Processing Time for Events in Language Scales Logarithmically with their Real-World Duration

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> **Longer events take a longer time to process, controlling for complexity. Processing time increases at a log-linear rate with the event's actual duration.**

1. Introduction

How do we represent the temporal duration of events as they unfold through language?

- Comprehending an event in language takes less time than experiencing it.
- Embodied accounts of cognition suggest we might take longer to process longer events if we "simulate" them in our minds.
- Some studies have looked at the relationship between temporal structure[1] or relative event duration[2,3] and processing time.
- Others have looked at the effect of absolute duration on episodic shifts[4,5,6], but not the time taken to process the events themselves.

> Coll-Florit and Gennari (2011) found that RT on **sensicality judgments** for punctual events was faster vs durative ones. They also found a correlation between Likert-scale estimates of event time and RT. However, **a direct link between external and internal time (i.e. a _rate_ of compression) has not been established.**

> **Question: Does the processing time for events in language scale with their real-world duration?**

2. Methods

2 online experiments measuring **RT** for **sensicality judgments.** Stimuli were 3-word sentences in the form "the [noun] [verb]-ed", expressing _bounded_ events.

Examples:

Targets (sensible)	**Foils (nonsensible)**
The mug shattered.	The coin shattered.
The mountain eroded.	The mountain dissolved.

	Experiment 1	Experiment 2
Task	Does the sentence make sense? (YES/NO judgments as quickly as possible)	
Participants	Right-handed, English monolinguals	
	80 (6 exclusions)	80 (3 exclusions)
Duration range	Punctual --> 2 days	Punctual --> Millenia
Stimuli	80 targets, 80 foils	90 targets, 90 foils

Stimulus Norming

Subjects
30 online participants

Task
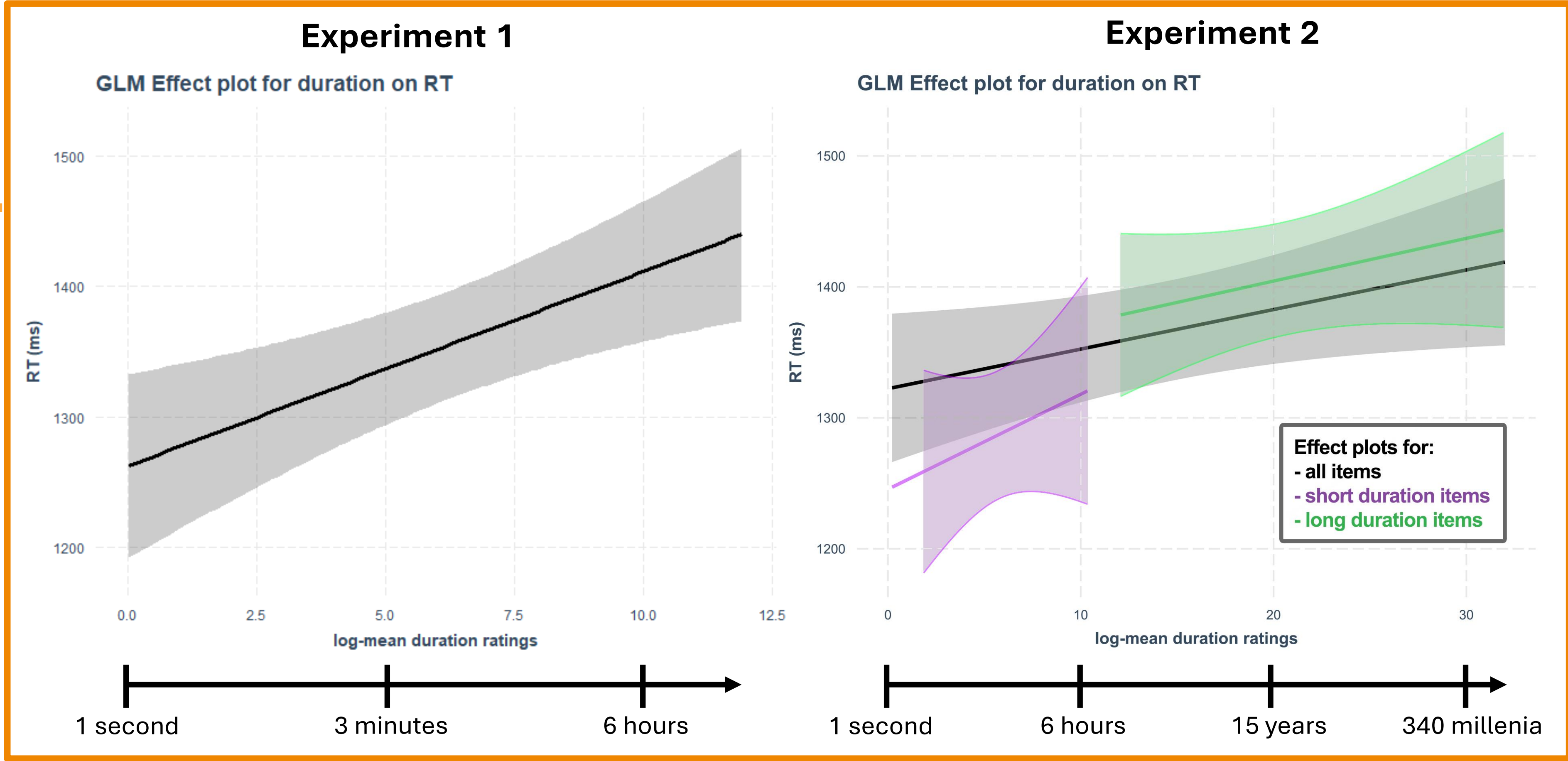Give duration estimates for all targets, e.g. "1 hour"

Mean duration estimates (in seconds) were calculated, then $\log_e$-transformed

3. Results

We used a generalized linear mixed-effects model (Gamma link) to estimate the effect of **event duration** (log-transformed means) on **reaction time**. Covariates included semantic diversity, lexical properties like word length, and random effects for participants and items.

ReactionTime ~ EventDuration +
ItemAgreement +
Sent2vecDistances +
Length_N + Length_V + Age_Of_Acquisition_N + Age_Of_Acquisition_V + Surprisal_N + Surprisal_V +
(1+EventDuration|Participant) + (1|Item)

GLMM effect plots for event duration

Experiment 1 — GLM Effect plot for duration on RT
Experiment 2 — GLM Effect plot for duration on RT

Effect plots for:
- all items
- short duration items
- long duration items

Model output

Experiment 1				
Term	B	SE	t	p
(Intercept)	2,945.27	328.7	8.96	< .001***
log-mean event duration	**14.92**	**4.65**	**3.21**	**.001** **
item agreement	-1,836.29	256.7	-7.2	< .001***
semantic diversity	-70.69	40.49	-1.8	0.081
length (noun)	15.43	7.65	2.02	.044*
length (verb)	-4.71	7.9	-0.6	0.551
age of acquisition (noun)	18.35	7	2.62	.009**
age of acquisition (verb)	10.21	7.05	1.45	0.148
surprisal (noun)	-7.63	7.68	-1	0.321
surprisal (verb)	9.59	4.45	2.16	.031*

Experiment 2				
Term	B	SE	t	p
(Intercept)	2,095.22	269.3	7.78	< .001***
log-mean event duration	**3.02**	**1.48**	**2.04**	**.041***
item agreement	-1,265.48	224.3	-5.6	< .001***
semantic diversity	19.32	28.67	0.67	0.501
length (noun)	8.47	5.47	1.55	0.121
length (verb)	5.95	8.17	0.73	0.467
age of acquisition (noun)	14.12	5.8	2.43	.015*
age of acquisition (verb)	13.22	5.6	2.36	.018*
surprisal (noun)	-0.09	4.98	-0	0.986
surprisal (verb)	3.85	4.05	0.95	0.343

Ruling out a potential confound

- Reaction time was _faster_ for items about which there was _more agreement_ on the sensicality judgment task.
- Slower RTs might therefore reflect _confidence_ or _certainty_ – as participants get less certain about a sensicality judgment, they might make slower responses.
- Since there is no "ground truth" for sensicality, item agreement (% of participants who responded "sensible" to a target sentence) was included in the model.

RT as a function of item agreement
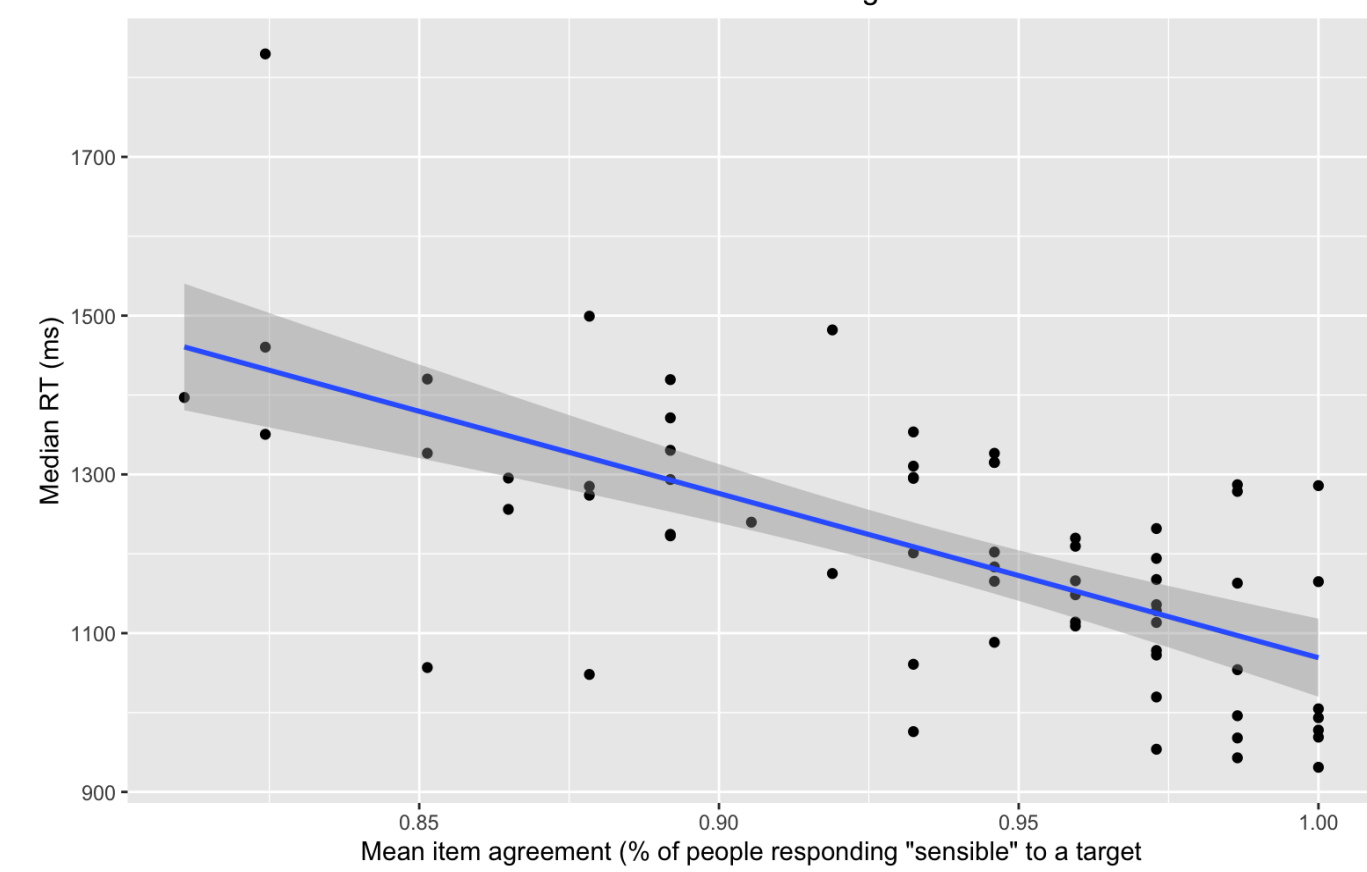
Semantic diversity
- We've taken a similar approach to Coll-Florit and Gennari (2011) by operationalizing semantic diversity for a given item as the averaged sent2vec distance[8] to all others in the experiment.

Is the relationship log-linear?
- Model comparison using Akaike's Information Criterion showed that log-scaling event durations provides a better fit than other transformations (e.g. unscaled)

4. Discussion

- The processing time for events in language scales at a log-linear rate with their real-world duration.
- Events are necessarily compressed in our minds. The question is whether they are simulated at a compressed _rate_, or if duration is simply encoded as encyclopedic knowledge. These results suggest the former.

Connections to other studies

- Coll-Florit and Gennari (2011) found that RT on a sensicality judgment task correlated positively with Likert-scale duration estimates. They attributed their effect to the diversity of semantic associations, which we've taken into account in our model and still see an effect of duration.
- Davis and Yee (2022)[7] found that the time taken to perceive individual concepts correlates with RT on a variety of tasks – these results extend that finding into the event domain.

Future Work

- We are designing experiments to fully isolate the contribution of an event's duration to its processing time (as activated by its label).

References
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