A new conception of working memory resources.

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Mental Effort differs across people & also within a person









Contextual Fan Effect: Studied word better recognized at test when font at test matched word vs. **WORD** but only when font rarely used, i.e., (low fan)fonts.

<u>Study Words</u>	<u>Test Words, Old</u>	l <u>Condition</u>	Test Words, New
Board	₽ ₿ ₫₽Ļ₿	(Original Font, High Fan)	· · · · ·
LINE	Spirit	(Original Font, Low Fan)	
Spirit	Million	(Swap Font, High Fan)	Back
Ţſ₽Ĕ	Year	(Swap Font, Low Fan)	amount
VEAR			
FEDFLE			
Farm			
Earth	*12 words per font for High Fan Font		
Home	1 word per font for Low Fan Font		
a ir			

Reder, Donavos,, & Erickson (2002).

At test, a matching low fan font sends more activation



Advantage of re-instating context at test disappeared for faces!

 Instead of easier to recognize face when the encoding accessory was relatively unique, recognition was better when accessory was used often AND it did not matter whether the accessory was re-instated!



Rate how likely for the person to go to this location (during encoding). At test: did you see this person before?

Easier to associate famous person with its background than unknown face





Reder, Victoria, Manelis, Oates, et al., *Psychological Science* (2012)

SAC Model previously accounted for many phenomena but now failed; need to revised *bc* strength/familiarity behave differently at encoding.

- WM Resources are consumed as an inverse function of familiarity/strength of the chunks being processed
- Resources replenish over time at a fixed rate
 - Whether resource is exhausted depends how unfamiliar the items are how many there are, that is the rate of presentation
- If resources overwhelmed/cannot replenish fast enough:
 - totally fail
 - or partial match unfamiliar chunks to more familiar chunks that are more easily processed
- Resources used to bind chunks together as well as all other cognitive processes

Reder, Paynter, Diana, Ngiam, & Dickison (2007) Experience is a double-edged sword: A computational model of the encoding/retrieval tradeoff with familiarity.

WM resource consumption affected by familiarity and presentation rate of stimuli



Problem: *quasi-experiments invite* alternative explanations

- More familiar stimuli seem easier to bind
- Important to demonstrate effects when frequency is *manipulated*
 - randomly assign stimuli to be high or low frequency and *experimentally induce* frequency differences among stimuli
 - Then can be confident that familiarity/frequency is the *cause* of the results

3 training trials per week for 4 weeks One Paired-Associate Learning test per week starting with week 2



Reder, Liu, Keinath, & Popov (2016)

Faster & more accurate at visual search over weeks; always better for high frequency (20 times the exposure)



Equally novel pairs were better in cued recall if the constituents were more familiar



Left panel is during training;

Right panel is 2 to 4 weeks after training.

Chunk Familiarity really affecting Working Memory? N-Back task

 6 types of blocks: 1 vs. 2 vs. 3 back crossed with Low vs. Hi Freq characters

 Theory predicts advantage for HF characters should increase with N (working memory difficulty)

Performance is worse when task is more difficult (3back). Disadvantage for Low Freq Chinese increases when demands on WM increase (3-back).



Replicated N-back result using Fribbles



12 families of Fribbles

Within-family Variability



N-back task: Familiar animals (like bunny or bear) are most accurate and hurt least by N-back level; Low frequency fribbles hurt most.



Will less familiar chunks act like a longer digit span in a divided attention math task?

- Anderson, Reder, Lebiere (1996) examined algebra problem solving when varied size of concurrent digit span of 2, 4 or 6 digits
 - Time and Accuracy to solve equations hurt with:
 - with more digits to remember
 - with more complicated equations
 - when had to use digits from span to solve equation
- Instead of varying # of digits, we used High vs. Low Frequency Chinese characters
 - 20::1 difference in exposure as before

Shen, Popov, Delahay & Reder, Memory & Cognition, 2017



Shen, Popov, Delahay & Reder, Memory & Cognition, 2017



炮=6 泡=2

泡十x=炮









Accuracy better with HF Chinese characters & frequency advantage grows with increasing task demands on working memory



Probability of binding to context *interacts* with Familiarity & Presentation Rate



Varied rate of presentation, pure vs mixed lists of frequency;

Measured degree of distortion of arrow click from where presented.

Popov, So & Reder (2021)

More errors for LF words, especially at faster rates; More errors for HF words when more LF words on list



Figure 8. The effect of word frequency, presentation rate and list-composition on raw recall error. 1) Experiment 2, pure lists of 100% HF or 100% LF; 2) Experiment 3, mixed lists.

Error bars represent ± 1 *SE*.

Experience Trade-off on Memory



Figure 1. Illustration of the trade-off between an HF encoding advantage and an LF retrieval cue advantage. A memory task will produce either positive (P_{HF}>P_{LF}) or negative (P_{HF}<P_{LF}) effects of word frequency depending on whether the HF encoding advantage exceeds the LF retrieval cue advantage. Factors such as pure lists or faster presentation rate increase the HF encoding advantage and as such increase P_{HF} (memory performance for HF words) relative to P_{LF} (memory performance for LF words).

Reder, Paynter, Diana, Ngiam, & Dickison (2007)

Summary & Implications

- Learning is easier when the information to be learned can be "chunked" but also when *chunks are more familiar* (stronger)
- Since working memory resources are consumed faster when information is less familiar, presentation rates need to be slower for unfamiliar.
- We talk to children more slowly because they have fewer chunks, smaller chunks and weaker chunks.
 - Maybe they have more WM than adults, but it just gets consumed faster.
- When training new complex chunks, discrimination training is needed
 - Otherwise, we tend to build incomplete representations that are vulnerable to partial matching
- Stimuli that are more similar/harder to discriminate do worse initially but actually are acquired faster if trained on the discrimination.

Thank you for listening: Questions?

Thank you to my wonderful collaborators

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Thank you for listening! Questions?

- Reder, L.M., Paynter, C., Diana, R.A., Ngiam, J., & Dickison, D. (2007). Experience is a double-edged sword: A computational model of the encoding/retrieval tradeoff with familiarity. In Ross, B. & Benjamin, A.S. (Eds.), *The Psychology of Learning and Motivation,* Academic Press, 271-312
- Reder, L. M., Victoria, L. W., Manelis, A., Oates, J. M., Dutcher, J. M., Bates, J. T., Cook, S., Aizenstein, H. A., Quinlan, J., Gyulai, F. (2012). Why it's easier to remember seeing a face we already know than one we don't: pre-existing memory representations facilitate memory formation. *Psychological Science*. 24(3), 363-72.
- Reder, L. M., Liu, X. L., Keinath, A., & Popov, V. (2016). Building knowledge requires bricks, not sand: The critical role of familiar constituents in learning. *Psychonomic Bulletin & Review. 23(1), 271-277.*
- Shen, Z., Popov, V., Delahay, A., & Reder, L. (2018). Item strength affects working memory capacity. *Memory & Cognition.* 46(2), 204-215
- Popov, V., Marevic, I., Rummel, J., & Reder, L. (2019). Forgetting is a feature, not a bug: Intentionally forgetting some things helps us remember others by freeing up working memory resources. *Psychological Science.* 30(9), 1303-1317.
- Popov, V., & Reder, L. (2020). Frequency effects on memory: A resource-limited theory. *Psychological Review.* 127(1), 1-46.
- Popov, V., & Reder, L.M. (2020). Greater discrimination difficulty during perceptual learning leads to stronger and more distinct representations. *Psychonomic Bulletin & Review 27(6)*, 768–775.
- Zhang, J., Liu, X. L., So, M., & Reder, L. M. (2020). Familiarity acts as a reduction in objective complexity. Memory & cognition. 48(8), 1376-1387.
- Popov, V., So, M., & Reder, L. M. (2021). Memory resources recover gradually over time: The effects of word frequency, presentation rate, and list composition on binding errors and mnemonic precision in source memory. Journal of Experimental Psychology: Learning, Memory, and Cognition.
- Popov, V., & Reder, L. (2022). Frequency effects in recognition and recall. In Wagmer. A & Kahana, M. (Eds.). The Oxford Handbook of Memory. Oxford University Press.

ERP study contrasting words vs pseudo-words and famous vs. unknown faces

 Recognition memory test for words and non-words, famous and unknown faces using ERP/EEG

- Results suggest that prior research using ERPs that claimed words and faces shown different patterns had confounded known vs. unknown chunks.
- Famous faces behaved like words while pseudo-words behaved like unknown faces.

Is the effect due to known vs. unknown or just different degrees of familiarity?



- Recognition was worse for pictures that had LF word on top even though the picture was shown longer.
 - Takes longer to read the Low Frequency words

Background: what motivated reconceptualization of working memory?

 Predictions of SAC model easily confirmed for many experiments using words with different fonts (and also different voices)

- didn't replicate when stimuli were faces with different accessories.
- Big Question was whether difference in patterns due to: words vs. faces OR familiar vs. unfamiliar stimuli

Advantage of re-instating context at test disappeared for (unfamiliar) faces

- Faces were **better** recognized if the accessory was **high fan**
- The advantage of high fan accessory did not depend on whether reinstated at test
- maybe the high fan accessory had its benefit at encoding when stimuli were unfamiliar.
 - Is it harder to bind (associate) a context to a stimulus if it is unfamiliar
 - Or are faces just different from words?