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Differentiation of holistic processing in the time course of letter recognition

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ABSTRACT

Pairs of letters, pseudo-letters, and basic 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, in accordance with earlier findings, 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.

1. Introduction

The process by which initial representations of visual sensory features give rise to integral texture and tentative object structure is called visual feature integration (Pomerantz & Lockhead, 1994). Over time, the feature integration process could be modified by perceptual learning (Goldstone, 1998). In these modifications, categorical information can play an effective role (Notman, Sowden, & Özgen, 2005). We may even expect, contrary to what has often been assumed (Massaro, 1998; McClelland, 1976; Posner & Mitchell, 1967), an influence of higher-order semantic categories on the early perceptual integration process (Ahissar & Hochstein, 1997; Pylyshyn, 1999; Schyns & Oliva, 1999; Stins & van Leeuwen, 1993).

This study addresses the role of semantic knowledge in visual feature integration, using the congruence effect (Bavelier, Deruelle, & Proksch, 2000; Lachmann & van Leeuwen, 2004; Lockhead & Pomerantz, 1994; Pomerantz & Pristach, 1989; van Leeuwen & Lachmann, 2004). This effect implies that it is easier to recognize a visual object when it is surrounded by a similar shape than when it is surrounded by a dissimilar one (see Fig. 1, bottom row), because early feature integration has combined features of an object with those of its surrounding. If the congruence effect fails to occur, this indicates that target and non-target features have not been integrated to the same degree. They can be separated without effort. Congruence effects may therefore be used to measure the degree of perceptual feature integration.

We will investigate 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". 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 will lead to differences in congruence effects. We tested this prediction, comparing congruence effects for letters and non-letters (Lachmann & van Leeuwen, 2004; van Leeuwen & Lachmann, 2004). Lachmann and van Leeuwen (2004) used a *same–different* task (e.g., Nickerson, 1969) in which two items were presented subsequently for comparison. First and second items could be letters, pseudo-letters, or geometrical shapes. First items were always presented in isolation; second items were presented either in isolation or surrounded by a congruent or incongruent geometrical shape. For pseudo-letters and

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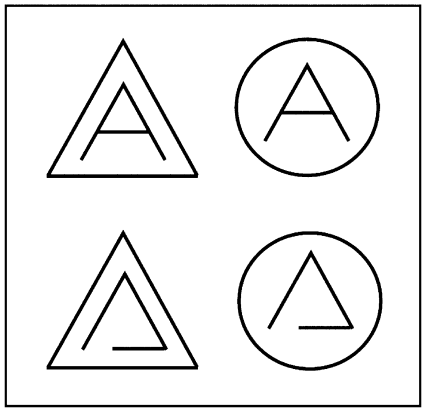

Fig. 1. Letters and non-letter shapes in congruent and incongruent surroundings.

shapes, a congruence effect was obtained; comparison was faster when an item appeared in congruent surrounding, compared to incongruent surrounding. For letters, however, no such congruence effect occurred.

The contrasting results for letters and non-letters were obtained for a small, restricted set of stimuli. There is only a small subset of letters, all capitals, that fits nicely within surrounding frames, the shape of simple, geometrical figures such as circles, triangles, and rectangles. This will necessarily restrict our conclusions, as these stimuli might be special. However, more recently, the effects were replicated with Japanese participants using kana and kanji, which allowed more variation (Jincho, Lachmann, & Van Leeuwen, 2008).

The dissociation of effects for letters and non-letters was attributed to differences in visual feature integration strategies between these categories. These could be understood as follows: practice has endowed experienced readers with a special visual feature integration mode for letters (Burgund, Schlaggar, & Petersen, 2006; Lachmann, 2002). Whereas single non-letter shapes are preferably grouped with their immediate surroundings, single letters are not. In this specific sense, referring to objects and their neighboring context, shapes are processed more holistically (e.g., Kimchi, 1992); letters less holistically.

Note that this differentiation has no implications for how strongly the features are bound together at the within-object level. For this, one could argue that it depends on the Goodness of the object (van der Helm & Leeuwenberg, 1996; Wagemans, 1999), e.g., the symmetry of the triangle or the letter "A". On the other hand, observers tend to ignore symmetry in letters (Lachmann & van Leeuwen, 2007), suggesting that letters are also processed less holistically at this level. Neither does the differentiation in holistic processing at any of these levels have any implications for the next higher level, which for letters would be that of morphemes or words. Our claim that letters are processed less holistically than non-letters, therefore, is not in conflict with the well-known word-superiority effect (Reicher, 1969). This effect applies at the level of groupings between letters. It could be argued that, in fact, recognition at this level might benefit from non-holistic processing at our current level (Freeman, Driver, Sagi, & Zhaoping, 2003); word-level processes, for instance, will have difficulty matching individual letters whose features have mistakenly been bound, based on pre-semantic information, to their surroundings. In sum, therefore, our claim of a distinction in holistic processing between letters and non-letters belongs exclusively to the level of visual integration between these objects and their immediate surroundings.

A further issue of interest is that perceptual feature integration depends on set or task (e.g., Schyns & Oliva, 1999; Stins & van Leeuwen, 1993). This applies specifically to processing of letters; in a choice-response task, van Leeuwen and Lachmann (2004) observed that non-letters were processed more holistically than letters when letters and non-letters similar in shape were assigned to opposite response alternatives (Experiment 4). However, the dissociation disappeared when letters and non-letters similar in shape were assigned to the same response alternative (Experiment 5). In this case the overall shape could be used as a response criterion. This resulted in identical congruence effects for letters and non-letters. It was concluded that in this case, both letters and non-letters were processed holistically.

The task dependency of the dissociation between letters and shapes rules out some alternative explanations for the effect. It could be argued, for instance, that the effect is due to a difference, not in the type, but in the rate of processing for more or less practiced stimuli. Differences in processing rate would then exist, however, in both tasks.

A further alternative explanation would invoke levels of processing. The task in which the dissociation disappears involves categories, in which global similarity is sufficient for making the distinction. This, presumably, is easier, and so one would expect the task is performed faster than the other task, in which distinctions between similar shapes are to be made. However, this is not the case. Especially for letters, an increase rather than a decrease in RT was observed from Experiment 4 to Experiment 5. In our understanding, this shows that holistic processing is less than optimal for letters. This is because letter-specific processing in experienced readers is highly automatized, and, therefore, considerably faster than the more holistic mode adopted for non-letters.

It is intriguing that skilled readers, who have learned to process letters less holistically than non-letter shapes, suddenly seem to process letters equally holistically, once their categorical identity becomes irrelevant. This would suggest that in this case the letter-specific processing mode, although preferable for letters, is actually less preferred. It is possible, however, that what is really un-preferred is having to switch between the letter and the non-letter mode on a case-by-case basis, so that perceivers prefer to have a uniform mode for letters and non-letters as soon as the task allows this, even if this implies a considerable reaction time cost. Indeed, between Experiment 5 and 6 in van Leeuwen and Lachmann (2004), a huge decrease in RT was observed, when letter and non-letter stimuli were blocked, rather than randomly intermixed.

2. Experiments

Let us consider an explanation for the above-mentioned results, based on the opposite assumption, viz. that early visual processing is independent of semantic category. One might then argue that non-letter processing is finished when this information is available, whereas for letters, further processing is automatized, and, therefore, mandatory. It then takes a while for the system to trace back to the visual information. This would explain why RTs are longer in conditions where a congruence effects is observed for letters. Such an explanation would predict as most likely that congruence effects in letters are the largest in cases where retracing the information is maximally difficult, i.e., in conditions where stimuli are presented at a relatively fast rate.

From our perspective, a contrasting predicting could be made. Several studies suggested that more holistic processing is characteristic of deferred stimuli, whereas, early on, processing is less holistic (Goldstone & Medin, 1994; van Leeuwen, Buffart, & van der Vegt, 1988). Comparing this for letters and non-letter shapes, we predict for the latter a steady preference for holistic processing, whereas, for letters we expect that holistic processing will appear later if the task enables this.