Gradient use of Tagalog voice for the prediction and belief-update of argument order

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Despite growing evidence for the role of prediction and belief-updating in information processing [1-3], much is underexplored, such as the parser's ability to generate expectations for multiple upcoming arguments, and the ability to immediately adjust expectations upon accruing information incongruent with expectations for sentential arguments. We investigate this question with Tagalog, a verb-initial language in which grammatical information on the verb (voice morphology) is probabilistically informative of the likely unfolding arguments and their particular positions [4-6; see page 3]. Three experiments tested whether comprehenders use verb+voice morphology to generate and update argument order expectations.

Exp1: Self-Paced Reading (n=71). We hypothesized that comprehenders would use verb+voice information (Table1, Region 2), to develop gradient expectations across voices for the likely order of the next two arguments. The nominal marking of NP1 (Table1, Region 3) indicates whether this expectation has been met. Therefore, if voice has immediate effects on expectations, we predicted Region 3 would manifest gradient reading times, reflecting gradient surprisal: sentence (2) would have the lowest surprisal, (4) the highest, with (1) and (3) in between. Moreover, since NP1 virtually eliminates uncertainty about the syntactic role of NP2, we predicted that if comprehenders immediately update their beliefs about word order at NP1, there should be no surprisal differences across conditions at the second nominal marking (Region 5). At the earliest evidence of (dis)confirmation, Region 3, did not show the predicted Voice*Word Order interaction of a gradient surprisal pattern ($t = 1.72$). The interaction did however reach full significance at Region 5 ($t = 2.52$; Fig1). These findings suggest the non-immediacy of fully predicting and updating expectations for argument order, and are consistent with either noisy processing of the first nominal marker [7,8], or the need for further sentential information, such as at least one of the complete arguments [9,10] for robust belief-update.

Exp2: RSVP (n=114). Exp2 probed whether the non-significant effects of predicting and updating argument order could be due to nominal markers being perceived as less informative than lexical items. We used a time-constrained task to examine the uptake of the nominal markers. The same materials as in Exp1 were tested in a moving-window RSVP task with between-participant stimulus-onset-asynchronies (SOAs) of 500ms or 750ms per region. We hypothesized that reliable uptake of morphosyntactic information would lead to above-chance accuracy rates for post-sentential comprehension questions across conditions, since the voice and nominal marking determined the correct answers. Maximal logistic MEMs showed that comprehenders performed significantly above chance (Fig2) in each condition; they engaged in significant uptake of morphosyntactic information even under time pressure.

Exp3: Self-Paced Reading with Memory Load (n=97). To further probe the processing of morphosyntactic information in real-time, we tested whether predicting and updating expectations would change with the addition of a memory load, created by having participants store a novel letter string for each trial [11]. As in Exp1, the interaction of Voice and Word Order was not significant at Region 3 ($t = 1.61$), but did emerge at Region 5 ($t = 2.73$). A joint analysis of Exp1 and 3 RTs using maximal MEMs showed a significant interaction effect at Region 3 ($t = 2.51$), and even a more robust effect at Region 5 ($t = 4.15$; Fig1), suggesting weak effects of predicting (Region 3) as well as strong and consistent non-immediate effects of updating expectations on argument order (Region 5).

We interpret the weak effects at Region 3 as evidence of (some degree of) pre-activation for multiple aspects of a linguistic structure (e.g., upcoming nominal markers, arguments, syntactic form, etc), and partial surprisal, due to surprisal just for some of the predictions that are inconsistent with the unfolding information (e.g., the first nominal marker). After the accrual and integration of argument information from the remainder of NP1 in Region 4, robust effects were observed at Region 5, as further detection of unmet predictions and full updating occurred. These findings illustrate the variability and dynamism of prediction and belief-updating within the same stimuli, i.e., that the generation and adjustment of expectations change over time, and that full update does not always occur at the logically earliest point.

Table 1. Stimuli items used in Exps 1 to 3, for the sentence "*Because of the accident, the two poor families looked for the three wise doctors in the province earlier.*" Items cross Voice and Word Order.

	Region1	Region2	Region3	Region4	Region5	Region6	Region7
	Adjunct	**V + TimeExp**	**NM + Num**	**Adj + N**	**NM + Num**	**Adj + N**	**Adjunct**
(1)	**Agent Voice x Verb-Agent-Patient [equally preferred with (3)]**						
	Dahil sa aksidente *Because of the accident*	h**um**anap kanina *looked for earlier*	**ang** dalawang *the two*	dukhang pamilya *poor families*	**ng** tatlong *the three*	matalinong doktor *wise doctors*	sa probinsya. *in the province*
(2)	**Patient Voice x Verb-Agent-Patient [strongly preferred pattern]**						
	Dahil sa aksidente *Because of the accident*	h**in**anap kanina *looked for earlier*	**ng** dalawang *the two*	dukhang pamilya *poor families*	**ang** tatlong *the three*	matalinong doktor *wise doctors*	sa probinsya. *in the province*
(3)	**Agent Voice x Verb-Patient-Agent [equally preferred with (1)]**						
	Dahil sa aksidente *Because of the accident*	h**um**anap kanina *looked for earlier*	**ng** tatlong *the three*	matalinong doktor *wise doctors*	**ang** dalawang *the two*	dukhang pamilya *poor families*	sa probinsya. *in the province*
(4)	**Patient Voice x Verb-Patient-Agent [strongly dispreferred pattern]**						
	Dahil sa aksidente *Because of the accident*	h**in**anap kanina *looked for earlier*	**ang** tatlong *the three*	matalinong doktor *wise doctors*	**ng** dalawang *the two*	dukhang pamilya *poor families*	sa probinsya. *in the province*

Figure 1. Log-transformed reading times by Voice and Word Order across sentence regions in Exp1 and 3. Error bars reflect 95% CI.

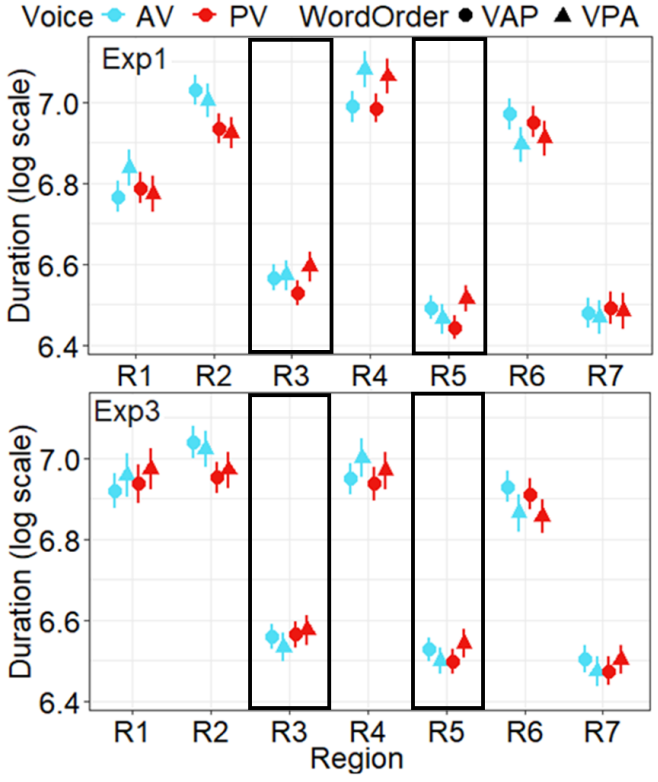
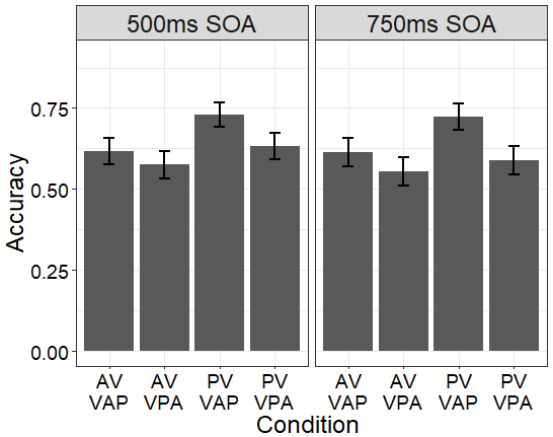


Figure 2. Accuracy rates by Voice (AV/PV) and Word Order (VAP/VPA) across the two RSVP tasks (500ms and 750ms). Error bars reflect 95% CI.



References: *[1] Kuperberg & Jaeger (2016). [2] Kutas, DeLong, & Smith (2014). [3] Pickering & Gambi (2018). [4] Kroeger (1993). [5] Garcia et al. (2018). [6] Bondoc (2020). [7] Futrell & Levy (2017). [8] Futrell et al. (2020). [9] Kukona, Fang, Aicher, Chen, & Magnuson (2011). [10] Chow, Lau, Wang, & Phillips (2018). [11] Fedorenko et al. (2007).*

Page 3: Information on Tagalog

Tagalog, a major language spoken in the Philippines, is a verb-initial language. Tagalog verbs contain voice morphology that determines the element accessible to most syntactic phenomena. This element is called the pivot, marked by *ang* [ʔaŋ]. For example, the verb 'search' in (5) contains the agent voice affix -um-, which selects the agent *pamilya* 'family' as its pivot. In (6) the same verb contains the patient voice null affix, which identifies the patient *doktor* 'doctor' as the pivot. The other non-pivot element in each of these sentences is marked by *ng* [naŋ] (Kroeger, 1993; Latrouite, 2011; Schachter & Otanes, 1972).

Agent Voice, Verb-Agent-Patient Order

(5)	H**<um>**anap	**ang**	**pamilya**	ng	doktor.
	<AV.PRF>search	PVT	family	NPVT	doctor
	'The family looked for a/the doctor.'				

Patient Voice, Verb-Agent-Patient Order

(6)	**ø**-H<in>anap	ng	pamilya	**ang**	**doktor**.
	PV-<PRF>search	NPVT	family	PVT	doctor
	'A/The family looked for the doctor.'				

Tagalog also allows flexible word order; thus, sentences (5) and (6) are in verb-agent-patient order, while sentences (7) and (8) are in verb-patient-agent order.

Agent Voice, Verb-Patient-Agent Order

(7)	H**<um>**anap	ng	doktor	**ang**	**pamilya**.
	<AV.PRF>search	NPVT	doctor	PVT	family
	'The family looked for a/the doctor.'				

Patient Voice, Verb-Patient-Agent Order

(8)	**ø**-H<in>anap	**ang**	**doktor**	ng	pamilya.
	PV-<PRF>search	PVT	doctor	NPVT	family
	'A/The family looked for the doctor.'				

Scholars have long disagreed on what the preferred argument order pattern is in Tagalog (Himmelmann, 2005; Kroeger, 1993; Schachter, 2015). More recent studies have demonstrated that voice morphology determines the likely argument order patterns in the language. Verbs in the patient voice (PV) produce a strong preference for Verb-Agent-Patient (VAP) word order over Verb-Patient-Agent (VPA) order, while verbs in the agent voice allow for two equally preferred patterns (VAP/VPA) (Bondoc, 2020; Garcia et al., 2018, Hsieh, 2016). These speaker preferences should translate to probabilities that comprehenders can use in generating and updating expectations on argument order in real-time. We predict in our experiments that these probabilities would be demonstrated as gradient surprisal in Region 3, where (6) would have the lowest surprisal, (8) the highest, and (5) and (7) in between.