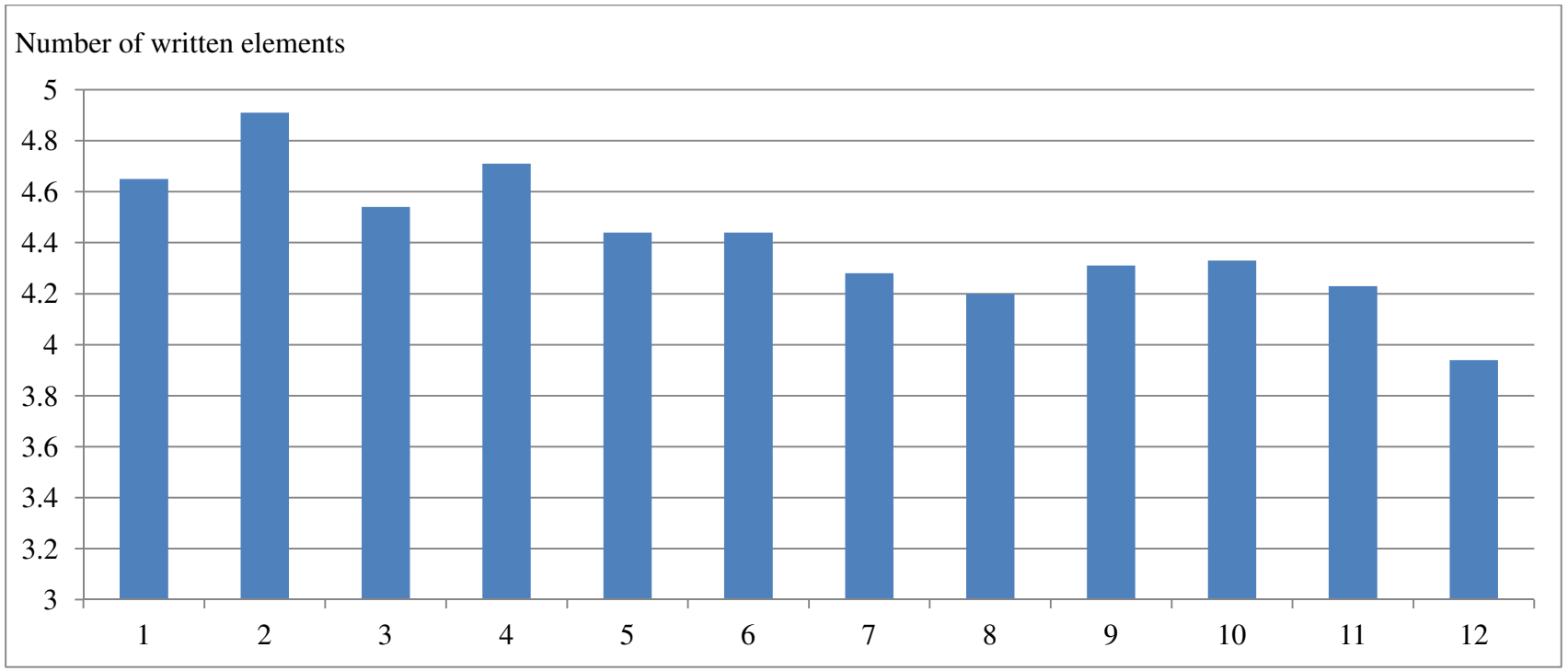


*Figure 2.* Number of written elements as a function of order of presentation of words.

Appendix 1

*Words and Sentences Used in the Spelling Task*

| Word | Object length (in meters) | Number of syllables | Sentence | Position of target word in sentence |
|---|---|---|---|---|
| ant | 0.007 | 1 | An ant is walking on the table. | 2 |
| asparagus | 0.114 | 4 | Eating asparagus is good for our body. | 2 |
| bear | 0.875 | 1 | A bear jumps out of the forest. | 2 |
| beetle | 0.015 | 2 | A beetle is sleeping in the grass. | 2 |
| bug | 0.025 | 1 | Jimmy chases a bug flying around him. | 4 |
| bus | 12 | 1 | John takes a bus to his school. | 4 |
| butterfly | 0.1 | 2 | A butterfly is resting on the flower. | 2 |
| button | 0.042 | 2 | Nancy loses a button on her shirt. | 4 |
| castle | 108 | 2 | Lily builds a castle with her friends. | 4 |
| dinosaur | 24 | 3 | A dinosaur is getting close to Anna! | 2 |
| drop | 0.006 | 1 | Cindy drinks a drop of apple juice. | 4 |
| grasshopper | 0.042 | 3 | A grasshopper is jumping on the floor. | 2 |

| | | | | |
|---|---|---|---|---|
| macaroni | 0.019 | 4 | Susan had some macaroni for her lunch. | 4 |
| mosquito | 0.016 | 3 | Laura sees a mosquito biting her arm. | 4 |
| motorcycle | 2.1 | 4 | Chuck rides a motorcycle to the mall. | 4 |
| orangutan | 1.1 | 4 | An orangutan is happily eating a banana. | 2 |
| spider | 0.0064 | 2 | A spider is sitting on its web. | 2 |
| teacher | 0.35 | 2 | Our teacher is telling a long story. | 2 |
| thermometer | 0.16 | 4 | Mommy uses a thermometer when I'm sick. | 4 |
| tiger | 3 | 2 | A tiger is running in the cage. | 2 |
| truck | 5.685 | 1 | Daddy drives a truck to the store. | 4 |
| volcano | 1281 | 3 | A volcano may erupt at any time. | 2 |
| waterfall | 37 | 3 | Julia visited a waterfall during her holidays. | 4 |
| watermelon | 0.229 | 4 | Dan eats a watermelon with his family. | 4 |

| | | | | | |
|---|---|---|---|---|---|
| Mean | 62.09 | 2.5 | – | | – |

Appendix 2

*Stimuli Used in the Graphotactic Task*

| Shape variation trials | | Color variation trials | |
|---|---|---|---|
| Variation | No variation | Variation | No variation |
| dwp | ddd | ddd | ddd |
| lfc | lll | lll | lll |
| pqj | ppp | ppp | ppp |
| syz | sss | sss | sss |
| tjy | sss | ttt | ttt |
| bymq | bbbb | bbbb | bbbb |
| czxv | cccc | cccc | cccc |
| fwyx | ffff | ffff | ffff |
| gyxz | gggg | gggg | gggg |
| ncbv | nnnn | nnnn | nnnn |

*Appendix 3*

*Phoneme–grapheme Correspondences Used for the Identification of Prephonological Spellers*

| Stimulus | Response(s) |
|---|---|
| a□ | i, y |
| a□ | o |
| b | b |
| b□ | b, p |
| d | d |
| d□ | g, j |
| d□ | d, g, j |
| d□ | d, t |
| d□□ | c, d, g, j |
| e | a |
| f | f |
| g | g |
| g□ | c, g, k, q |
| h | h |
| i | e, i, y |
| j | y |
| k | c, k, q |
| l | l |
| m | m |
| n | n |

| | |
|---|---|
| o | o |
| p | p |
| r | r |
| s | c, s |
| t | t |
| t□ | c |
| t□ | c, t |
| u | o, u |
| v | v |
| w | w, y |
| z | s, z |
| æ | a |
| ð | t |
| ŋ | n |
| □ | a, o |
| □ | a, o |
| □□ | o |
| ə | |
| □ | r |
| □ | a, e |
| □ | r |
| □ | g |
| □□ | c, g, k, q |

| | |
|---|---|
| □ | i |
| □ | d, t |
| □ | s |
| □ | o, u |
| □ | u |
| □ | s |
| θ | t |

Appendix 4

*Examples of Prephonological Spellings*

| Child | Word | Spelling response |
|---|---|---|
| 1 | asparagus | llllollllllccy |
| 1 | bear | luuuuuuuccy |
| 1 | beetle | lucy |
| 1 | button | luuuucy |
| 1 | castle | ly |
| 1 | orangutan | llyy |
| 2 | asparagus | sd |
| 2 | beetle | ds |
| 2 | bug | ss |
| 2 | button | ds |
| 2 | truck | ds |
| 2 | waterfall | sd |
| 3 | bear | tith |
| 3 | beetle | giit |
| 3 | drop | zsitth |
| 3 | grasshopper | mtii |
| 3 | teacher | itoot |
| 3 | tiger | ittig |
| 4 | castle | prea |
| 4 | mosquito | darpe |

| | | |
|---|---|---|
| 4 | orangutan | rdd |
| 4 | tiger | mloyco |
| 4 | truck | drpe |
| 4 | volcano | adr |
| 5 | button | tielfmt |
| 5 | grasshopper | lam |
| 5 | mosquito | lan |
| 5 | motocycle | famel |
| 5 | thermometer | lanlef |
| 5 | waterfall | lmple |