Title

English Words Are Processed Like Objects

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 35(35)

ISSN

1069-7977

Authors

Revie, Gavin
Kamide, Yuki

Publication Date

2013

Peer reviewed

English Words Are Processed Like Objects

Gavin F. Revie (G.F.Revie@dundee.ac.uk)
Yuki Kamide (Y.Kamide@dundee.ac.uk)
School of Psychology, University of Dundee, Dundee, UK, DD1 4HN

Abstract

This experiment sought to explore the theory that familiar English words are processed similarly to objects. To do this, we looked for object-based attentional facilitation where cues in a different location to the target still facilitate target detection as long as they are inside the same object. Participants were shown two English words in an array, and cues and targets were embedded inside them. Reaction times for target detection were measured. It was found that in horizontally presented English words, cues presented in a different location to the target still facilitated target detection if they occurred inside the same word. This was not the case for vertically oriented words. It was concluded that familiar words in a familiar orientation are indeed processed in a similar way to objects. These findings may be indicative that the cortical networks that evolved for object processing are also involved in the processing of words.

Keywords: object based; attention; reading;

Introduction

It has been long understood that humans are capable of focussing their visual attention in one place in preference over another. This is commonly described as *spatial* attention. However, humans also have the capacity to allocate their attention to a particular object regardless of where it happens to be located (Blake & Sekuler, 2006). This is known as *object based* attention. In day to day scenarios these two types of visual attention will interact and overlap. However, how object based attention contributes to the process of reading (if at all) is not well understood.

Egly, Driver, & Rafal, (1994) conducted a study on attention within objects. Participants saw a 2x2 array with a fixation point in the middle. The array contained 2 rectangular shapes which each spanned two of the quadrants. These shapes could be oriented with either both of them vertical or both of them horizontal. Within the individual cells of the array very brief cues and targets were presented. Participants had to detect the onset of a grey target square following presentation of a 100ms brightening cue. They had 3 possible cuing conditions in their experiment. In the *valid* condition, the cue and the target would appear in the same location. In the *invalid within-object* condition, the cue and the target were in different locations, but still within the same object. In the *invalid different-object* condition, the cue and the target were in different locations and within different objects. The targets in both of the invalid conditions were the same distance from their cue, and they were equally often oriented vertically as horizontally. The corner to corner diagonal separation of the cue and target was not used due to non-equal distance.

Egly et al. (1994) successfully manipulated the deployment of attention. The valid trial types were consistently responded to the fastest of all trial types, indicating that the cues were successful in heightening attention at their location. The crucial point came in the comparison of the 2 invalid trial types. Despite being the same distance away from the cue and subject to the same variations of orientation, the within-object invalid trials were responded to faster than the different-object invalid trials. This suggests that an advantage was conferred upon the invalid-within object trials simply due to the presence of a shape containing both cue and target locations. This has been described as “Object Based Attention” – that attending to a cue within an object will heighten attention deployment to the whole object, including non-cued locations. More recently Luo, Lupiáñez, Funes, & Fu (2011) replicated these findings, and found that these object-based effects could be expected to be present even at very short stimulus onset asynchronies. They also highlighted problems in using cues and targets which contain implicit spatial information - something which was deliberately avoided in this study.

Li & Logan (2008) sought to explore how object based attention relates to reading. They performed an almost direct replication of Egly et al. (1994), but replaced the shapes with 2-character Chinese words. The words could be oriented either horizontally or vertically in their experiment, following the rules in the Chinese writing system. The study was a target detection task with three conditions of cue-target relationship. The cues could be valid, invalid but within the same word, and invalid and located in a different word. Replicating Egly et al. (1994), Li and Logan (2008) found that valid trials were responded to fastest. Comparing the invalid trials it was found that invalid targets occurring within the same word as the cue were responded to faster than invalid targets occurring within a different word from the cue. This successful replication of Egly et al. (1994) and may be taken as evidence that words are treated like objects inasmuch that cues falling within a word measurably facilitate target detection elsewhere within that word, presumably through elevated attentional deployment.

Li and Logan have demonstrated that the visual contiguity of shapes can be "simulated" by the abstract lexical contiguity of words. There were no physical connections between the characters in their array, and yet the participants clearly treated them as in some way connected. One way of explaining this is that the participants were treating the 2-character words as if they were a single object. However, their findings might not be easily translatable into English reading processes. Chinese is both more visually dense than English, and more spatially plastic in that the character meaning is not necessarily extracted in a left-to-right fashion. Traditionally, it could also be written legally both left-to-right and top-to-bottom, although that has become much rarer. As a consequence the importance of serial order and direction could be said to be comparatively lower than in English, whereas the importance of what lexical groups the symbols form could be said to be greater. This may lend itself well to an object based decoding strategy. Would the within-word benefit carry over to English? We devised a study to try and answer that question. In our study, we stuck as close as possible to the method employed by Li and Logan. There is no English equivalent to the many 2-character words available in Chinese, so in our experiment we transitioned to using 4-character English words. Each quadrant of the 2x2 array would contain 2 characters. In our experiment, the words were presented either horizontally or vertically. In particular it would be interesting to see what effect the more linear and less dense script of English has on the effects found in comparison with Chinese. Can an object based account explain reading single words generally, or is it only a special-case phenomenon?

Method

Participants

The participants in this study were 25 female and 7 male students from the University of Dundee. They were paid in course credits for their time. Their ages ranged from 17 to 40. All participants were fluent in English. This experiment utilized a within subjects design so all participants were exposed to all conditions of the stimuli. An additional 4 participants were tested but their data was not included due to abnormally high error rates.

Apparatus

Stimuli were presented through an 18" monitor running at 100 Hz and detection responses were recorded on a gamepad, with the response button pressed by the dominant hand. An SR Research Eyelink-1000 desk-based eye tracker recorded monocular eye position at 1000 Hz. A desk-mounted chinrest kept participants' eyes 60cm from the screen and both their peripheral vision and vision in their non-dominant eye were eliminated through blinkered spectacles.

Stimuli

288 4-character words with a lemma frequency of at least 200 per 16 million were selected using the CELEX word database (Baayen, Piepenbrock, & Gulikers, 1995). The 288 stimuli words were used to create 144 test arrays containing 2 words each. Each of these arrays was used only once per subject. The letters were printed lowercase in black, 46 point Monaco. Targets were background colour patches that were red and cues were background colour patches that were green. Cues and targets would always span 2 characters of the 4 character word in which they occurred. Stimuli arrays were assembled from several bitmaps and controlled using a variable grid. Individual bitmaps were created for each word, the fixation cross, the cue and the target.

Design

The experiment consisted of an individually randomized sequence of 144 trials: 72 *valid* trials (cue and target were the same two letters), 24 *invalid-within* trials (cue and target were different letter pairs in the same word), 24 *invalid-between* trials (cue and target were in different words but never in diagonally opposed letter pairs, to maintain equidistance between cue and target across all invalid trials; see Figure 1), and 20 catch trials (no target appeared). Half of the arrays were horizontally oriented and half were vertically oriented for each subject. All stimulus arrays appeared only once per subject. In the horizontal version of the experiment the arrays were configured in the traditional left-to-right writing mode of English. In the vertical version of the experiment, the array was configured in a more novel top-to-bottom writing mode

Task and Procedure

After giving informed consent the eye tracker was calibrated on the participant's dominant eye, determined via majority result from the Miles, Porta, and Camera tests (Roth, Lora, & Heilman, 1992). Peripheral vision and non-dominant eye were occluded with blinkered spectacles. Participants were informed that they would be periodically asked about the last array they had seen in order to highlight the importance of actually reading the words onscreen.

Figure 1 gives a schematic representation of trial events. The start array for each trial contained two words. These were presented for 1500 ms, followed by an additional fixation cross for 300 ms. Participants were told to read the words silently and then fixate the cross. The eye tracker was used to ensure participants were indeed looking at the fixation cross. A green colour patch was flashed behind the first or last 2 letters of one of the words for 100ms to cue attention to this location. Following a further 100 ms of displaying the array with words and the fixation cross but no cue or target, a red target would appear under the first or last two characters one of the words. The trial proceeded only if fixation was within the region in which the cues and targets would appear during this cue-target onset asynchrony, or else an error message appeared and the trial was discarded. Participants were instructed to press the response button as soon as they were aware of the appearance of the target, but to avoid pressing the response button when there was no target. Thus this was a simple go/no-go task. The time from the target onset to the button press was the reaction time (RT). Participants were instructed to respond as fast as possible to each target and to refrain from responding in catch trials. Responses were issued via a gamepad held in front of the participant, as close to their midline as possible. The response button was pressed with the dominant hand. If no response was issued a new trial started after 3000 ms.

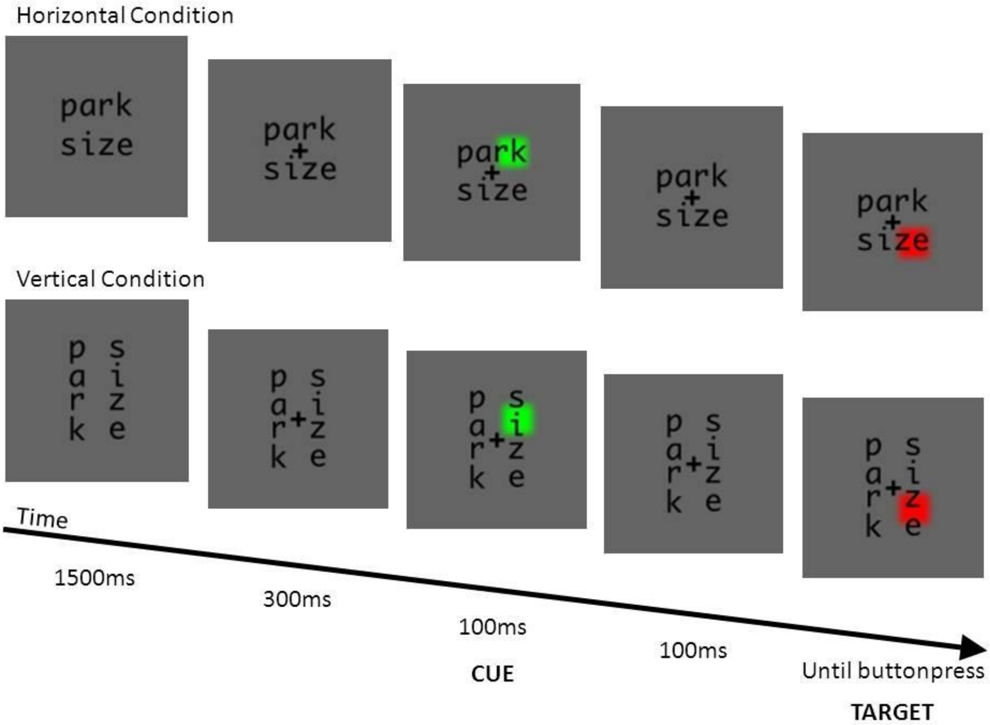

Figure 1. Trial sequence, illustrating an invalid-between word trial in the horizontal condition, and an invalid-within word trial in the vertical condition. Not drawn to scale

Results

Performance Data

The miss rate for present targets was extremely low, less than 5%. Because of this false alarm rates on catch trials (which tended to be higher) were used as a criterion to remove underperforming subjects. Any participants who achieved less than 75% correct on catch trials were removed from the data. 4 participants were removed from the data for this reason. This left 32 participants who responded correctly to catch trials 86% of the time.

Reaction Time Data

Outlier reaction times were removed through the application of a 100-700ms reaction time filter. Less than 2% of the most extreme scores were removed by this filter. Filtered reaction times from all participants were analysed using a 2 (word orientation) by 3 (levels of validity) repeated measures ANOVA. There was a significant main effect of validity ($F(2,62)=3.163$, $p=.049$), indicating that on average validly cued trials tended to be responded to fast. Additionally there was a significant interaction between word orientation and validity ($F(1.624,50.352)=3.507$, $p=.047$ (Greenhouse-Geisser transformed)). Simple planned comparisons in SPSS were used to explore these effects. Since it was necessary that we demonstrate that cuing had an effect, both classes of invalid trial were compared to valid trials which should always be the fastest. The difference between reaction times for Invalid Between trials and Valid trials was significant when both orientations were analysed together ($F(1, 31)=4.705$, $p=.038$), indicating that Invalid Between trials were *always* slow compared to valid trials. However, it was found that there was only a marginally significant difference between reaction times for Invalid Within trials and Valid trials when both horizontal and vertical trials were analysed together $F(1, 32)=3.828$, $p=.059$). Looking at the graph it is evident that there is a big difference between horizontal and vertical reaction times for Invalid Within trials. This discrepancy was studied using post-hoc Bonferoni corrected t-tests where it was found that on Invalid Within trials, targets inside horizontal words were responded to significantly faster than targets inside vertical words ($t(31)=2.901$, $p<.05$). However, on both the Invalid Between and Valid trials were was no significant difference between targets inside horizontal and vertical words ($t(31)=0.385$, $p>.05$ and $t(31)=0.697$, $p>.05$ respectively). Thus, only on the trials containing horizontally oriented words did participants respond quickly to invalidly cued targets that occurred inside the same word as the cue. This is in accord with what would be expected from object based facilitation since cues inside a word are improving reaction times for targets elsewhere in that word.

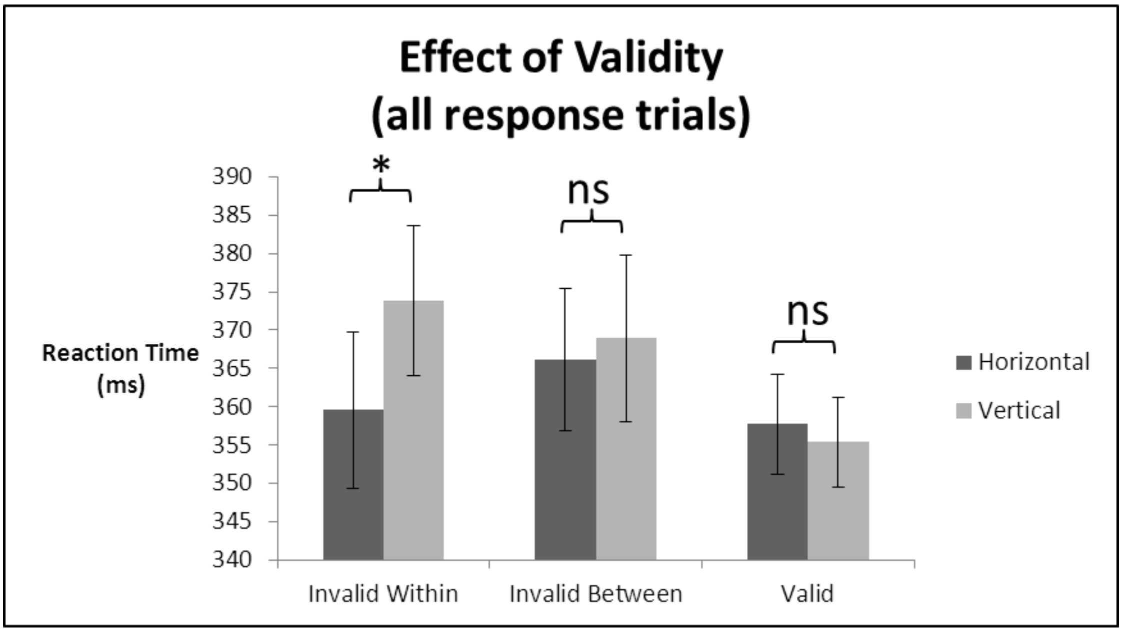

Figure 2. Reaction times for each level of validity and each word orientation. Error bars represent 1 standard error.

Discussion

This experiment was partially successful in replicating Li & Logan's (2008) Chinese experiment, using a typologically different language, English. Whilst they found that in both the horizontal and vertical orientations invalid cues within the same word as the target facilitated reaction times, we found this effect only in the horizontal orientation. For horizontally oriented words, invalid cues that occurred inside the same word as the target facilitated target detection reaction times up to a level that was almost indistinguishable from true valid cuing. This indicates that a cue landing anywhere within a horizontally oriented English word will elevate attention levels to the whole word and thereby facilitate target detection in non-cued locations. This supports the idea that words can be treated like objects because this is an "object based effect". However, this effect was not present when the words were oriented vertically.

Since it can be shown that English words have attentional properties of the sort that would normally be associated with objects, this can be seen as evidence for the role of object based attention in reading. However it is of interest that we were unsuccessful in demonstrating this effect in the vertical orientation, where invalid but within word cues were responded to just as slowly as invalid different word cues. The fact that Li and Logan (2008) managed to show this effect in Chinese, whereas we were unsuccessful in doing so for English may be related to the properties of the two languages. It is evident that characters in English and Chinese are very different visually, but they are also processed in different ways. In Chinese there are radicals embedded inside characters that provide phonological and semantic information about that character to the reader, and they are not necessarily read in a strictly linear, left to right fashion. Likewise up until fairly recently Chinese could legitimately be written either left to right, or top to bottom. This is now rare in mainland China but still encountered in other Chinese reading countries. Conversely, top to bottom writing is fairly novel in English. As a consequence it is fair to say that Chinese readers will be much more receptive to seeing Chinese written top to bottom than English readers will be to seeing their language written top to bottom. In English, it would appear that the object based representation of a word which produces these effects is only activated when viewing the word in the familiar orientation. This would imply that when written in the vertical format, English words are decoded using an alternative method which does not produce object based attentional effects.

There are some criticisms that could be levelled at this study. Unlike Li and Logan (2008) background colour patches were used instead of character illumination. This was done in an attempt to control the stimulus intensity of the cues and targets. If we had illuminated letters then the number of pixels that changed colour for any given cue or target would vary wildly from trial to trial based on which letters occupied that slot. Using the background colour patches enabled us to ensure a much more constant degree of stimulus intensity. However this approach did force certain compromises. In order to have the same size, shape and location of cues/targets between the horizontal and vertical trials it was unavoidable that there would be a better fit in one orientation, in our case horizontal (see Figure 1). There is a possibility that this poor fit may go some way to account for the differences between the horizontal and vertical trials. Also, this was not an experiment that actually involved *reading* per se. The words that were on screen did not have any bearing on how participants tackled the target detection task. The experimenter did take some steps to ensure the participants were not ignoring the words outright by asking participants to identify the previous pair of words they had just seen. If a participant was repeatedly unable to answer these questions, their data would have been removed. However, no participants needed to be removed for this reason. Nonetheless, the requirement of being able to identify the previously shown array is not nearly as high level as what would typically be considered a reading task.

Consequently, a new experiment is proposed that ensures that cues and targets fit both orientations of words equally well, and goes to additional lengths to ensure participants were actually reading words. Following every trial, participants could be asked to use the previously seen words in a sentence. This would enhance the level of processing the words were subjected to. A further experiment could do exactly the opposite, reproduce this task using non-lexical symbol strings. This would remove reading as a component entirely and address the possibility that these effects are artefacts of tasks where cues and targets are embedded inside letter-like stimuli.

Conclusion

This study found evidence that supports the idea that words are sometimes treated as if they were objects by the human attentional system. Reaction time effects normally associated with objects were observed using English words when they were presented horizontally. Thus, the lexical contiguity of words must have been acting in a similar way to the visual contiguity of objects. These findings may support the idea that the parts of the brain that evolved to cope with object perception are at least a part of the network deployed to assist in the novel process of reading.

Acknowledgments

This study was funded by the School of Psychology, University of Dundee (PhD studentship awarded to GR). We would like to thank Martin Fischer for helpful discussion.

References

Baayen, R. H., Piepenbrock, R., & Gulikers, L. (1995). The CELEX lexical database (release 2)[cd-rom]. *Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania [Distributor]*. Philidelphia, PA: Linguistic Data Consortium, University of Pennsylvania [Distributor]. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:The+CELEX+Lexical+Database#0

Blake, R., & Sekuler, R. (2006). *Perception* (5th ed.). New York, NY: McGraw-Hill.

Egly, R., Driver, J., & Rafal, R. D. (1994). Shifting visual attention between objects and locations: evidence from normal and parietal lesion subjects. *Journal of experimental psychology. General*, *123*(2), 161–77. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8014611

Li, X., & Logan, G. D. (2008). Object-based attention in Chinese readers of Chinese words: beyond Gestalt principles. *Psychonomic bulletin & review*, *15*(5), 945–9. doi:10.3758/PBR.15.5.945

Luo, C., Lupiáñez, J., Funes, M., & Fu, X. (2011). The modulation of spatial congruency by object-based attention: Analysing the "locus" of the modulation. *The Quarterly Journal of …*, (April 2013), 37–41. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/17470218.2011.591935

Roth, H., Lora, A., & Heilman, K. (1992). Effects of monocular viewing and eye dominance on spatial attention. *Brain*, *125*, 2023–2035. Retrieved from http://brain.oxfordjournals.org/content/125/9/2023.short