A Holographic Model Of Frequency And Interference: Rethinking The Problem Size Effect

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Abstract

In this paper we used a holographic memory system to model Zbrodoff's (1995) findings on the problem size effect, a well-known effect in the area of Math Cognition. The data showed the effects of manipulating both frequency and interference.

Keywords: fan effect; frequency; holographic memory; interference; arithmetic

The Dynamically Structured Holographic Memory system (DSHM) uses holographic representations as a way of modeling human memory. It is based on Jones and Mewhort's BEAGLE lexicon model. The details of DSHM and the similarities to BEAGLE are discussed in Rutledge-Taylor & West (2007). One function that DSHM models well is memory interference. Rutledge-Taylor & West (2008) showed that the *fan effect* (Anderson, 1974) falls naturally out of the DSHM architecture.

The *fan effect* is a term used to describe a memory phenomenon in which the time needed to verify a fact is related to the number of other facts in memory that include concepts in common with the target fact (Anderson, 1974). The fan refers to how many facts share memory elements with the target. For example, if a person's declarative memory contained three propositions: "the hippie is in the park", "the lawyer is in the store", and "the lawyer is in the bank", then the fan of the terms 'hippie', 'park', 'store', and 'bank' are one, while the fan of the term 'lawyer' is two. As first demonstrated by Anderson (1974), larger fans cause slower reaction times in human subjects. This result is consistent with the theory that similar facts cause interference in the retrieval process.

The DSHM model has been used to model the fan effect (Rutledge-Taylor & West, 2008). However, the fan effect addresses only the effect of inter-fact 'interference' on the efficiency of fact retrieval. But, there is another factor that also strongly impacts retrieval speed/efficiency: the person's frequency of exposure to that fact. For example, if a participant reads "the lawyer is in the store" once and "the lawyer is in the bank" four times, the fans of 'store' and 'bank' are each still one. However, one would expect that the association between 'lawyer' and 'bank' to be stronger than the association between 'lawyer' and 'store'. Thus, both fan effects and frequency effects impact the efficiency of fact retrieval. To test the interaction of frequency and fan in DSHM we modeled the data of Zbrodoff (1995), who manipulated both of these in the context of learning alphabet arithmetic facts (e.g., A + 3 = D, which indicates that the number three letters past A is D). Zbrodoff repeatedly represented these facts and measured true/false response reaction times across trials to study learning.

In Experiment 4 all of the problems were presented with equal frequency. To model this, each problem, including the answer and whether the answer was true or false, was represented as a random vector and entered into the DSHM, so that one entry equaled one presentation to a subject. There were two ways the model could decide if a question was true. One was to submit a question vector with the problem plus the answer and a *blank* for whether it was true or false. The model would then return whether or not it believed the question was true or false. The second way was to submit the question with the answer as a *blank* and whether or not it was true filled in with *true*. In this case the model would return what it believed to be the correct answer (note, the model can make errors but this data is not presented here).

The second method fit the data better than the first, suggesting that people were recalling the answers to see if the questions were true or false. In this case the model makes the same predictions for true and false questions. Consistent with this, the human data was very similar for the true and false questions. To get accurate reaction times from the model the inverse of the activation levels were scaled up by a factor of 400. Note that this represents a claim that the activation levels of the model translate directly into reaction times. Figure 1 presents the results.

Experiment 3 was the same as Experiment 4 except that frequency was manipulated so that the questions with the smaller numerical addends were presented more frequently. The model used here was exactly the same as the one used to model Experiment 4. No parameters were altered! Figure 2 shows the human data and the simulation results. Overall, the model does a good job of accounting for the results. The only exception occurs in the later blocks (not shown on the graphs) where the model continues to have the addends 2 and 4 close together with the addend 3 higher. In contrast, in the human data, the addend 4 moves back up closer to the addend 3. This result is difficult to interpret. It could be that the model does not predict well for long term learning, although it did accurately predict long-term learning for Experiment 4. Another possibility is that subjects were using a rehearsal strategy between sessions. If subjects were recalling the questions and checking them by calculation, or rehearsing them, it could produce this effect since the addend-4 questions would be harder to recall due to the low frequency of presentation (for random recall without a cue, interference should not play a role).

Figure 1: Data and Simulation for Experiment 4

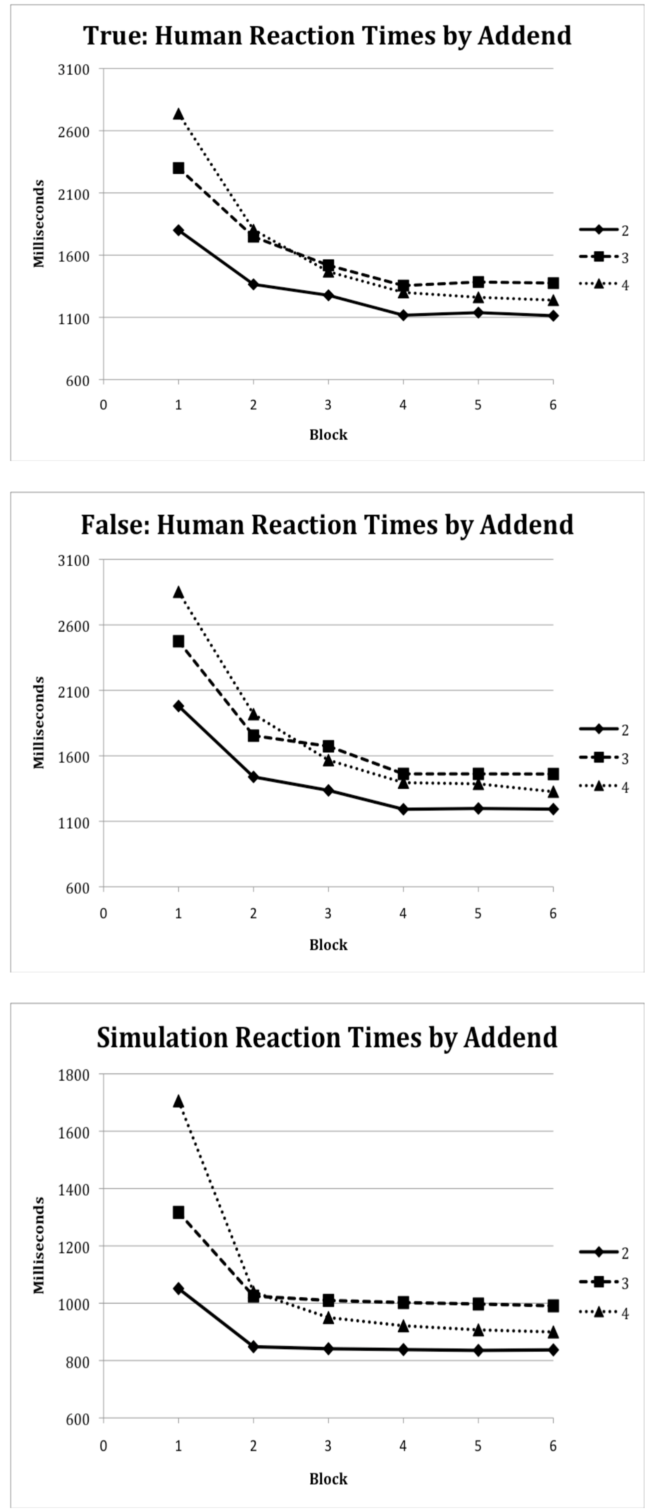

Figure 2: Data and Simulation for Experiment 3

References

Anderson, J. R. (1974). Retrieval of propositional information from long-term memory. *Cognitive Psychology, 6,* 451-474.

Rutledge-Taylor, & West, R. L. (2008). Modeling The Fan Effect Using DSHM. *Cognitive Science Procedings.*

Zbrodoff, N. J. (1995). Why is 9 + 7 harder than 2 + 3? Strength and interference as explanations of the problem-size effect. *Memory and Cognition*, 23(6), 689–700.