The influence of cloze probability and item constraint on cloze task reponse time

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Goal: investigate the effect of probability and item constraint on reaction times during cloze probability tasks.

Findings: higher probability responses are produced faster; responses to high-constraint items are produced faster.

Interpretation: cloze probability is a measure of lexical pre-activation best captured by an activation-based race model.

1 Cloze probability

Cloze probability: proportion of participants who give the word as the next word in a sentence.

Sometimes whole sentence completions are collected; sometimes just the next word.

Different groups of participants do the cloze task and the main task

Prompt varies: "most likely next word", "most natural continuation", "first word that comes to mind", ...

Usually, either the contexts are contrasted or the words are contrasted:

1. Word contrast:
   (a) Before warming the milk, the babysitter took the infant's **bottle** out of the travel bag.
   (b) Before warming the milk, the babysitter took the infant's **diaper** out of the travel bag.
2. Context contrast:
   (a) Before warming the milk, the babysitter took the infant's **bottle** out of the travel bag.
   (b) To prevent a mess, the caregiver checked the baby's **bottle** before leaving.

Assumption: the off-line task of cloze completion predicts some part of on-line comprehension.

1.1 How do participants generate cloze completions?

Say 20% of participants give "cat" and 80% give "dog". What does this mean?

Theory 1: There are 2 groups of speakers: 20% of the population has "cat" as their most expected word, while 80% of the population has "dog" as their most expected word.

Theory 2: All speakers have the same underlying probability distribution, and each response represents a sample from this distribution.

Under Theory 2, we don't expect RT differences in between high- and low-cloze completions, since participants sample from the same distribution in either case.

Goal: test the effect of item constraint and cloze probability on cloze completion reaction times.

Item constraint: how probable is the highest-probability completion?[1]

2 Experiment 1

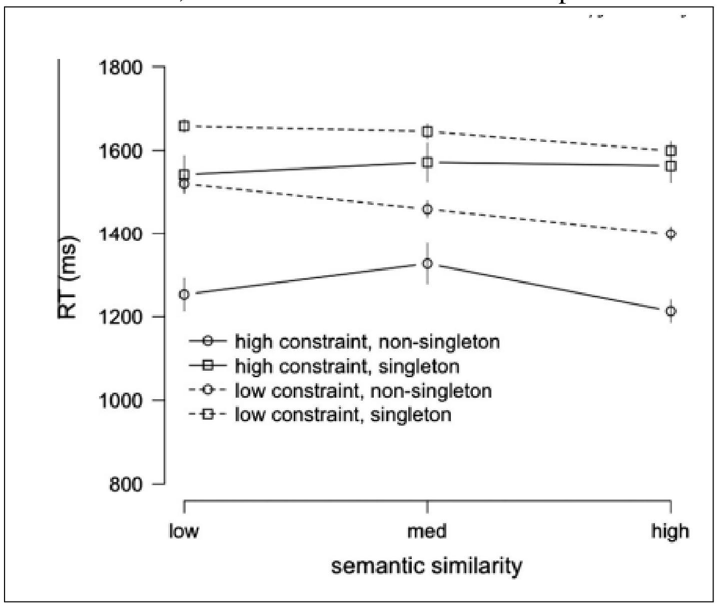
Reaction time data was gathered using sentence fragments with existing cloze norms. Participants heard the stimuli and responded verbally.

2.1 Results

The influence of different factors on reaction times was analyzed using a linear mixed-effects model that included the maximal random effects

[1] Entropy is another way to measure this, but the authors note that it correlated very closely with the probability of the most likely completion.

Figure 1: Exp. 1 mean RT for non-modal responses by status as singleton, item constraint, and LSA cosine with modal response



structure for subjects, but not for items.

2.1.1 Model 1

The first model included only cloze probability as a fixed effect, and found a large, significant effect of cloze probability on reaction times.

2.1.2 Model 2

This model included both item constraint and whether the word was the most common response as fixed effects. It found significant effects for both as well as for the interaction.

2.1.3 Model 3

This model included only responses with cloze probability less than 0.4 (so, not the most popular responses).

It included cloze probability, item constraint, and their interaction as fixed effects, and found significant effects for cloze probability and item constraint, but not for their interaction.

2.1.4 Model 4

The last model looked at whether lexical similarity between cloze completions affects reaction time. In particular, this could explain the finding that low close reponses are faster in constraining contexts than in unconstrained contexts.

The semantic relatedness of the completions was calculated using Latent Semantic Analysis and this was included as a fixed effect along with item constraint and cloze probability.

The effect semantic similarity was significant, but smaller than the effects of item constraint and cloze probability.

2.2 Interpretation

The results show that participants produce high-cloze completions much faster than low-cloze completions. They also produce completions for high-constraint items faster than for low-constraint items.

These effects do not seem to be due to differences in frequency or semantic similarity.

3 Experiment 2

This experiment replicated Experiment 1, but made the point at which the response prompt appeared predictable.

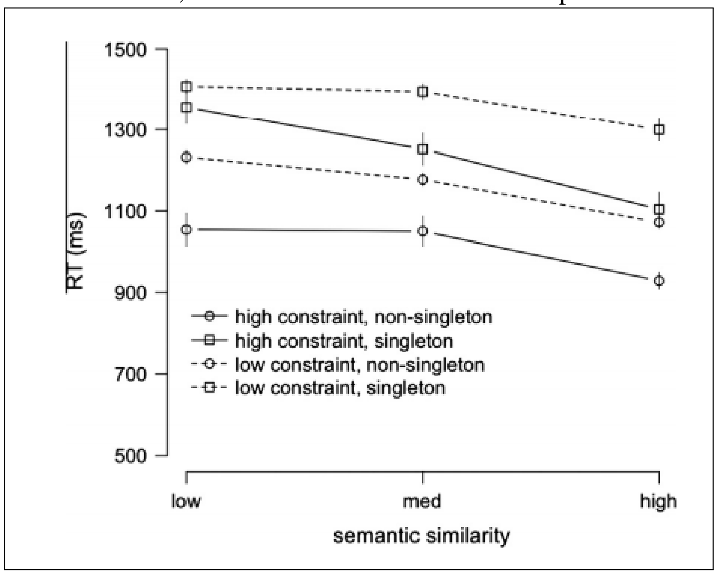
All items used in this experiment had the same length and sentence structure:

The ADJ NOUN VERB[+ past] DET ____

3.1 Results

Results were similar to Experiment 1, except that reaction times were faster in general.

Figure 2: Exp. 2 mean RT for non-modal responses by status as singleton, item constraint, and LSA cosine with modal response



3.2 Discussion

Two main RT effects:

(1) Higher probability responses are produced faster than lower probability responses

(2) Responses at a given cloze probability level are produced faster in high constraint contexts than in low constraint contexts.

These effects are unpredicted under a probabilistic sampling view of cloze completion.

4 Activation-based race model

Staub et al. propose an activation-based race model of cloze completion.

Proposal: Producing a cloze completion involves the gradual accumulation of evidence for that completion over time. Whichever response is the first to reach an evidence threshold is selected.

4.1 Race simulations

Staub et al. simulate the race process by selecting a number of possible responses to a given sentence fragment. Each response accrues evidence at some (variable rate).

The rates vary in two ways: between-response variability, which reflects stable differences in the relative rates they are activated by the context; and within-response variability, which reflects variability in the activation rate per trial.

4.1.1 Explaining fast RTs for high probability items

Trials won by higher probability winners will be completed faster, because when a fast finishing time is sampled from the distribution of finishing times, it will almost always be a winning finishing time, since a finishing time of that speed is rare.

The response with the second-fasting average time will rarely win, because it can only win if the first-fastest is slow on that particular trial.

4.1.2 Explaining fast RTs in high constraint contexts

Capturing the effect of item constraint requires making some assumptions about how to model item constraint.

One possibility is that in high constraint contexts, activation is spread less evenly: there is a greater activation difference between the most- and least-activated words.

In this scenario, high-probability completions with be produced more quickly, since they are more activated to begin with (it is rare for a completion that starts with low-activation to overcome this and win).

Another possibility is that high constraint contexts give extra activation to one completion without decreasing the amount that other completions get. In this scenario, the high-probability completion will again finish faster.

5 Conclusion

Staub et al. conclude that the RT data argues in favor of a view of cloze completion as a measure of activation, not of prediction.

What is the relationship between the probability that a word is the first to reach a threshold of activation, and a speaker's estimate of a word's conditional probability?

Lots of factors that affect cloze probability:

- Familiarity (Smith & Levy 2011)
- Lexical priming (Smith & Levy 2011)
- Phonological or orthographic priming
- Activation of syntactic structures
- Idioms

References

[1] Staub, Adrian, Margaret Grant, Lori Astheimer, & Andrew Cohen. (2015). "The influence of cloze probability and item constraint on cloze task response time." *Journal of Memory and Language* 82.

[2] Smith, N. J. & R. Levy. (2011). "Cloze but no cigar: The complex relationship between cloze, corpus, and subjective probabilities in language processing. *Proceedings of the 33rd Annual Conference of the Cognitive Science Society*.