Individual differences in predictive processing:
Evidence from Turkish-speaking monolingual adults

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Language prediction is well attested in languages with strict Subject-Verb-Object word order. For example, listeners may use semantic restrictions of the verb (e.g., eat) to predict an upcoming object (e.g., cake) in a sentence (e.g., Altmann & Kamide, 1999). Previous work has also shown that prediction skills may be modulated by individual-level factors (e.g., Huettig & Janse, 2016). However, only few studies have investigated predictive processing in languages with flexible word order, and these have not considered the role of individual-level factors. For instance, Turkish-speaking monolingual adults appear to use both verb-semantics and case-marking cues predictively (Brouwer et al., 2018; Özge et al., 2019), but how individual differences modulate the predictive processing of these cues is yet to be examined.

The current study investigates to what extent cognitive (i.e., processing speed) and linguistic (i.e., language proficiency) factors modulate the predictive use of case-marking cues in Turkish, using a visual world eye-tracking experiment. Turkish-speaking monolingual participants (N=21, M_{age}= 26 years) listened to sentences in which case marking on NP1 (accusative/nominative) and the position of the verb (sentence-medial/sentence-final) were manipulated (see Table 1), while looking at a visual context with three related images (partly from Özge et al., 2019). These images represented the NP1 (e.g., rabbit), a plausible patient in a context where NP1 was the agent (e.g., carrot), and a plausible agent in a context where NP1 was the patient (e.g., fox). The order of verb-final and verb-medial blocks was counterbalanced across participants. Language proficiency was measured with a C-test (Karayayla, 2018), and processing speed with symbol search and symbol coding subtests from WAIS-IV (2004).

Generalized mixed effect logistic regression models were fitted to binominal fixations of the participants on the agent image (1) versus patient image (0) during the predictive time window between NP1 and NP2. For the verb-final condition, only case-marking cues on NP1 were available in the predictive time window, whereas for the verb-medial condition, both case-marking on NP1 and verb-semantics were available. All models included random intercepts for items and random slopes for condition and participants.

The results showed a significant interaction between time and condition (accusative vs. nominative) in the verb-final condition (β=0.36, SE=0.03, z-value=11.14, p< .001) and in the verb-medial condition (β=0.44, SE=0.03, z-value=16.63, p< .001), suggesting that as the sentence unfolded, participants looked at the agent image significantly more if NP1 was marked with accusative case compared to when it was marked with nominative case (see Figure 1). These predictive patterns were modulated by processing speed in both the verb-final (symbol coding: β=-0.61, SE=0.11, z-value=-5.41, p< .001; symbol search: β=-0.39, SE=0.06, z-value=-6.13, p< .001) and the verb-medial condition (symbol coding: β=-0.35, SE=0.09, z-value=-3.76, p< .001; symbol search: β=-0.26, SE=0.05, z-value=-4.81, p< .001). They were furthermore modulated by language proficiency in the verb-final condition (β=0.05, SE=0.01, z-value=6.67, p< .001), but only marginally in the verb-medial condition (β=0.01, SE=0.01, z-value=1.75, p=0.08) (see Figure 2).

To conclude, we found that Turkish-speaking monolingual adults were able to use case-marking cues predictively in both verb-final and verb-medial sentences, in line with Özge et al. (2019). Both higher processing speed and higher language proficiency facilitated predictive processing when case-marking information was the only available cue (i.e., verb-final condition). When information was available from two sources (i.e., integrating cues from case-marking and verb-semantics, as in the verb-medial condition), the effect of language proficiency (but not processing speed) decreased. These findings suggest that both cognitive and linguistic factors are at play in predictive processing, but perhaps not to the same extent for morphosyntactic and semantic cues.
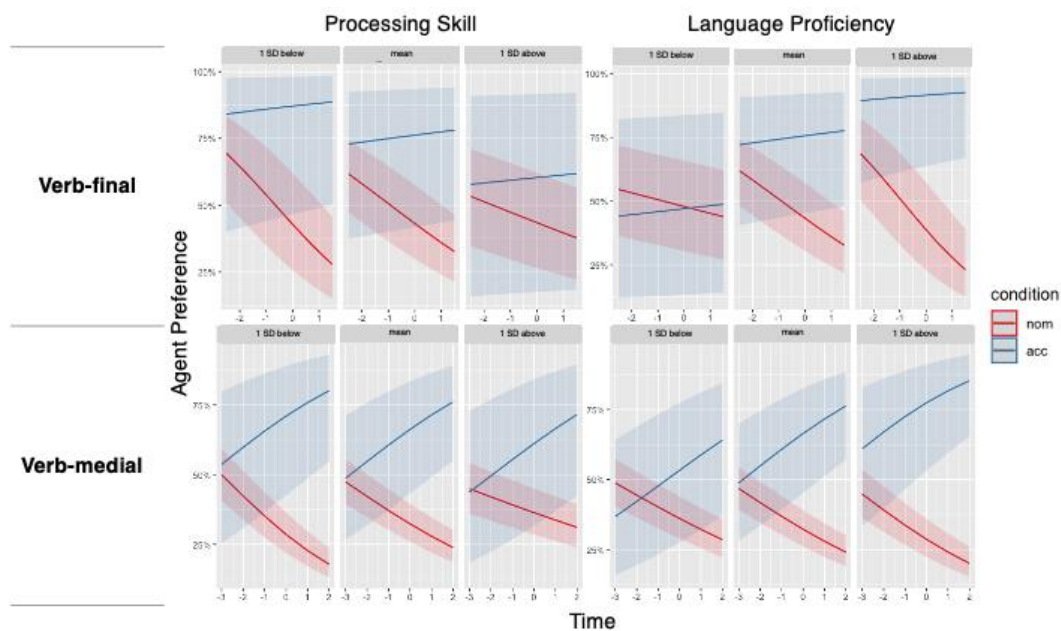
References
Altmann, G. T. M. & Kamide, Y. (1999). *Cognition, 73*, 247-264.
Brouwer, S., Özkan, D., & Küntay, A. C. (2018). *Journal of Child Language*, *46*(1), 80–97.
Huettig, F., & Janse, E. (2016). *Language, Cognition and Neuroscience, 31*(1), 80-93.
Karayayla, T. (2018). PhD dissertation, University of Essex.
Özge, D., Küntay, A., & Snedeker, J. (2019). *Cognition, 183*, 152–180.

Figure 1: Agent preference in verb-final and verb-medial conditions
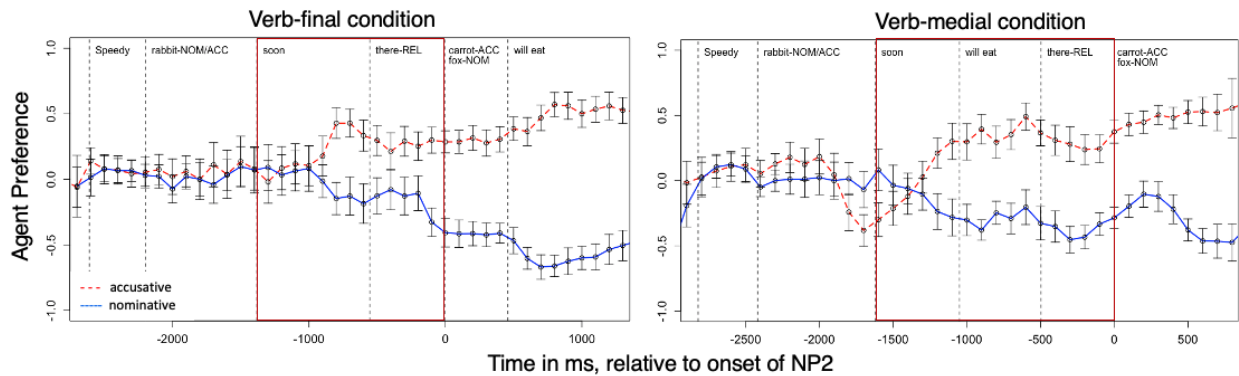
Note 1: Fixation patterns for agent preference in 100 ms bins across participants and trials, with error bars for standard error of the mean. Positive and negative values for agent preference indicate looks to the agent and patient, respectively. The dotted red line is for the accusative condition and the solid blue line is for nominative condition. The predictive windows are shown with red rectangles.

Figure 2: The effect of cognitive and linguistic factors on prediction skills

Note 2: Predicted probabilities of agent preference based on model calculations. The verb-final condition is shown on the top row, verb-medial condition on the bottom row. In all panels, the middle section represents when the value is at the mean, the left is 1 SD below and the right is 1 SD above the mean. Smaller numbers indicate faster processing speed and lower language proficiency. The blue line is for the accusative condition and the red line is for nominative condition.

Background on Turkish Language

Turkish is an agglutinative language with flexible word order. Even though the canonical word order is Subject-Object-Verb, other word order variations, including Subject-Verb-Object, are also possible. Definite direct objects are marked with accusative case –(y)I, and subjects bear nominative case, which is not overtly marked. In Table 1, the first and fourth sentences start with a noun phrase that bears accusative case, which suggests that the first noun phrase is the object. Upon hearing a sentence initial object, listeners were expected to make use of the information provided by accusative case to look at the agent image in the visual context in order to predict the second noun phrase in the sentence.

Table 1: *Examples of the Turkish sentences used in the four different conditions (partly based on Özge et al., 2019).*

First NP-Case	Verb Position	Sentence
accusative	final	Hızlı tavşanı birazdan şuradaki kurt **yiyecek**. Speedy rabbit**ACC** soon there wolf**NOM** **eat** *"The wolf over there will soon eat the speedy rabbit."*
nominative	final	Hızlı tavşan birazdan şuradaki havuc**u** **yiyecek**. Speedy rabbit**NOM** soon there carrot**ACC** **eat** *"The speedy rabbit will soon eat the carrot over there."*
nominative	medial	Hızlı tavşan birazdan **yiyecek** şuradaki havuc**u**. Speedy rabbit**NOM** soon **eat** there carrot**ACC** *"The speedy rabbit will soon eat the carrot over there."*
accusative	medial	Hızlı tavşanı birazdan **yiyecek** şuradaki kurt. Speedy rabbit**ACC** soon **eat** there wolf**NOM** *"The wolf over there will soon eat the speedy rabbit."*