The interaction of working memory and expectation-based processes in sentence comprehension

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Abstract   Husain and colleagues [1] have shown using self-paced reading that, in Hindi, when the expectation for an upcoming head is strong (i.e., when the exact identity of a head is highly predictable), delaying the appearance of the head leads to facilitation in processing (the anti-locality effect); but when the expectation is weak (i.e., when only a verb is highly predictable, but its exact identity is not), increasing distance leads to a tendency towards a classical locality effect of the type that Grodner and Gibson have found [2]. Building on this work, two self-paced reading experiments involving Hindi show that strong and weak expectation (in the sense of Husain and colleagues) interacts with reactivation, which has been proposed as an explanation for anti-locality effects [3]. The reactivation explanation for anti-locality effects is that increasing distance by interposing material between a dependent and a head can result in facilitation in processing at the head if the interposed material attaches to the upcoming head, because this attachment process boosts the activation of the predicted head phrase. We show that when expectation is weak (i.e., when the exact identity of a verb is not predictable), reactivation effects appear, and when expectation is strong, reactivation effects disappear. This result suggests that strong expectation may lead to high activation of the predicted phrase, with the consequence that reactivating an already highly active element yields no processing advantage; by contrast, when expectation is weak (in Husain et al's sense), the activation of the predicted phrase is low, with the consequence that reactivating a phrase with low activation leads to an activation boost, causing a facilitation in processing. This is, to our knowledge, the first demonstration of an interaction between (re)activation and expectation in sentence comprehension.

Key words   sentence comprehension, expectation, locality, reactivation, self-paced reading, Hindi

Husain and colleagues [1] have shown using self-paced reading that, in Hindi, when the expectation for an upcoming head is strong (i.e., when the exact identity of a head is highly predictable), delaying the appearance of the head leads to facilitation in processing (the anti-locality effect); but when the expectation is weak (i.e., when only a verb is highly predictable, but its exact identity is not), increasing distance leads to a tendency towards a classical locality effect of the type that Grodner and Gibson have found [2]. Building on this work, two self-paced reading experiments involving Hindi show that strong and weak expectation (in the sense of Husain and colleagues) interacts with reactivation, which has been proposed as an explanation for anti-locality effects [3].

Vasishth and Lewis [3] have proposed that reactivation of upcoming VPs by adjuncts, and/or reactivation of arguments by intervening adjuncts might account for anti-locality effects, i.e., facilitation at the verb with increasing distance. This explanation is in contrast to the Levy account for anti-locality effects [4]. Two Hindi self-paced reading studies (82 participants in each) show that expectation strength in the sense of Husain and colleagues, and reactivation effects in the sense of Vasishth and Lewis interact.

Experiment 1 manipulated whether an NP (the sub-ject of a matrix verb) is reactivated, by either making this NP a subject of an embedded nonfinite clause or not:

(1) NP [...nonfinite-verb] ...matrix-verb ...

Under the reactivation account, when there is a dependency between the NP and the nonfinite verb, the NP is reactivated, leading to faster access of the NP at the matrix verb. This two-level NP- reactivation factor was crossed with a VP-reactivation factor: additional adverbials were either present or absent before the matrix verb that reactivated the matrix verb. This 2×2 factorial design was further crossed with a context factor (prediction context vs no-prediction context) that makes the critical matrix-verb (and the NP subject) either completely predictable or not. This gives us a $2 \times 2 \times 2$ design, crossing NP-reactivation, VP-reactivation, and predictability of the matrix verb/NP subject. Results show a significant interaction (t=2.14) between the three factors, such that NP- and VP-reactivation jointly lead to a facilitation at the matrix verb in the no-prediction context condition only; in the prediction condition, no facilitation is seen at the matrix verb; see Figure 1.

This experiment points to a model of processing where memory activation and expectation are not mutually exclusive factors but closely interact.

Experiment 2 replicated the results of Experiment 1;

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here, activation of the critical nonfinite verb was manipulated by placing an adjunct that either modified (i.e., reactivated) the nonfinite verb (NFV-reactivation) or the matrix verb (MV-reactivation):

(2) [NP adjunct . . . nonfinite-verb] . . . matrix-verb . . .

As in Experiment 1, this two-level reactivation factor was crossed with distance (long vs short); long distance conditions had additional adverbials before the nonfinite verb that, by assumption, further reactivate the nonfinite verb in the course of modifying it. This 2×2 factorial design was crossed with a context factor as in Experiment 1 to yield a $2 \times 2 \times 2$ design; the context ensured that the nonfinite verb was either predictable (prediction context condition) or not predictable (no-prediction context condition). Results show a significant interaction (t=-2.04) between the three factors, such that there is facilitation at the nonfinite verb due to increased distance in the NFV-reactivation, no-prediction conditions; but no facilitation at the nonfinite verb in the prediction conditions (see Figure 2). This replicates Experiment 1's findings.
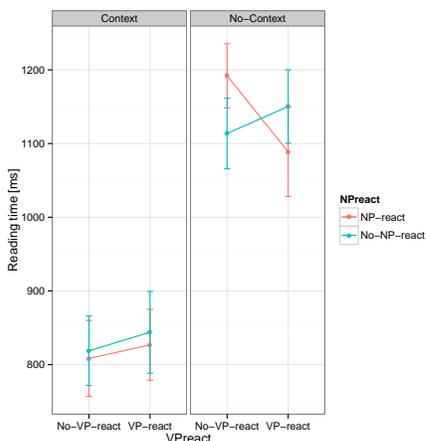

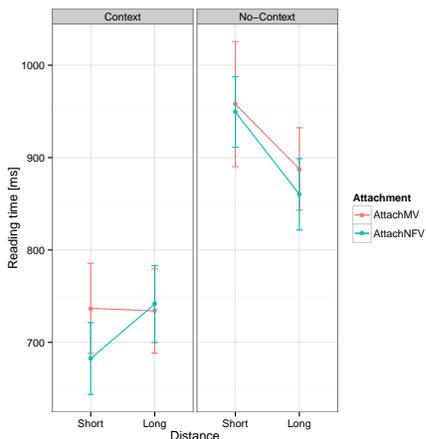Figure 1: Experiment 1: Reading times in ms at the critical region (matrix verb).

Figure 2: Experiment 2: Reading times in ms at the critical region (non-finite verb).

This is, to our knowledge, the first set of studies to show the interaction between activation and expectation strength. Experiment 1 and 2 show that facilitation due to reactivation can disappear when the reactivated phrase is strongly expected (i.e. its exact identity is predictable). In experiment 1 the NP subject and the VP were strongly expected in the prediction context condition, while in experiment 2's prediction context condition the critical nonfinite verb was expected. We propose that the effect of strong (respectively, weak) expectation should lead to relatively high (respectively, low) activation of the predicted phrase. For example, in experiment 2, when the activation of the predicted nonfinite verb is high (i.e., in strong expectation conditions), reactivation of this nonfinite verb does not have any effect; but when the activation of the nonfinite verb is low (i.e., in weak expectation conditions), reactivation of the nonfinite verb shows a facilitatory effect.

References

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