Psychological Research (2008) 72:641–647
DOI 10.1007/s00426-008-0169-z

ORIGINAL ARTICLE

Position effects in encoding briefly exposed item matrices: evidence for a reading bias or merely a matter of the selection criterion?

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Received: 12 June 2007 / Accepted: 28 January 2008 / Published online: 8 October 2008

Abstract Position effects are frequently reported in experiments that investigate the recognition of items from briefly exposed stimulus matrices. A reliable finding is the ability to report items from the first row of the matrix more accurately than from the second row. The present experiments explore whether this position effect depends upon the selection criterion used to indicate the subgroup of items that has to be reported in a given trial. In Experiment 1, German and Chinese participants were presented with language-specific items which had to be selected by column. In Experiment 2, Germans were presented with Latin letters and the selection criterion was letter color. A strong row effect was evident in both experiments although the selection criteria did not prompt a line-by-line grouping of the items. The row effect is seen as a manifestation of top-down processing that is derived from reading habits.

Introduction

In previous experiments that focused on the influence of native language on encoding briefly exposed items, we observed a very reliable position effect (Lass et al. 2003, 2006). In our experiments we made use of an experimental technique that was originally designed by Sperling (1960): A cue following the 50 ms-presentation of a two-row matrix at varying delays indicated whether all matrix items had to be reported (full report) or only a subset, namely those from either the first row or the second row (partial report). With two-row matrices and linguistic items our German and Chinese participants reported more items correctly from the first row than from the second row. This row effect is consistent with results in the classic experiments by Sperling (1960, Exp. 7) and Averbach and Coriell (1961), who also utilized two-row matrices.

In our opinion, the row effect is caused by a scanning strategy by which attention is allocated on a “first row first” basis. There is substantial evidence that participants begin encoding as soon as possible even though they do not yet know which items will be cued (e.g., Averbach and Coriell 1961; Gegenfurtner and Sperling 1993; Loftus et al. 1985; Rumelhart 1970; Sperling 1960). This so-called nonselective readout from the visual buffer continues until the cue following the offset of the matrix indicates which subset of matrix items has to be reported. Then the attention window might be shifted and selective readout begins. As the visual buffer is strictly time-limited the number of items identified by selective readout will decrease with increasing cue delay (for details of the interplay between nonselective and selective readout, see Gegenfurtner and Sperling 1993).

According to the scanning strategy mentioned above, the participants, knowing about the format of the stimulus array in advance, approach the task with the most efficient strategy available to them. In the case of a matrix containing linguistic items (single Latin letters, compounds of consonants and vowels (CVs), signs composed by elements from Chinese characters), it is plausible that spontaneous encoding was accomplished through an analogy with reading, which proceeds in German and Chinese language by

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line and begins with the upper row (for a related view, see Heron 1957). Experiments that made use of single sequences of letters that were to be reported presented evidence of sequential left-to-right processing thus supporting the reading hypothesis: accuracy of report decreased and reaction time increased from left to right within a sequence (e.g., Lefton et al. 1978; Merikle et al. 1971).

As outlined above, we favor an explanation of the row effect in terms of reading habits. That is, we see the row effect as a manifestation of top down processing. But there is a reasonable alternative explanation for the row effect as well. In the experiments under discussion, the selection criterion for partial report was the position of the row. The items from either the first or the second row had to be reported. Subsets of items that share a spatial location provide an optimal situation for the focusing of attention (Kahneman 1973). Following Kahneman, attention can most effectively be focused on subsets of items that form "good" perceptual groups, and the formation of perceptual groups depends to a large extent on Gestalt principles of organization. For example, the items in a subset specified by the criterion row are easily grouped together according to the principle of proximity. There is evidence that "good" groupings determined by spacial arrangement lead to high levels of report (Fryklund 1975; Kahneman and Henrik 1977). In keeping with these findings, Merikle (1980) observed that the spatial selection criteria in partial report were more effective when their demand characteristics were compatible with the implied perceptual groups in the stimulus array.

Thus, it is possible that the compatibility between the demand characteristics of the selection criterion in question, namely to select one row, and the "goodness" of the perceptual grouping is a precondition for the row effect to appear. Since scanning the item matrix by line is highly compatible with a perceptual grouping by row, reading habits may be of secondary importance for the interpretation of the row effect. The present experiments explored whether perceptual grouping provides an alternative explanation for the first-row-first strategy observed in our previous experiments (Lass et al. 2003, 2006).

Experiment 1

The purpose of the experiment was to investigate whether the row effect that might be attributed to reading habits survived when the selection criterion did not prompt a line-by-line grouping of the matrix items. Since the row effect had been found with both Germans and Chinese (Lass et al. 2003, 2006), participants from both language groups took part in the experiment. The participants were asked to report as many items as possible from a briefly presented item matrix, either from the whole matrix (full report) or from one column of the matrix (partial report). If the selection criterion can lead to a specific perceptual grouping of the matrix items, then columns of items should result from such processing. As a consequence, there should exist no compatibility between the perceptual grouping and the scanning of the items by line. The replication of a significant row effect under these conditions would provide implicit support for the reading hypothesis by proving that the row effect found in the previous experiments was not prompted by the selection criterion.

Language-specific items were used that had been controlled for visual complexity (Lass et al. 2006, Exp. 3). The Germans were presented with CV items and the Chinese with radicals. Radicals represent one type of the basic components of Chinese characters. Approximately 80% of all frequent Chinese characters are phonograms that contain one radical and one phonic (Zhou 1978). The radical indicates the general semantic category to which the character belongs. The radicals used in our experiment can neither stand alone nor in combination with each other as characters. The phonic contains information as to how a character is pronounced. In a previous experiment we had found that single radicals clearly made higher encoding demands on the Chinese participants than single Latin letters did on the Germans (Lass et al. 2006, Exp. 3). In other words, there are no components in the Chinese writing system that are equivalent to single Latin letters. With the use of CV-items for the Germans and radicals for the Chinese, however, there were no significant differences between Germans and Chinese in the overall performance levels, neither in full nor in partial reports (Lass et al. 2006, Exp. 4).

Method

Participants

Forty-eight German students from Göttingen ranging in age from 19 to 25 years ($M = 22.1$) and 48 Chinese students from Shanghai ranging in age from 17 to 21 years ($M = 18.9$) took part in the experiment that was run in Göttingen and Shanghai in the respective native languages. All the participants had normal or corrected-to-normal visual acuity. They were either paid for their participation or received course credit.

Apparatus

Stimuli were presented on a monitor, and a touch screen registered the participant's responses. In both laboratories, Macintosh computers of the type iMac with a 15 inch CRT color monitor (95 Hz) were used.

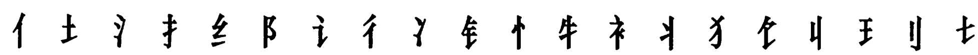

Fig. 1 Radicals used in Experiment 1

Stimuli

The item set for the German participants included 20 CV items: FA, FE, FI, FO, LA, LE, LI, LO, TA, TE, TI, TO, WA, WE, WI, WU, XA, XE, XI, XU. The item set for the Chinese participants included 20 different radicals that are shown in Fig. 1. The construction of the item matrix was based on a non visible grid comprising two horizontal cells and three vertical cells. The items that appeared in the center of the cells were selected randomly from the relevant set with the restriction that no item appeared more than twice in the matrix. The matrix subtended 2.39° of visual angle horizontally and 3.63° vertically. The CV-items were shown in Times font and were 0.38° in height. There was a variation in width between 0.38° and 0.76°. The radicals were shown in Song type and were 0.86° in height. The variation in width was between 0.29° and 0.44°.

The type of report (full report or partial report) was indicated by arrows to the left and right of the matrix position (see Fig. 2). Arrows subtended 0.76°. The distance of the arrowhead from the center of the matrix position was 1.34°. Latin letters, radicals, and arrows were displayed as black symbols on a gray background.

Procedure

The participant was seated in a semi-darkened room with a light intensity of approximately 460 lux facing the monitor. Each trial started with the presentation of a fixation cross in the center of the screen. When the participant pressed the return key, the fixation cross-started blinking, and then a matrix with six items was presented for 50 ms. The matrix was succeeded by a 50-ms exposure of one or two arrows that appeared to the left and/or to the right of the no longer visible matrix. An arrow on the left side was the cue to report the items from the left column (see Fig. 2). An arrow on the right side, correspondingly, meant that the right column had to be recalled. When both arrows appeared, all matrix items had to be reported. For the partial-report condition, the intervals between the offset of the stimulus matrix and the onset of the cue were 0, 100, 300, and 1,000 ms. For the full-report condition, the cue delay was always 0 ms. A response grid would then appear in the middle of the screen. At the same time, all 20 items were shown at the bottom of the screen. The interval between the offset of the arrows and the onset of the grid was 950 ms. In the full report the grid was a 3 × 2-matrix while in the partial report it was a 3-cell column. A cursor appeared in the upper cell of the response grid. The subject could enter an item into this cell by touching one of the 20 items. The cursor then appeared in the next cell of the column and so on. In the case of a full report the cursor first appeared in the left column of the response grid. The cursor could be arbitrarily moved by the participant by touching any cell of the grid. Entries could be corrected. The participant could finish the response by touching an "OK" button on the screen but only after all the cells had been filled. The number of correctly entered items was displayed on the screen as feedback. The next trial was then started with the presentation of the fixation cross.

An individual session consisted of 20 practice trials and 240 test trials and lasted about 1.5 h. At the beginning of the session, all items were displayed. Each participant was presented with 48 full-report trials and with 48 partial-report trials per cue delay. The order of the trials within an individual session was random. After every 30 trials, a pause was indicated by a symbol on the screen.

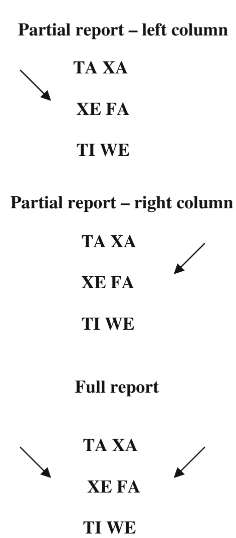

Fig. 2 Stimulus configuration in full report and partial report in Experiment 1. The *arrows* were presented after the offset of the matrix

Results

The number of correctly reported items per trial was used as the dependent variable. An input into a cell of the response matrix was scored as correct if the correct item was entered in the correct position. As to the full-report scores, there was no statistically significant difference between the Germans ($M = 1.80$, SD = 0.35) and the Chinese ($M = 1.71$, SD = 0.34), $t(94) = 1.30$, $p = 0.197$.

The superiority of the partial report as compared to the full report is a precondition for attributing performance in

this task to a time-limited visual buffer (see e.g., Coltheart 1980; Merikle 1980; Sperling 1960). The test for partial-report superiority was done by adding together the number of correct items in left column-report and right-column report in the trials with a cue delay of 0 ms. A comparison of this sum (the total number of encoded items) with the number of correct items in full report yielded a significant difference for both the Germans, $t(47) = 13.04$, $p < 0.001$, $\varepsilon = 2.96$, and for the Chinese, $t(47) = 13.04$, $p < 0.001$, $\varepsilon = 3.90$.

The partial-report scores were evaluated by a four-factor MANOVA using language group (Germans, Chinese) as the between-subjects factor and cue delay (0, 100, 300, 1,000 ms), selection criterion (left column, right column), and row (first, second, third) as the within-subject factors. For all the analyses of variance presented in this article Pillai's trace statistic was used as a multivariate test of significance, and the approximated *F*-values resulting from this procedure are reported. There were significant main effects for the factors cue delay, $F(3, 92) = 72.25$, $p < 0.001$, $\eta^2 = 0.70$, and row, $F(2, 93) = 699.27$, $p < 0.001$, $\eta^2 = 0.94$. From Fig. 3 it can be seen that accuracy declined as a function of cue delay and was lowest when items from the third row were reported. The interaction between the two factors was significant, $F(6, 89) = 11.85$, $p < 0.001$, $\eta^2 = 0.44$, indicating that the influence of cue delay was less pronounced with the low scores when items from the third row were reported (see Fig. 3).

The analysis yielded a tendency of the Chinese participants to perform somewhat better than the Germans, $F(1, 94) = 3.42$, $p = 0.068$, $\eta^2 = 0.04$. There were significant interactions of the factor language group with cue delay, $F(3, 92) = 4.02$, $p = 0.010$, $\eta^2 = 0.12$, and row, $F(2, 93) = 5.26$, $p = 0.007$, $\eta^2 = 0.10$. In addition the three-way interaction language group by cue delay by row narrowly missed significance, $F(6, 89) = 2.14$, $p = 0.056$, $\eta^2 = 0.13$. Pairwise comparisons between the two language groups for each row and cue delay level showed that the performance lead of the Chinese was restricted to items from the first row of the matrix in conditions with a cue delay of 0, 100, and 300 ms (all *t*-tests Bonferroni corrected: $\alpha = 0.004$). For a closer inspection of the row effect, we ran pairwise comparisons between the three row levels for each cue delay and language group (all *t*-tests Bonferroni corrected: $\alpha = 0.004$). German and Chinese participants reported significantly more correct items from the first and second row of the matrix than from the third row. In addition, there were significant differences between the first and second row in the Chinese group. In the German group there were only numerical differences in the same direction (see Fig. 3).

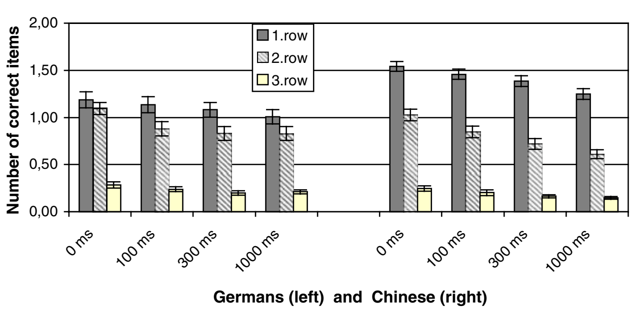

Fig. 3 Mean numbers and standard error of means for correct items in the partial report as a function of language group, cue delay, and row (Experiment 1 $N = 48$ Germans and $N = 48$ Chinese)

The main effect of selection criterion was not significant, $F(1, 94) = 1.62$, $p = 0.21$. No more than one of the interactions involving this variable yielded statistical significance, namely the interaction between the factors selection criterion and row, $F(2, 93) = 4.40$, $p = 0.015$, $\eta^2 = 0.09$: The influence of cue delay was more pronounced with the right-column report.

Discussion

Experiment 1 yielded three main results. First, there was a significant superiority of the partial report as compared to the full report in both language groups. The superiority effect diminished with increases in cue delay as can be seen by the decline of accuracy in partial report as a function of cue delay. The result pattern described is a very reliable one and has often been replicated since Sperling's pioneering work in 1960 (e.g., Gegenfurtner and Sperling 1993; for review, see Coltheart 1980; Long 1980). The superiority effect is attributed to the time limitation of the visual buffer. The representations in the visual buffer that are not selected by the attention window fade quickly with the passage of time.

Second, while the selection criterion had little effect on performance there was a strong row effect. The German and Chinese participants reached higher scores in partial report with items that had been shown in the first and second row of the matrix. According to the reading account, however, a clear first-row advantage should be expected. This discrepancy may be resolved by taking into account the size of the stimulus matrix as well as the intensity of the participants' training. When probability of selection is equally distributed across a three-row matrix, the middle row is the most appropriate choice for the initial attention window. If the first or third row later turns out to be the one selected by a cue, the effort involved in switching attention to that row should be the same in both instances and, more importantly, it should be smaller than that needed to switch from the first to the third row (or vice versa). Gegenfurtner and Sperling (1993) presented strong evidence that, prior to the cue, subjects attended primarily to the middle row of a three-row

matrix. In spite of these advantages, however, our participants in Experiment 1 seemed to favor the first row of the matrix as initial attention window at least as much as the middle row. The reason may be that our participants were not as highly trained as those in Gegenfurtner and Sperling's experiments who had a minimum of 1,000 practice trials and were tested on approximately 5,000 trials. It may be assumed that the degree to which everyday reading strategies are implemented in these experiments declines as the intensity of laboratory-specific training increases.

Third, presenting the Germans with CV-items and the Chinese with radicals led to comparable performance levels in full report. In partial report there was a tendency of the Chinese to perform somewhat better than the Germans. This pattern of results is consistent with the findings of a previous experiment as far as the full report is concerned and suggests that two Latin letters correspond to the encoding demands of one radical (Lass et al. 2006, Exp. 4). In the previous experiment, however, similar levels of overall performance for the Germans and Chinese were also evident in partial report. These inconsistent results may be reconciled by taking into account both the nature of the selection criterion and, most interestingly, cultural differences in reading habits. In the partial report trials of the previous experiment, the items had to be reported by row whereas selection in the present experiment was done by column. Reading and writing linguistic symbols by line is characteristic not only of the German language, but has also become common in the Chinese language since the mid-20th century. Before then, however, the Chinese language was usually represented in columns. This style of writing is still used today to emphasize parts of a text, i.e., in newspapers. Since multiple reading directions are common in Chinese, the scan patterns of Chinese readers may be more flexible when they are presented with a matrix composed of linguistic symbols arranged in a meaningless way (cf. Chen 1996). The superiority of the Chinese participants in the present experiment may thus result from a higher flexibility in perceptual grouping with Chinese characters.

The strong row effect found in Experiment 1 provides implicit support for the reading hypothesis since compatible perceptual grouping elicited by the selection criterion does not appear to be a necessary precondition for the row effect to appear.

Experiment 2

Besides location (e.g., row or column), a variety of selection criteria can produce partial-report superiorities: color (Clark 1969; Coltheart et al. 1974; Dick 1969; von Wright 1968), brightness (von Wright 1968), shape (Turvey and Kravetz 1970), and direction of rotary or linear motion (Demkiw and Michaels 1976; Treisman et al. 1975). In Experiment 2, the items had to be selected by their color. Half of the matrix items were of one and the other half of another color. As the location of the colors was randomly varied it is plausible that this selection criterion did not elicit any constant spatial grouping of the matrix items. It is suggested that a significant row effect under these conditions is primarily attributable to reading habits. In addition, the response mode was modified. While in Experiment 1 the cursor automatically appeared in the top row first, in Experiment 2 it appeared in a random cell of the response grid.

Method

Participants

Thirty-two German students from Göttingen took part in the experiment. The age of the participants ranged from 19 to 26 years ($M = 22.2$). None of them had taken part in Experiment 1. All had normal color vision and normal or corrected-to-normal visual acuity.

Apparatus

Stimuli were presented on a color monitor (60.2 Hz) under the control of an Apple Macintosh Powerbook (G3), and a touch screen registered the participant's responses.

Stimuli

The 20 consonants of the alphabet excluding Y were used as stimuli. The construction of the item matrix was based on a non visible grid comprising four horizontal cells and two vertical cells. The letters that appeared in the center of the cells were selected randomly without replacement. The matrix subtended 3.06° horizontally and 1.15° vertically. The letters were shown in uppercase Times font. They were 0.48° in height and varied in width from 0.29° to 0.57°. The color of the letters, red and green, was the partial-report criterion. The location of the colors was randomly varied, subject only to the constraint that half of the letters in each row were shown in red and the other half in green. The colors used were matched for brightness and saturation. The letters were displayed on a gray background.

Procedure

The participant was seated in a semi-darkened room with a light intensity of approximately 460 lux facing the monitor with the fixation cross. Each trial was started by the participant pressing a key which triggered a 50-ms exposure of the 8-letter matrix. The matrix was succeeded by a tone

lasting 200 ms. A high tone (2,093 Hz) was the cue to report the green letters and a low tone (1,047 Hz) was the cue to report the red letters. The experiment comprised solely partial-report trials. The intervals between the offset of the stimulus matrix and the onset of the tone were 0, 100, 300, and 1,000 ms. A 2 × 4-response grid would then appear in the middle of the screen. At the same time, all 20 consonants were shown at the bottom of the screen. The interval between the offset of the tone and the onset of the grid was 800 ms. A cursor appeared in a cell of the response grid at a random location. The participant could enter an item into this cell by touching one of the 20 consonants. The cursor was moved by the participant by touching another cell of the grid. Entries could be corrected. The participant could finish the response by touching an "OK" button on the screen but only after four cells had been filled. The number of correctly entered items was displayed on the screen as feedback. The next trial was then started with the presentation of the fixation cross.

An individual session consisted of 20 practice trials and 256 test trials and lasted about 1.5 h. At the beginning of the session the stimuli used were displayed. Each participant was presented with 64 partial-report trials per cue delay. The order of the trials within an individual session was random. After every 32 trials a pause was indicated by a symbol on the screen.

Results

A three-factor MANOVA using cue delay (0, 100, 300, 1,000 ms), selection criterion (red, green), and row (first, second) as the within-subject factors yielded significant main effects for cue delay, $F(3, 29) = 16.86$, $p < 0.001$, $\eta^2 = 0.64$, and row, $F(1, 31) = 474.21$, $p < 0.001$, $\eta^2 = 0.94$. Scores declined with increases in cue delay, and more items from the first row were reported correctly than from the second row (see Fig. 4). There was a weak interaction between the two factors, $F(3, 29) = 2.57$, $p = 0.074$, $\eta^2 = 0.21$, but pairwise comparisons between the first and second row revealed significant differences for each cue delay level (all *t*-tests Bonferroni corrected: $\alpha = 0.0125$). Neither the main effect of the selection criterion, $F(1, 31) = 1.61$, $p = 0.214$, nor the interactions including this factor yielded any statistical significance.

Discussion

The most interesting outcome is the replication of a strong row effect: The participants reported more items correctly from the first row of the matrix than from the second row though in all trials the whole matrix had to be scanned in order to satisfy the selection criterion. Even if the selection criterion does not elicit spatial grouping of the matrix items

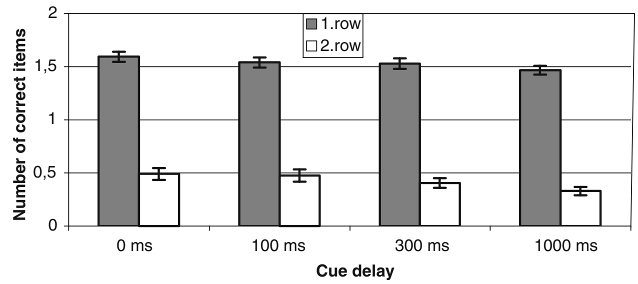

Fig. 4 Mean numbers and standard error of means for correct items as a function of cue delay and row (Experiment 2 $N = 32$ Germans)

there is strong evidence for a position effect, namely the row effect.

General discussion

In previous experiments that focused on the influence of native language on encoding briefly exposed items, we observed a reliable position effect with German and Chinese participants (Lass et al. 2003, 2006): With two-row matrices, higher scores resulted for items that had been presented in the top row of the matrix. This row effect is consistent with results in the classic experiments by Sperling (1960, Exp. 7) and Averbach and Coriell (1961) who also utilized two-row matrices. The present experiments explored whether the first-row advantage depended upon the selection criterion used to indicate the subgroup of items that had to be reported: The "goodness" of perceptional grouping elicited by the selection criterion might be a precondition for the first-row advantage. In Experiment 1 items had to be selected by column, in Experiment 2 the selection criterion was letter color.

Both experiments yielded results compatible with the hypothesis that spontaneous encoding of briefly exposed linguistic items arranged as a matrix is accomplished through an analogy with reading which proceeds by line and begins with the upper row. The alternative hypothesis in terms of perceptual grouping cannot completely explain the pattern of results. The fact that both selection criteria, namely location in Experiment 1 and color in Experiment 2, were not compatible with a grouping by row did not eliminate the row effect. However, with the three-row matrix used in Experiment 1, the advantage of the first row over the second row was reduced. We suppose that with larger matrices there may be a concurrent strategy that relies on the advantage of choosing the middle row for the initial attention window by taking into account subsequent switching costs of attention (cf. Gegenfurtner and Sperling 1993).

Interestingly, the tendency of the Chinese to perform better than the Germans in Experiment 1, where selection

in partial report had to be done by column, also can be explained by cultural differences in reading habits. Chinese characters were usually written in columns up to the mid-20th century. This style of writing can still be found when parts of a text are intended to stand out. Due to this tradition, the grouping of language items by column may be more convenient to Chinese than to Germans, leading to more efficient reports by the Chinese because of the higher compatibility between the "goodness" of perceptual grouping and the demand characteristics of the selection criterion. Similarly, Merikle (1980) observed that the partial reports were more effective when the spatial selection criteria used were compatible with the implied perceptual groups in the stimulus array.

In summary, the row effect was neither critically dependent on the ease with which the selection criterion allowed the formation of "good" perceptual groups nor on the compatibility between the demands of the selection criterion and the preferential grouping. Therefore, we continue to see the first-row advantage as a manifestation of top down processing and favor the explanation that the results were largely determined by a simple transfer of reading habits from daily life to the laboratory.

Acknowledgments We thank Simone-Jeannette Schmieder, Göttingen, and Xiaoli Wang, Shanghai, for their help in running the experiments.

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