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Development of children's identity and position processing for letter, digit, and symbol strings: A cross-sectional study of the primary school years

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Letter recognition and digit recognition are critical skills for literate adults, yet few studies have considered the development of these skills in children. We conducted a nine-alternative forced-choice (9AFC) partial report task with strings of letters and digits, with typographical symbols (e.g., $, @) as a control, to investigate the development of identity and position processing in children. This task allows for the delineation of identity processing (as overall accuracy) and position coding (as the proportion of position errors). Our participants were students in Grade 1 to Grade 6, allowing us to track the development of these abilities across the primary school years. Our data suggest that although digit processing and letter processing end up with many similarities in adult readers, the developmental trajectories for identity and position processing for the two character types differ. Symbol processing showed little developmental change in terms of identity or position accuracy. We discuss the implications of our results for theories of identity and position coding: modified receptive field, multiple-route model, and lexical tuning. Despite moderate success for some theories, considerable theoretical work is required to explain the developmental trajectories of letter processing and digit processing, which might not be as closely tied in child readers as they are in adult readers.

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Introduction

For literate adults, recognizing letters occurs automatically and nearly flawlessly, yet written language depends on our domain-general systems for seeing and remembering. In the modern world, digits and symbols are also encountered and processed quickly and easily. Currently, the trajectory of the acquisition of accurate and efficient processing of these characters is not clear. In this study, we investigated character identification and position representation in primary school children and the factors that affect the development of these cognitive skills.

Although letters are usually processed within words during reading tasks, our aim in this study was to investigate the stages of identification that happen before words are read. To this end, we used strings of random letters, digits, and symbols in a partial report task where participants briefly view a string of five characters and are cued to recall the character that was present at a particular position. This task has been argued to index bottom-up processes in character identification (e.g., Grainger, Bertrand, Lété, Beyersmann, & Ziegler, 2016; Mason, 1982; Tydgat & Grainger, 2009). Using random letter strings rather than words avoids some differences between letters, on the one hand, and digits and symbols, on the other (e.g., letters are usually combined to form meaningful units, whereas digits or symbols carry meaning even when presented singly), thereby allowing a purer comparison among character types. Identification tasks with character string stimuli like these have been used in a number of studies with adults to assess processing of letters, digits, and (to a lesser extent) symbols and other two-dimensional shapes.

Adult letter and digit identification

What are the cognitive processes required to complete a partial report task? We assume that when letters and digits are presented, identification processes are automatically engaged. According to one theory, visual features of the letter/digit shape are represented and then mapped to stored visual forms and finally abstract letter and digit identities (Caramazza & Hillis, 1990; McCloskey & Schubert, 2014; Schubert & McCloskey, 2013). Another theory posits an early stage of abstract letter/digit detectors, followed by two types of representations for letters: one in which position is coded coarsely and another in which position is coded more precisely (Grainger, Dufau, & Ziegler, 2016). Both theories contend that the highest representations are location invariant; that is, they indicate the presence of a letter independent of its location in the visual field. Although the partial report task could be successfully completed by matching the response options to early visual representations (i.e., visual features or letter/digit detectors) of the stimulus, it is commonly assumed that processing continues throughout the identification system unless disrupted (e.g., masked presentation). Accordingly, we consider that the results obtained in this task are relevant to understanding the representation of location-invariant abstract letter and digit identities.

Because position is cued only after stimulus offset, participants must represent the stimuli in all positions. (Note that this does not imply uniform accuracy for all positions, but a floor effect at particular positions might suggest a failure to attend to all positions.) The most common string length for studying these character identification processes is five because this allows examination of string positions with different properties. Initial and final positions (1 and 5, respectively) can be distinguished from medial positions (2–4). Furthermore, fixation is generally on the central position (3), allowing for contrasts between the fixated medial position and nonfixated medial positions (2 and 4).

When adults are asked to report letters and digits presented in such a manner, a W-shaped accuracy function across serial positions is often obtained (see Fig. 1A for an example). This pattern reflects high accuracy at the central, initial, and end positions and reflects lower accuracy at medial nonfixated positions (e.g., Collis, Kohnen, & Kinoshita, 2013; Hammond & Green, 1982; Mason, 1982; Tydgat & Grainger, 2009). In contrast to this W shape found for letter and digit accuracy, the pattern found with symbols is reported as a V shape (Hammond & Green, 1982; Tydgat & Grainger, 2009) or a flat (or very shallow W-shaped) serial position function (Collis et al., 2013). A number of explanations have been proposed to explain the accuracy discrepancies across positions for character strings. For example,