DIFFERENTIATION OF HOLISTIC PROCESSING IN THE TIME COURSE OF LETTER RECOGNITION

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Abstract

Pairs of letters, pseudo-letters, and geometrical shapes were presented in a sequential same–different task, in which the time between the first and second items was varied. The second item was either presented in isolation or surrounded by an irrelevant geometrical shape that could be congruent or incongruent to the target. Congruence effects were obtained for shapes and pseudo-letters, but not for letters if the interval between the first and second items was short. Absence of congruence effects was interpreted as categorical influence on early visual integration processes; letters are processed less holistically than non-letter shapes. The present result indicates that categorical influence of letters depends on the time course of stimulus processing. As a highly automatized process, it is effective for stimuli appearing at a relatively fast rate, whereas, a slower rate of stimulus presentation eliminates task-irrelevant categorical influences.

We investigated whether higher-order semantic knowledge influences the degree of perceptual feature integration. An important semantically informed categorical distinction in visual information is “letters” vs. “non-letters” (e.g., Burgund, Schlaggar & Petersen, 2006). Such a distinction is not easily translated into visual features. For instance, the capital “A” and the non-letter in Fig. 1 are similar in shape, and yet they belong to distinct semantic categories. For this reason, it is unlikely that dissociation in early processing is driven solely by pre-categorical visual features. If these distinctions, nevertheless, play a role at the level of visual feature integration processes, these might lead to differences in congruence effects (Bavelier, Deruelle & Proksch, 2000).

![Fig. 1. Letters and non-letter shapes in congruent and incongruent surroundings (left) and reaction time data (right) from van Leeuwen and Lachmann (2004).](image-url)
We tested this prediction by comparing congruence effects for letters and non-letters for different task demands (Lachmann & van Leeuwen, 2004, 2008 a,b; van Leeuwen & Lachmann, 2004).

**Letter vs. Shape categorization**

In van Leeuwen and Lachmann (2004) we performed six experiments in which a speeded binary classification task was used, letter and nonletter (geometrical shapes, pseudoletters, or rotated letters) targets were presented either in isolation or surrounded by a geometrical shape. The surrounding shape was irrelevant for the task. It could be congruent or incongruent with the target regarding its geometrical form (for example see Fig. 1 left side: first column = congruent surrounded letter and shape; second column = incongruent surrounded letter and shape). When the classification required from the participants a distinction between “letters” versus “nonletters”, either explicitly (Experiments 1–3) or implicitly (Experiment 4), a negative congruence effect was obtained for letters, contrasting with a regular, positive congruence effect for nonletters (see Fig. 1 right, and Fig. 2 left).

![Response categories used in Experiments 4 and 5 in van Leeuwen & Lachmann (2004).](image)

Fig. 2. Response categories used in Experiments 4 and 5 in van Leeuwen & Lachmann (2004). The conditions displayed left led to negative congruence effects for letters, whereas for conditions shown on the right side positive congruence effects were obtained. Note that in the right conditions letters and non-letters of one category are similar in shape.
In Experiments 5 and 6, in contrast, no distinction between letters and nonletters was required. Here, response categories were varied in a way allowing participants to solve the task based on a purely visual strategy. For instance, the task was to classify two letters as one and two other letters as the other category. As a consequence, letters and nonletters invariably showed a positive congruence effect. Thus, we concluded that between Experiments 1–4 and Experiments 5–6, the occurrence of negative or positive congruence effects for the same stimuli depended on the task (see Fig. 2). Feature interaction, target selection, and response competition explanations were tested against a feature integration approach. The results were explained in terms of different feature integration strategies for letters and nonletters.

In Lachmann and van Leeuwen (2004) we used the introduced material in a successive same-different task, in which the material classes letters versus shapes were mixed within a pair (different responses). Again, the direction of congruence effects when the second item was a letter depended on whether distracter shape (S1) was visually similar or dissimilar to the letter configuration (S2).

For illustration see Figure 3. The graph at the right side displays a condition in which implicitly a categorization requires a distinction between letter and non-letter shape (in the conditions leps and psle; e.g., between “A” and “triangle”; “implicit”, because the instruction was not to distinguish between the letters and non-letters categories). This leads to a negative congruence effect for letters (leps and psle) and a positive congruence effect for pairs where both items were either shapes (psps) or letters (lele). The negative congruence effect for letters is similar to that displayed in Figure 1 (right side), for a task where explicitly a distinction between letters and shapes was required.

In contrast, for the condition displayed in the left side of Fig.3, where the categorization can be managed by a visual strategy, without distinction between letter and shapes, positive effects occur for both letters and shapes.
Congruence effects depend on the time course of letter recognition

The difference in congruence effects between letters and shapes were interpreted in terms of a more holistic processing of shapes (Kimchi, 1992), and a more analytic processing of letters (Lachmann and van Leeuwen, 2008a). In the latter study we investigated congruence effects of letters and shapes in same-different task in which the first and the second item always belonged to the same category, i.e., either two letters or two shapes, same or different, respectively. The dependency of congruence effects on the time course of processing was studied by varying the presentation time of the first item (S1) and the inter-stimulus-interval (ISI).

If the ISI was short, congruence effects were obtained for non-letters, but not for letters (see Fig. 4). The absence of congruence effects was interpreted, in accordance with the findings described before, as categorical influence on early visual integration processes; letters are processed less holistically than non-letter shapes. These results indicate that categorical influence of letters depends on the time course of stimulus processing. As a highly automatized process, it is effective for stimuli appearing at a relatively fast rate, whereas, a slower rate of stimulus presentation eliminates task-irrelevant categorical influences.

Fig. 4. Mean reaction times (RT in ms) for pairs of letters, pseudo-letters, and shapes (Material). The second item of the pair was surrounded by a congruent or incongruent shape. Upper left: short presentation time of the first item (80 ms) and short inter-stimulus-interval between the first and the second item (ISI = 320 ms); upper right: long presentation of the first item (300 ms) and short inter-stimulus-interval (ISI = 320 ms); lower left: short presentation time of the first item (80 ms) and long inter-stimulus-interval (ISI = 2920 ms); lower right: long presentation of the first item (300 ms) and long inter-stimulus-interval (ISI = 2920 ms). Error bars indicate 5% confidence intervals.
Fig. 5. Congruence effects, RT(incongruent) – RT(congruent), for data from Lachmann and van Leeuwen (2008a) and for four subgroups from Lachmann and van Leeuwen (2008 b): normally reading adults, children, and frequent-word reading impaired (FWRI) and non-word reading impaired (NWRI) dyslexics.

**Applied aspects**

Recently, the development of letter-specific processing was investigated (Burgund & Abernathy, 2008; Burgund, Schlaggar & Petersen, 2006). We (Lachmann and van Leeuwen, 2008 b) used the paradigm introduced above to investigate the letter processing strategies in subgroups of children with developmental dyslexia as compared to normally reading children and adults. All groups performed the successive *same–different* task with pairs of letters and nonletters (pseudoletters or geometrical shapes), as in the study introduced above. Adults showed congruence effects with nonletters but not with letters, and children with both types of stimuli (see Fig. 5). Frequent-word reading-impaired dyslexics in addition showed dramatically slower overall reaction times. Nonword reading-impaired dyslexics showed congruence effects with nonletters but negative congruence effects with letters (see Fig. 5). The results support the notion that normal readers have established a special visual processing strategy for letters. Processing speed rather than reading expertise seems crucial for this strategy to emerge. The contrasting effects between subgroups of dyslexics reveal specific underlying deficits.

**Discussion**

We found that congruence effects differ between letters and shapes if the task requires a distinction between the categories letter versus shape or if the task requires a phonological coding (Interestingly, the direction of the congruence effect differs also between Kana versus
Kanji processing in Japanese, cf. Jincho, Lachmann & van Leeuwen, 2008). This effect arises very early (we generally proposed that interference occurs very early, e.g., Boenke et al., 2009) and could be seen as an argument against traditional serial letter processing models (Posner & Mitchell, 1967). The effect, however, depends on the time course of information processing. In the latter same-different task (Lachmann and van Leeuwen, 2009) congruence effects became increasingly positive when the period between the onset of first and second stimuli was increased. This result appeared to be independent on whether the first stimulus was visually present for a long period during the Interval (S1). This suggests that these effects are mediated by phonological encodings and/or letter name codes (Posner, 1969). They may become effective gradually and slowly by activating top–down pattern recognition routines for letters. This top–down activity, according to our hypothesis, has the effect of rendering the letter-specific visual representation of the second stimulus task irrelevant, so that the letter-specific processing mode can be abandoned and a holistic feature integration mode uniformly adopted for letters as well as for non-letter shapes.

References


