a time-critical simulation of language comprehension

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proceeding

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greater picture

this paper is one of the results of a bigger project to simulate the generation of a mental model from the cognitive system's own perspective

consider the process of mental modelling under phenomenological aspects: how is the conversion of immediate feelings to abstract knowledge *experienced* by the system itself?

one of the resulting observations was that *the prediction of sequential data can benefit considerably from learning a discrete segmentation in real time*

computational procedures that realize such a segmentation can be shown to outperform history-based models in a symbolic one-step-prediction task

language as cognitive product

how can models for linguistic processes help explain this observation?
reading text implies the segmentation of a symbolic sequence in real time

mental processes are *not intrinsically linguistic* but linguistic processes *can give insights on general mental processes* that are not immediately accessible to the observer

a *cognitively plausible computational procedure* for...

(1) the identification of synonyms can show how cognitive systems recognize *different* sensorimotor data as instances of *the same concept*

(2) the disambiguation of homonyms can show how *identical* sensorimotor data is recognized as *different concept* in another situation

basic definitions

a **cognitively plausible procedure** is supposed *to identify "synonyms"* and *disambiguate "homonyms"* under *time pressure* with regard to *the discrete representations it generated* from *a natural sequence of symbolic examples*

"synonyms" are *different* segments that have *the same* representation
"homonyms" are *identical* segments that have *different* representations

the **example** at time *t* consists of the *input* letter at index *t - 1* and the *target* output letter at index *t*
(targets are not a function of their inputs!)

approach

predicting output *that is not determined by input* is achieved with a stateful model with representations for *predictable segments* in the sequence

computationally, the task is similar to learning a *context-sensitive grammar* or a *partially observable Markov decision process* (see, for example, *perceptual aliasing* in reinforcement learning)

to be plausible the same procedure must also be applicable to...

(1) sensorimotor input to simulate *text generation* more authentically
(2) sensorimotor output to simulate *text interpretation* more authentically

specifications

natural sequences are regarded as *dynamic hierarchical trajectories* with *emission functions that can change* with each time step *t*, where the example is $< i_t , o_t >$

order-*1* emission functions:	$f_t^1(i_t) = o_t,$	$f_t^1 \in F^1:$	I	$\rightarrow$	O
order-*2* emission functions:	$f_t^2(f_{t-1}^1) = f_t^1,$	$f_t^2 \in F^2:$	F^1	$\rightarrow$	F^1
order-*n* emission functions:	$f_t^n(f_{t-1}^{n-1}) = f_t^{n-1},$	$f_t^n \in F^n:$	F^{n-1}	$\rightarrow$	F^{n-1}

accordingly, the semiotic model of a natural sequence consists of *a list of sets of approximations* to the true emission functions $[\dot{F}^1, \dot{F}^2, ..., \dot{F}^n]$

the current function approximation at each level is stored in a list that represents the *state* of the natural sequence at multiple levels of abstraction $[\dot{f}^1, \dot{f}^2, ..., \dot{f}^n]$

procedure

once the current approximator makes a wrong prediction, the unexpected example enables the selection of an approximator that would have been more fit

previous and new approximator at level *n* are *propagated as input and target output* to the current approximator at level *n + 1* and the new approximator is *adapted* to the unexpected example

this allows to *predict the appropriate approximator* immediately if the same previous approximator turns out to be inappropriate again in the future

a new approximator is introduced if there is no approximator fit for the current example and a new layer is introduced once the top layer has two approximators

evaluation

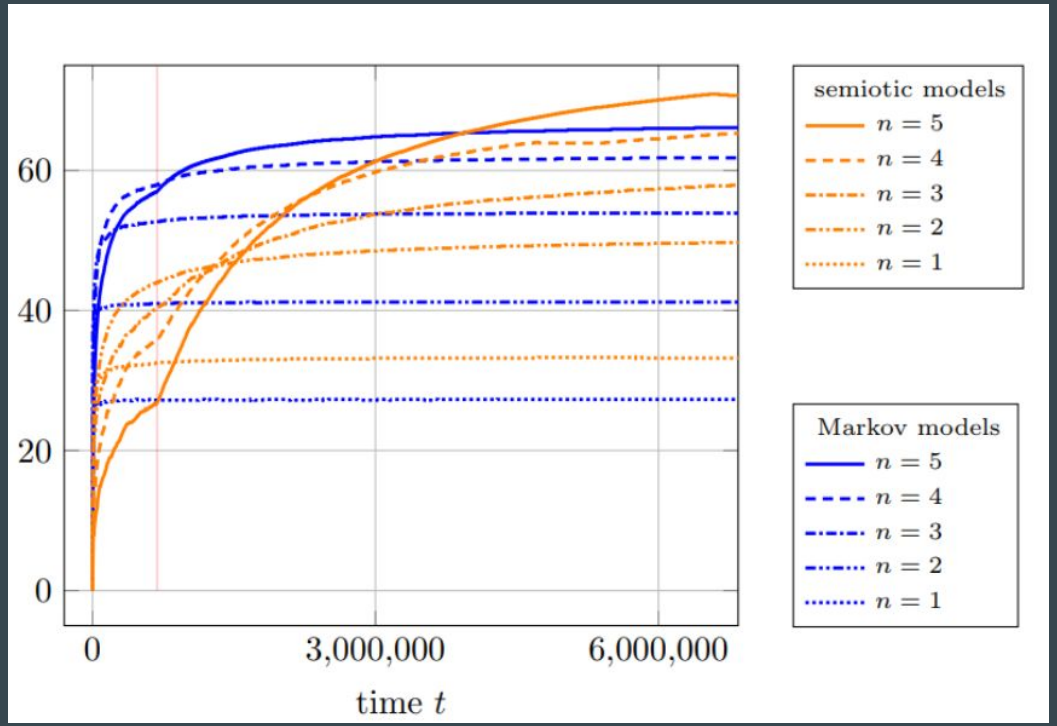
she gave way to all the genuine frankness of her character in her reply to the letter which announced its arrangement, she sent him language so very abusive, especially of elizabeth, that for some time all intercourse was at an end. but at length, by elizabeth's persuasion, he was prevailed on to overlook the offence, and seek a reconciliation; and, after a little further resistance on the part of his aunt, her resentment gave way, either to her affection for him, or her curiosity to see how his wife conducted herself; and she condescended to wait on them at pemberley, in spite of that pollution which its woods had received, not merely from the presence of such a mistress, but the visits of her uncle and aunt from the city.

evaluation

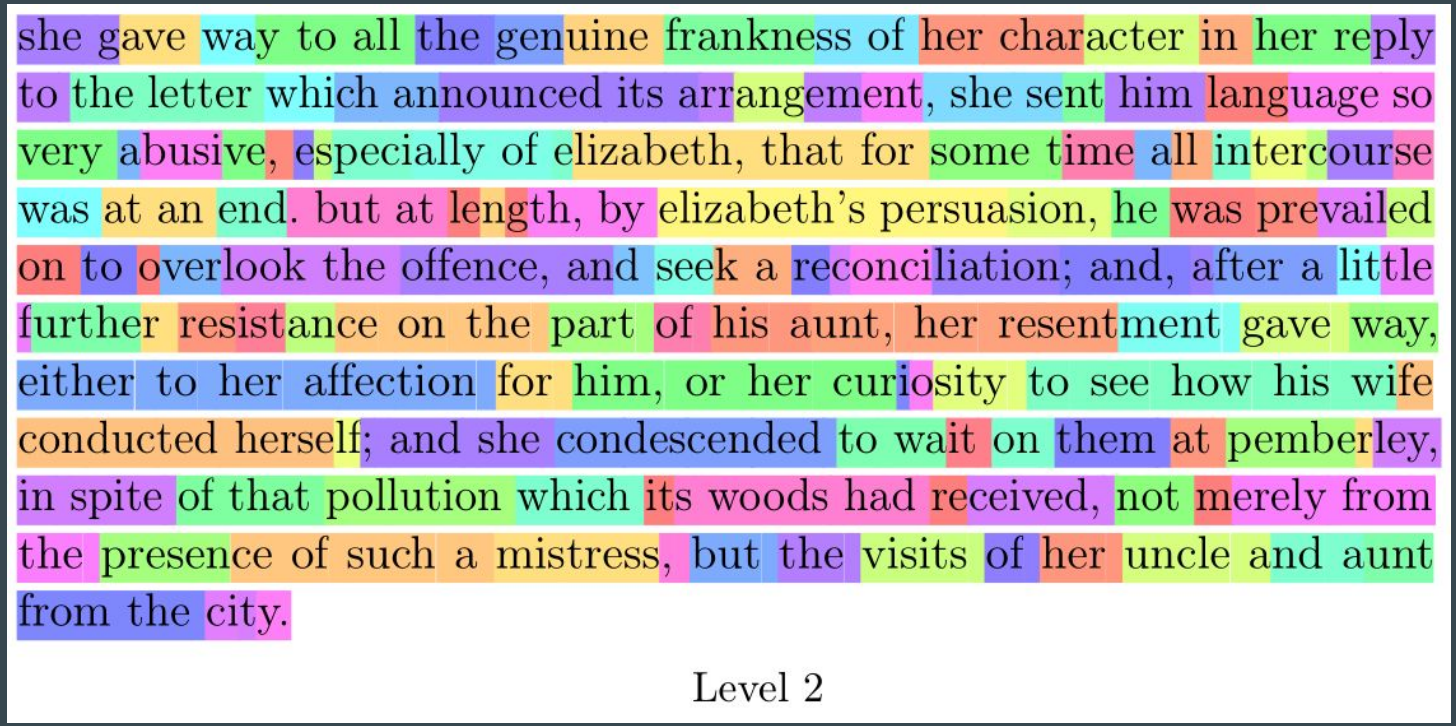
each state layer is considered as history of the last *n* approximators, where *n = 1*

increasing *n* and redefining input as the last *n* elements enables comparison to order-*n* Markov predictors

semiotic models *generalize text segments* and *maintain long term relations beyond* n



evaluation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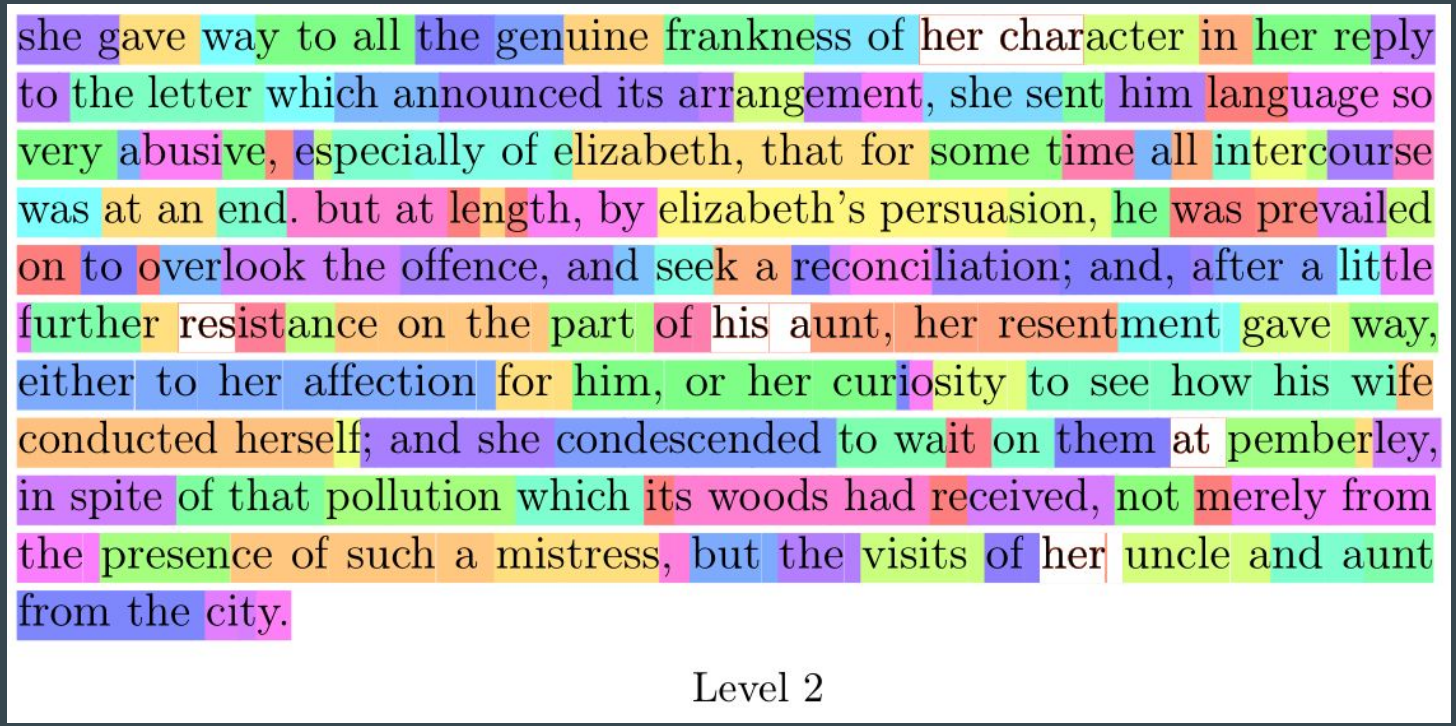
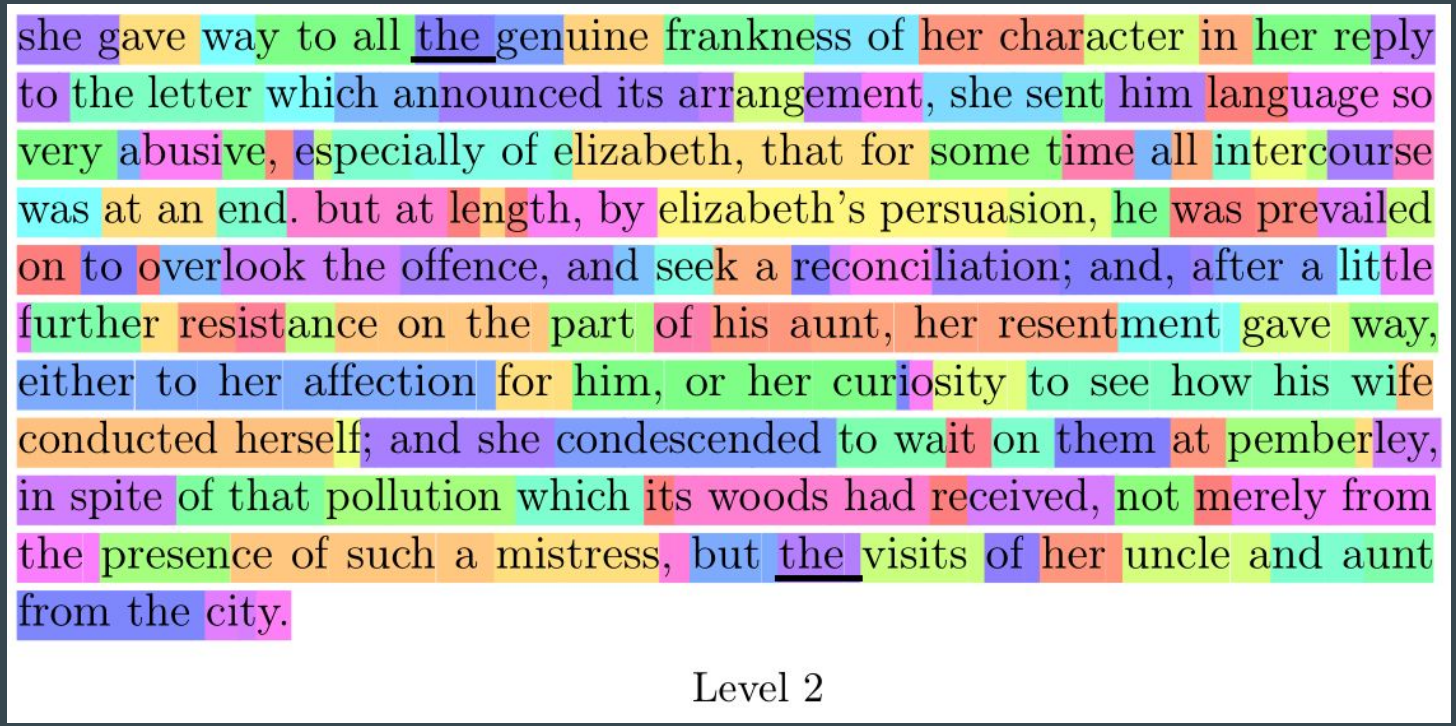
Level 2

evaluation (synonyms)



evaluation (homonyms)



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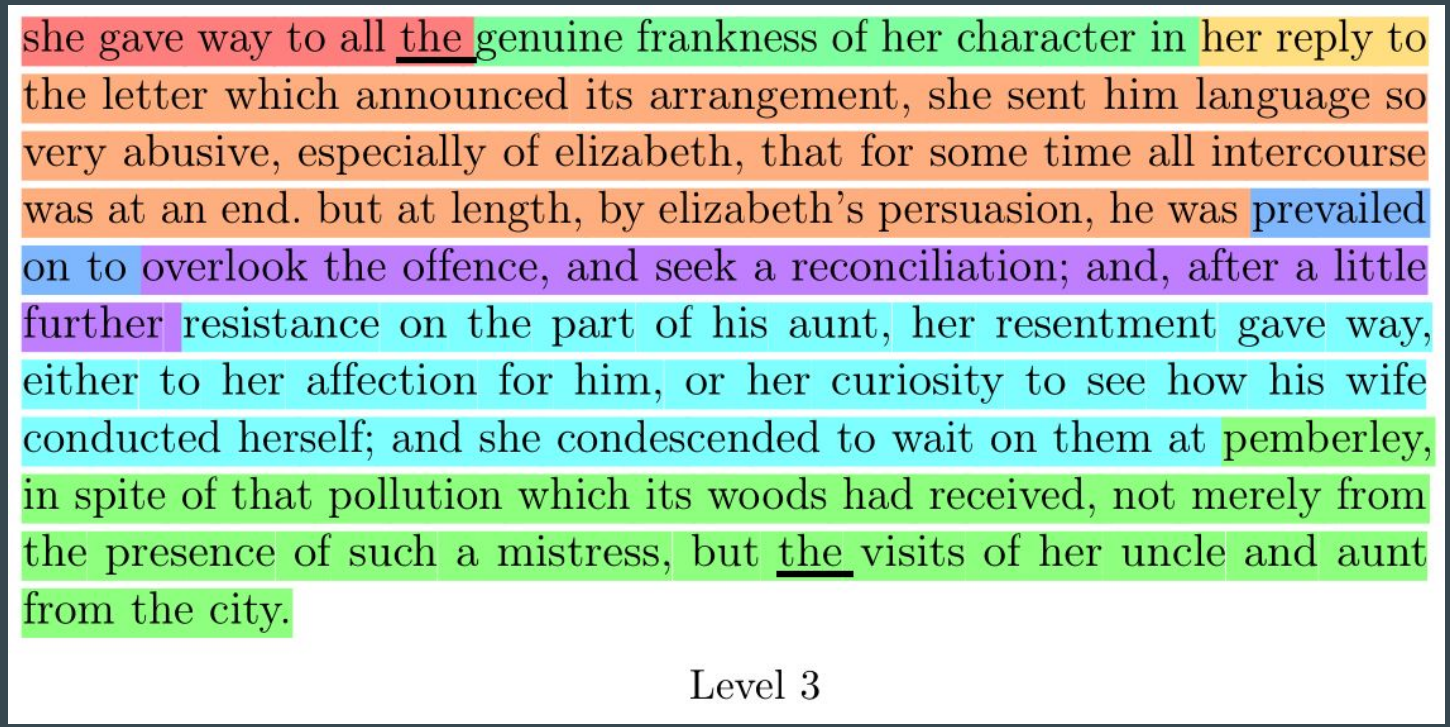
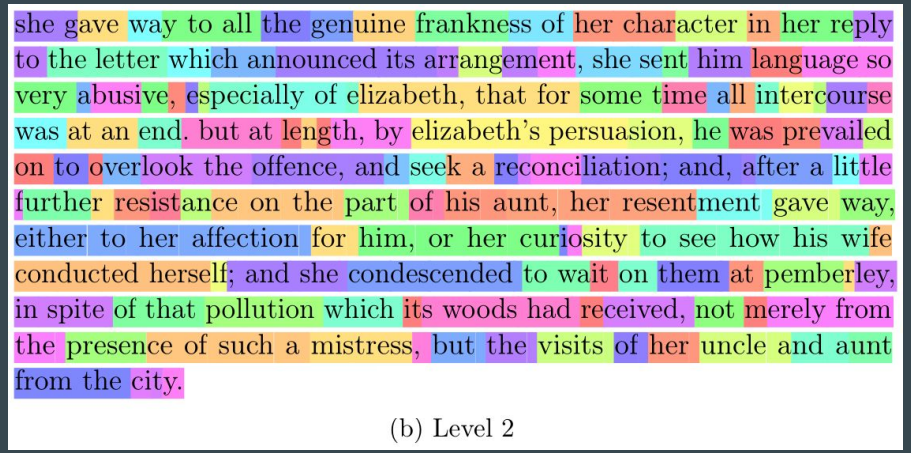


evaluation

the generated representations end significantly more often *with* a word than *within* one

this is due to the fact that representations at this level cannot reliably predict *the successor of a space character*



(b) Level 2

the same would be the case with a failure to predict any (e.g. sensorimotor) target

this corresponds to *the change of semantic content* from one word to another

final remarks

an algorithm that cannot perceive *anything but letters* cannot segment text that is composed of these letters according to human semantics

to mirror particular human semantics probably not only requires sensorimotor data from a *human-like body* but also that this body is *in a "compatible" society*

nonetheless, functions that are *analogous* to linguistic synonym identification and homonym disambiguation turn out to improve predictive performance

transferring this insight back onto cognitive processing *in general* suggests that **mental segmentation of the world into discrete objects might be *a cognitive tool* to improve predictive performance**

related articles (containing additional information and complete bibliography)

Wernsdorfer, M. (2018). A time-critical simulation of language comprehension. In *International Conference on Artificial General Intelligence* (pp. 281-291). Springer, Cham.

Wernsdorfer, M. (2018). How failure facilitates success. In *International Conference on Artificial General Intelligence* (pp. 292-302). Springer, Cham.

Wernsdorfer, M. (2018). A phenomenologically justifiable simulation of mental modeling. In *International Conference on Artificial General Intelligence* (pp. 270-280). Springer, Cham.