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Literacy effects on language and vision: Emergent effects from an amodal shared resource (ASR) computational model

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ABSTRACT

Learning to read and write requires an individual to connect additional orthographic representations to pre-existing mappings between phonological and semantic representations of words. Past empirical results suggest that the process of learning to read and write (at least in alphabetic languages) elicits changes in the language processing system, by either increasing the cognitive efficiency of mapping between representations associated with a word, or by changing the granularity of phonological processing of spoken language, or through a combination of both. Behavioural effects of literacy have typically been assessed in offline explicit tasks that have addressed only phonological processing. However, a recent eye tracking study compared high and low literate participants on effects of phonology and semantics in processing measured implicitly using eye movements. High literates' eye movements were more affected by phonological overlap in online speech than low literates, with only subtle differences observed in semantics. We determined whether these effects were due to cognitive efficiency and/or granularity of speech processing in a multimodal model of speech processing – the amodal shared resource model (ASR, Smith, Monaghan, & Huettig, 2013a,b). We found that cognitive efficiency in the model had only a marginal effect on semantic processing and did not affect performance for phonological processing, whereas fine-grained versus coarse-grained

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phonological representations in the model simulated the high/low literacy effects on phonological processing, suggesting that literacy has a focused effect in changing the grain-size of phonological mappings.

1. Introduction

Approximately 16% of the world's adult population are illiterate, defined as "the ability to read and write with understanding a simple statement related to one's daily life" (UNESCO Institute for Statistics., 2013). Learning to read has a profound effect on cognitive processing, resulting in qualitative changes to the representation of phonological information about words, but also correlating with a general increase in cognitive processing performance. Much of our understanding of language processing is based on data and theoretical and computational models only of literate participants, but a full understanding of language comprehension and production must also take into account the role of literacy in processing. Previous models of literacy effects on language processing have not effectively distinguished between accounts based on a general cognitive ability increase and more specific phonological processing changes.

Here, we test an implemented computational model of language processing that was previously applied only to data from literate participants. We extended the model to simulate both the general cognitive processing account as well as the phonological representation account in order to account for data from literate and illiterate participants in language processing tasks. We first review the two theoretical accounts of effects of literacy on language processing – the phonological processing change and the general cognitive processing accounts – before describing previous models of effects of literacy on language processing. We then present the advantages of a language processing task that tests online, implicit processing of information between vision, phonology and semantics in order to examine the effects of literacy on the language processing system, before presenting our model's design and results.

1.1. Changes to phonological representations and literacy

The aspect of speech processing for which there has been most exploration for an influence of literacy is in the domain of phonological awareness, defined as "one's degree of sensitivity to the sound structure of oral language" (Anthony & Francis, 2005). There is substantial evidence indicating that, over the course of development, individuals become increasingly sensitive to smaller linguistic units within the speech signal. Children first gain awareness of larger units such as syllables before they are able to display an awareness of smaller units such as onsets and rhymes (Alcock, Ngorosho, Deus, & Jukes, 2010; Anthony & Francis, 2005; Goswami, 2003). However, debate remains as to the cause of this improvement. Firstly, what is the role of literacy acquisition? Is perceptual categorisation of speech sounds dependent on reading acquisition (Burnham, 2003)? Does literacy lead to a finer tuning of perceptual categories and, consequently, improvements in the precision of phoneme identification (Hoonhorst et al., 2011; Serniclaes, Ventura, Morais, & Kolinsky, 2005)? Or does literacy not play a crucial role, instead is it that the fidelity of phonological representations increases across development driven by the need to differentiate, within an increasingly large lexicon, between an increasing number of phonologically similar items (Garlock, Walley, & Metsala, 2001; Storkel, 2002)?

There is growing evidence that for (at least) explicit awareness of fine grain phonological units, individuals require exposure to alphabetic literacy training. Experiments that require children to make explicit judgements regarding a word's phonological structure show that children perform largely at chance prior to literacy training, however once engaged in training their performance on such tasks greatly improves (Alcock et al., 2010; De Jong & Van Der Leij, 2003; Hulme, Snowling, Caravolas, &