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Connections are not enough for membership: Letter/non-letter distinction persists through phonological association learning

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ABSTRACT

In compound, hierarchical stimuli (also known as Navon figures), a Global Precedence Effect (GPE) can reliably be observed for both letters and non-letters. However, when presentation conditions sufficiently resemble those of reading, the GPE for letters has occasionally been found to disappear. We corroborate this effect in a study with a large group of participants. In addition, in-between two sessions, participants were trained in associating the non-letters with either *phonological* or *non-phonological* sounds. We reasoned that learning distinctive phonological associations might be akin to the acquisition of letter knowledge. This might eliminate the GPE also for the non-letters. However, the GPE persisted for the trained non-letters in both conditions. The large number of participants in this study revealed additional effects in the letter condition, which enabled further insights in the processing dissociation between letters and non-letter shapes.

1. Introduction

In the world of 2-dimensional graphics, letters play a special role. Even when contrasted with similarly discrete objects (pseudo-letters), letters are processed faster and with greater accuracy across a variety of tasks (Burgund, Schlaggar, & Petersen, 2006; Burgund & Abernathy, 2008; Fernandes, Vale, Martins, Morais, & Kolinsky, 2014; Lachmann & van Leeuwen, 2007, 2008a; Lachmann, Khera, Srinivasan, & van Leeuwen, 2012; Poirel, Pineau, & Mellet, 2008; van Leeuwen & Lachmann, 2004). This holds even if the task is not explicitly linguistic in nature (e.g., Lachmann & van Leeuwen, 2004). Letter familiarity, resulting from extended exposure to reading material, may explain this effect (Burgund & Abernathy, 2008; James, James, Jobard, Wong, & Gauthier, 2005). Evidence suggests, however, that letters are not just be processed faster, but also differently from other likewise familiar stimuli, such as pictorial symbols (Fernandes et al., 2014; van Leeuwen & Lachmann, 2004) or faces (Piepers & Robbins, 2012; Tanaka & Farah, 1993). The specific letter processing strategy is established during the early stages of reading acquisition and automatized over extensive reading and writing practice (Burgund et al., 2006; Fernandes et al., 2014; Lachmann & van Leeuwen, 2014).

The purported strategy involves an analytic-holistic processing distinction. This distinction is known under a variety of, often conflicting, terminology (Piepers & Robbins, 2012; Wagemans et al., 2012; Wong et al., 2011) and relates to a number of empirical distinctions, such as the extent to which symmetries in the percept are being suppressed (Lachmann, 2002; Lachmann & van Leeuwen, 2007, 2014), the extent to which items are perceived as independent of their context (Fernandes et al., 2014; Lachmann & van Leeuwen, 2014; van Leeuwen & Lachmann, 2004), or the extent to which the percept emphasizes properties of the parts over the whole (Lachmann, Schmitt, Braet, & van Leeuwen, 2014).

Both letter and non-letter objects can be perceived either holistically or analytically (Farah, 1996; Piepers & Robbins, 2012). But whereas for non-letters, analytic processing is generally slower and more effortful than holistic processing, in letters it is the other way around (Lachmann & van Leeuwen, 2004, 2007, 2008a, 2008b; van Leeuwen & Lachmann, 2004). This analytic preference may arise because in distinguishing letters, details matter. There is, however, at least one paradigm in which letters seem to be predominantly processed holistically. This paradigm uses compound letters (Kinchla, 1974; Navon, 1977; see Kimchi, 2015, for a review), such as a large F composed of a number of identical small Fs (congruent), or a large F composed of small Hs (incongruent). The large letters are called "global" items, the small ones "local" items. With this type of stimuli, *global precedence* has been established, which consists of a combination of *global advantage*, i.e. faster processing of the global level than the local level, and an *asymmetric congruence effect*, i.e. incongruency interferes with the local-level target responses but not with global level ones. Global precedence is generally acknowledged as evidence of

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holistic processing and its absence as evidence of analytic processing.

Lachmann et al. (2014) argued that even in this paradigm, analytic processing could be observed in letters. Whereas for non-letter compound figures, a robust global precedence effect was obtained, it was absent for letters. This takes presentation conditions sufficiently similar to reading: foveal presentation of the stimuli, the local stimulus approximately matching the size critical for fluent reading of individual letters, and a global stimulus size close to the functional visual field in word reading. Presenting compound stimuli in conditions optimally suitable for reading, we proposed, elicited letter-specific processing even in this paradigm.

The present aim is twofold: first, the absence of the GPE in Lachmann et al. (2014) was obtained with a relatively small sample. To assure that this effect was not due to lack of power, we wanted to corroborate it with a larger group of participants. Second, as shown by Fernandes et al. (2014), letter-knowledge is required for the letter/non-letter distinction in non-readers to arise. To see if, and what kind of, letter-knowledge is not only necessary, but also sufficient, we sandwiched a short training in-between two sessions of the experiment. In one group, non-letter shapes were associated with non-phonological auditory stimuli. The other group learned phonological associations to the non-letter shapes. Both conditions were aimed to investigate whether a relatively short training could reduce the holistic processing strategy for non-letters. On the one hand, a reduction of holistic processing in both training groups would suggest that paired association leads to fine-tuning of visual representations (James et al., 2005). By associating letters to sounds, their distinctive details might become more relevant to the perceiver. On the other hand, the training may only have an effect in the phonological group. Skilled readers can easily accommodate new letters, suggesting that learning distinctive *phonological* associations to non-letters might be necessary and sufficient to elicit the analytic processing strategy. This would result in the disappearance of the global precedence effect for non-letters only in the phonological training group.

2. Method

2.1. Participants

Seventy-five students (between 19 and 29 years old) from the University of Kaiserslautern (Germany) were paid 35 Euro for their participation in this study. All participants were skilled readers of German and/or English with normal hearing and normal or corrected-to-normal vision. None of them was diagnosed as having any reading or writing disorder. Participants were randomly assigned to one of two training conditions, a *phonological training group* (N = 36) and a *non-phonological training group* (N = 39). Participants signed consent forms prior to the study. The study was approved by the ethical committee of the Faculty of Social Science of the University of Kaiserslautern.

2.2. Material and procedure

2.2.1. Pre- and post-test

Identical replications of Lachmann et al. (2014) were used as pre- and post-test. Eight compound stimuli were used, as illustrated in Fig. 1. Four of them were letters composed of letters (C or F) and the other four were non-letters composed of non-letters. Letter and non-letter stimuli were similar in visual complexity. Of both, half were congruent, i.e. a global level composed of smaller versions of the same (e.g., a large C composed of small Cs or a large non-letter shape composed of small versions of the same shape); the other half were incongruent, i.e. global and local levels were different (e.g., a large C composed of small Fs or a large non-letter shape composed of small versions of a different shape). The global stimuli appeared with a visual angle of approximately 6.5° in height and 5.5° in width, the local stimuli with a visual angle of approximately 0.5°. Here as well as in the training, all visual stimuli were presented in black (0.4 cd/m^2) against a white background (28.9 cd/m^2) on a 15″ laptop screen running Windows XP and E-Prime 2.0 (Psychology Software Tools, Pittsburg, USA). There was no fixation of the head. The experiment took place in a sound attenuated test cubicle under light- controlled condition.

Both pre- and post-test consisted of four blocks each, two blocks with letters and two blocks with non-letters. In half of the blocks, participants responded to the global figure regardless of the local components (global condition), and vice versa in the other half (local condition). The order of the four blocks was randomized across participants. Each of the blocks contained 100 trails, half with congruent and half with incongruent stimuli in random order. Participants performed a two-alternative forced-choice identification task by pressing the left or right button of the embedded laptop mouse with their index fingers. Response conditions changed between blocks (e.g., level = local: “F” = right key, “C” = left key) and were counterbalanced between participants. Prior to each block, eight practice trials were presented, each followed by visual feedback (“correct”/“incorrect”) lasting 500 ms. When more than two errors were made during the practice trials, the instruction was repeated followed by another eight practice trials.

Each trial started with a fixation cross displayed for 250 ms at the

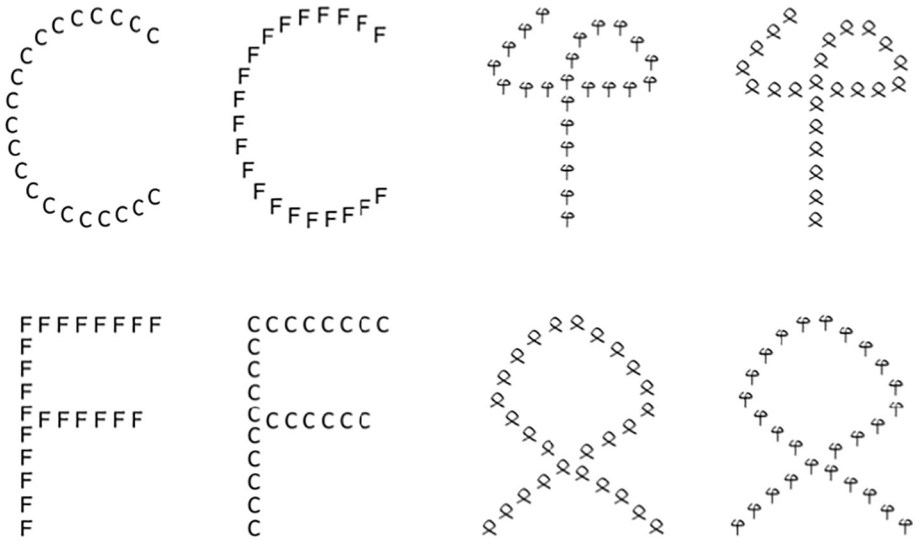

Fig. 1. Compound, hierarchical figures used in the pre- and post-test.