Multinomial Processing Tree Models of Recognition Memory

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Multinomial Processing Trees

Multinomial Processing Trees (MPTs) are a modeling approach (not a specific model), and have been used in a wide variety of areas including memory, decision making, and social psychology (Batchelder & Riefer, 1980; Erdfelder et al., 2009)

MPTs are usually applied to categorical data

- e.g., discrete decisions rather than continuous response times

MPTs make assumptions about how the different categories of behavior could be generated, in terms of probabilistic processes controlled by underlying psychological variables

The easiest way to understand MPTs is with examples

- two MPT models of recognition memory
- an MPT model of the weapon-priming effect from social psychology

Recognition memory task

In an old/new recognition memory task (example here), there are two parts

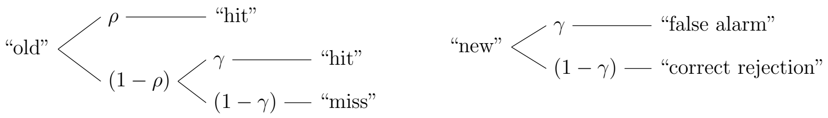
- **study**: a list of items (words, pictures, ...) are presented, usually one at a time
- **test**: a list of items is presented, one at a time, with some items coming from the original study list and some items being new

On each test trial, the participant is asked whether the item is "old" or "new"

The participant's behavior can be summarized in terms of four counts

	Study Item	Not Study Item
Answer "Old"	hit	false alarm
Answer "New"	miss	correct rejection

One-High Threshold Model



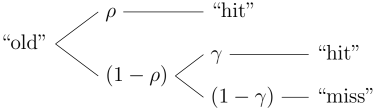
The one-high threshold MPT model assumes that a participant has some probability of remembering an item was on the study list

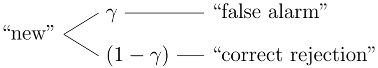
- if they remember the item, they correctly say "old"
- if they do not remember the item (either because it was on the study list but they forget, or because it was not on the study list) they guess

The model has two parameters

- a probability ρ of remembering a studied item when it is presented during testing
- a probability γ of guessing by responding "old" if there is no memory of the item

One-High Threshold Model





The remembering and guessing parameters can be inferred based solely on the counts of the numbers of hits and false alarms from the number of old and new test trials

misses and correct rejections are just the complement of hits and false alarms, and do not provide extra information

The one-high threshold model assume the hit rate θ^{h} and the false alarm rate θ^{f} are

$$\begin{aligned}\theta^{\mathrm{h}} &= \rho + (1-\rho)\,\gamma \\ \theta^{\mathrm{f}} &= \gamma\end{aligned}$$

One-High Threshold Model

For data that have k^{h} hits out of n_o old items and k^{f} false alarms out of n_n new items, the one-high threshold model assumes and

$$\begin{aligned} k^{\text{h}} &\sim \text{binomial}(\theta^{\text{h}}, n_o) \\ k^{\text{f}} &\sim \text{binomial}(\theta^{\text{f}}, n_n) \end{aligned}$$

The model also assumes that all remembering rates ρ and guessing rates γ are a priori equally likely, so that

$$\begin{aligned} \rho &\sim \text{uniform}(0, 1) \\ \gamma &\sim \text{uniform}(0, 1) \end{aligned}$$

Amyloid positivity data

Amyloid Status	Hits	False Alarms
positive	8	4
negative	12	1
negative	14	0
positive	9	4
...	...	...

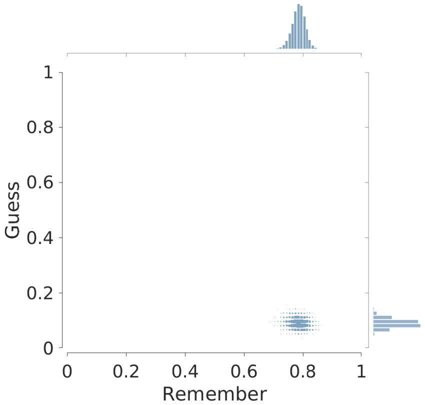
These data come from a clinical setting, and involve memory ability tests for 60 patients using the Rey auditory verbal learning test (Bean, 2011)

- In the recognition task, the patients study a set of 15 words, and tested on 30 words, made up of 15 old and 15 new words

Patients also had a cerebrospinal fluid measurement taken to classify their levels beta amyloid as "positive" or "negative"

- amyloid positivity is thought to be a pre-sympotic indicator of Alzheimer's disease

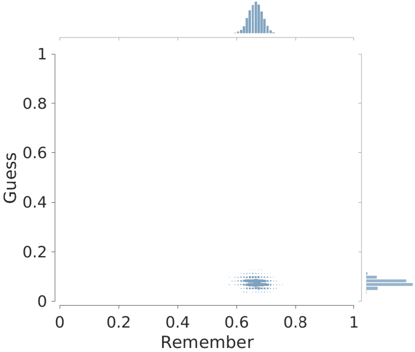
Amyloid negative inferences



The figure shows the joint and marginal posterior distributions for the remembering and guessing parameters

Patients remember around 80% of the items, and guess “old” about 10% of the time when they do not remember

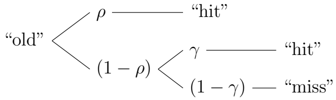
Amyloid Positive Inferences

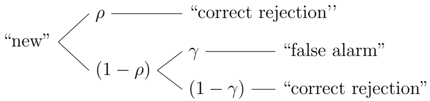


Patients remember around 60-70% of the items, and guess "old" about 10% of the time when they do not remember

Very similar guessing behavior to amyloid negative group, but lower probabiiity of remembering

Two-High Threshold Model



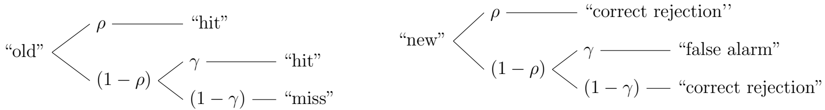


The two-high threshold MPT model has the same two paramaters, and still assumes that a participant has some probability of remembering an item was on the study list

The decision process during testing now works a little differently

- if they remember the item, they correctly say "old"
- if they remember that the item was not on the study list, they correctly say "new"
- if they do not remember the item, they guess

Two-High Threshold Model



The new assumptions do not change how hits are produced

Either by remembering the item or guessing "old"

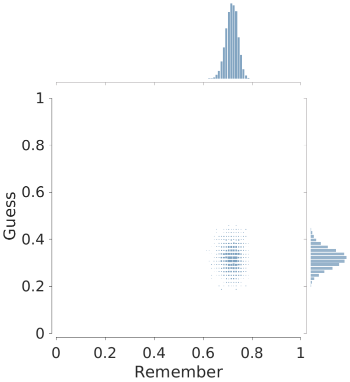
But they do change how false alarms are produced

By explicitly remembering the item was not on the list, or by guessing "old"

The hit rate θ^{h} and the false alarm rate θ^{f} are now

$$\begin{aligned}\theta^{\mathrm{h}} &= \rho + (1-\rho)\,\gamma \\ \theta^{\mathrm{f}} &= (1-\rho)\,\gamma\end{aligned}$$

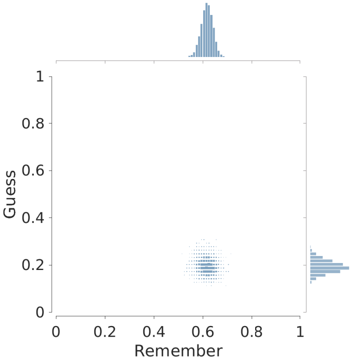
Amyloid negative inferences



The figure shows the joint and marginal posterior distributions for the remembering and guessing parameters

Patients remember around 70-80% of the items, and guess “old” about 30% of the time when they do not remember

Amyloid positive inferences



Patients remember around 60% of the items, and guess “old” about 20% of the time when they do not remember

The remembering rate is lower, and the guessing rate now also differs between the amyloid negative and positive groups

Key points

MPT models make assumptions about how categorical observed behavior can be decomposed into sequences of probabilistic events

The one-high threshold and two-high threshold models of recognition memory are widely-used MPT models

The inferences for the amyloid positivity data showed meaningful differences between the clinical groups, but the exact nature of the differences in remembering and guessing depends on the model

References

Batchelder, W. H., & Riefer, D. M. (1980). Separation of storage and retrieval factors in free recall of clusterable pairs. *Psychological Review*, *87*, 375–397.

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Erdfelder, E., Auer, T.-S., Hilbig, B. E., Aßfalg, A., Moshagen, M., & Nadarevic, L. (2009). Multinomial processing tree models: A review of the literature. *Zeitschrift für Psychologie/Journal of Psychology*, *217*, 108–124.