Domain-general cognitive control and linguistic prediction: Cross-task adaptation

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Introduction: As fine-grained knowledge is accumulated regarding the mechanisms of prediction in language processing, the question of whether these mechanisms are language-specific or whether domain-general processes are also involved in linguistic prediction remains under debate (see Ryskin, Levy, & Fedorenko, 2020, for a recent review). In order to shed light on this question, the current study employed the cross-task paradigm (Hsu & Novick, 2016) to test whether (and how) prediction effects in a linguistic task are modulated by the preceding trial type in the flanker task (Eriksen & Eriksen, 1974), a non-linguistic task which manipulates cognitive control demands. The results show cross-task adaptation, indicating that domain-general cognitive control is involved in linguistic prediction processes.

Methods: One hundred and sixty participants took part in the experiment. The experimental materials consisted of 108 two-word phrases of the following types (see Table 1 for examples):

1. High constraint – High cloze probability (HH): the first word is highly constraining (has one highly probable completion), and the second word is its most common completion.
2. High constraint – Low cloze probability (HL): the first word is highly constraining, but the second word is not a common completion.
3. Low constraint – Low cloze probability (LL): the first word is not highly constraining (does not have any highly probable completion), and the second word is not a common completion.

The phrases were presented word-by-word (SOA = 1s). Participants had to indicate whether the phrase was anomalous or not, by pressing the down/up key (respectively) as quickly as possible once the second word appeared (anomalous filler trials were included to enable the task).

These linguistic trials were interleaved with flanker trials, in which five arrows appeared on the screen and the participant had to indicate the direction of the middle arrow (by pressing the right/left key as quickly as possible). In congruent flanker trials all five arrows pointed in the same direction; in incongruent trials the middle arrow pointed in the opposite direction than the outer arrows. Half of the 36 experimental items in each linguistic trial type were preceded by a congruent flanker trial and half by an incongruent one (counterbalanced across lists). Filler trials were included to prevent participants from anticipating which task will appear next.

Results: Reaction times (RTs) are shown in Figure 1. A Bayesian analysis of mixed-effects models was conducted. Sampled posterior distributions of mean effects are shown in Figure 2. RTs in the flanker task show the classical flanker effect, i.e. increased RTs in the incongruent relative to congruent trials (Est. = 76ms, CrI = [70,82], $Pr(\beta>0) = 100\%$). In the linguistic task, shorter RTs were observed for HH compared to LL trials (Est. = -161ms, CrI = [-183,-139], $Pr(\beta<0)=100\%$), reflecting facilitation due to successful prediction in the HH trials. In addition, longer RTs were observed for HL compared to LL trials (Est. = 24ms, CrI = [-4,52], $Pr(\beta>0) = 95.39\%$), reflecting prediction failure costs in the HL trials. RTs in the linguistic task were overall longer when the trial was preceded by an incongruent flanker trial relative to a congruent preceding flanker trial (Est. = 6ms, CrI = [-2,13], $Pr(\beta>0) = 93.57\%$), which may reflect a general increase in cautiousness following a difficult trial. Importantly, we additionally found moderate evidence of an interaction between preceding flanker trial type and linguistic trial type at the levels of HL vs. LL (Est. = -12ms, CrI = [-29,6], $Pr(\beta<0) = 90.73\%$). This result indicates that in the HL trials, upregulated cognitive control, due to an incongruent flanker trial, reduced prediction failure costs (thus negating the general slowdown that should have otherwise been similar to that in the LL trials). There was no evidence of an interaction between preceding flanker trial type and linguistic trial type at the levels of HH vs. LL (Est. = 0ms, CrI = [-17,18], $Pr(\beta>0) = 51.23\%$).

Discussion: The interaction between linguistic trial type and preceding flanker trial type provides (moderate) evidence for the involvement of cognitive control in linguistic prediction. Specifically, the results provide indication that upregulating cognitive control may not influence the generation of predictions (since facilitation for successful predictions was not modulated by preceding flanker trial type); instead, upregulating cognitive control influences prediction failure costs. This means that domain-general cognitive control may take part in resolving the conflict between the strongly predicted word and the word that appeared in the input, and/or in the inhibition of the wrongly predicted word.

Table 1: Example materials

Condition	Example phrase	
HH (High constraint, High cloze probability)	'Climate change'	Constraint: 93% Cloze probability: 93%
HL (High constraint, Low cloze probability)	'Rearview camera'	Constraint: 93% (Best completion: 'mirror') Cloze probability: 6%
LL (Low constraint, Low cloze probability)	'Repetitive work'	Constraint: 10% (Best completion: 'task') Cloze probability: 6%

Figure 1: (A) Average RTs in the flanker task. (B) Average RTs in the linguistic task, by linguistic trial type and preceding flanker trial type.

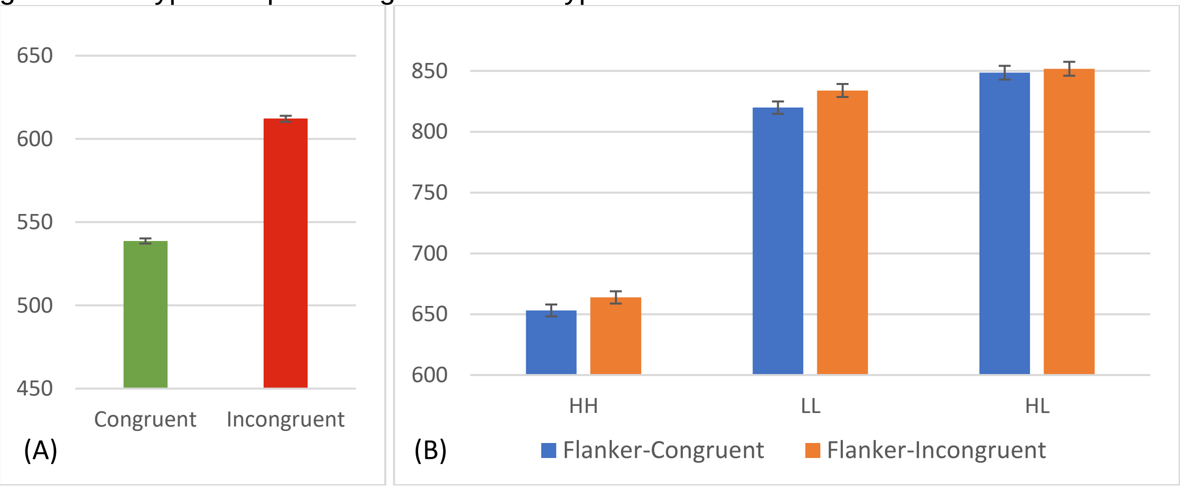
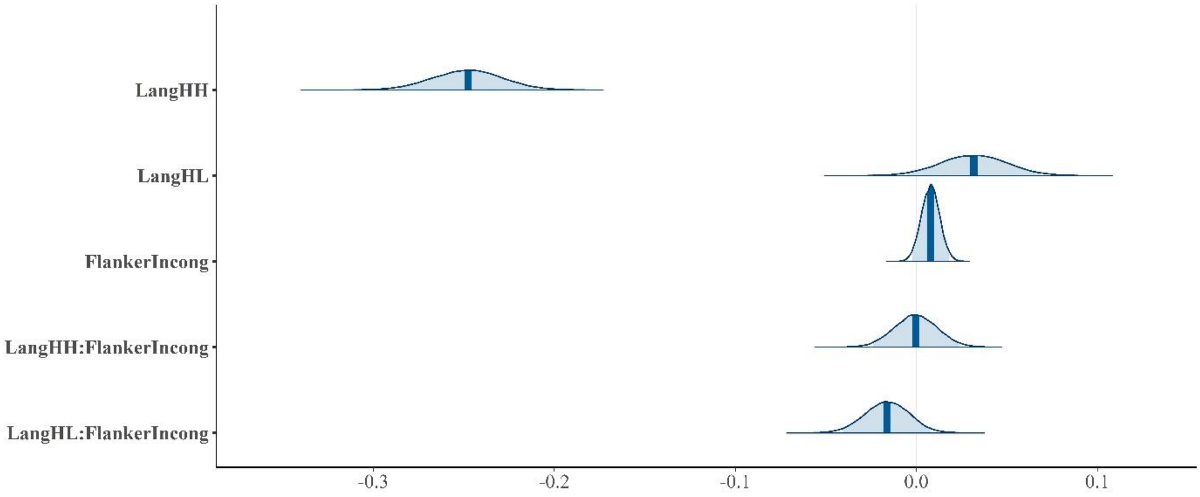


Figure 2: Sampled posterior distributions of mean effects on RTs in the linguistic task.



X axis is in a log-scale. 95% CrI shaded in blue.

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