Dissociating congruence effects in letters versus shapes: Kanji and kana

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ABSTRACT

In order to consolidate the dissociation in feature integration found in earlier studies between letters of the Roman alphabet and corresponding pseudo-letters, the present study used kanji and kana and corresponding pseudo-letters, presented visually, either in isolation or surrounded by congruent or incongruent shape, as targets in a choice-response task with three different response criteria. When the criterion was shape, congruence effects were obtained for both real and pseudo-letters. With the second and third response criteria this result was found for pseudo-letters, but not for letters. These criteria either involved distinguishing between letters and visually similar pseudo-letters or distinguishing between visually similar letters. The dissociation of congruence effects between letters and pseudo-letters was therefore shown to depend on visual similarity between targets, independent of their category. This effect was found to be robust for kanji but not for kana, which is related to distinctions between these two writing systems.

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1. Introduction

Our reading skills depend on the ability to encode visual materials such as letters or words in reference to their role as symbols, i.e. as graphemes and lexical items (Lachmann, 2002). These encodings may be contrasted with those of, for instance, line drawings of geometrical shapes. Whereas the more familiar of these have symbolic names (“square”, “triangle”), they are not essential for their visual presentation. It is clear, therefore, that the visual representation of letters differs from that of shapes (Burgund, Schlaggar, & Petersen, 2006; Lachmann & van Leeuwen, 2007), at the latest in the stage where meaning is attached to them.

For understanding the process of reading, it is of interest to know how early the visual processing of letters and shapes begins to differ. Letters are not intrinsically different in visual appearance from geometrical shapes; a triangle shape, when used consistently in a text to replace the letter “A”, would not cause any ambiguity in reading. This might suggest that letters and non-letter shapes are represented in similar ways in the earliest stages of visual process-
features of target and surrounding, or analytic perceptual representation (Pomerantz, Pristach, & Carson, 1988). Holistic processing emphasizes properties such as symmetry that can be used for greater efficiency in encoding non-letter graphics. We tend to see the properties of their shape as representing a wider class. For this reason, we are quick to recognize items that are the same under transformation. Object constancy is one important consequence of this representation strategy (Lachmann, 2002).

Representing visual objects as the same under transformation may be useful for representing non-letter shapes, but not for reading letters, for instance: “b” vs. “d” (Badian, 2005; Friederici & Lachmann, 2002; Lachmann & Geyer, 2003). The visual similarity of these graphemes interferes with their mapping onto phonemes. Thus, applying a holistic strategy would make letters harder to process. We may expect letter processing to be analytic at an early stage, resulting in separation of target letter and surrounding non-target features. This may facilitate identification at a higher level with a phonological (Posner, 1978) or abstract letter-identity code (Bigsby, 1988), rather than their shape code (Krueger, 1975; Krueger & Shapiro, 1979). Integration at the higher level with other letters to form words, and with lexical knowledge, will then facilitate identification of letters in word contexts in a top-down manner, as demonstrated in the word superiority effect (Baron & Thurston, 1973; Krueger, 1975; Reicher, 1969).

For these reasons, van Leeuwen and Lachmann (2004) proposed that, whereas early visual feature integration in non-letter shapes is preferably holistic, in letters it is preferably analytic, in the sense that features that would normally be integrated in visual shapes to form a global structure will remain separate.

Analytic processing would normally lead us merely to expect absence of congruence effects in letters, not necessarily negative congruence effects. Negative congruence effects arise when feature integration has to be actively suppressed (Bavelier, Deruelle, & Promatic, 2000; Briand, 1994; van Leeuwen & Bakker, 1995). For the letters in Fig. 1 (upper half), this may be the case because the surrounding frame acts as a source of bias to process the image holistically. This tendency will be stronger if the frame is congruent in shape with the letter, and so holistic processing will be harder to suppress. Thus, the negative congruence effects could be interpreted from the need to actively suppress global regularities for optimal efficiency in processing letters.

In our present study, we investigated contrasting effects of letters and non-letter shapes by using the specific orthographic characteristics of Japanese (Hanavan & Coney, 2005). Our first experiment is focused on kanji characters. These are graphic elements representing morphological units (ideograms), such as nouns, verb and adjective stems.

The use of kanji will enable us to pinpoint the dissociation in congruence effects between letters and shapes. Van Leeuwen and Lachmann (2004, Experiments 5–6) found that the negative congruence effect for letters fails to occur if choice can be based on global perceptual similarity: When, for instance, Response Category 1 was for “A” or “triangle” versus Response Category 2 was for “C” or “circle”, items that are similar in shape are in the same response categories, so the decision could be made according to shape. In this case a congruence effect was observed for both shapes and letters (van Leeuwen & Lachmann, 2004; Experiments 5–6). By contrast, when Response Category 1 was for “circle” or “A” and Response Category 2 was for “C” or “triangle”, for non-letters there is still a congruence effect but for letters the negative congruence effect is obtained (van Leeuwen & Lachmann, 2004; Experiments 3–4). Here, items similar in shape are associated with different response categories. The dissociation in feature integration processes between letters and non-letters, therefore, depends on the task.

The restricted number of items that make up the Roman alphabet imposed inevitable limitations on these previous experiments. In particular, although it was possible to include pairs of similar letters and pseudo-letters, different letters were always dissimilar from each other. Thus, it is impossible to disentangle effects of visual similarity from abstract (letter) category. To distinguish between these two, kanji items have the useful feature that several of them share the same outline shape, meaning that the same surrounding can be congruent with similar, but different, letters.

In our present Experiment 1, we were therefore able to compare congruence effects for three conditions, rather than for two conditions as in the previous study. Each condition involves a different choice response criterion. In the first condition, as in van Leeuwen and Lachmann (2004), Experiments 5–6, items with different global shapes belong to different response categories. Visual shape is therefore sufficient to respond. In the second condition, different letters similar in shape still belong to the same response category, but the non-letter similar in shape belongs to the opposite category. Finally, in the third condition, letters similar in shape belong to opposite response categories. We expect in the first condition congruence effects for both letters and non-letters, as in van Leeuwen and Lachmann (2004), Experiments 5–6. The last two conditions allow us to pin down the dissociation between letters and non-letters obtained in van Leeuwen and Lachmann (2004), Experiments 3–4. Both task conditions reduce the role of within-category similarity as a decision criterion. In accordance with these earlier experiments, we may expect as a result a more analytic strategy for letters, but not for non-letters: the congruence effect for non-letters will therefore remain unaffected, but the one for letters will disappear (possibly leading to a negative congruence effect). The question, however, is whether this dissociation depends on categorical information or visual similarity. If it depends on abstract category, (letter vs. non-letter) we would expect the dissociation to appear in the second, but not in the third condition. If it requires a distinction between individual letters, we expect it in the third condition but not in the second. If it requires a distinction between visually similar items (regardless whether across letter and shape categories or within the letter category), we expect the dissociation to arise both in the second and third condition.
The validity of these predictions, and the relevance of the outcome, depends on how well early visual processing compares between Roman alphabet and kanji. Both differ in how they relate to their content (pictorial versus phonological coding; Osaka, 1992). Kanji encoding is therefore possibly more similar to that of non-letter shapes. In that case, however, we would expect to see the same congruence effect in all three of the above-mentioned conditions, and therefore no dissociation, neither in the second nor in the third condition. On the other hand, a comparison between early processing in different writing systems has broader significance.

Modern Japanese is a mixture of two writing systems, kanji and kana. In contrast to kanji, kana are phonographic characters (phonograms) representing syllables (syllabaries). There are two subtypes of kana: hiragana and katakana. Hiragana is used mainly (but not exclusively) for auxiliary elements such as particles and inflections. Katakana, by contrast, is commonly used to write loan words. In principle, a Japanese text could be written entirely in kana (e.g., Besner, 1987).

As ideograms and syllabaries, kanji and kana both differ from each other and from Roman alphabet. By comparing the congruence effects for these different writing systems, we should be able to determine whether the effects observed in Lachmann and van Leeuwen (2004) and van Leeuwen and Lachmann (2004) are specific to alphabetic languages or generalize to different writing systems. In addition, our investigation may shed light on differences in early visual processing between these writing systems.

Several studies have suggested differences in processing strategies between kanji and kana (Ito & Hatta, 2003; Osaka, 1989, 1992; Shimizu, Endo, & Nakamura, 1983; Yamaguchi, Toyoda, Xu, Kobayashi, & Henik, 2002), others failed to obtain any difference (Koyama, Kakigi, Hoshiyama, & Kitamura, 1998). However, these studies have focused on rather high-level processing, such as detection of word meanings.

Early processes of kana and kanji were emphasized in Osaka (1992) and Matsuda (1998). Eye-movement studies revealed contrasting strategies for reading kanji and kana (Osaka, 1989, 1992) between the reader switch while reading a Japanese text (Shaifullah & Monsell, 1999). Matsuda (1998) showed that the rate of detection and identification of kanji varied with their complexity. The complexity affects visual span in detection and recognition tasks (Matsuda, 1998). Kanji characters can use up to 20 strokes, whereas as kana uses no more than six. The former usually contains less information than the latter, and “nyu” and “kou” (public) and “hi” and “me” have a rectangular shape, whereas “hi” can be represented by different kanji characters, meaning ‘fire’, ‘sun’, ‘ratio’, ‘monument’, or ‘error’.

The difference in transparency between kanji and kana could, in principle, affect the dissociation in congruence effect in two opposite ways. According to one line of reasoning, because the grapheme–phoneme mapping will be harder to perform, the system in the present task will rely more on visual encoding for kanji than compared to kana. According to this assumption, early processing of letters should resemble that of non-letter shapes more in kanji than in kana. The dissociation should therefore be more robust in kana than in kanji. The other line of reasoning leads to the opposite prediction. Because it is harder to perform the mapping in kanji, it is even more important to exclude interference from surrounding visual information. This means that the dissociation should be more prominent in kanji than in kana. The result of this experiment is important for the question, to what extent phonological encoding of letters can be avoided strategically.

2. Experiment 1

2.1. Method

2.1.1. Participants

There were 18 participants (4 males), between 18 and 26 years old (\(M = 20.8; SD = 1.7\)). All of them lived in or near by Tokyo. They were native speakers of Japanese and had normal or corrected to normal vision and normal hearing. They were paid 2000 Japanese Yen (about £15/€) for their participation.

2.1.2. Materials

Targets consisted of kanji letters and pseudo-kanji shapes of 45 \(\times\) 45 mm. Kanji letters were “hi” (sun), “me” (eye), “nyu” (energy) and “kou” (police). “Hi” and “me” have a rectangular shape, and “nyu” and “kou” have a triangular shape. The two pseudo-kanji shapes were modified versions of the characters “hi” and “nyu”, such that the first still has a rectangular and the second has a triangular shape (see Fig. 2).

Each target occurred in isolation as well as two different 90 \(\times\) 90 mm contexts: surrounded by a rectangle, or surrounded by a triangle. The surrounding shape, therefore, was congruent with half of the enclosed targets and incongruent with the other half. A total of 18 stimuli were formed by combining targets and context conditions. Stimuli were drawn in black (0.46 cd/m²) on a CRT computer screen monitor set to white (28 cd/m²). They were presented with a distance of about 100 cm to the participant, resulting in a visual angle of about 2.6° without and 5.2° with surrounding. Participants used a button box for responses.

2.1.3. Procedure

Participants performed a two-alternative choice response task. Between participants, the task was varied in three conditions: shape, letter–shape, and letter condition (see Fig. 2). In all conditions, there were always two kanji characters and one pseudo-kanji shape together in each response category. In the shape condition, the kanji letters and the pseudo-kanji shape were assigned to a response category in terms of their geometrical shapes (i.e., “hi” and “me” and “pseudo-hi” vs. “nyu”, “kou” and “pseudo-nyu”). In the letter–shape condition, two kanji letters similar in shape and a pseudo-kanji different in shape were included in each response...
category. For instance, a response category included the kanji letters, “hi” and “me”, and pseudo-kanji shape “pseudo-nyu”, and the other category included “nyu”, “kou”, and “pseudo-hi”. In the letter condition, one response category consisted of two kanji letters whose shapes were different and a pseudo-kanji shape similar in shape to one of them. For instance: “hi”, “nyu”, and “pseudo-hi” versus “me”, “kou”, and “pseudo-nyu”. There are four alternative possible ways, shown in Fig. 2, to assign targets to response categories, eight if we consider the left–right response button switch. Each participant was assigned one of eight response combinations randomly.

The experiment was divided into four blocks. Each block was preceded by a practice session. Participants were seated comfortably in a dimly lit room. They were introduced to the stimulus material and the task. The introduction to the stimulus material was as follows: The three targets for which a left-hand response was required were presented on the left of a screen, and the other three for which a right-hand response was required, were presented on the right of a screen. Assignment of left or right hand response categories was balanced between participants. The order of items within each response category was varied across participants. Participants were instructed to remember which category a stimulus was presented and to press the left or right button on a response box at the appearance of a target, ignoring surrounding geometrical shapes. Participants were instructed to respond as fast and accurately as possible.

For each trial, a fixation cross appeared at the center of the screen for 150 ms, which was followed by a 300 ms blank screen. Then, a target stimulus was presented for 150 ms at the same position as the fixation cross was presented. After the offset of the target stimulus, the screen remained blank until response.

During practice, participants were given feedback after each response. When an error response was made, the two response categories were displayed again until participants recognized them and pressed the button to start a subsequent trial. The position of the targets within each category was varied randomly from one presentation to the next. The number of practice trials in the first block was at least 108 (practice continued until at least six correct responses for every stimulus were obtained) and at least 36 (at least two correct answers for the every stimulus) in the other three blocks.

Each block started after practice and a brief interruption. There were 16 trials for each of 18 patterns, which resulted in a total of 288 trials. Stimulus patterns were presented in random order. No feedback was given on experimental trials. There was a short break.
between blocks. All together the experiment took about one and a half hour.

2.2. Results

A grand total of 20,736 responses were obtained. In order to remove outliers, we excluded responses of which the reaction time (RT) was over 3000 ms. Of the remaining ones, those responses of which the RT was over 3SD from the individual RT were further excluded. A total of 227 responses were removed, which were dis-


Table 1

<table>
<thead>
<tr>
<th>Task</th>
<th>Material</th>
<th>Context</th>
<th>RT (ms)</th>
<th>SD (ms)</th>
<th>Error rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letter</td>
<td>Kanji</td>
<td>Isolated</td>
<td>428</td>
<td>43</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Congruent</td>
<td>439</td>
<td>43</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incongruent</td>
<td>441</td>
<td>46</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>Pseudo-kanji</td>
<td>Isolated</td>
<td>429</td>
<td>32</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Congruent</td>
<td>435</td>
<td>34</td>
<td>8.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incongruent</td>
<td>442</td>
<td>30</td>
<td>8.1</td>
</tr>
<tr>
<td>Letter–shape</td>
<td>Kanji</td>
<td>Isolated</td>
<td>425</td>
<td>62</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Congruent</td>
<td>432</td>
<td>60</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incongruent</td>
<td>433</td>
<td>64</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Pseudo-kanji</td>
<td>Isolated</td>
<td>441</td>
<td>57</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Congruent</td>
<td>467</td>
<td>61</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incongruent</td>
<td>473</td>
<td>58</td>
<td>7.4</td>
</tr>
<tr>
<td>Shape</td>
<td>Kanji</td>
<td>Isolated</td>
<td>362</td>
<td>37</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Congruent</td>
<td>367</td>
<td>41</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incongruent</td>
<td>386</td>
<td>41</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td>Pseudo-kanji</td>
<td>Isolated</td>
<td>367</td>
<td>43</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Congruent</td>
<td>373</td>
<td>47</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incongruent</td>
<td>389</td>
<td>40</td>
<td>7.0</td>
</tr>
</tbody>
</table>

(Letter task; letter–shape task and shape task N = 6).

Fig. 3 shows differences in RTs between congruence- and incongruence-surrounded contexts for each combination of stim-
ulus (kanji or pseudo-kanji) and experimental task, that is the status of congruence effects. Positive or negative value means a
positive or a negative congruence effect. We conducted an analy-

sis of variance (ANOVA) and post-hoc pair-wise comparisons (LSD test) on RT using the two within-subject factors (Material and Context) and the one between-subject factor (Task). The 2 (Mate-
rial: kanji versus pseudo-kanji) × 3 (Context: isolated, congruent surrounded, incongruent surrounded) × 3 (Task: letter–shape, let-
ter, shape) ANOVA showed a significant main effect for Material, $F(1, 15) = 5.45$, $p < .05$. Kanji (412 ms) was responded to faster than pseudo-kanji (428 ms). A main effect of Context also was significant, $F(2, 30) = 80.19$, $p < .001$. RTs for isolated stimuli (409 ms) were faster than those for congruent surrounded (419 ms) and incongruent surrounded ones (427 ms), both $p < .001$. Congruent surrounded stimuli were responded to faster than incongruent surrounded ones, $p < .001$. In addition, a main effect of Task was significant, $F(2, 15) = 4.12$, $p < .05$. Post-hoc paired comparisons showed that RTs for the shape task (374 ms) were faster than those for the letter–shape (445 ms) or letter tasks (435 ms), both $p < .05$. However, a difference between letter–shape and letter tasks was not significant.

We found a significant two-way interaction between Material and Context, $F(2, 30) = 3.63$, $p < .05$. Pseudo-kanji in isolated presentation (405 ms) were responded to faster than in congruent surrounded (413 ms) or incongruent surrounded context (420 ms), both $p < .001$. The difference between congruent and incongruent conditions was significant, $p < .001$. Kanji in isolated conditions (412 ms) were faster than in congruent (425 ms) and incongruent surrounded conditions (434 ms), both $p < .001$, and congruent was faster than incongruent, $p < .001$. An interaction between Material and Task was obtained, $F(2, 15) = 3.90$, $p < .05$. Whereas in the letter–shape task RTs for kanji (430 ms) were marginally shorter than those for pseudo-kanji (460 ms), $p < .06$ (n.s.), both were identical in the letter task (for kanji: 436 ms; for pseudo-kanji: 435 m) and shape task (372 ms and 376 ms, respectively). Moreover, an interaction between Context and Task was significant, $F(4, 30) = 5.98$, $p < .01$. In the letter and letter–shape tasks, iso-
lated stimuli were responded to faster than congruent- and incongruent-surrounded contexts, all $p < .05$ (isolated, congruent, and incongruent in the letter task, respectively: 428, 437, and 441 ms; in the letter–shape task, respectively: 433, 449, 452 ms). However, congruent and incongruent surrounded stimul-
us did not differ. In the shape task isolated stimulus (364 ms) were faster than incongruent stimulus (387 ms) as in the other tasks, $p < .001$, but otherwise a contrasting pattern of results was obtained: the difference between isolated (364 ms) and congruent stimulus (370 ms) was not significant, $p > .10$, and congruent stimuli (370 ms) were responded to faster than incongruent ones (387 ms), $p < .001$.

Above interactions were qualified by a three-way interaction involving Material, Context and Task, $F(4, 30) = 5.46$, $p < .01$. Pair-
wise comparisons were conducted among Context in each Material for each Task condition separately. Isolated kanji and pseudo-kanji were significantly faster than ones in congruent or congruent surroundings in the shape condition, all $p < .001$, and in the letter–shape condition, all $p < .05$. In the letter condition, isolated kanji and pseudo-kanji were significantly faster than incongruent ones (both $p < .001$). For pseudo-kanji, the difference in RT be-
tween congruent and incongruent surrounded targets was signific-
ant in the shape condition and the letter condition, both $p < .05$. In the letter–shape condition, RT for congruent surrounding was shorter than for incongruent surrounding but this difference did not reach significance, $p < .08$ (n.s.). For kanji, RT for congruent sur-
roundings was shorter than for incongruent surroundings in the shape condition, $p < .001$. In the letter–shape condition and the letter condition, differences between congruent and incongruent sur-
roundings were not significant. For the means of this analysis, see Table 1.
Table 2
Overview of predicted effects and results in Experiment 1

<table>
<thead>
<tr>
<th>Task</th>
<th>Material</th>
<th>Context</th>
<th>Result</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Kanji</td>
<td>Congruent</td>
<td>+</td>
<td>Ok1</td>
</tr>
<tr>
<td></td>
<td>Pseudo-kanji</td>
<td>Congruent</td>
<td>+</td>
<td>Ok1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incongruent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter–shape</td>
<td>Kanji</td>
<td>Congruent</td>
<td>n.s.</td>
<td>Ok2, *</td>
</tr>
<tr>
<td></td>
<td>Pseudo-kanji</td>
<td>Congruent</td>
<td>n.s.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incongruent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter</td>
<td>Kanji</td>
<td>Congruent</td>
<td>+</td>
<td>Ok2, +</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incongruent</td>
<td></td>
<td>Ok1</td>
</tr>
<tr>
<td></td>
<td>Pseudo-kanji</td>
<td>Congruent</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

Note. Ok1, congruence effect predicted; Ok2, dissociation from congruence effect predicted on the basis of; *, the need to distinguish between a visually similar letter and a pseudo-letter; +, the need to distinguish between visually similar letters.

2.3. Discussion
Isolated targets were generally responded to faster than surrounded ones, most likely because the effects of surrounding shapes were related to early visual perception and targets in isolation are easier to detect. We examined whether congruence effects in kanji letters dissociate from those in pseudo-kanji shapes, similarly to the Roman alphabet. A congruence effect was found for pseudo-kanji targets generally across task conditions, although it failed to reach significance in the letter–shape condition. For kanji targets, there is a congruence effect in the shape condition (van Leeuwen & Lachmann (2004), Experiments 5–6). Congruence effects for kanji were absent, however, in the other two conditions (see Table 2). One of these conditions, the Letter–shape condition required perceivers to distinguish a letter from a visually similar non-letter; the other, the Letter condition, required them to distinguish between two visually similar letters. The dissociation in congruence effect between kanji and pseudo-kanji in both conditions implies, according to our hypothesis, that letter-specific processing depends on similarity between response alternatives, irrespective of the categorical nature of the items. This interpretation of the results is in accordance with our hypothesis that these effects belong to early visual processing.

The results are consistent with that for alphabet in van Leeuwen and Lachmann (2004) and eliminate the confounding of categorical information and similarity from this study. Note, however, that in the 2004 study a stronger dissociation between letters and non-letters was obtained: positive vs. negative congruence effects, compared to the present absence of congruence effects in the present experiment (see Fig. 3).

All the previous studies used the Roman alphabet. We may consider differences in the nature of the representation (Osaka, 1992) for the weaker dissociation. Possibly, kanji are more pictorial, and for this reason their visual encoding is somewhat more similar to that of shapes. On the other hand, such a difference was unable to eliminate the dissociation completely. If this difference is relevant, we should observe in Experiment 2 a more robust dissociation in kana than in kanji.

3. Experiment 2

3.1. Method

3.1.1. Participants
There were 16 native speakers of Japanese between 21 and 35 years old (4 males, M = 23.2, SD = 4.4). All of them reported normal or corrected to normal vision. They were paid 2000 yen for their participation.

3.1.2. Materials
We used eight target stimuli that consisted of two kanji letters, two hiragana letters, two pseudo-kanji shapes, and two pseudo-hiragana shapes. Kanji letters (“hi” [sun] and “nyu” [enter]) and pseudo-kanji shapes were same as in Experiment 1. Hiragana letters were “no” and “se”. “No” had a circle shape, and “se” had a rectangle outline shape. Pseudo-hiragana shapes were made from the two hiragana letters by changing the positions of strings. Shape of “pseudo-no” and “pseudo-se” was circle and rectangle, respectively. The stimuli were intuitively chosen to balance figural complexity. These target stimuli were drawn in the 45 x 45 mm square (see Fig. 3).

As in Experiment 1, the kanji letter and the pseudo-kanji shape were presented in three contexts: isolated, surrounded by a rectangle, or surrounded by a triangle. The hiragana letter and the pseudo-hiragana shape were also presented in three contexts but surrounding shapes were different from those with the kanji letters and pseudo-kanji shapes: isolated, surrounded by a rectangle, or surrounded by a circle. In both cases, the surrounding shapes were incongruent or congruent with the targets. A total of 24 stimuli were made with combination of eight target stimuli and three surrounding contexts. All surrounding shapes were drawn in the 90 x 90 mm square.

We presented kanji letter and hiragana letter conditions in separate blocks. Thus, only kanji and pseudo-kanji appeared in two of four blocks, while only hiragana and pseudo-hiragana appeared in the other two.

In this experiment, we investigated congruence effects for both letters and pseudo-letters under a balanced situation, in which letters and pseudo-letters were presented in equal ratio and distributed to both left and right response categories in balance. Therefore, in kanji blocks, kanji letters were divided into two different response categories, and pseudo-kanji shapes were also divided and assigned to the category in which there was a kanji letter whose outline shape was different. In hiragana blocks, hiragana letters and pseudo-hiragana shapes were divided and assigned to response categories in the same way. Fig. 4 shows the possible stimulus combinations.

3.1.3. Procedure
The procedure was the same as in Experiment 1. There were 72 practice trials (practice continued until at least six correct responses for every stimulus were obtained) prior to the first and third block and 36 practice trials (at least three times correct answers for the every stimulus) prior to the second and fourth block.

Each experimental block contained a total of 576 trials in which each stimulus was presented 48 times. Within each experimental block, stimuli were presented in random order. No feedback was given in the experimental blocks. Half of the participants conducted two kanji blocks first, and the other half of them conducted two hiragana blocks first. There was a short break between blocks. The whole experiment took about one and a half hour.

3.2. Results
We excluded outlier responses (237 trials; 1.3%) using the same criterion as Experiment 1. Mean RTs for correct responses and error rates for the conditions are displayed in Table 3. The overall mean RT was 436 ms (SD = 38 ms) and ranged between 360 ms (SD = 65 ms) and 501 ms (SD = 109 ms) for individuals. The mean error rate was 6.1% and ranged from 1.1% to 10.9% for individuals. Since individual’s mean error rates and RTs were negatively correlated (r = -.72; p < .01), both RT and error rates were analyzed.
We conducted ANOVAs and post-hoc LSD tests on RTs and error rates including the within-subject factors Orthography (hiragana, kanji), Material (letter, pseudo-letter), and Context (isolated, congruent surrounded, incongruent surrounded); see Table 3. For RT, a main effect of Orthography was found, $F(1, 15) = 4.78, p < .05$. Hiragana (429 ms) was responded to faster than kanji (444 ms). A main effect of Material was also significant, $F(1, 15) = 6.22, p < .05$. Letters (431 ms) were faster than pseudo-letters (441 ms). In addition, a Context effect was found to be significant, $F(2, 30) = 22.87, p < .001$. Isolated stimuli (431 ms) were faster than congruent (438 ms) and incongruent (440 ms) surrounded stimuli, both $p < .001$. However, RT differences between congruent and incongruent were not significant. An interaction was obtained between Material and Context, $F(2, 30) = 12.28, p < .001$. Fig. 5 shows mean RTs for letters and pseudo-letters for each context. For pseudo-letters, isolated targets resulted in shorter RTs (434 ms) than congruent surrounding (442 ms), $p < .001$, and both of these were shorter than incongruent surrounding (448 ms), $p < .001$ for isolated vs. incongruent surrounding and $p < .05$ for congruent vs. incongruent. The last difference indicates a congruence effect for pseudo-letters. For letters, RTs for isolated (429 ms) were not different from incongruent (432 ms) but shorter than for congruent surrounding (433 ms), $p < .05$. Clearly, there is no congruence effect in this condition. In Table 3, however, this result is shown to differ between hiragana and kanji. For pseudo-hiragana, planned paired comparisons revealed that RTs were faster with isolated targets.
than with congruent surrounded ones, \(p < .05\), and incongruent surrounded ones, \(p < .001\). In addition, RTs for congruent surrounded context were shorter than for incongruent surrounded one, \(p < .05\). For hiragana, no paired comparison among the three context conditions was significant. For pseudo-kanji, isolated targets were faster than both congruent and incongruent surrounding, both \(p < .001\), and pseudo-kanji in congruent surrounding were responded to faster than in incongruent surrounding, \(p < .05\). For kanji, isolated targets were significantly faster than congruent surroundings, \(p < .01\), but the difference between isolated and incongruent surrounded ones did not reach significance, \(p < .09\). The difference between congruent and incongruent surrounded targets was not significant, either. Fig. 6 shows the status of congruence effects in terms of RT differences between congruent and incongruent surrounded contexts for letters and non-letters. The ANOVA on error rates revealed no main effects at all. There was, however, a two-way interaction between Material and Context, \(F(2, 30) = 3.81, p < .05\). In isolated and congruent surrounded presentation, error rates did not differ between letters and pseudo-letters (isolated letters and pseudo-letters 6% and 6%; congruent ones, respectively, 5% and 6%) in the incongruent surrounded condition, however, more errors were made for pseudo-letters (8%) than for letters (5%), \(p < .01\). A three-way interaction involving Orthography, Material, and Context was also significant, \(F(2, 30) = 4.52, p < .05\). Post-hoc analyses showed different congruence effects among different orthographies and materials (See Table 3). For pseudo-hiragana, error rates in the isolated targets were marginally lower than those in the incongruent surrounded targets, \(p < .06\) (n.s.), but no other effects were near significance. For hiragana targets, error rates were marginally higher in the isolated than in the congruent condition, \(p < .06\) (n.s.), and significantly higher in the incongruent than in the congruent condition, \(p < .05\). Thus, a congruence effect was obtained for hiragana. For pseudo-kanji, fewer errors were made in the congruent than in the incongruent condition, \(p < .05\). For kanji, fewer errors were made in the isolated than in the incongruent condition, \(p < .01\). Error rate in the congruent condition was marginally lower than in the congruent condition, \(p < .07\) (n.s.). This is a negative congruence tendency.

3.3 Discussion

This experiment was performed to investigate how the dissociation in congruence effects was influenced by differences between orthographic systems. We compared the two writing systems that coexist in Modern Japanese, kanji and kana (hiragana). The results are summarized in Table 4. As in the previous experiment, isolated pseudo-letters and letters were usually responded to faster than to ones surrounded by a congruent or incongruent shape. This effect was more prominent in kanji than in hiragana orthography where, in addition, isolated hiragana letters received an increased error rate.

Congruence effects were obtained for both pseudo-hiragana and pseudo-kanji. The absence of congruence effects in the reaction times for letters for kanji echoes the result of the first experiment. We may say that the dissociation observed in Experiment 2 was similar to that in the previous one.

We observed a weaker dissociation in kana than in kanji. In the error rates, a congruence effect was found for hiragana but a negative congruence tendency in the error rates. This result is opposite to what we would have expected from the view, expressed in the discussion of the previous experiment, that kana is visually encoded more similar to non-letters than Roman alphabet, because its representation is pictorial as opposed to phonemic. This distinction, therefore, seems not relevant for the current congruency effects.

In terms of the role of phonemic transparency, if we assume that this is the crucial distinction between our stimuli, we should conclude that the weaker the phonemic transparency, the more important it is to dissociate letters from non-letter shapes. This conclusion is, however, somewhat counter-intuitive if we take into account the earlier observations on Roman alphabet, where the dissociation was stronger for items which are phonologically more transparent than kanji. Perhaps the limited set of stimuli should be drawn into consideration, which implies that this result is, at best, preliminary.

4. General discussion

We exploited the features of the Japanese writing system to study the dissociation in congruence effects between letters and non-letters. Throughout our experiments, we obtained robust congruence effects for non-letters. These effects are generally related to early feature integration (Pomerantz & Pristach, 1989; Pomerantz et al., 1988). In accordance with this interpretation, isolated targets were generally processed faster than ones surrounded by a congruent or incongruent shape.

Congruence effects were also obtained for kanji when visual shape information alone was enough to distinguish the response alternatives. This effect is in accordance with findings in the Roman alphabet (van Leeuwen & Lachmann, 2004). As with Roman letters, kanji are processed with the same holistic feature integration strategy as for non-letter shapes, when no distinction between the specific, distinguishing features of letters and shapes is required by the task.

The question which these earlier studies left unanswered, however, was whether there are influences of the categorical distinction between letters and shapes on the task effect. In the previous experiments, which were limited by the number of items in Roman alphabet, categorical distinctions always implied
absence of similarity, and vice versa. The larger variety of kanji enabled us to distinguish these two. One task condition required a distinction between a letter and a similar non-letter (Letter–shape condition); the other task a distinction between two similar letters (Letter condition). Congruence effects in letters dissociated from those in non-letters in both tasks indicated that the task-effect is independent of categorical distinctions between stimuli, and results from visual similarity between the response alternatives. This result is in accordance with the view that the distinction in holistic processing between non-letters and letters is made in the early stage of visual feature integration.

It might seem odd to conclude that category information is irrelevant to the task effect, if the task effect itself involves differential processing of stimuli depending on which category they belong to (letters vs. pseudo-letters). However, there is nothing contradictory about this; the task-specificity involves the question whether a holistic processing strategy is sufficient to perform the task. Once this is no longer the case, categorical distinctions in more holistic (shape) vs. less holistic processing (letters) emerge. These distinctions, however, need not be present at an early stage in an explicit or unambiguous form. It is possible, for instance, that analytic and holistic stimulus processing occur in parallel and that only those survive that can be matched, interactively, with the appropriate categorical information (cf. Osaka, 1992).

The dissociation observed in both Experiments 1 and 2 for kanji was weaker than that for the Roman alphabet. The latter showed negative congruence effects, whereas the former merely showed an absence of congruence effects. We might suppose that kanji are processed somewhat more holistically by default than Roman alphabet, i.e. more like non-letter shapes, presumably because kanji codes linguistic information in a pictorial manner (Osaka, 1992).

However, comparing kanji with kana in Experiment 2, showed an even weaker dissociation in kana. This is the opposite to what we would have expected, given that kana is phonetically more transparent in its grapheme–phoneme mapping than kanji and in this respect more similar to Roman alphabet. Stimulus complexity (Matsuda, 1998) may be a factor. However, we made efforts to balance the complexity of our stimulus set between kana and kanji. It is therefore perhaps more important for kanji than for kana to maintain an analytic processing strategy during visual encoding, as it takes longer to achieve the grapheme–phoneme mapping. If we consider this explanation, the comparison of kanji and roman alphabet remains a puzzle. In this respect, a more systematic study is needed, using a larger variety of stimuli. This remains our goal for the future. The observation of a smaller advantage of isolated kana over surrounded ones as compared to kanji, goes to support this explanation.

The present results support the notion that letters are not necessarily encoded by activating their phonological representation. This does not happen if holistic shape encoding is sufficient to perform the task. Letters need not therefore automatically evoke their phonology; once when the letter-specific encoding strategy is invoked, however, they do.

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