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Short Communication

The sentence superiority effect revisited

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ABSTRACT

A sentence superiority effect was investigated using post-cued word-in-sequence identification with the rapid parallel visual presentation (RPVP) of four horizontally aligned words. The four words were presented for 200 ms followed by a post-mask and cue for partial report. They could form a grammatically correct sentence or were formed of the same words in a scrambled agrammatical sequence. Word identification was higher in the syntactically correct sequences, and crucially, this sentence superiority effect did not vary as a function of the target's position in the sequence. Cloze probability measures for words at the final, arguably most predictable position, revealed overall low values that did not interact with the effects of sentence context, suggesting that these effects were not driven by word predictability. The results point to a level of parallel processing across multiple words that enables rapid extraction of their syntactic categories. These generate a sentence-level representation that constrains the recognition process for individual words, thus facilitating parallel word processing when the sequence is grammatically sound.

1. Introduction

James McKeen Cattell, the first Professor of Psychology in the USA, is well known for having reported a "word superiority effect" whereby word naming latencies for monosyllabic words are faster than single letter naming times, and more letters can be reported from briefly presented words than scrambled letter strings. What is less well known, however, is that Cattell also discovered a "sentence superiority effect". That is, he reported that sentences containing up to seven words could be recalled correctly after a single exposure, while the corresponding number of recalled words when these were unrelated was three to four (Cattell, 1886; reported in Scheerer, 1981). Can Cattell's sentence superiority effect be taken as evidence in favor of rapid parallel processing of syntactic and semantic information across multiple words during sentence reading? As was the case with the word superiority effect, the methodology used in Cattell's experiments left open possible roles for memory and guessing. Indeed, Cattell's sentence superiority effect is very likely to have been influenced by memory factors, such that a correct sentence is easier to maintain in working memory compared with an sequence of unrelated words. In line with this, more recent research has shown that recall of grammatically correct sentences is superior to recall of scrambled lists of the same words (e.g., Baddeley, Hitch, & Allen, 2009; Toyota, 2001).

The work of Reicher (1969) and Wheeler (1970) renewed interest in the word superiority effect by showing that it can be observed with a post-cued partial report procedure following brief presentations of words and nonwords. The research spurred by this methodological development provided the empirical foundations for current theoretical accounts of letter and word processing, and in particular, the parallel, cascaded, interactive nature of such processing (McClelland & Rumelhart, 1981). Crucially, superior report of letters in words compared with pseudoword stimuli (e.g., B in TABLE vs. PABLE) suggests that whole-word representations can be activated before identification of the constituent letters (i.e., parallel, cascaded transmission of information from letters to words), and once a word representation is activated it can influence letter identification either via feedback and/or via decision making processes (Grainger & Jacobs, 1994, 2005). In the present study, we apply the same logic to word and sentence processing. If post-cued partial report of words is more accurate in grammatically correct sentences compared with scrambled sequences of the same words, then this would imply parallel, cascaded transmission of information from word identities to sentence-level representations.

Asano and Yokosawa (2011) were the first to use a partial report procedure to study the sentence superiority effect. They employed a post-cued 4-alternative forced choice procedure with brief presentation of sentences and agrammatical lists of words. Sentences

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were on average 12–14 Japanese Kanji characters long and were presented for 200 ms and followed by a continuous pattern mask. Targets were 2-character words randomly located at different positions in the sentence, and the four response alternatives were presented vertically aligned below the location of the target word in the sentence. Asana and Yokosawa found that semantic relatedness, rather than syntactic structure, facilitated word identification. However, this might be due to the specific nature of Kanji text that imposes less grammatical constraint compared with other writing systems. In line with this reasoning, it should be noted that in an earlier study, Toyota (2001) found an effect of syntactic structure on the recall of Japanese words written in Hiragana, an alphabetic script. Furthermore, in a sequential variant of the word-in-sequence identification paradigm, with target words being presented after a sentence context and not simultaneously with the context, Jordan and Thomas (2002) found evidence for effects of syntactic coherence rather than between-word semantic priming in English.

Asano and Yokosawa's (2011) findings are important in two respects. First, to our knowledge this is the first published report using rapid parallel visual presentation (RPVP) of word sequences accompanied with a post-cued partial report procedure. Second, the effect of semantic relatedness reported by Asano and Yokosawa is further evidence in favor of parallel processing of words up to the semantic level, in line with the growing evidence for semantic processing of words in the parafovea[1] (e.g., Engbert & Kliegl, 2011; Hohenstein & Kliegl, 2014; Schotter, 2013; Veldre & Andrews, 2015, 2016,2017). There is also growing evidence for syntactic processing of multiple words in parallel. Snell, Meeter, and Grainger (2017) found that readers were faster to categorize foveal target words as noun or verb, when those targets were flanked by syntactically congruent words. In sentence reading, on the other hand, syntactically similar adjacent words seemed to interfere with, rather than facilitate, foveal word processing (see also Brothers & Traxler, 2016; Snell, Vitu, & Grainger, 2017).

If higher-order processing can indeed occur for multiple words in parallel, then it is possible that the semantic and syntactic properties of words can mutually influence their identification. Snell et al. (2017) proposed that during sentence reading, feedback from a sentence-level representation to individual word positions guides identification of these words via semantic and syntactic constraints. For example, if word n was recognized as a noun, word $n + 1$ could be expected to be a verb (in English) – and word $n + 1$ may constrain word n in a similar way. Crucially, higher-order processing can occur for multiple words in parallel via position-specific processes that interact only via sentence-level representations. This account of word identification and sentence reading therefore predicts that a syntactic sentence superiority effect should be observed in a post-cued RPVP word-in-sequence identification paradigm, where the sequence of words can either be a grammatically correct sentence or an agrammatical re-arrangement of the same words.

2. Methods

2.1. Participants

Thirty students from Aix-Marseille University were paid €5 to participate in the experiment. All participants reported to be native speakers of French, non-dyslexic, and having normal or corrected-to-normal vision.

2.2. Materials

We constructed 200 sentences that consisted of four words each. Word length was from three to five letters, and the average word frequency (Ferrand et al., 2010) was 6.48 (SD = 1.02) Zipf (3 + log10 per billion occurrences: Van Heuven, Mandera, Keuleers, & Brysbaert, 2014). We constructed grammatically correct sentences that were as semantically neutral as possible. This was evaluated by obtaining cloze probability measures for the last word in each sentence.[2] The average cloze probability of these words was 0.005 (SD = 0.009). In every sentence one of the four words was marked as the target word, at varying positions, so that the total of 200 sentences yielded 50 targets for each word position. For every sentence we further constructed a scrambled version in which all words but the target switched positions (see Fig. 1). We made sure that these scrambled sentences were syntactically incorrect.

2.3. Design

A 2×4 factorial design was used, with Context (normal vs. scrambled) and Target Position (1–4) as variables. Participants were Latin-squared into two groups so that all sentences were shown in both context conditions, but only once per participant. The experiment thus consisted of 200 trials, and sentences were presented in a different randomized order for each participant.

2.4. Software and apparatus

The experiment was implemented with OpenSesame (Mathôt, Schreij & Theeuwes, 2012). Stimuli were presented on a gamma-calibrated 21-in. screen (1024×768 px, 150 Hz). Responses were collected with an azerty-layout keyboard. Participants were seated at a 80 cm distance from the display, so that each character space subtended 0.35 degrees of visual angle.

2.5. Procedure

Participants were seated in a comfortable chair in a dimly lit testing room, and received instructions verbally by the experimenter and visually onscreen. Each trial started with a display of two vertical bars positioned at the screen center, and participants were instructed to fixate between these two bars. A sequence of four words was then briefly presented at the screen center, so that two words appeared to the left of fixation and two words to the right of fixation (Fig. 2). This display was followed by a backward mask, consisting of hash marks ('#') at all prior letter locations, and a post-cue for the target, consisting of a dot above the target location. Participants could type in their response at this point, and their response appeared in a box located slightly below the string of hash marks. Responses were finalized by pressing the return key. Feedback was given in the form of a briefly presented green (correct) or red (incorrect) dot. Prior to the main experiment, participants received eight practice trials. The experiment lasted approximately 25 minutes.

[1] We acknowledge that semantic parafoveal preview effects are not necessarily evidence for parallel processing of semantic information across multiple words (e.g., Schotter, Reichle, & Rayner, 2014), but note that the RPVP paradigm might offer stronger evidence for parallel processing, albeit in the context of reading without eye movements.

[2] Cloze probability values were obtained via an on-line experiment containing 50 questions. Each question consisted of the first three words of each sentence of the main experiment, and participants were asked to type in the first word that came to mind as a likely continuation of the sentence. The sentences were presented in a different randomized order for each participant. 128 volunteers (74 female; age 17–26 years; reporting to be native speakers of French) were recruited via the RISC network of departments in the Cognitive Sciences in France. Cloze probability was calculated as the number of answers that corresponded to the word at position 4 in the original sentence (ignoring diacritics) divided by the number of participants.