Rational adaptation in lexical prediction: The influence of prediction strength

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Processing an unexpected word entails measurable costs when the initial prediction is strong [1]. This penalty was suggested to stem from commitment to the strongly predicted word, requiring its inhibition [2]. In the current study we hypothesized that since the disconfirmation of strong predictions incurs costs, it would also trigger adaptation mechanisms influencing the processing of subsequent (potentially) strong predictions. This is in line with recent studies showing rational adaptation of predictions [3]. In two experiments, we tested whether repeated disconfirmation of predictions in high constraint contexts results in lesser commitment to predictions in subsequent high constraint contexts in the experiment.

Experiment 1 (N = 120) was conducted in Hebrew. Materials included two-word phrases in which the first word was either highly constraining (e.g. 'climate' strongly predicts 'change') or not (e.g. 'vegetable' does not have any highly probable completion). The second word was unexpected (i.e. low cloze) in both cases, e.g. 'climate activist' (HL - high constraint, low cloze), 'vegetable garden' (LL). Twelve critical trials from each condition were presented to all participants. The proportion of HL and LL filler trials was manipulated between participants: half were presented with 72 additional HL trials, and half 72 additional LL trials (see Table 1). The trials were distributed throughout the experiment in a pseudo-randomized order (different for each participant). Participants had to quickly determine whether the phrase was anomalous, as soon as the second word was presented (anomalous fillers were included).

Experiment 2 (N = 150) was conducted in English. It was aimed to replicate Experiment 1, and to extend the findings by manipulating the proportion of HL filler trials in a more graded manner and by adding HH trials (high constraint, high cloze). As in Experiment 1, twelve HL and twelve LL critical trials were presented to all participants. Additionally, twelve HH critical trials were included (e.g. 'scrambled eggs'). Filler trials were manipulated between participants, such that one third of the participants encountered 60 additional HL trials, one third encountered 60 additional LL trials, and one third encountered 30 additional HL trials and 30 additional LL trials. The different trial types were distributed throughout the experiment in a pseudorandomized order. Fifteen additional HH trials were presented to all participants at the beginning of the experiment, in order to make sure all participants could initially assume that forming predictions is beneficial in the experimental context.

Results and discussion. In both experiments, reaction times were higher in HL relative to LL trials, reflecting the costs of disconfirmed strong predictions ($p < .001$). Additionally, both experiments showed a significant interaction such that a higher proportion of disconfirmed strong predictions reduced the processing costs incurred by HL trials relative to LL (Exp. 1: $p = .048$; Exp. 2: $p = .012$), indicating that participants adjusted the strength of their predictions when strong prediction was discouraged, alleviating prediction failure costs (see Figure 1).

We formulated a Bayesian adaptation model whereby inhibition cost was modeled as μ*PE. μ was defined as the mean of a beta distribution representing the participant's belief, updated on each trial, about the likelihood of encountering the expected word (i.e. their current estimation of predictive validity). The initial prior was beta(1, 1), and updating occurred whenever the participant encountered a high constraint trial: beta(1 + number of HH trials encountered, 1 + number of HL trials encountered). PE is the prediction error, defined as the difference between the constraint of the item and the cloze probability of the second word. The inhibition index (μ*PE) was calculated for each trial, experimental and filler (Figure 2), and entered into a linear mixed-effect regression (with cloze probability as an additional predictor, to account for facilitatory effects of correct predictions). In both experiments, the inhibition index was a significant predictor of reaction times ($p < .001$), and it remained significant after including trial type, list, and trial number ($p < .001$). A model including this inhibition index thus accounts for the trial-by-trial data.

We conclude that adaptation is triggered by disconfirmation of strong predictions, and that participants rationally adapt to the experimental context by using their belief about predictive validity to weigh the strength of subsequent predictions.

Table 1: Trial composition in each list

Experiment 1 (Hebrew)		Experiment 2 (English)		
Low-Low list	**High-Low list**	**Low-Low list**	**Mixed list**	**High-Low list**
		15 HH trials 3 Anomalies	15 HH trials 3 Anomalies	15 HH trials 3 Anomalies
12 HL critical trials 12 LL critical trials **72 LL filler trials** 24 Anomalies	12 HL critical trials 12 LL critical trials **72 HL filler trials** 24 Anomalies	12 HL critical trials 12 LL critical trials 12 HH critical trials **60 LL filler trials** 24 Anomalies	12 HL critical trials 12 LL critical trials 12 HH critical trials **30 HL filler trials** **30 LL filler trials** 24 Anomalies	12 HL critical trials 12 LL critical trials 12 HH critical trials **60 HL filler trials** 24 Anomalies

Note: Presentation order of the trials listed in each cell of the table was pseudo-randomized for each participant (keeping each trial type evenly distributed). The LL and HL items were matched for cloze probability and lexical properties.

Figure 1: Reaction times in the critical trials in Experiments 1 and 2

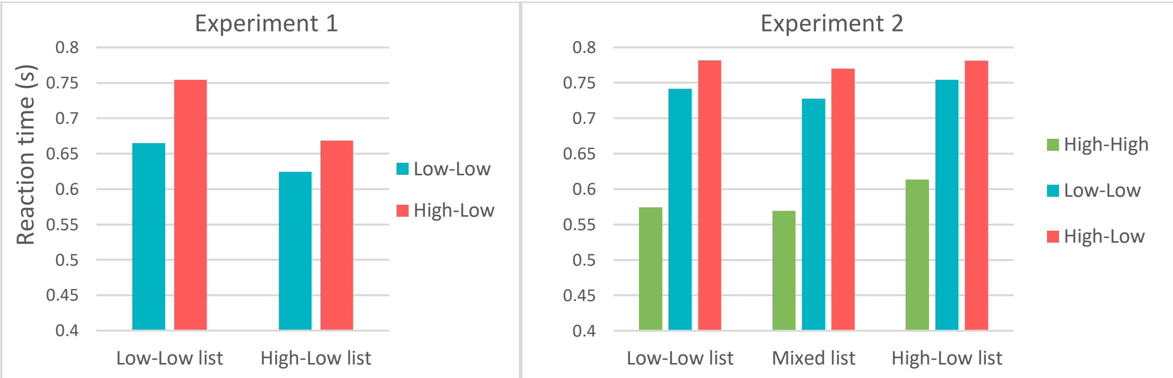
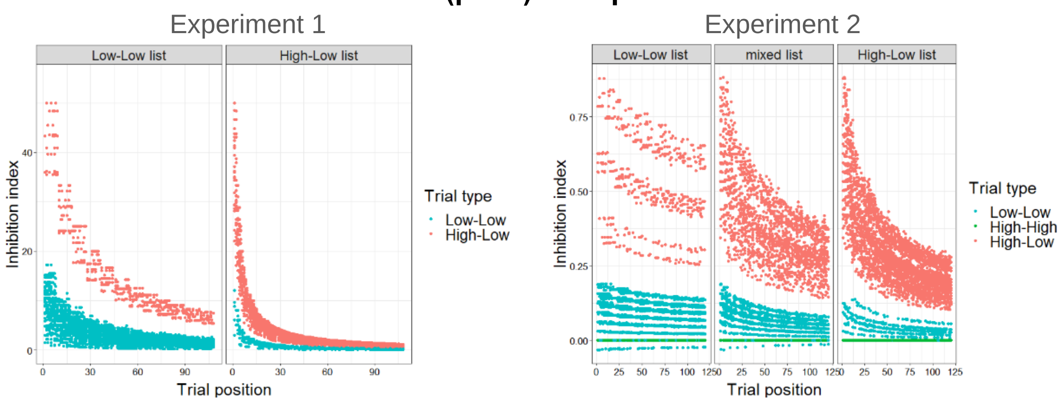


Figure 2: Calculated Inhibition index (μ*PE) in Experiments 1 and 2



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