Learning of letter names follows similar principles across languages: Evidence from Hebrew

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Abstract

Letter names play an important role in early literacy. Previous studies of letter name learning have examined the Latin alphabet. The current study tested learners of Hebrew, comparing their patterns of performance and types of errors with those of English learners. We analyzed letter-naming data from 645 Israeli children who had not begun formal reading instruction: a younger group (mean age 5 years 2 months) and an older group (mean age 6 years 2 months). Children's errors often involved letters with similar shapes or letters adjacent to one another in the alphabet. Most Hebrew letter names are not very similar to one another phonologically, and there were fewer phonologically based confusions than in English. We found both general frequency effects and frequency effects that reflected the letters in individual children's names. On average, girls knew more letter names than did boys. The results suggest that letter name learning follows similar principles across languages.
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Introduction

Children in literate societies are surrounded by print from an early age. They start to learn about some aspects of their writing system even before formal instruction in reading

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and writing begins. For example, children learn that writing is composed of units that are arranged along a line and that writing differs from drawing in these and other ways (e.g., Levin & Bus, 2003). Children also learn that people refer to the units of writing by conventional names. The first (leftmost) letter of *BOOK* is called /bi/, for example, and the first (rightmost) letter in the Hebrew equivalent ספר /sefer/ is called /samex/. (For an explanation of the phonetic symbols used in this article, see International Phonetic Association, 1999.) Preschoolers learn about the names of letters through activities such as singing songs that include the letter names and talking with parents about the letters in their own names and other words (e.g., Aram & Levin, 2002; Levin & Aram, 2004). In the work reported here, we focused on letter names as one important aspect of emergent literacy.

At first, children appear to learn about the names of letters in much the same way as they learn about other words in the vocabulary of their language (Treiman, Kessler, & Pollo, 2006). The link between the phonological form /bi/ and the shape B is arbitrary, just like the link between the label /skwɛr/ and the shape □. Both links must be memorized. After letter names are known, however, children can learn from the names in a way that they cannot learn from labels such as *square*. Children can use the fact that most letter names are phonetically *iconic; that is,* letter names contain the sounds that the letters represent (Treiman & Kessler, 2003). English-speaking children can use their knowledge of the name of *B* to help learn that this letter stands for /b/, and Hebrew-speaking children can use their knowledge of the name of ס, /samex/, to help learn that this letter has the sound /s/ (e.g., Levin, Shatil-Carmon, & Asif-Rave, 2006; Share, 2004; Treiman, Tincoff, Rodriguez, Mouzaki, & Francis, 1998). Knowledge of letter names appears to boost phonemic sensitivity as well as knowledge of letter sounds, thereby promoting the acquisition of alphabetic literacy (for a review, see Foulin, 2005). Given the role of letter names in the development of reading and spelling, we need to learn more about how children acquire their knowledge of letter names in the first place. Such work can inform us about the processes involved in letter name learning and the factors that influence performance. The findings should have practical applications as well, for example in designing curricula for young children.

Much of the existing data on young children's learning of letter names come from children in the United States. For example, researchers have examined the numbers of letter names known by U.S. children of different ages and have compared performance on uppercase and lowercase letters (e.g., Worden & Boettcher, 1990). Researchers have also examined the factors that make some letter shape–letter name pairs easier for children to learn than other letter shape–letter name pairs (e.g., Treiman & Kessler, 2003). Before drawing strong conclusions about the factors that affect children's learning of letter names, however, it is important to examine children outside the United States. We must ensure that our conclusions are not limited to one particular alphabet, language, or culture.

Treiman and colleagues (2006) carried out an initial cross-linguistic study of letter name learning by examining English-speaking children in the United States and Portuguese-speaking children in Brazil. Data were collected on a letter-naming task from more than 300 children in each country. The analyses reported by Treiman and colleagues focused on *replacement errors,* that is, cases in which children mistakenly labeled one letter with a name that was appropriate for another letter. For example, children sometimes called *W* by the name of *M*, an error that reflects the similarity between these letters' shapes. However, visual similarity was not the only factor that influenced replacement errors.

Phonological similarity was influential as well in that children were especially likely to confuse a pair of similar-looking letters if their names were also similar, as with *B* and *D*. This led to some differences in the specific errors committed by U.S. and Brazilian children because letters that have similar names in one language do not always have similar names in the other language. Performance was also affected by letter frequency, both general frequency and occurrence of letters in individual children's own names. The U.S. children, but not the Brazilian children, were significantly more likely to confuse letters that were adjacent to one another in the alphabet than to confuse letters that were not adjacent to one another. For example, U.S. children sometimes called *F* by the name of *G* even though these letters are not very similar in their shapes or names.

The results of Treiman and colleagues (2006) suggest that the early learning of letter names follows many of the same principles that apply to vocabulary learning in general. One important part of vocabulary learning is identifying which objects should be placed in the same category and given the same label. With letters, as with many concrete objects, children appear to form their categories largely on the basis of shape (e.g., Clark, 1993). Another important ingredient of vocabulary learning is frequency of exposure, with repetition being required to fix arbitrary associations in memory. With letters, some aspects of frequency apply to all children (children generally have more opportunities to learn about the name of *O* than about the name of *Q*) and some aspects are individual (a child named Zoe has more opportunities to learn about *Z* than do other children). Because languages differ in their letter names, letter frequencies, and other factors, the specific letters that are confused most often in one country are not necessarily the same letters that are confused most often in another country. However, Treiman and colleagues (2006) suggested that the same general principles explain the patterns.

Stronger support for the idea that the same factors affect the learning of letter names across languages would come from studying a script different from that used by the English and Portuguese languages examined by Treiman and colleagues (2006). Both English and Portuguese use letters of the Latin alphabet. The U.S. and Brazilian names of the letters are similar in some respects, deriving as they do from the Latin names. The similar results that Treiman and colleagues found for English and Portuguese might reflect these superficial similarities rather than deeper properties of the learning process. In the current study, we examined Hebrew-speaking children's knowledge of letter names and compared the results with those for U.S. children. Hebrew is of interest because its letter shapes and system of letter naming differ substantially from those of the Latin alphabet. If Israeli children's learning of letter names is affected by similar factors as in the earlier studies with Latin letters, this would implicate deeper properties of the learning process. In what follows, we discuss the linguistic and cultural factors that may affect Israeli children's learning of letter names.

The first three columns of Table 1 show the names, shapes, and sounds of the Hebrew letters. Hebrew has four letters (ב, כ, פ, and שׁ) that sometimes are named differently depending on what sounds they make in particular words—differences that are reflected in the presence or location of a dot in the pointed text that is widely used for young children. The basic names for these letters are /bet/, /kaf/, /pei/, and /ʃin/, but they occasionally may be called /vet/, /xaf/, /fei/, and /sin/ when specifically alluding to their pronunciation as /v/ rather than /b/ and so on.

Another characteristic of Hebrew that is apparent from Table 1 is that certain letters (כ /kaf/, מ /mem/, נ /nun/, פ /pei/, and צ /tsadik/) have special shapes when they are found at

Table 1
Name(s), shape in font used in the current study, and sound(s) of each Hebrew letter together with replacement errors that occurred more than 10 times, pooling over younger and older Israeli children, in decreasing order of frequency

Name(s)	Shape	Sound(s)	Replacement errors
Basic letter forms			
alef	א	silent, /a/	--
bet, vet	ב	/b/, /v/	ג gimel
gimel	ג	/g/	ד daled
daled	ד	/d/	ג gimel, ר reʃ, ו vav, ז zajin
hei	ה	/h/, /a/, /e/, /o/, silent	ד daled, ג gimel
vav	ו	/v/, /u/, /o/	נ nun, ר reʃ, ד daled, ז zajin, י jud, ן nun sofit
zajin	ז	/z/	ו vav, ד daled, נ nun, י jud
xet	ח	/x/	כ kaf, ה hei, ט tet
tet	ט	/t/	ח xet, מ mem, פ pei, ד daled, ה hei
jud	י	/j/, /i/, /e/, /ei/	נ nun
kaf, xaf	כ	/k/, /x/	ב bet, ג gimel, ס samex, נ nun, ק kuf
lamed	ל	/l/	ד daled, ג gimel
mem	מ	/m/	--
nun	נ	/n/	ב bet, ג gimel, ד daled
samex	ס	/s/	ג gimel
ajin	ע	silent	ש ʃin, ז zajin, ג gimel, צ tsadik
pei, fei	פ	/p/, /f/	ג gimel, מ mem, ש ʃin
tsadik	צ	/ts/	ע ajin, א alef, ה hei
kuf	ק	/k/	ר reʃ, פ pei
reʃ	ר	/r/	ד daled, ו vav, ש ʃin
ʃin, sin	ש	/ʃ/, /s/	ר reʃ, ד daled
taf	ת	/t/	ח xet, ד daled, ג gimel, ט tet
Word-final letter forms (name is typically followed by the word /sofit/ *'final')*			
kaf, xaf	ך	/x/	ר reʃ, ו vav, ן nun sofit, נ nun, ש ʃin
mem	ם	/m/	ס samex, מ mem
nun	ן	/n/	ז zajin, ו vav, נ nun, ג gimel
pei, fei	ף	/f/	פ pei, ץ tsadik sofit
tsadik	ץ	/ts/	ג gimel, צ tsadik, ע ajin, ז zajin

Note. Minor variants in pronunciations of certain letter names are not listed.

the end of a word (ך, ם, ן, ף, and ץ). Position-based alternations in shape are not unique to Hebrew. In Arabic, most letters have two or three distinct forms depending on their position in a word, and the Greek letter sigma, σ, has the special form ς at the end of a word. The names of final letters in Hebrew usually are distinguished from the names of the corresponding nonfinal letters by adding the qualifier /sofit/ 'final' as in /mem sofit/. (This qualifier is stressed on the second syllable, unlike the basic letter names, all of which have first-syllable stress.) The final letters present unusually severe issues with visual identification. Most of them are quite similar to certain other letters, and some of them are distinguishable from other letters only because they extend a bit below the line of print—a cue that was not available in the current study, where children saw letters one at a time on unruled cards. This, together with the fact that most Hebrew letters do not

have a final version and the fact that the final forms are not separately included in alphabet songs and early alphabet books, may be responsible for the difficulties that Israeli children have in naming final letters (Levin, Patel, Margalit, & Barad, 2002).

Hebrew differs from English in the phonological properties of its letter names. In English, as in many other languages, letter names typically contain one or two phonemes and are markedly shorter than most other words of the language. In Hebrew, many letter names are disyllabic, and even the monosyllabic names often contain three phonemes. Hebrew letter names are also less phonologically similar to one another than are the letter names of most other languages. Even when Hebrew letter names share a phoneme, such as the /e/ in /mem/ and /bet/, there typically are two or more other unshared phonemes as well. The Hebrew alphabet does not include any large set of highly similar letter names like the English *B*, *C*, *D*, *G*, *P*, *T*, *V*, and *Z*, whose names differ only in their initial phoneme, or *F*, *L*, *M*, *N*, and *S*, which are identical except for the last phoneme. (The largest such set in Hebrew is *bet*, *tet*, and *xet*.) The letter names of Hebrew are similar to one another in some ways. All disyllabic names have stress on the first syllable, as mentioned above, and the /CaCeC/ (where C = consonant) pattern that is found in several letter names is otherwise rare. But the phonological similarities among the names are less marked than in many other languages, and the letter names are not very different from the normal words of the language. Like Greek, Hebrew retains the original Semitic letter names, which are mostly words for concrete objects whose names begin with the same letters; for example, the name of the letter א originally was אלף /alp/ 'ox'. Because Hebrew is very similar to the language in which those letter names were first developed and has lightly modified the letter names to conform to its own sound system, Hebrew letter names sound much like ordinary common nouns. In contrast, the Latin letter names used in English are fundamentally just the letter sounds themselves, usually with a single vowel added to make them more pronounceable.

A look at the letter shapes in Table 1 suggests that the possibilities for visual confusion are not confined to the five word-final letter forms. Most Hebrew letters are formed in a block-like architecture, with a predominance of very similar horizontal and vertical strokes. There are few distinctive curves and diagonals as there are with Latin letters. Indeed, several authorities have suggested that Hebrew letters resemble one another more than do Latin letters (e.g., Sampson, 1985). We examined the effects of this visual similarity on children's letter identification in the current study.

The relations between the names and the sounds of letters are different in Hebrew than in English. Hebrew letter names are generally acrophonic; letter names begin with the sounds that the letters spell. There are several letters that can represent vowels as well as consonants, as Table 1 shows, but these letters nearly always have the acrophonic pronunciations when they occur at the beginning of a word, the position that is most salient to children. In English, in contrast, the names of a few letters do not contain the phonemes that the letters typically represent. For example, the name of *H*, /etʃ/, does not contain /h/. For those letter names that do contain the sounds, the sounds may be at the end of the letters' names, as with *M* and *L*, rather than at the beginning. The results of Treiman and colleagues (2006) suggest that young children are not influenced by the sound-symbolizing function of the letters when they first learn their names, but this is a factor that could influence them later and so is another difference that needs to be considered in comparing Hebrew with other languages.

In addition to the linguistic differences between the Hebrew and English letter name systems, there are cultural differences in how children in Israel and the United States are exposed to letters and differences in education prior to first grade. In the state schools that serve the

majority of Israeli children, children typically enter a preschool class the September after they turn 4 years old and enter a kindergarten class a year later. Children enter first grade the fall after they turn 6 years old, at which time formal literacy instruction begins. Traditionally, teaching of letters prior to first grade was frowned on in Israel. At the time the current data were collected, most preschools and kindergartens in Israel did not view teaching children about letters as an educational aim. In addition, Israeli and U.S. parents have different attitudes. Many U.S. parents feel that their children should be able to identify at least some letters when they begin kindergarten. Parents encourage their preschool children to learn the alphabet through activities such as singing the alphabet song, watching educational television programs, and playing with blocks in the shapes of letters. Many Israeli parents traditionally have placed less emphasis on such activities. For example, although there are Israeli alphabet songs, they are not as widespread as the alphabet song in the United States. A small percentage of boys attend a school system serving some religious sectors in which they start learning about letters and reading when they are approximately $3\frac{1}{2}$ years old. However, we did not test children from these schools in the current study.

Given the linguistic and cultural differences between Israel and the United States, it is of interest to compare the letter name knowledge of Israeli children with that of U.S. children. We assessed Israeli preschoolers' knowledge of letter names using a procedure similar to that of Treiman and colleagues (2006), showing children each letter of the alphabet and asking them to provide its name. We compared their results with those of the U.S. children tested by Treiman and colleagues. The current article includes some analyses of the U.S. data that were reported previously as well as a number of new analyses that are parallel to the analyses reported for Hebrew.

Method

Israeli procedure

The Israeli children were shown each letter of the Hebrew alphabet and were asked to provide the letter's name. Each letter was printed on a separate unruled card using a bold Aharoni font like that I shown in Table 1. The letters were approximately 55 mm high. The cards were presented one at a time in a scrambled order that differed from one child to the next. Several cards with simple drawings on them were interspersed with the letters. Children were asked to name the drawings to provide experiences of success and to preserve motivation. Children were tested individually in a quiet location at their school. All 27 Hebrew letters were presented in a single session. The experimenter encouraged children to give a response to each letter.

Israeli participants

We analyzed data from a total of 645 children recruited from state schools attended by Hebrew-speaking preschoolers and kindergartners in Israel. Children were sampled from a variety of preschools and kindergartens that served different socioeconomic classes. The majority of the schools were located in urban areas, although some were in rural areas. Most of the participants studied in classrooms composed of preschoolers and kindergartners, with both age groups being exposed to the same curriculum by the same teacher. For

Table 2
Information about groups of Israeli children and U.S. comparison children

Measure	Younger Israeli group	Older Israeli Group	U.S. children
N	325	320	318
Mean age	5 years 2 months	6 years 2 months	4 years 8 months
Age range	3 years 11 months to 5 years 9 months	5 years 10 months to 6 years 11 months	3 years 11 months to 5 years 9 months
Proportion boys[a]	.46	.49	.48
Proportion of correct responses to all letters	.41 (.33)	.66 (.28)	.64 (.36)
Proportion of correct responses to nonfinal Hebrew letters	.47 (.36)	.74 (.29)	
Proportion of responses that are names of letters other than the presented letter	.26 (.29)	.19 (.22)	.16 (.24)
Proportion of responses that are "don't know", failures to respond, or nonspecific statements	.28 (.28)	.13 (.18)	.18 (.28)
Proportion of responses that are of other types	.05 (.15)	.02 (.07)	.02 (.19)

Note. Standard deviations are in parentheses.

[a] Sex was not recorded for two children in the younger Israeli group and one child in the older Israeli group.

the current analyses, the children were divided using a median split into younger and older groups (and one child who was markedly older than the others was eliminated from the analyses). The left columns of Table 2 provide information about the composition of the two Israeli groups.

U.S. comparison children

One of our goals was to compare the results for the Israeli children with the results for the U.S. children studied by Treiman and colleagues (2006) who were tested with upper-case letters. As the rightmost column of Table 2 shows, the U.S. children were on average 6 months younger than the younger group of Israeli children. Despite this, the U.S. children's mean proportion of correct responses on the letter-naming task was nearly as high as that for the older group of Israeli children. This outcome likely reflects the cultural differences discussed earlier: Less stress was put on early learning of letter names in Israel, at the time our data were collected, than in the United States. The fact that the Israeli children saw pictures interspersed with the letters, whereas the U.S. children did not, probably is not responsible for the group difference because the distinction between letter shapes and drawings is acquired very early (e.g., Tolchinsky-Landsmann & Levin, 1985).

Results

Response types

Israeli children

Table 2 shows the mean proportions of correct responses for the younger and older Israeli groups on the total set of 27 letters and on the 22 regular or nonfinal letters. The

minor pronunciation variants that exist for some letter names were counted as correct. Responses to the final letters were coded in both a strict fashion, where the child had to provide the correct letter name and the descriptor /sofit/ to be counted as correct, and a lenient fashion, where a response omitting /sofit/ was accepted. The two systems yielded very similar results, and we report here the results for the lenient system. A previous study in which 93 Israeli children were asked to name the 22 nonfinal letters, using a procedure similar to that used here, found a test–retest reliability of .99 for proportion of correct responses (Freedman, 2002). (The data from the current study for each letter, together with other details of the results, may be found at http://brettkessler.com/HebrewLetterNames.)

Incorrect responses fell into several categories. One type of error occurred when a child provided the name of another Hebrew letter. For example, a child might misidentify ד /daled/ as /zajin/ ז. The most common such replacement errors are shown in the right column of Table 1, and we report analyses that examine the factors that are associated with such errors. ''Don't know'' answers, failures to respond, and nonspecific statements (e.g., ''That looks like a letter from my name'') were grouped together in another error category. An additional type of error, which we call ''other'' errors, included cases in which letters were specifically but incorrectly identified and in which errors were not the names of Hebrew letters. For the younger Israeli group, approximately 60% of the errors in the ''other'' category were numbers. These often were numbers that were visually similar to the presented letters, for example /exad/ '1' for נ /nun/ and /arba/ '4' for צ /tsadik/. Such errors reflect visual confusions between elements of the letter and number systems. In some cases, children provided numbers that were not visually similar to the presented letters, suggesting a more general confusion between the symbolic systems of letters and numbers. For the older group, approximately 10% of the errors in the ''other'' category were numbers. An error in this category that was more common among the older children than the younger ones involved use of the qualifier /sofit/ for a letter that does not have a final form. For both groups, however, errors that were real letter names greatly outnumbered specific errors that were not real letter names.

U.S. children

The right column of Table 2 provides comparable data for the U.S. children. They showed a breakdown of response types similar to that of the older Israeli group. For the U.S. children, approximately 80% of the errors in the ''other'' category were numbers. These usually were numbers that were visually similar to the presented letters, for example, *two* '2' for *S*.

Correct responses to individual letters

The letters of the alphabet varied a good deal in ease of naming for both English and Hebrew. For example, ך /kaf sofit/ was the hardest letter for both the younger and older groups of Israeli children, and א /alef/ was the easiest letter for both groups. In this section, we report regression analyses in which we attempted to predict performance on each letter from various factors. Several factors related to the letters themselves, such as their frequencies, were considered in these analyses.

Israeli children

Letters that are seen and discussed most often may be learned more rapidly. We used the frequency of each letter in printed texts as one measure of general frequency. We reasoned that children would see the common letters more often and that parents and teachers would be more likely to discuss such letters with them. The letter frequency data we used were from Wintner and Yona (2003) and were based on newswire feeds from an Israeli radio station. We used this source because frequency norms based on large samples of printed material for Israeli children were not available. The frequencies were log transformed to make the distribution more normal. We hypothesized that children would be more familiar with א /alef/ and ב /bet/ than with the other letters because the Hebrew alphabet is called the /alef-bet/. Children hear these letter names especially often and may see the corresponding shapes often as well, for example if they ask adults to show them letters whose names they know. Thus, a second variable coded א /alef/ and ב /bet/ as 1 and coded other letters as 0. A third variable singled out the word-final letters of Hebrew. The final letters have some special characteristics that were expected to make them difficult to learn, as discussed earlier.

Simultaneous multiple regression analyses were performed using the data from each group of Israeli children. We analyzed the data both including and excluding the final letters. The results, shown in Table 3, indicate that frequent letters were significantly more likely to be named correctly than were less frequent letters. Performance on א /alef/ and ב /bet/ was significantly better than anticipated given the frequencies of these letters in texts. Also, performance on final letters was significantly worse than was expected on the basis of other factors, confirming the findings of Levin and colleagues (2002). The three variables considered in the regressions accounted for the majority of the variance in letter-naming difficulty.

U.S. children

Similar analyses were carried out for the U.S. children; such analyses were not reported previously by Treiman and colleagues (2006). The measure of letter frequency was that used by Treiman and colleagues and was based on frequencies of letters in books designed for young children. We anticipated that children would perform well on *A*, *B*, and *C*

Table 3

Standardized regression coefficients for variables in regressions predicting correct responses on letters for Israeli children

Variable or measure	Analyses excluding final letters		Analyses including final letters	
	Younger group	Older group	Younger group	Older group
Letter frequency	.37[*]	.42[*]	.24[*]	.21[*]
Letter /alef/ or /bet/	.61[***]	.55[**]	.39[***]	.27[**]
Final letter	—	—	−.72[***]	−.82[***]
R^2 for regression	.60 (.56)[***]	.57 (.53)[***]	.83 (.80)[***]	.85 (.83)[***]

Note. Adjusted R^2 values are in parentheses.
[*] $p < .05$.
[**] $p < .01$.
[***] $p < .001$.

Table 4
Standardized regression coefficients for variables in regressions predicting correct responses on letters for U.S. children

Variable or measure	Value
Letter frequency	.05
Letter *A*, *B*, or *C*	.44[**]
Letter *X* or *O*	.73[***]
R^2 for regression	.65 (.60)[***]

Note. Adjusted R^2 value is in parentheses.
[**] $p < .01$.
[***] $p < .001$.

because the alphabet often is called the *ABC*s and because these letters are especially well represented in informal and formal alphabet teaching. Thus, another variable coded *A*, *B*, and *C* as 1 and coded other letters as 0. A third variable distinguished *X* and *O* from the other letters. This variable was included because *X* and *O* are basic shapes that typically are labeled with the names of those letters in English. For example, a child may have heard /o/ used to describe the shape of a piece of cereal, and this may boost the child's performance on the letter *O*. Hebrew letters do not include any comparable cases.

As the results in Table 4 show, the U.S. children performed significantly better than would be expected on *A*, *B*, and *C*. They also performed better on *X* and *O*. The relation between letter frequency in texts and proportion of correct responses, although in the expected positive direction, was not statistically significant.

Replacement errors

The analyses of correct responses to individual letters consider the properties of letters themselves, not their relations with other letters. To gain more insight into these relations, and to shed light on the specific errors that children made, we examined the children's replacement errors. For example, ז /zajin/ is one of the least frequent letters in Hebrew and gave rise to a higher than average number of errors, and it is of interest to examine the specific errors that children made on this letter and other letters. One relatively common error on ז was /nun/, the name of a visually similar letter, ן. To examine visual similarity and other factors that may be associated with replacement errors, we tabulated the number of errors on each letter that involved each other letter as a response. This was done separately for the younger and older groups of Israeli children. Multiple regression analyses were performed to predict the number of confusions on each of the stimulus–response pairs, where *stimulus* refers to the letter that the children saw and *response* refers to the erroneous letter name that the children said. For example, we tabulated the number of errors on א /alef/ where children said /bet/, /gimel/, /daled/, and so on and similarly for each other letter. Because the raw data on number of confusions did not conform to a normal distribution, log-transformed data were used in the analyses.

Israeli children

A number of predictor variables were included in the regression analyses for the Israeli children. One variable was designed to capture the visual similarity between the stimulus

and response letters in each pair. This was expected to contribute to children's replacement errors, as with the confusions of נ and ו mentioned earlier. To obtain a measure of visual similarity, we had 30 Israeli college students rate the visual similarity of all pairs of letters on a scale from 1 (*not at all similar*) to 7 (*very similar*). We used 10 different random orders of the pairs, and three participants were assigned to each order. Across participants, half of the students saw the letters of a pair in one order (e.g., נ ו) and half saw them in the other order (ו נ). The letters were presented in the same font that was used with the children.[1] These procedures were the same as those used by Treiman and colleagues (2006) when collecting similar rating data from U.S. students, and the number of Israeli raters was the same as the number of raters in the U.S. study. The regression analyses that we report for Hebrew used the Israeli ratings, log transformed to make their distribution more normal.

Letters were coded as having phonologically similar names if either the basic or alternate forms of the names included a shared phoneme among their first two phonemes. Shared phonemes beyond the initial two were not credited in light of evidence that initial phonemes generally contribute to phonological proximity more strongly than do later phonemes (Monsell & Hirsh, 1998). All rhyming letter names in Hebrew as well as English share a phoneme within the first two positions, and so this coding scheme is compatible with the elevated similarity ratings that people typically give to rhymes (e.g., Nelson & Nelson, 1970). Also, all disyllabic Hebrew letter names have stress on the first syllable.

We also coded whether the stimulus and response letters were adjacent to one another in the Hebrew alphabet. As mentioned previously, Israeli children sometimes are exposed to songs and alphabet books in which the 22 basic letters of the alphabet are presented in order. We anticipated that children sometimes might confuse letters that are next to one another in the alphabet. Final letters are not separately included in alphabet songs and beginning alphabet books, and so these letters were not coded as adjacent to any other letters.

For each stimulus–response pair, we coded both the frequency of the stimulus letter and the frequency of the response letter. The letter frequency data from Wintner and Yona (2003) were used for this purpose, log transformed to make the distribution more normal. We also coded whether the stimulus letter in each pair was א /alef/ or ב /bet/ and whether the response letter was /alef/ or /bet/.

The number of syllables in the stimulus letter and the number of syllables in the response letter were additional variables. We ignored the /sofit/ in the coding of syllable length for final letters. Disyllabic letter names contain more phonemes than monosyllabic letter names, and this greater complexity might mean that children would produce disyllabic letter names less often. On the other hand, most Hebrew words are longer than a single syllable, and this could lead to an advantage for disyllabic letter names. In the analyses

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[1] A potential concern with the use of rating data from Hebrew speakers is that even though the participants were asked to rate the visual similarity of the letters, their ratings could have been affected by knowledge of the letters' names, sounds, or idealized shapes. To address this issue, we collected rating data from U.S. college students who were not familiar with Hebrew. With an average of 28 U.S. participants rating each letter pair, the ratings by Hebrew speakers and English speakers correlated highly ($r = .86$). This correlation gives us reason to believe that the ratings of the Israeli participants reflect, for the most part, characteristics of letters' visual forms that are salient regardless of a viewer's familiarity with the letters. The regression analyses we report use the Hebrew speakers' ratings of visual similarity to be parallel with the analyses of the U.S. data, which use the English speakers' ratings of visual similarity.

that included the final letters, we also included variables for whether the stimulus letter and the response letter in each pair was a final letter.

The variables just described were included in the first stage of the regression analysis. In a second stage, we asked whether adding the interaction between visual similarity and phonological similarity accounted for significant additional variance, as it did for English and Portuguese in the study of Treiman and Colleagues' (2006).

Table 5 shows the results of the regressions for the younger and older Israeli groups. Results are shown for both analyses including the final letters and analyses excluding the final letters. The results shown in Table 5 are for the first stage of the regressions, before the interaction term involving visual similarity and name similarity was included. This interaction did not account for significant additional variance in any of the analyses.

The regression results reveal that children tended to make more replacement errors when they were shown final letters than when they were shown nonfinal letters. This was true for both the younger and older children. This outcome is consistent with the earlier findings that errors of all types were more common on final letters than on nonfinal letters. Incorrect responses that were letter names tended not to have the /sofit/ descriptor, accounting for the negative association between final letter responses and replacement errors. This held true for both the younger and older children. These effects were rather large, explaining why the proportion of variance accounted for by the regressions was higher when the final letters were included in the analyses than when they were excluded.

Among the other variables, visual similarity played the largest role for both the younger and older Israeli children. Children were more likely to confuse letters that looked similar to one another than to confuse letters that looked less similar. As mentioned previously, for example, /nun/ נ was a relatively common error on ז /zajin/. Confusions involving less similar letters, such as נ /nun/ and ס /samex/, were less common.

Table 5
Standardized regression coefficients for variables in regressions predicting confusions between pairs of letters for Israeli children

Variable or measure	Analyses excluding final letters		Analyses including final letters	
	Younger group	Older group	Younger group	Older group
Visual similarity of letters' shapes	.27***	.27***	.27***	.29***
Phonological similarity of letters' names	.01	.11*	−.03	.03
Adjacency of letters in alphabet	.10*	.15***	.07*	.12***
Stimulus letter frequency	−.06	−.15***	−.05	−.11**
Response letter frequency	.23***	.01	.20***	.01
Stimulus א /alef/ or ב /bet/	−.16***	−.24***	−.10**	−.16***
Response /alef/ or /bet/	.15***	−.09*	.12***	−.09**
Number of syllables in stimulus letter	−.02	−.03	.02	−.01
Number of syllables in response letter	.11*	.03	.10**	.02
Stimulus final letter	—	—	.11***	.15***
Response final letter	—	—	−.48***	−.35***
R^2 for regression	.21 (.19)***	.23 (.21)***	.42 (.41)***	.31 (.30)***

Note. Adjusted R^2 values are in parentheses.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

Phonological similarity had a significant effect on the older group when the final letters were excluded from the analyses. However, the effect of phonological similarity was no longer significant when the final letters were included. Given the lack of consistent findings, we cannot conclude with certainty that phonological similarity was influential for the older Israeli group. Phonological similarity was not significantly associated with confusions for the younger group, according to the results shown in Table 5. Thus, although the Israeli children tended to confuse letters with similar shapes, there is no strong evidence that they confused letters with similar names.

Replacement errors that involved letters that were adjacent to one another in the alphabet were significantly more common than was expected on the basis of other factors. This was true for both groups of children, although the effect of adjacency appeared to be stronger for the older group than for the younger group.

Stimulus letter frequency and response letter frequency played different roles for the younger and older Israeli children. The frequency of the response letters was influential for the younger children: The erroneous letter names that they produced tended to be common letter names. These children apparently were more familiar with the names of common letters, such as ר /reʃ/, than of less common letters, such as פ /pei/, and so were more likely to produce the former than the latter. The older children did not show a significant effect of response letter frequency, but they did show a significant effect of stimulus letter frequency. They were less likely to make replacement errors when shown common letters than when shown uncommon letters. This effect of stimulus letter frequency was not significant for replacement errors for the younger group. The younger children made more errors in general on uncommon letters than on common ones (Table 3), but their errors on uncommon letters often were "don't know". This was confirmed by an additional regression analysis carried out on "don't know" errors on individual letters.

Even after letter frequency was considered, both groups of children tended to make fewer replacement errors on א /alef/ and ב /bet/, the letters whose names form the name of the Hebrew alphabet, than on other letters. This result fits with the finding that children made fewer total errors on א /alef/ and ב /bet/ than on other letters (Table 3). The younger children also showed a significant tendency to say /alef/ and /bet/ as erroneous responses, labeling other letters by these names when they could not name the letters correctly. This result probably reflects the children's familiarity with the names /alef/ and /bet/. The children knew that these phonological forms belong to the correct response set in a letter-naming task. The older children showed the opposite result. They were less likely than was expected, on the basis of other factors, to say /alef/ and /bet/ in error. In addition to being familiar with the names /alef/ and /bet/, the older children probably were quite familiar with the shapes that correspond to these names. As a result, the older children did not often mistakenly identify letters with other shapes as /alef/ or /bet/.

The number of syllables in the stimulus letter was not associated with replacement errors. However, the younger children were significantly more likely to produce incorrect responses that were disyllabic letter names than to produce incorrect responses that were monosyllabic letter names. This outcome may reflect the fact that, as mentioned earlier, words of more than one syllable are more typical of Hebrew than are monosyllabic words. The younger children, searching for legitimate responses in the letter-naming task, may have favored disyllables over monosyllables, just as they favored /alef/ and /bet/ and common letter names.

Additional analyses, not shown in Table 5, indicated that variables that reflect similarities in the sound-symbolizing functions of letters in a pair did not generally contribute to the regressions. These analyses considered whether the two letters agree in whether they usually are pronounced and in whether they can represent a vowel, as well as in whether the two letters can represent the same phoneme.

U.S. children

Table 6 shows the results of a regression analysis on the U.S. data. Recall that the U.S. children were younger, on average, than the younger Israeli group but that they performed at approximately the same level as the older Israeli group. The analysis shown in Table 6 is similar, but not identical, to the one reported by Treiman and colleagues (2006). The main difference is that the current analysis included a variable representing whether the stimulus letter was X or O—basic shapes whose names are used in other contexts—and a variable representing whether the response letter was X or O. These variables were included because, as demonstrated previously, children know the names of X and O better than would be expected on the basis of other factors. The same transformations that were applied to the variables in the Hebrew analysis were also used in the U.S. analysis. We did not include variables reflecting the number of syllables in the stimulus and response letters for English, as we did for Hebrew, because only one English letter has a name of more than one syllable. In the English analysis, inclusion of a variable reflecting the interaction between visual similarity and phonological similarity led to a significant increase in the proportion of variance explained ($p = .019$), as Treiman and colleagues also found. The results depicted in Table 6 are from the second stage of the regression, when the interaction term was included.

For the U.S. children, as for the Israeli children, visual similarity was the major determinant of replacement errors. However, the U.S. children were affected by phonological similarity as well in that they tended to confuse letters that had similar names as well as

Table 6
Standardized regression coefficients for variables in second stage of regression predicting confusions between pairs of letters for U.S. comparison children

Variable or measure	Value
Visual similarity of letters' shapes	.30***
Phonological similarity of letters' names	.00
Visual similarity × phonological similarity	.22*
Adjacency of letters in alphabet	.12***
Stimulus letter frequency	−.03
Response letter frequency	.08*
Stimulus A, B, or C	−.13***
Response A, B, or C	.10**
Stimulus X or O	−.15***
Response X or O	.01
R^2 for regression	.25 (.24)***

Note. Adjusted R^2 value is in parentheses.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

similar shapes. For example, they confused *B* /bi/ with *D* /di/. Recall that effects of pho-
nological similarity were at best weak for the Israeli children, and there was no interaction
between phonological similarity and visual similarity for either the younger or older Israeli
group.

The U.S. children, like the Israeli children, confused letters that were adjacent to one
another in the alphabet more often than was anticipated on the basis of other factors.
The U.S. children also had some tendency to respond with common letter names and with
the names of *A*, *B*, and *C*. These tendencies were similar to those seen among the young
Israeli children. In addition, as anticipated on the basis of the results in Table 4, the U.S.
children tended to make fewer replacement errors than was expected on the basis of other
factors when they were shown *X* and *O*, the names of which children are likely to learn
outside the letter-naming context.

Effects of children's own names

In the analyses reported so far, the data were pooled across children. This allows us to
look at one aspect of letter frequency, namely general frequency effects that hold across
children. However, it does not allow us to look at frequency effects that are specific to indi-
vidual children. One factor that is specific to individual children concerns the letters in the
children's own names. To examine how performance may differ as a function of the letters
in children's names, we tabulated the results for each letter for children who had that letter
as the first letter of their first names or commonly used nicknames, children who had that
letter only in a noninitial position of their first names, and children who did not have the
letter in their first names. The results are shown in Table 7. The Israeli results are pooled
over the younger and older groups to increase reliability; additional analyses revealed that
the younger and older children showed similar patterns of performance as a function of
own-name membership, although the older children produced more correct responses than
did the younger children. To ensure that the proportions could be calculated reliably,
Table 7 and the corresponding analyses are based on only those letters for which the
denominator used in calculating the proportion of correct responses was greater than 9
for each position category. There were 15 such letters for the Israeli children, pooling over
the younger and older age groups, and 9 for the smaller group of U.S. children.

An analysis of variance (ANOVA) using the factors of position (initial in name, later in
name, or not in name) and language (Hebrew or English) showed a main effect of position,
$F(2,44) = 46.67$, $p < .001$. Performance was best if the letter was in the initial position of
the name, intermediate if it appeared later in the name, and poorest if it was not in the
name. Each of these differences was significant. Levin and Aram (2004) hypothesized that
the initial letter of the name is more salient for children learning English than for children
learning Hebrew because the initial letters of names are capitalized in English but not in

Table 7
Mean proportions of correct responses as a function of position of letters in children's names for Israeli children
(younger and older groups pooled) and U.S. comparison children

Position	Israeli groups	U.S. group
Initial position in first name	.77	.86
Later position in first name	.70	.71
Not in first name	.60	.63

Hebrew and because first names tend to be longer in English than in Hebrew. Consistent with this hypothesis, the advantage for the first letter in the name over the later letters was numerically larger in English than in Hebrew. However, the interaction between position and language was not statistically significant in the ANOVA.

Sex differences

We carried out a final set of analyses to ask whether boys and girls differed in ability to name visually presented letters. Among the U.S. and Brazilian children tested by Treiman and colleagues (2006), girls tended to know more letter names than did boys. However, the differences between boys and girls were not statistically significant for either country. Sex differences were also observed among the Israeli children tested here, and these were statistically significant. For the full group of Israeli children, the proportions of correct responses were .56 for girls and .51 for boys. This difference was significant at the .01 level by a Monte Carlo test with 10,000 rearrangements. This test was used, as it was in the study of Treiman and colleagues', because the data were not normally distributed. Significant differences were also observed when the final letters were omitted.

Discussion

Children in many countries begin to learn about the shapes and names of letters well before the onset of formal reading instruction. They use their knowledge of letters, together with their phonological skills, to try to make sense of writing (e.g., Foulin, 2005). Given the role of letter names in bridging the gap between speech and print, it is important to understand the factors that are involved in early learning of letter names. We addressed this issue in the current study by examining children's learning of Hebrew, an alphabet that is quite different from the Latin alphabet that has figured in most previous research. The current results, together with our earlier findings (Treiman et al., 2006), suggest that letter name learning follows similar principles across languages and cultures. Children initially learn the names of letters in much the same way as they learn other vocabulary words. The learning plays out in a way that is molded by the characteristics of the letter names in a particular language, and the specific letters that children confuse differ from one language to another. The underlying principles, however, are similar across languages.

In Israel and the United States, as in Brazil, preschoolers' errors in naming letters often are the names of other letters. This result suggests that an important first step in learning about letter names is identifying the names as a set. In languages such as English, this identification may be facilitated by the phonological similarities among the names of letters. For example, many English letter names are two-phoneme syllables that end with /i/ or begin with /ɛ/. The phonological similarities among Hebrew letter names are much less marked, and yet the Israeli children also were more likely to call a letter by the name of another letter than by some other label. Other factors, such as adults' tendency to talk about letters in particular settings and to use letter names in close sequence, likely play an important role in helping children to identify letter names as a set. Identification of the letter name set may begin with the letters that are conventionally used to label this set—/alef/ and /bet/ in Hebrew and /e/, /bi/, and /si/ in English—as shown by the younger children's tendency to produce these letter names as errors.

When children mistakenly call one letter by the name of another letter, the letters that they confuse often are similar to one another in shape. The letter shapes are different in the Hebrew and Latin alphabets, but the shape-based confusions that occur in both alphabets are similar in principle. Visually based confusions have been found in the learning of other vocabulary words as well (e.g., Clark, 1993), supporting the idea that children learn the labels for letters in much the same way as they learn the labels for other concrete objects.

Although visual similarity of letter shapes had similar effects on the Israeli and U.S. children, phonological similarity of letter names had stronger effects on the U.S. children. The different effects of phonological similarity in Israeli and U.S. children probably reflect the different characteristics of letter names in Hebrew and English. As we have mentioned, Hebrew does not contain the relatively large sets of phonologically similar letter names that English does and so offers fewer opportunities for name-based confusions. Within-category errors based on phonological similarity may be common for those categories in a language that have a high degree of phonological similarity, as with letter names in English and many other languages. Such errors may be less common when words in a category sound little alike, as with letter names in Hebrew, color words in English, and the words in many other semantic categories.

A dimension of similarity that affected both Israeli and U.S. children involved the order of letters in the alphabet. Children in both countries were significantly more likely to confuse letters that were next to one another in the conventional sequence than was anticipated on the basis of other factors. Letters such as *F* and *G* may become associated with one another because they are next to one another in alphabet songs and alphabet books. Children who often experience letters in such contexts sometimes may confuse adjacent letters for these reasons. We know of no previous research that asked whether confusions that reflect the dimension of order occur for other categories that have an intrinsic ordering that is salient to children, for example the category of numbers. If so, this would support the idea that the same principles affect the learning of letters and other items.

Because the link between a letter shape and its name is arbitrary, just like the links between other objects and their labels, we would expect to see frequency effects in learning. The Israeli children produced more correct responses when shown א /alef/ and ב /bet/ than was expected on the basis of other factors, and the U.S. children produced more correct responses for *A*, *B*, and *C*. We interpret these effects as reflecting children's frequent exposure to the letters whose names label the alphabet. Similarly, the U.S. children probably performed well on *X* and *O* because they encounter these shapes and names both outside and within the letter-learning context, boosting frequency of exposure. In both Israel and the United States, children did especially well on the letters of their own first names, particularly the initial letters of their names. These letters often are seen and discussed by children. For example, mothers sometimes teach children how to spell other words by referring to the letters in children's own names (Levin & Aram, 2004). Together, these results show that frequency of exposure affects the learning of letter names, as it does the learning of other vocabulary words (e.g., Schwartz & Terrell, 1983). The results further show that children's own names play an important role in learning to read and write (e.g., Levin & Aram, 2004; Treiman & Broderick, 1998; Villaume & Wilson, 1989), just as they do in learning to speak and listen (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Mandel, Jusczyk, & Pisoni, 1995).

We found somewhat different results for Israeli and U.S. children when we examined how letter-naming performance was associated with letter frequency in text. The Israeli

children produced significantly more correct responses for letters that are common in texts than for letters that are less common, and the younger Israeli children seemed more likely to identify frequent letters as members of the appropriate response set. For the U.S. children, these effects were weak and generally not statistically significant. The apparent differences must be interpreted with caution, in part because the frequency counts for Hebrew and English were computed in different ways. If the differences are real, one possible explanation centers on the fact that our U.S. participants tend to learn letter names at a younger age than do our Israeli participants. For young children, personal and idiosyncratic factors may play a large role in learning. For example, the letters that are discussed at home may be primarily letters from family members' names. Older preschoolers may be more likely than younger preschoolers to notice and discuss letters that appear in books (Williamson, Evans, & Pursoo, 2005), in which case text frequency may play a larger role for children who learn letter names at an older age.

Studies of vocabulary learning generally have found small advantages for girls over boys (e.g., Feldman et al., 2000). In the learning of letter names as well, girls often are at a small advantage. In the previous study of U.S. and Brazilian children (Treiman et al., 2006), preschool girls knew about one more letter on average than did boys. The sex difference in means was not statistically reliable, although boys showed significantly more variability. In the larger Israeli sample of the current study, girls knew about $1\frac{1}{2}$ more letters on average than did boys, and the sex difference was statistically significant. In these environments, then, more boys than girls appear to enter reading instruction lacking some important background knowledge. However, these sex differences are not immutable. Deutsch (1998) tested Israeli boys who attended the previously mentioned school system serving some religious sectors in which teaching about letters and reading begins at approximately $3\frac{1}{2}$ years of age. These boys outperformed girls from similar backgrounds who were not taught about letters and reading from such an early age. Thus, providing more intensive teaching to boys can nullify the typically observed sex differences and even change their direction.

When children are first learning about the shapes and names of letters, they may not understand that letters symbolize sounds. Consequently, their errors are little influenced by the letters' sound-symbolizing functions. As children master letter names and learn that letters represent sounds, they can use the iconicity of the letter names to help learn and remember the letters' sounds. The acrophonic nature of Hebrew letter names means that speakers of this language potentially have much to gain from knowledge of letter names. To realize these benefits, it may be important for children to know the names of the letters before they begin learning to read and write. Teaching of letter names to preschoolers was not considered to be an important educational goal in Israel at the time the data for the current study were collected, but the situation has begun to change recently. Curricula for 3- to 6-year-olds that emphasize letter knowledge, phonological awareness, and early spelling are now being developed and implemented in Israel. For example, children are taught about the letters in their own names, as well as in classmates' names, and play games with cards on which letters are written. The current data on which Hebrew letters are easier and harder to learn, and on which confusions are most likely to occur, can be useful in the design of such instruction. In our experience, teachers and parents in Israel and the United States are quite aware of children's difficulties with visually similar letters. The other factors that influence letter name learning are less apparent to adults but are important for children.

Acknowledgments

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