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Visual multi-element processing as a pre-reading predictor of decoding skill

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ABSTRACT

A lack of longitudinal studies impedes the understanding of whether visual processing skills significantly influence reading performance. The present study assessed if multi-element processing (MEP), a visual processing task comprising only non-verbal stimuli, was predominantly related with decoding or sight-word reading. One hundred Spanish pre-reading children were evaluated on their MEP, naming speed (RAN), phonemic awareness (PA), letter knowledge (LK) and IQ. Early reading level was measured in first grade. In third grade, four reading lists consisting of short and long, high- and low-frequency words were administered. Results from path analyses revealed that, after controlling for RAN, PA, LK, IQ and early reading level, MEP was a significant predictor of the reading of long low-frequency words only. This result suggests that, in the transparent Spanish orthography, pre-reading MEP is significantly linked to future decoding skill. This is the first study to provide empirical evidence that pre-reading MEP predicts future reading.

Introduction

Research in the field of literacy acquisition has firmly established that certain cognitive abilities, such as phonemic awareness (PA) and naming speed, are crucially involved in the process of learning to read (see Bowey, 2005; Kirby, Roth, Desrochers, & Lai, 2008 for reviews). However, the potential importance of another cognitive ability, visual processing skill (VPS), has been less explored. Although a link between visual skill and reading has been suggested for several decades (e.g., Cairns & Steward, 1970; Lovegrove, Martin, & Slaghuis, 1986; Mason & Katz, 1976), in recent years there has been a growing recognition of this possibility (Lallier, Valdois, Lassus-Sangosse, Prado, & Kandel, 2014; Lobier, Dubois, & Valdois, 2013; van den Boer & de Jong, 2015). However, whether visual skill is causally related to reading remains an open question (see Goswami, 2015a; Lobier & Valdois, 2015 for an interesting discussion on the topic) given that many studies have failed to find a significant relationship between the two (e.g., Shapiro, Carroll, & Solity, 2013; Vellutino, Scanlon, Small, & Tanzman, 1991).

Visual processing skills comprise several abilities which have been claimed to be associated with reading development and dyslexia (for reviews on the topic see Gori & Facoetti, 2015; Rayner, 2009; Vidyasagar & Pammer, 2010). Visual skills such as visual searching ability (e.g., Jones, Branigan, & Kelly, 2008), sensitivity to coherent motion (e.g., Witton et al., 1998), visual scanning ability (e.g., Kuperman, Van Dyke, & Henry, 2016) or visuo-spatial attention (e.g., Facoetti et al., 2010), have all been linked to reading performance. In general, MEP tasks assess the accuracy with which the participant can recognize or recall the identity or position of symbols previously presented in a multi-element array (e.g., Hawelka &

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Wimmer, 2005; Jones et al., 2008; Pammer, Lavis, Hansen, & Cornelissen, 2004). For instance, visual attention span – which according to Bosse and Valdois (2009) is defined as the number of distinct visual elements which can be simultaneously processed at a glance in a multi-element array – has been reported to contribute to reading performance in normally developing children, beyond other established predictors such as IQ, vocabulary, and PA (Bosse & Valdois, 2009; van den Boer, de Jong, & Haentjens-van Meeteren, 2013). However, one critical, yet unanswered question regarding the VPS-reading relationship is whether visual skill (and MEP in particular) is specifically related to analytical decoding of novel words, whether it is predominantly involved in global recognition of known words, or both.

Unknown words are decoded, known words are recognized by sight

Numerous reading models from different areas of literacy studies (e.g., Ans, Carbonnel, & Valdois, 1998; Ehri, 2005; Share, 2008) describe how readers use two critical procedures to decipher text. Although these two procedures have been assigned many labels (e.g., 'serial *vs.* parallel' or 'analytic *vs.* global'), for this study we will use the terms decoding and sight-word reading. As postulated by various developmental reading models (e.g., Backman, Bruck, Hebert, & Seidenberg, 1984; Ehri, 2005; Share, 2008), as well as several models of skilled reading (e.g., Ans et al., 1998; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Forster & Chambers, 1973; LaBerge & Samuels, 1974; Perry, Ziegler, & Zorzi, 2007; Ziegler, Perry, & Zorzi, 2014), orthographic familiarity is one key element which will determine how print will be processed.

According to these models, in order to process novel or unfamiliar words, the reader will use a slow sub-lexical decoding strategy which relies on graphemic parsing. Graphemic parsing can best be conceived as a process that operates via an attentional window which shifts from left to right parsing the letter string into graphemes in a serial fashion (e.g., Perry et al., 2007). These graphemes are then sequentially converted into their phonological counterparts and subsequently assembled into spoken words. In contrast, a different procedure is implemented when a known or familiar word is encountered. If the printed letter-string matches an entry in the orthographic lexicon the word will be automatically recognized as a whole unit. In this case the phonological representation associated with that word will be instantly activated via rapid direct-retrieval mechanisms. It should be noted that, according to most models of skilled reading (e.g., Dual Route Cascaded [DRC], Coltheart et al., 2001; Multiple-Trace Memory [MTM], Ans et al., 1998), all stimuli are processed through both reading procedures. However, familiar words tend to be processed more accurately and faster through sight-word reading while unfamiliar words cannot be accurately read by sight and therefore end up being decoded.

Of note, according to Grainger and colleagues (Grainger, Dufau, & Ziegler, 2016; Grainger & Ziegler, 2011), these two reading procedures require a different level of precision with respect to letter-position encoding. The sight-word reading strategy/procedure initially makes use of the most visible letters that best constrain word identity. Letter combination detectors allow the reader to code in parallel for approximate within-word letter position as a means to provide rapid bottom-up activation of familiar whole-word representations (Grainger & Ziegler, 2011). The use of coarse-grained features (not necessarily contiguous letter combinations) gives preference to speed over accuracy (Grainger et al., 2016). Processing through serial analytical decoding, on the other hand, requires more precise position-coded letter identities, which gives preference to accuracy over speed in generating sound from print (Grainger & Ziegler, 2011; Grainger et al., 2016). In support of this perspective, Ziegler et al.'s (2014) connectionist dual process computational model can simulate how letter-position encoding errors affect unfamiliar word reading.

In agreement with the notion that familiarity determines reading procedure, familiarity-related psycholinguistic factors such as 'word-frequency' or 'age-of-acquisition' have been reported to exert the strongest effects on reading speed (Italian: Barca, Burani, & Arduino, 2002; French: Bonin, Barry, Méot, & Chalard, 2004; Spanish: Cuetos & Barbón, 2006; Japanese Kanji: Yamazaki, Ellis, Morrison, & Ralph, 1997). The word frequency effect, whereby high frequency words are processed faster than matched low frequency words, is evidence that familiar words are processed through rapid sight-word reading, while unfamiliar words are slowly decoded (Share, 1995; Weekes, 1997).

A different effect, namely the length effect, is another marker of reading procedure. The length effect reflects how shorter words are processed faster than longer words (English: Weekes, 1997; Dutch: Marinus & de Jong, 2010; German: Ziegler, Perry, Jacobs, & Braun, 2001; Spanish: Cuetos & Barbón, 2006). Of relevance, it tends to be larger for unfamiliar words, which must be decoded through a length-sensitive sequential mechanism, than for familiar words, which are instantly recognized a in parallel manner (Weekes, 1997; Ziegler et al., 2001). Thus, this word-length by word-familiarity interaction on naming latencies is further evidence of sight-word reading for familiar words and serial decoding for unfamiliar words. In this way, word-frequency and -length are useful tools to determine which reading strategy is being used – decoding or sight word reading.

What is the role played by visual multi-element processing in reading?

The main research question of this study is whether visual skill, measured by means of visual MEP, is specifically related (1) to decoding, (2) to sight-word reading or (3) to both. Firstly, in support of the idea that MEP is only involved in decoding, Jones et al. (2008) and Pammer et al. (2004) found that performance on MEP was significantly correlated with reading accuracy of unfamiliar words and with passage reading accuracy respectively. According to Facoetti et al. (2006), focused visual attention is important for graphemic parsing during unfamiliar-word reading. As suggested in the connectionist dual process (CDP+) model