



Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp



Statistical learning of novel graphotactic constraints in children and adults



Anna Samara*, Markéta Caravolas

School of Psychology, Bangor University, Bangor LL57 2AS, UK

ARTICLE INFO

Article history:

Received 18 February 2013

Revised 15 November 2013

Available online 1 February 2014

Keywords:

Contextual constraints

Graphotactics

Orthographic knowledge

Positional constraints

Signal detection theory

Spelling development

Statistical learning

ABSTRACT

The current study explored statistical learning processes in the acquisition of orthographic knowledge in school-aged children and skilled adults. Learning of novel graphotactic constraints on the position and context of letter distributions was induced by means of a two-phase learning task adapted from Onishi, Chambers, and Fisher (*Cognition*, 83 (2002) B13–B23). Following incidental exposure to pattern-embedding stimuli in Phase 1, participants' learning generalization was tested in Phase 2 with legality judgments about novel conforming/nonconforming word-like strings. Test phase performance was above chance, suggesting that both types of constraints were reliably learned even after relatively brief exposure. As hypothesized, signal detection theory d' analyses confirmed that learning permissible letter positions ($d' = 0.97$) was easier than permissible neighboring letter contexts ($d' = 0.19$). Adults were more accurate than children in all but a strict analysis of the contextual constraints condition. Consistent with the statistical learning perspective in literacy, our results suggest that statistical learning mechanisms contribute to children's and adults' acquisition of knowledge about graphotactic constraints similar to those existing in their orthography.

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Introduction

There is a growing interest in the development of orthographic knowledge and its contribution to skilled reading and spelling. Learners become sensitive to general properties of their orthography—such as the frequency of occurrence of individual letters/letter sequences in print and the legality of different

* Corresponding author.

E-mail address: a.samara@bangor.ac.uk (A. Samara).

spelling patterns—earlier in development than previously thought (Cassar & Treiman, 1997; Ferreiro & Teberosky, 1982; Hayes, Treiman, & Kessler, 2006; Pacton, Perruchet, Fayol, & Cleeremans, 2001; Treiman, 1993). These findings challenge the long-standing view that phonological information is the only resource available to beginning spellers (e.g., Frith, 1985; Gentry, 1982). In fact, recent theorizing about spelling development emphasizes children's early insights into different types and levels of linguistic knowledge, including knowledge of simple orthographic and morphological conventions (Bourassa & Treiman, 2001; Deacon, Conrad, & Pacton, 2008; Treiman & Bourassa, 2000).

Given that some information about legal orthographic forms is available to children before or as soon as literacy instruction begins, learning must be, to some extent, incidental in nature. Accordingly, several authors have argued that children's pattern extraction skills rely on *implicit* or *statistical learning* processes (e.g., Kessler, 2009; Pollo, Treiman, & Kessler, 2007; Steffler, 2001; Treiman & Kessler, 2013). However, to date little empirical research has examined the mechanisms underpinning the acquisition of orthographic knowledge. In addition, very few studies have investigated learning of written language patterns under well-controlled experimental conditions that allow manipulations of the type and amount of exposure given to the observer. The goal of the current study was to address these issues in a group of 7-year-old children in comparison with a group of adults. We investigated whether sensitivity to novel orthographic constraints similar to those found in the English orthography develop under incidental learning conditions. Can learning be induced in 7-year-old typically developing children as well as in adults?

Development of sensitivity to orthographic structure

In a seminal study, Treiman (1993) examined a large corpus of naturalistic writing data produced by a group of U.S. English-speaking children at the end of kindergarten or beginning of first grade. Detailed analyses of children's misspellings revealed that even the youngest children actively used some knowledge of simple spelling conventions in their own written productions such as the positional constraint that “*ck* is not a legal onset in English.” Moreover, first graders rarely committed errors that were inconsistent with orthographic constraints on permissible letter doublets (e.g., *xx*, *kk*). Treiman further demonstrated that school beginners are sensitive to statistical probabilities in print using simple nonword judgment tasks (e.g., which one looks more like a real word, *moyl* or *moil*?).

The standard version of Treiman's (1993) now widely used orthographic constraints task presents participants with the oral pronunciation of a nonword and asks them to choose between two alternative written spellings, only one of which conforms to patterns in their orthography. In one of the first experimental studies of this sort, Cassar and Treiman (1997) assessed children's sensitivity to untaught constraints on allowable consonant and vowel doublets. Children in Grade 1 preferred nonwords containing doublets in allowable positions (in word middles but not at word beginnings) as well as permissible doublets (e.g., *ll* but not *xx*). Sensitivity to both types of constraints increased as a function of age. However, more complex relationships, such as the influence of phonological context on consonantal doubling, had an effect only in more advanced spellers' choices (Grade 6). Cassar and Treiman's key findings have been replicated in languages other than English (French: Pacton et al., 2001; Finnish: Lehtonen & Bryant, 2005). Moreover, Pacton and colleagues (2001) demonstrated in recognition (judgment) and fragment completion production tasks that French-speaking first graders have a preference for nonwords embedding letters that are frequently doubled in their orthography (e.g., *illaro* > *ivvaro*) and for stimuli containing a doublet in a medial legal position over stimuli where the doublet is illegally situated (e.g., *nmulor* < *nullor*).

Young learners' appreciation of positional constraints, such as those governing the legality of consonantal doublets, provides them with but one cue to correct spelling. Taking surrounding context into account further facilitates the process of translating speech to print, in inconsistent orthographies (Alegria & Mousty, 1996; Kessler & Treiman, 2001; Pacton, Fayol, & Perruchet, 2002, 2005) as well as more consistent orthographies (Caravolas & Mikulajová, 2008). Several studies in English have demonstrated that children and adults take advantage of contextually conditioned phonological patterns in order to spell consonants (Treiman & Kessler, 2006; Treiman, Kessler, & Bick, 2002) or vowels (Hayes et al., 2006; see also Varnhagen, Boechler, & Steffler, 1999), although this type of knowledge seems to develop gradually, with some contexts being learned more quickly than others. For example,

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