

# Modeling the Effects of Induced Frequency

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Differences in lifetime exposure to events, objects and concepts have a large impact on performance in cognitive tasks like perception and memory. A well known example is word frequency, but word frequency is correlated with numerous other variables, making it difficult to isolate the effects of experience per se. Some studies aimed to isolate the effects of experience differentially trained novel items like pseudowords (Reder et al., 2002). However, such stimuli are imperfect for this purpose because they carry forward aspects of wordness: E.g. they match words in bigram and phoneme frequency, and may remind subjects of similar words.

In order to examine pure frequency effects, Nelson and Shiffrin (2006) trained subjects on Chinese characters, likely to be novel on most dimensions. Subjects in this experiment were trained using a task from Shiffrin and Lightfoot (1997), where they searched for Chinese characters in visual displays, with the exposure frequencies of the characters varying geometrically. Several weeks of training produced significant learning, measured by both slope and intercepts of the response-time by display-size function. Following training the subjects completed an episodic recognition task, a forced choice perceptual identification task, and a pseudo-lexical decision task, each of which showed significant effects due to trained character frequency.

One model of frequency effects, the REM model of Shiffrin and Steyvers (1997), is inappropriate to apply to our results in several respects: REM assumes both that 1) higher frequency items are composed of higher frequency features, and 2) that higher frequency items share more features with each other than do low frequency items. Since our Chinese characters were randomly assigned to training-frequency, the second assumption is not reasonable. We developed an alternative version of REM appropriate for our task.

## Fuzzy-matching model

In order to more appropriately model the Chinese character stimuli used in our experiment, we assume in the current model that each item presented has unique features, and therefore the base rates induced by training will perfectly match the training frequencies. For subsequent memory and perception tasks, we use a REM-like Bayesian fuzzy-matching process: Each feature of the item being encoded is either copied correctly with a probability that depends on base rate, or is stored randomly. What is stored is an imprecise representation, with the system deciding a feature of a test alternative 'matches' if that feature is within some tolerance limit of similarity to the stored representation.

The system reaches a Bayesian decision on the basis of the matches and mismatches noted when one or more alternatives are compared to the fuzzy percept.

## Results

The results of the memory and perception tasks in the Nelson and Shiffrin (2006) study showed training frequency effects which were consistent with word frequency findings. In episodic recognition, the training produced a mirror effect: the low frequency characters had both a higher hit rate (correctly identifying old items as old), and a lower false alarm rate (incorrectly identifying new items as old) than the high frequency trained characters. The pseudo-lexical decision task also produced results consistent with word frequency: the high frequency trained characters produced both faster and more accurate responses than the low frequency trained characters. In forced choice perceptual identification, the high frequency characters were found to enhance performance in the task regardless of whether they were present as targets or foils.

The results described above show that differences in prior exposure alone produce significant frequency effects in memory and perception. Through the use of unique item features and a fuzzy matching procedure, our model is able to produce these frequency effects, while holding to the assumption that prior exposure is the only difference between the high frequency and low frequency characters. The model is shown to fit the results of perceptual identification, episodic recognition memory, and pseudo-lexical decision.

## References

- Nelson, A. B., & Shiffrin, R. M. (2006). How Experience Affects Perception and Memory. Manuscript in preparation, Indiana University.
- Reder, L. M., Angstadt, P., Cary, M., Erickson, M. A., & Ayers, M. S. (2002). A Reexamination of Stimulus-Frequency Effects in Recognition: Two Mirrors for Low- and High-Frequency Pseudowords. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 28, 138-152.
- Shiffrin, R. M., & Lightfoot, N. (1997). Perceptual Learning of Alphanumeric-like Characters. *The Psychology of Learning and Motivation*, 36, 45-81.
- Shiffrin, R. M., & Steyvers, M. (1997). A model for recognition memory: REM – retrieving effectively from memory. *Psychonomic Bulletin & Review*, 4, 145-166.