

# Free time, sharper mind: A computational dive into working memory improvement

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# Introduction

## Immediate serial recall (“simple span”)

**Encoding**

dog      arm      nuke      blend      tree      mug

**Recall**

**Score**

# Introduction

## Immediate serial recall (“simple span”)

**Encoding**

dog      arm      nuke      blend      tree      mug

**Recall**

dog      /      blend      nuke      bee      mug

**Score**

# Introduction

## Immediate serial recall (“simple span”)

<b>Encoding</b>	dog	arm	nuke	blend	tree	mug
<b>Recall</b>	dog	/	blend	nuke	bee	mug
<b>Score</b>	1	0	0	0	0	1

# Introduction

## Free-time manipulation

**0.5 s / item**

dog arm nuke blend tree mug

**1.0 s / item**

dog arm nuke blend tree mug

**2.0 s / item**

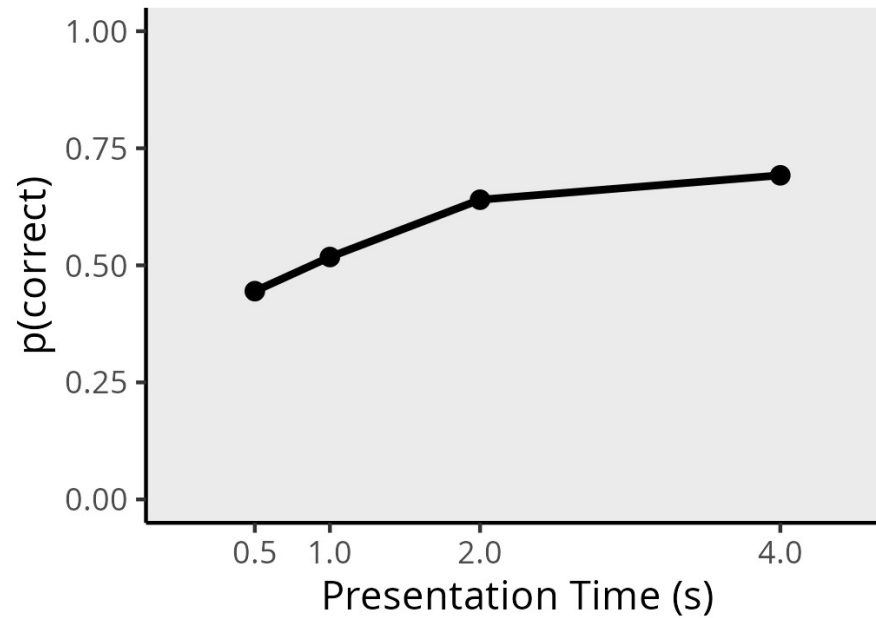
dog arm nuke blend tree mug

**4.0 s / item**

dog arm nuke blend tree mug

# Introduction

## “Free-time benefit”



(e.g., Tan & Ward, 2008, *M&C*)

# Introduction

**What causes the free-time benefit?**

# Introduction

## **Encoding-resource**



Introduction

**Encoding-resource**

Available resource

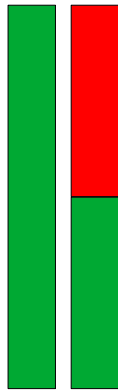


# Introduction

## Encoding-resource

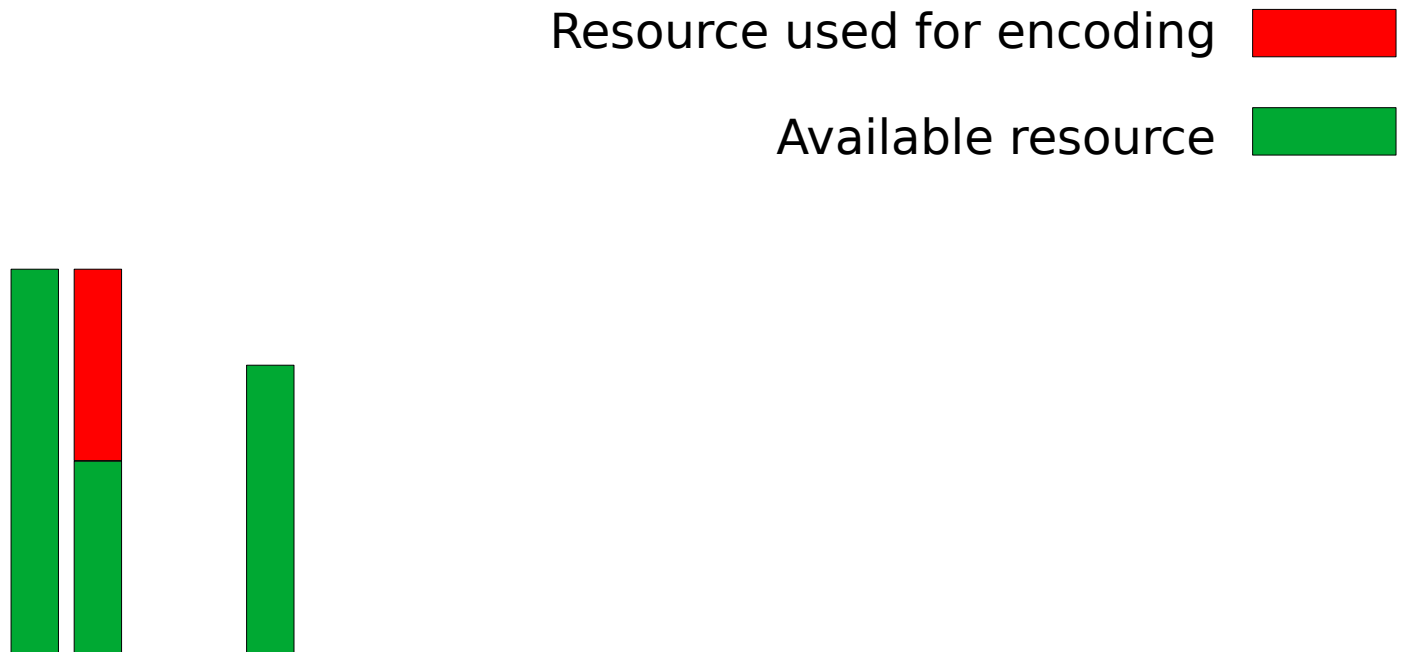
Resource used for encoding 

Available resource 



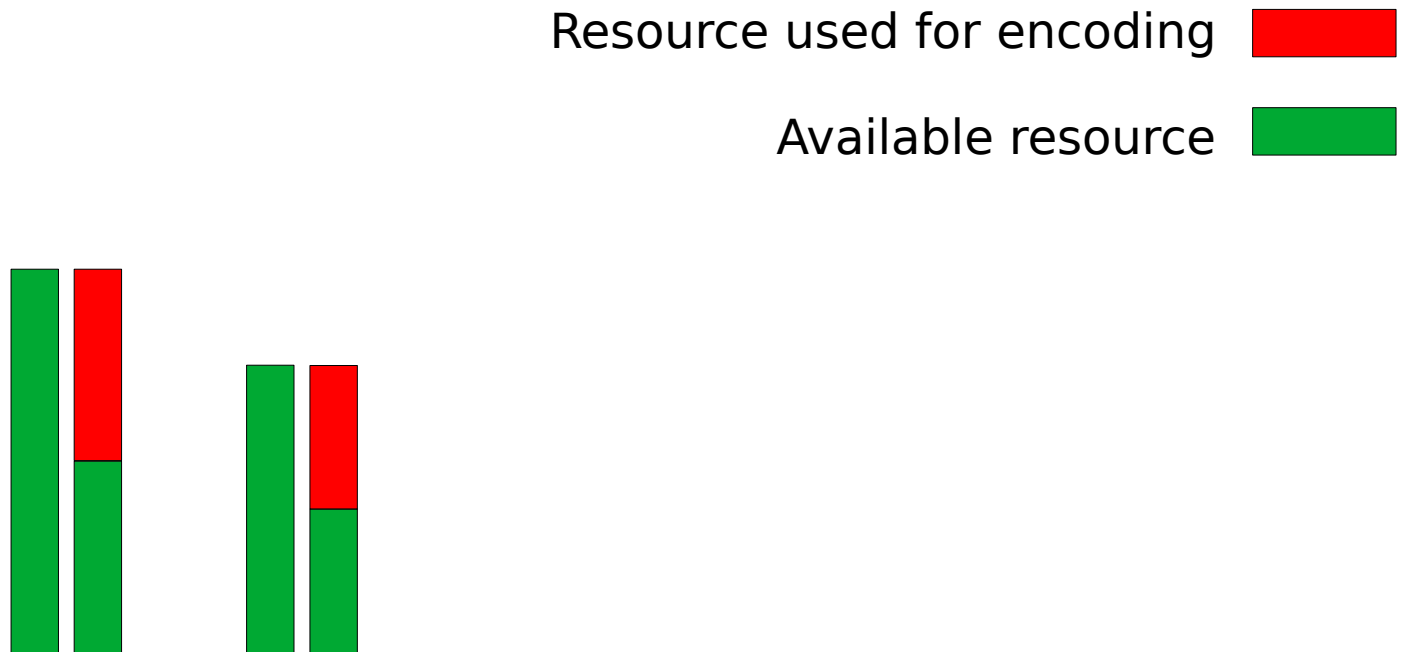
# Introduction

## Encoding-resource



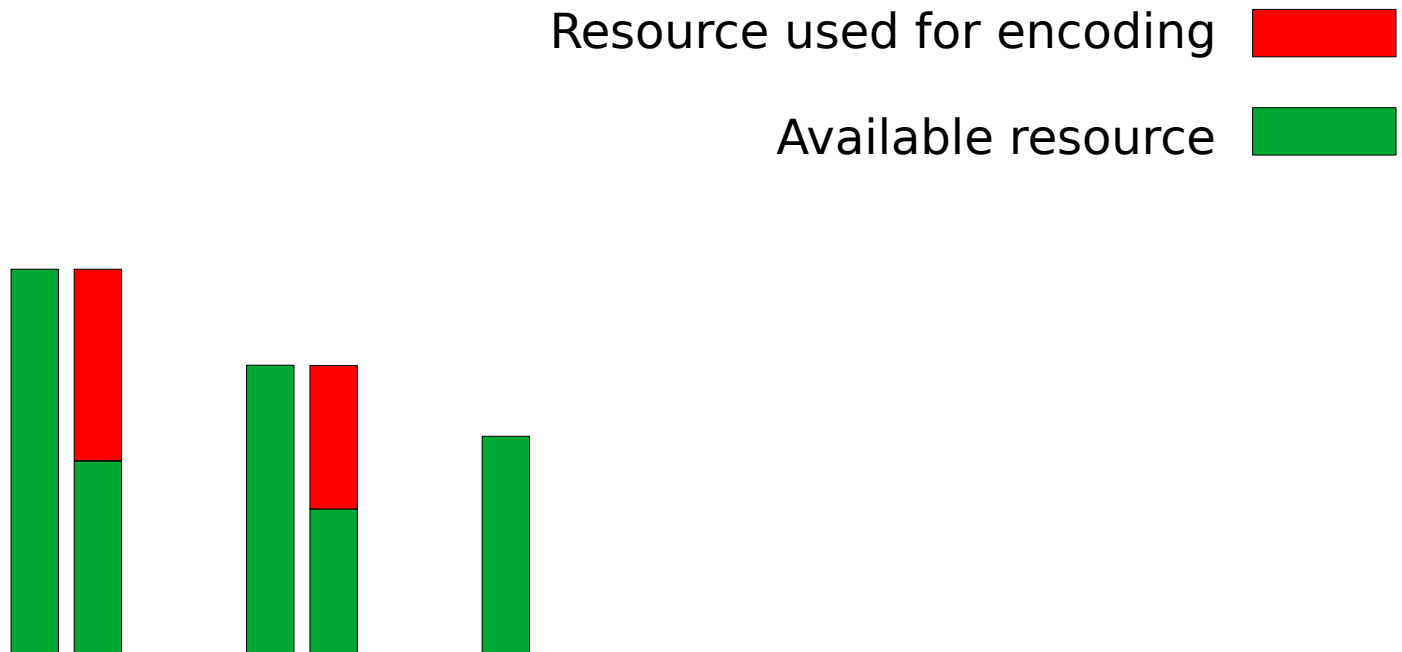
# Introduction

## Encoding-resource



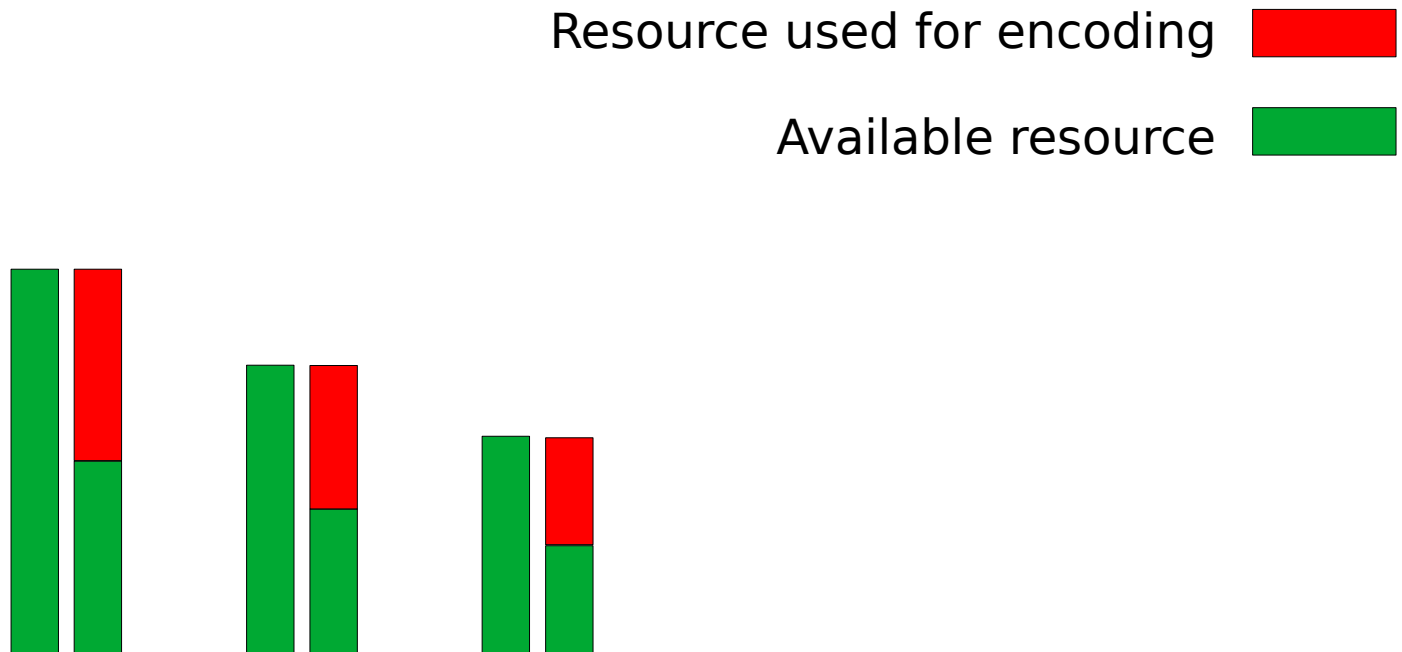
# Introduction

## Encoding-resource



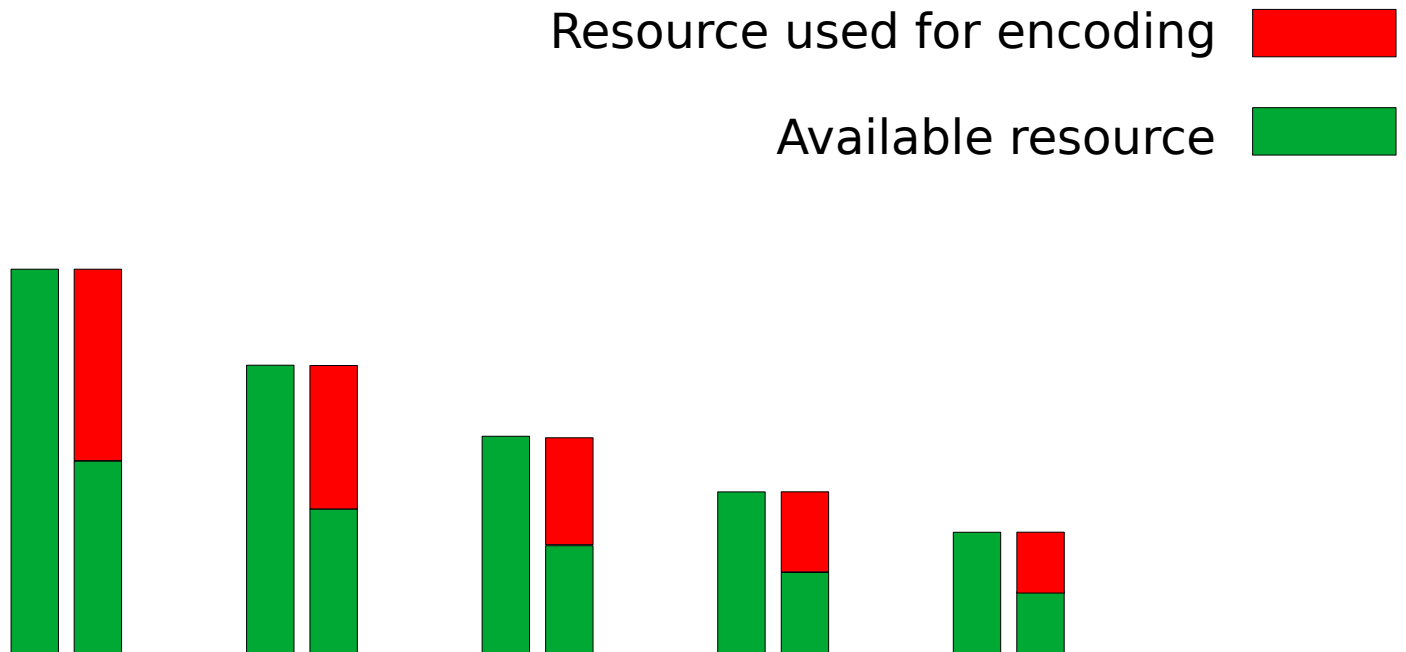
# Introduction

## Encoding-resource



# Introduction

## Encoding-resource

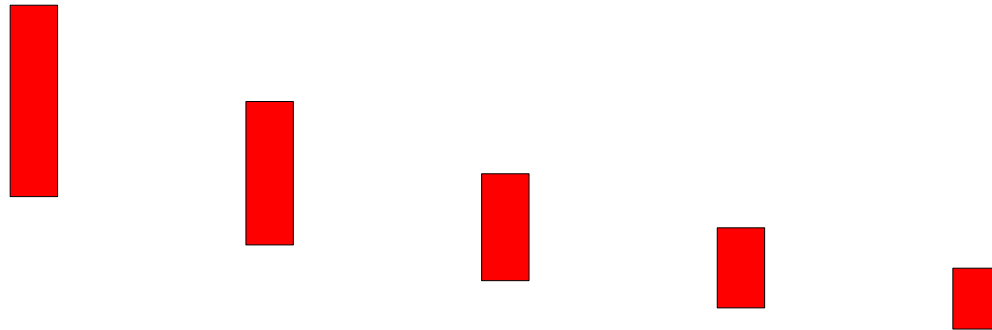


# Introduction

## Encoding-resource

Resource used for encoding 



Available resource 

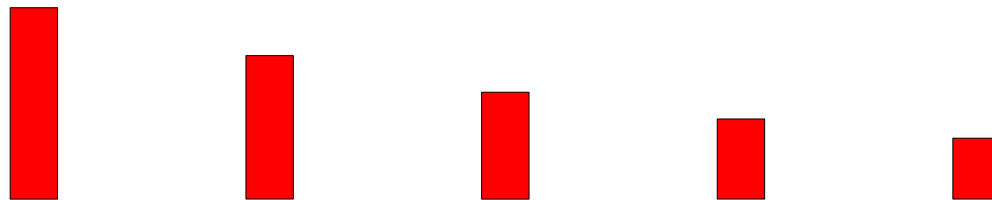




# Introduction

## Encoding-resource

Resource used for encoding   
Available resource 

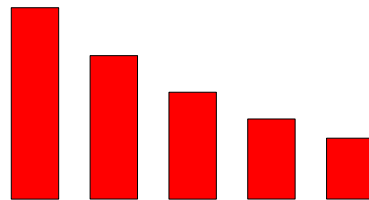


# Introduction

## Encoding-resource

Resource used for encoding 

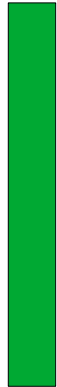
Available resource 



# Introduction

## Encoding-resource

Available resource



# Introduction

## Encoding-resource





# Introduction

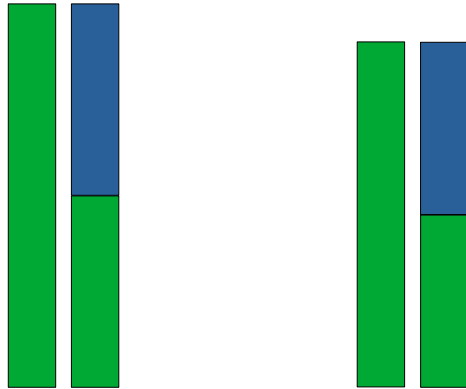
## Encoding-resource



# Introduction

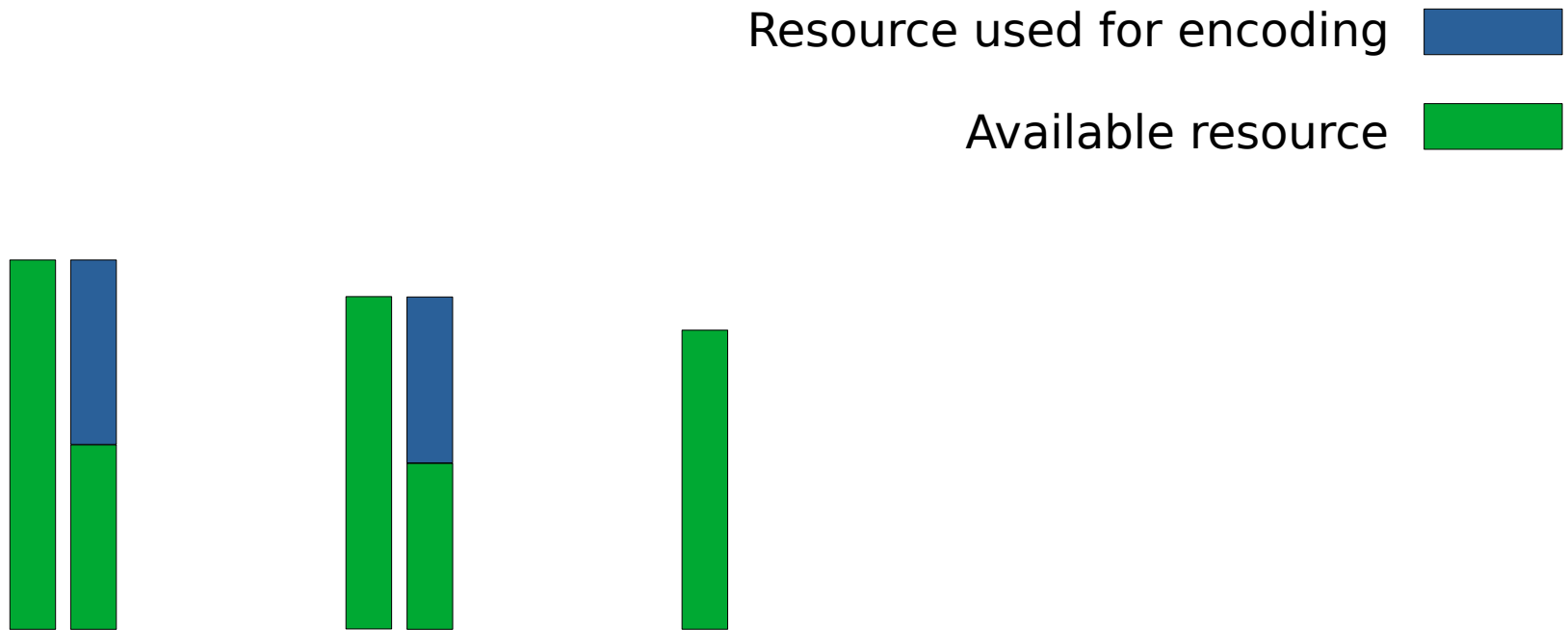
## Encoding-resource

Resource used for encoding   
Available resource 



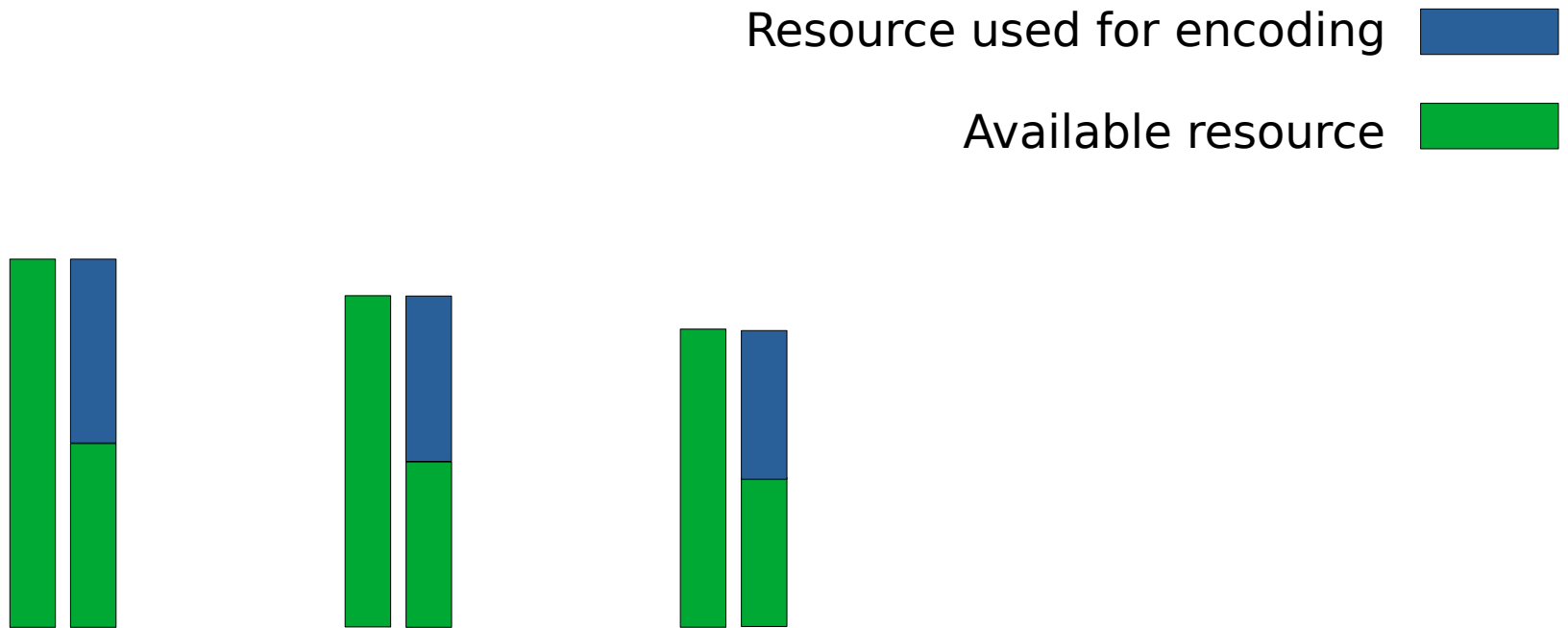
# Introduction

## Encoding-resource



# Introduction

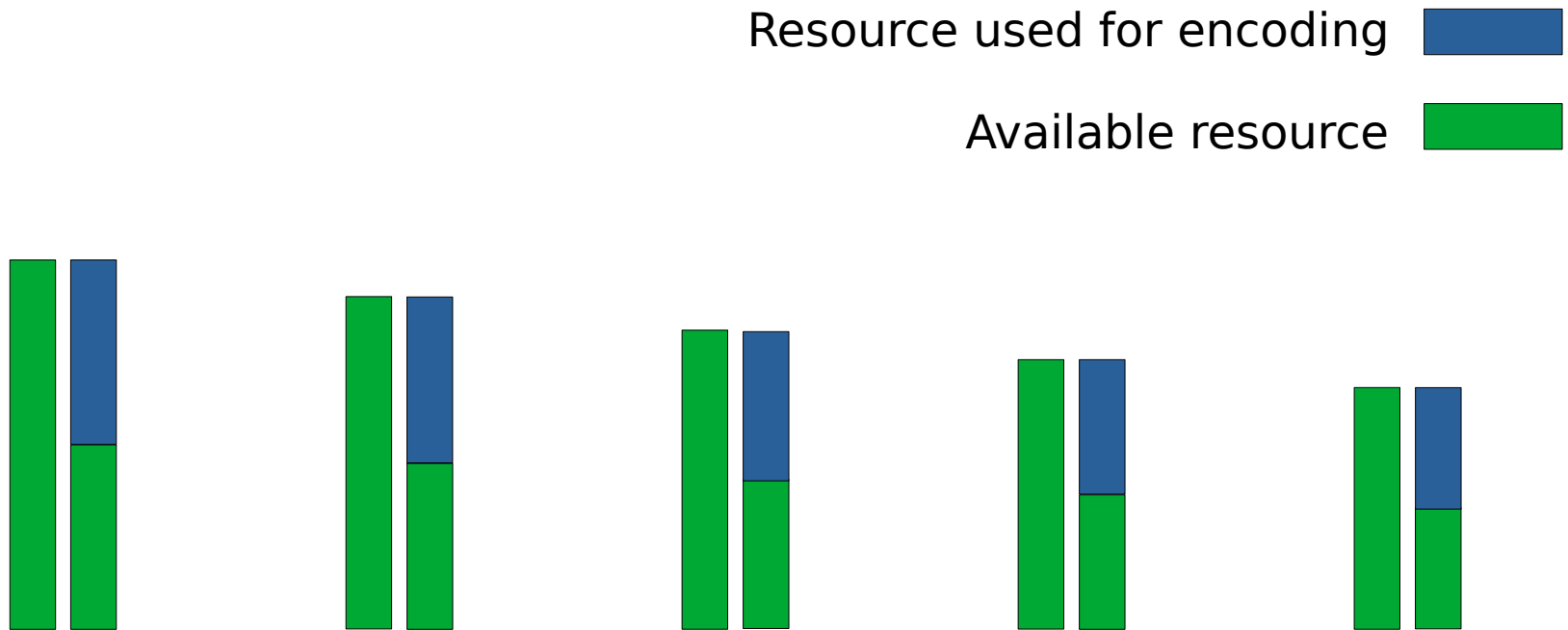
## Encoding-resource





# Introduction

## Encoding-resource



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## Encoding-resource

Resource used for encoding 

Available resource 



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## Encoding-resource

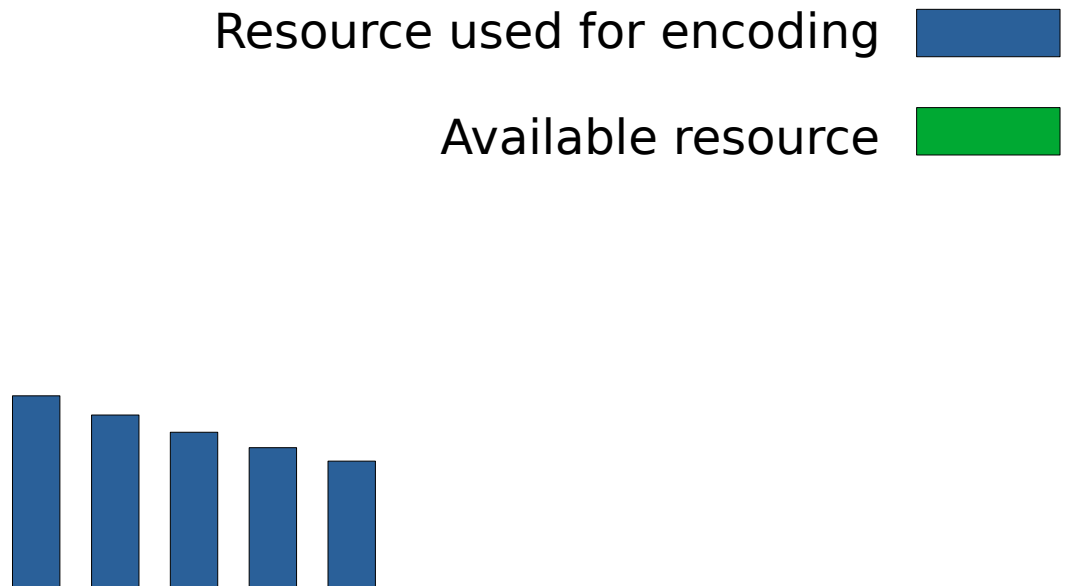
Resource used for encoding 

Available resource 



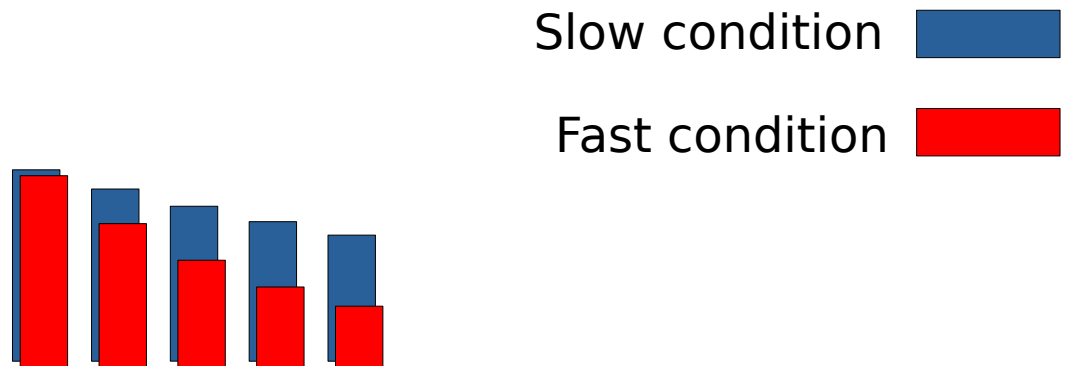
# Introduction

## Encoding-resource



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## Encoding-resource



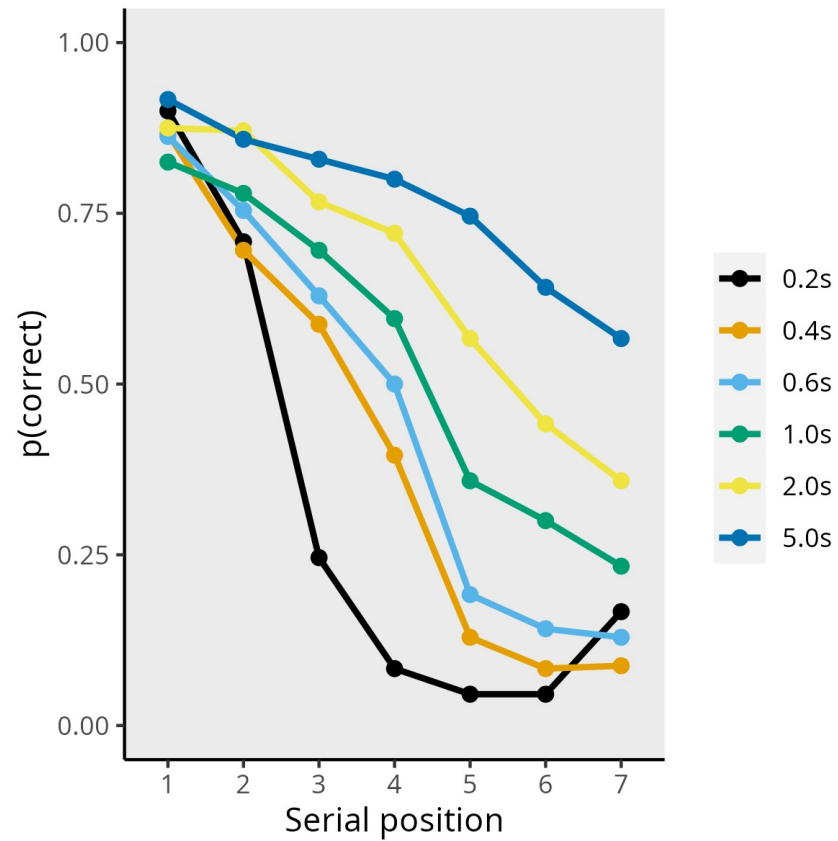
# Introduction

## **Encoding-resource**

**Prediction:** The free-time benefit should increase across serial position.

# Introduction

## The “fanning-out” effect



# Introduction

**Problem:** Serial position curves do not entirely reflect encoding strength.



# Introduction

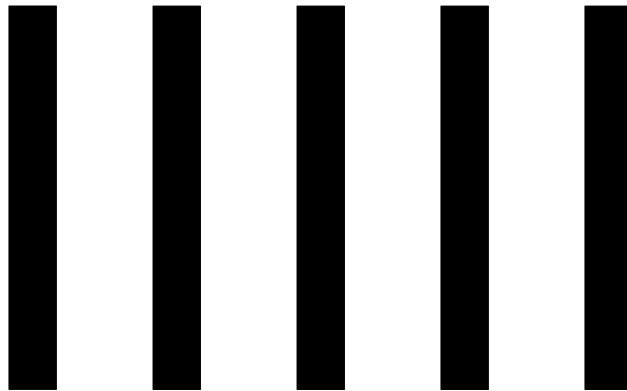
## **Output interference**

The mere fact of recalling an item interferes with the content of WM.

# Introduction

## **Output interference**

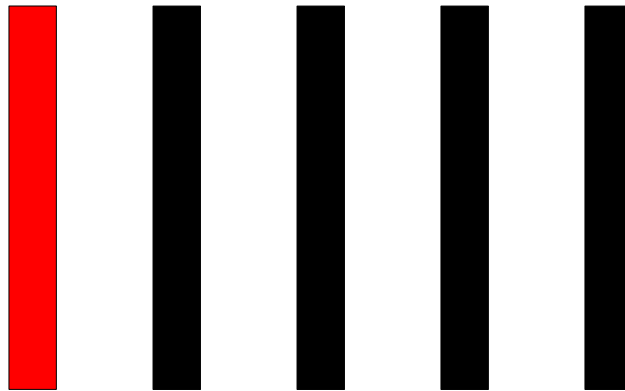
The mere fact of recalling an item interferes with the content of WM.



# Introduction

## **Output interference**

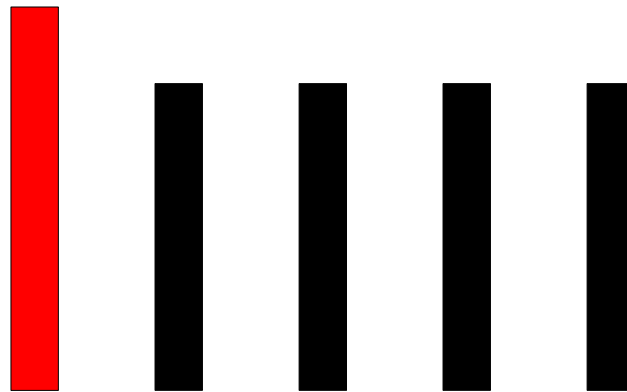
The mere fact of recalling an item interferes with the content of WM.



# Introduction

## **Output interference**

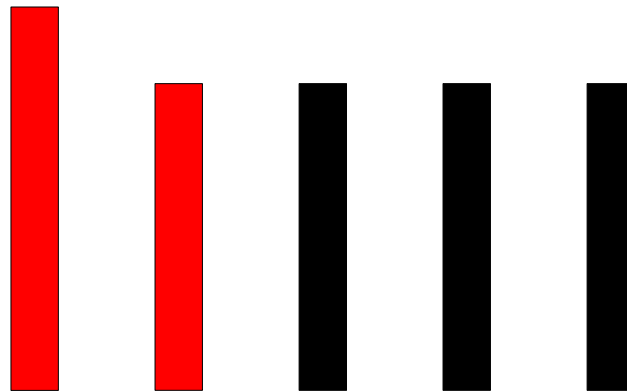
The mere fact of recalling an item interferes with the content of WM.



# Introduction

## **Output interference**

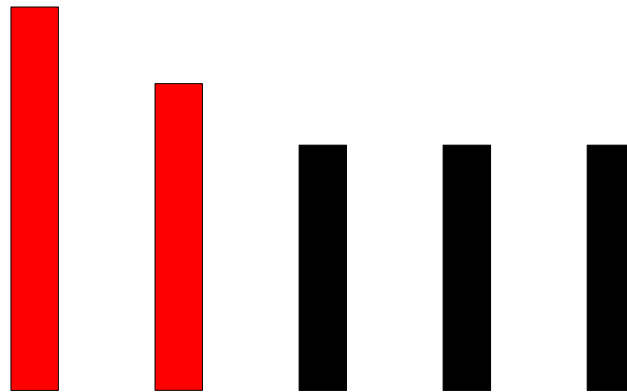
The mere fact of recalling an item interferes with the content of WM.



# Introduction

## Output interference

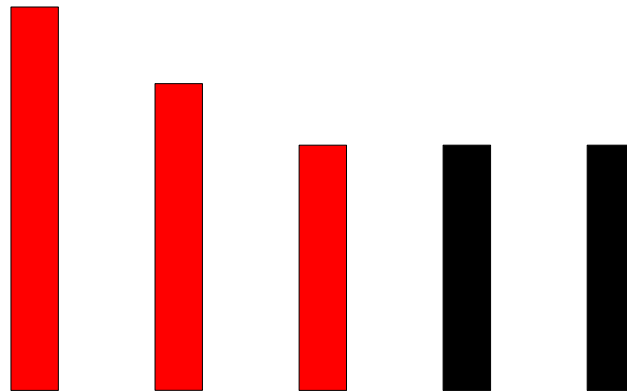
The mere fact of recalling an item interferes with the content of WM.



# Introduction

## Output interference

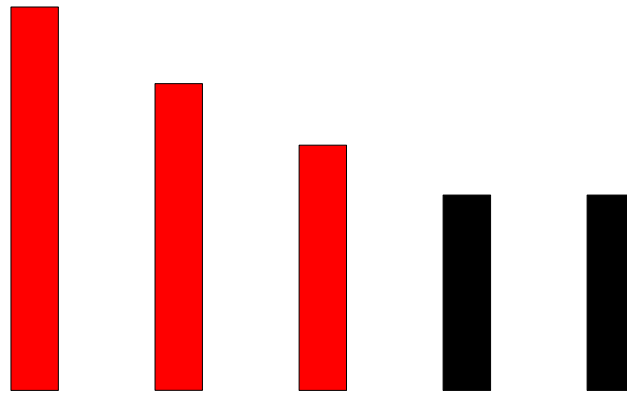
The mere fact of recalling an item interferes with the content of WM.



# Introduction

## Output interference

The mere fact of recalling an item interferes with the content of WM.

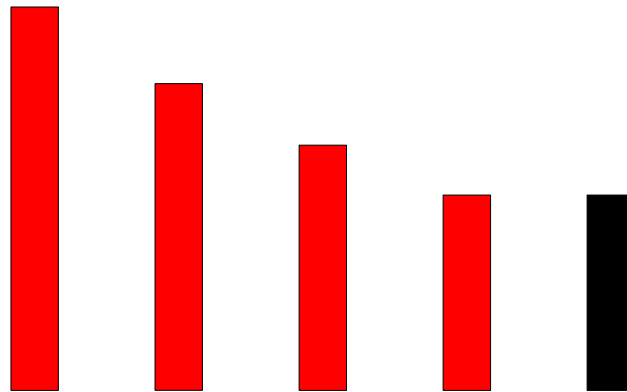




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## Output interference

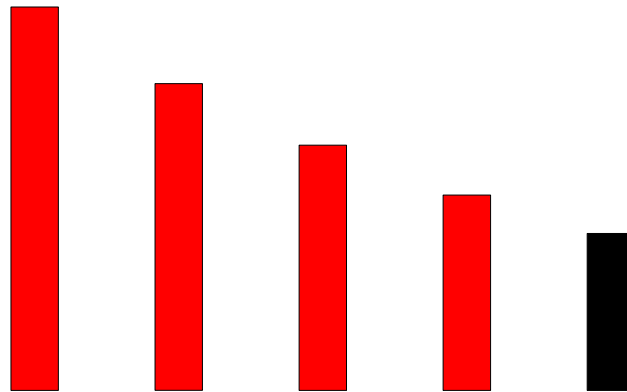
The mere fact of recalling an item interferes with the content of WM.



# Introduction

## Output interference

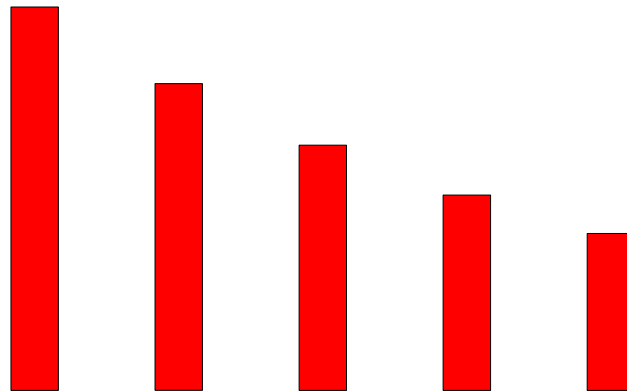
The mere fact of recalling an item interferes with the content of WM.



# Introduction

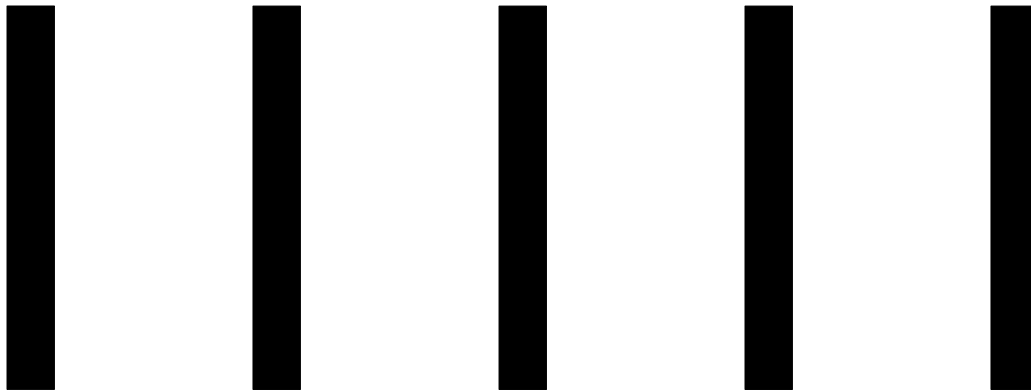
## **Output interference**

The mere fact of recalling an item interferes with the content of WM.



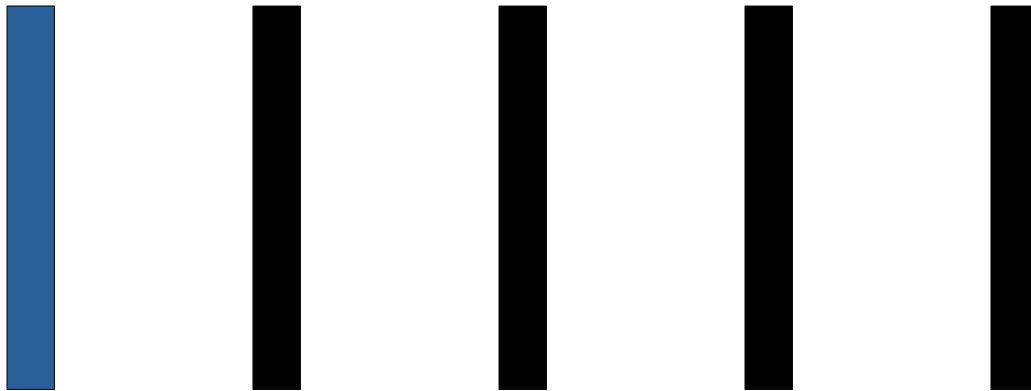
# Introduction

**Additional free-time  
=  
Resistance to output interference**



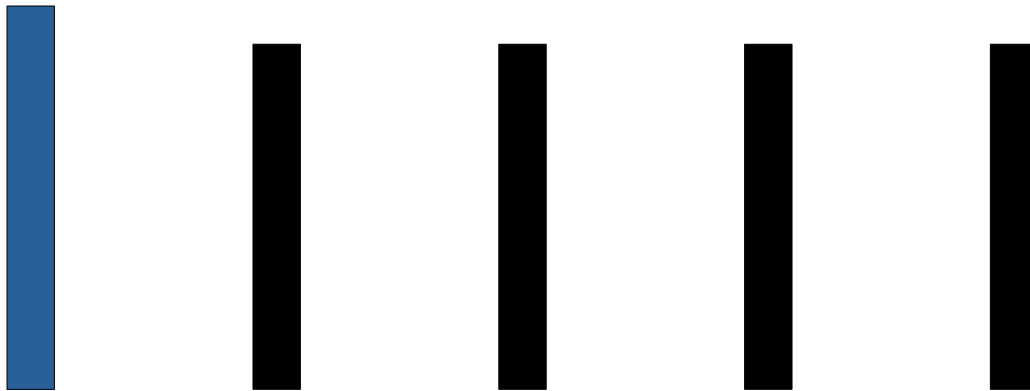
# Introduction

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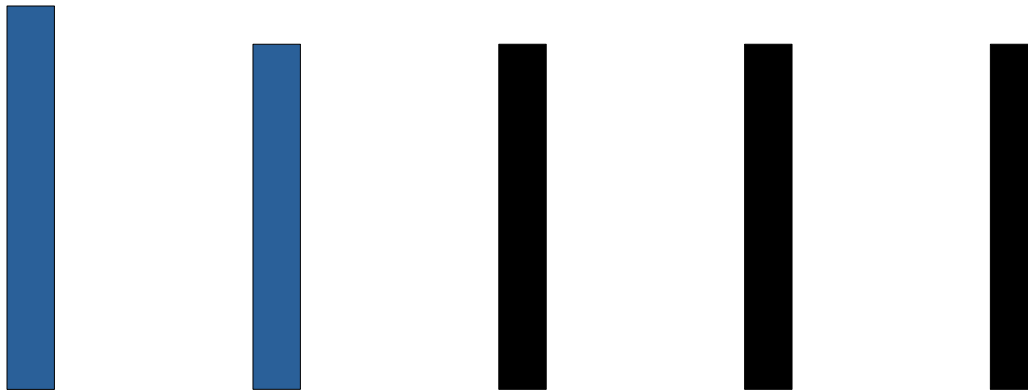
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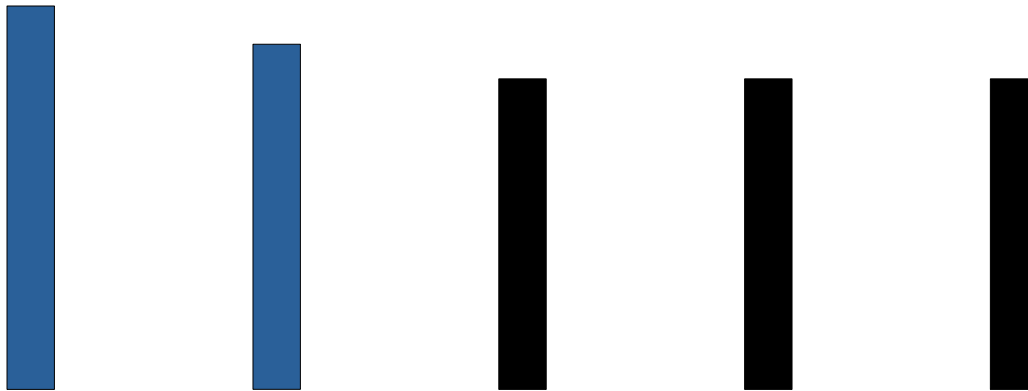
# Introduction

**Additional free-time**  
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**Resistance to output interference**



# Introduction

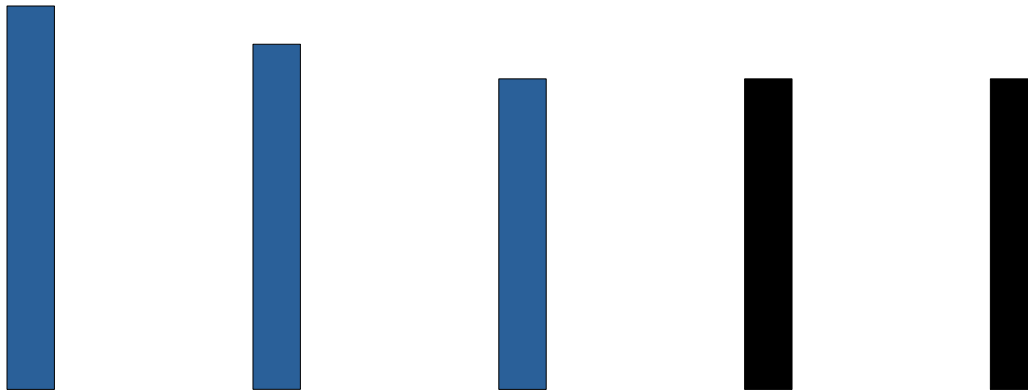
**Additional free-time  
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Resistance to output interference**





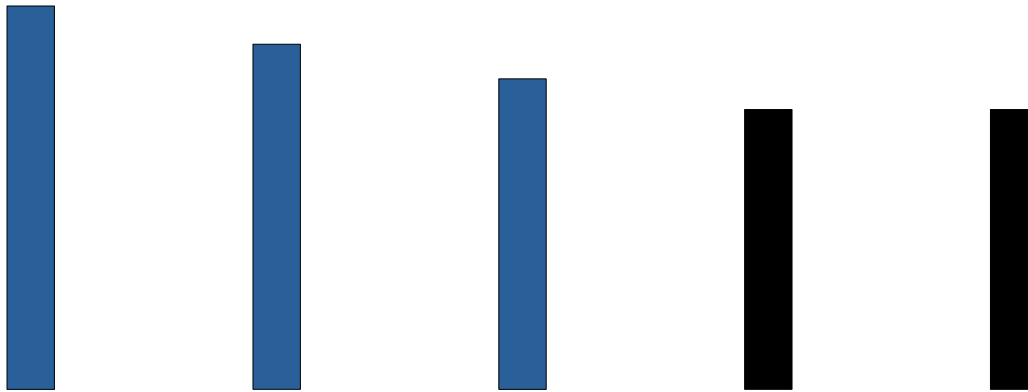
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**Additional free-time  
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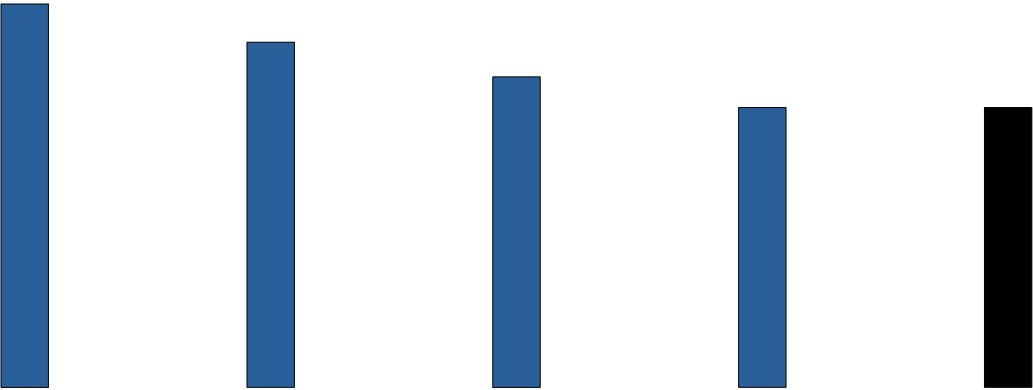
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**Additional free-time  
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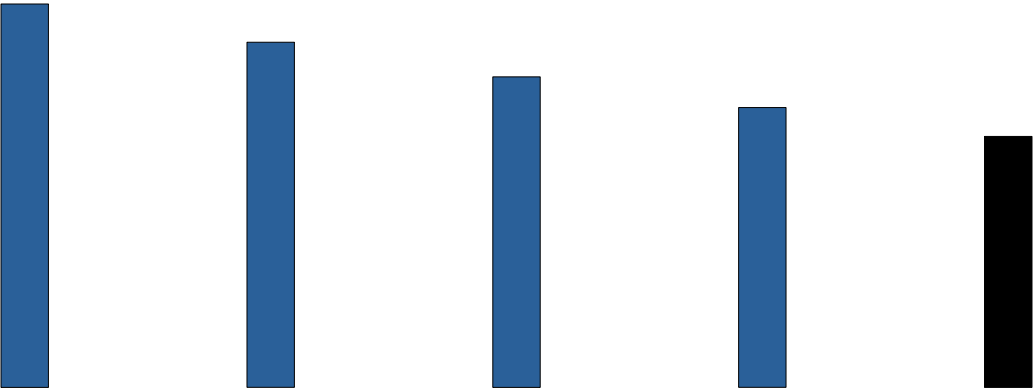
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**Additional free-time  
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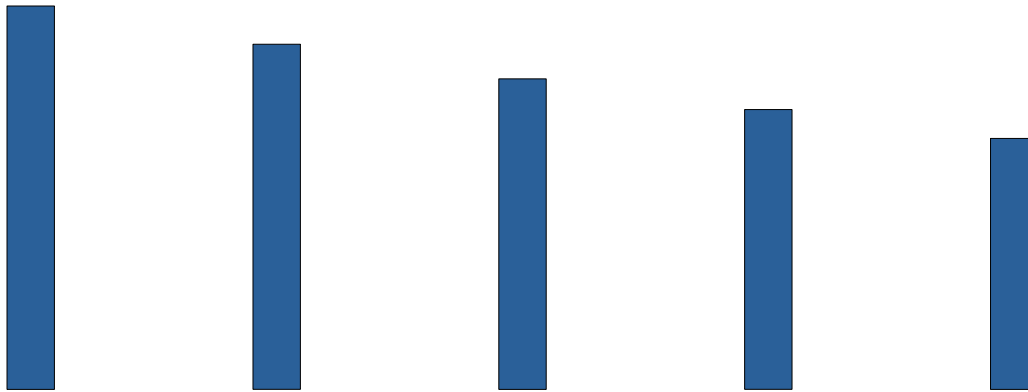
# Introduction

**Additional free-time  
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Resistance to output interference**



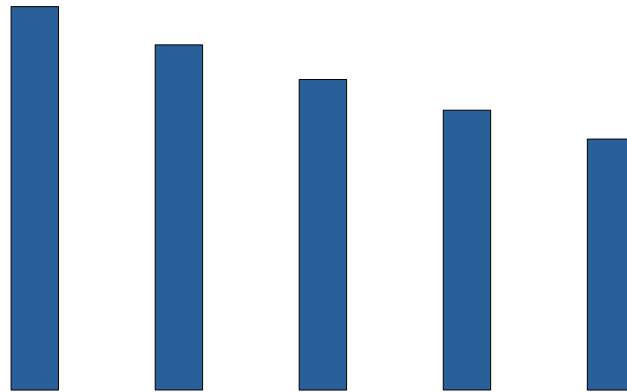
# Introduction

**Additional free-time  
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Resistance to output interference**



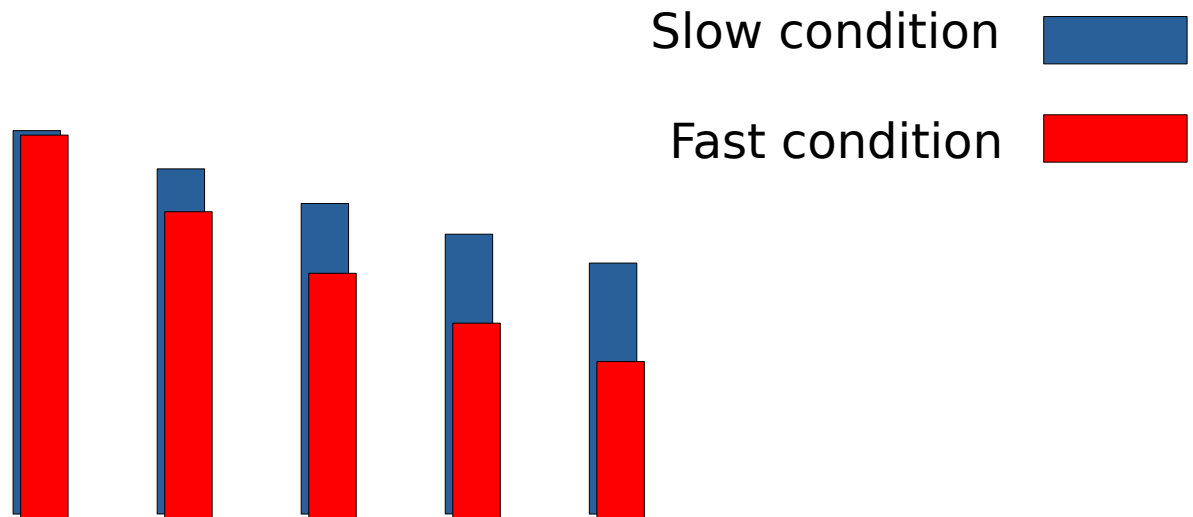
# Introduction

**Additional free-time  
=  
Resistance to output interference**



# Introduction

**Additional free-time**  
=  
**Resistance to output interference**



# Hypotheses

**Encoding resource**  
**Resistance to output interference**

Both hypotheses explain the fanning-out effect



# Hypotheses

## **Encoding resource:**

The fanning-out effect depends on **encoding**

## **Resistance to output interference:**

The fanning-out effect depends on the **direction** of retrieval

# Hypotheses

If we force people to recall items in **different directions**, we should be able to differentiate both hypotheses.

# Methods

## Free-time manipulation

**0.5 s / item**

dog arm nuke blend tree mug

**1.0 s / item**

dog arm nuke blend tree mug

**2.0 s / item**

dog arm nuke blend tree mug

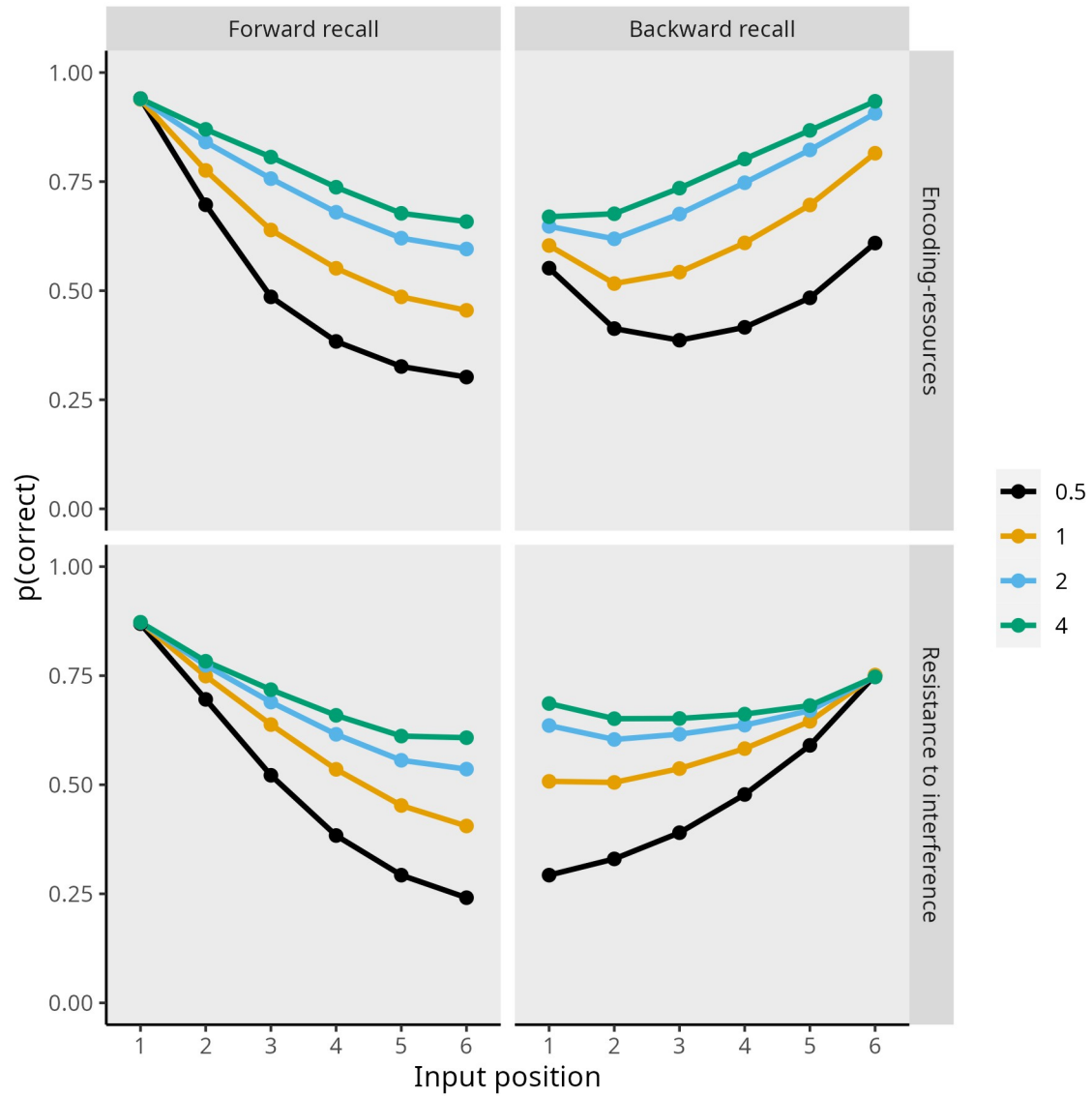
**4.0 s / item**

dog arm nuke blend tree mug

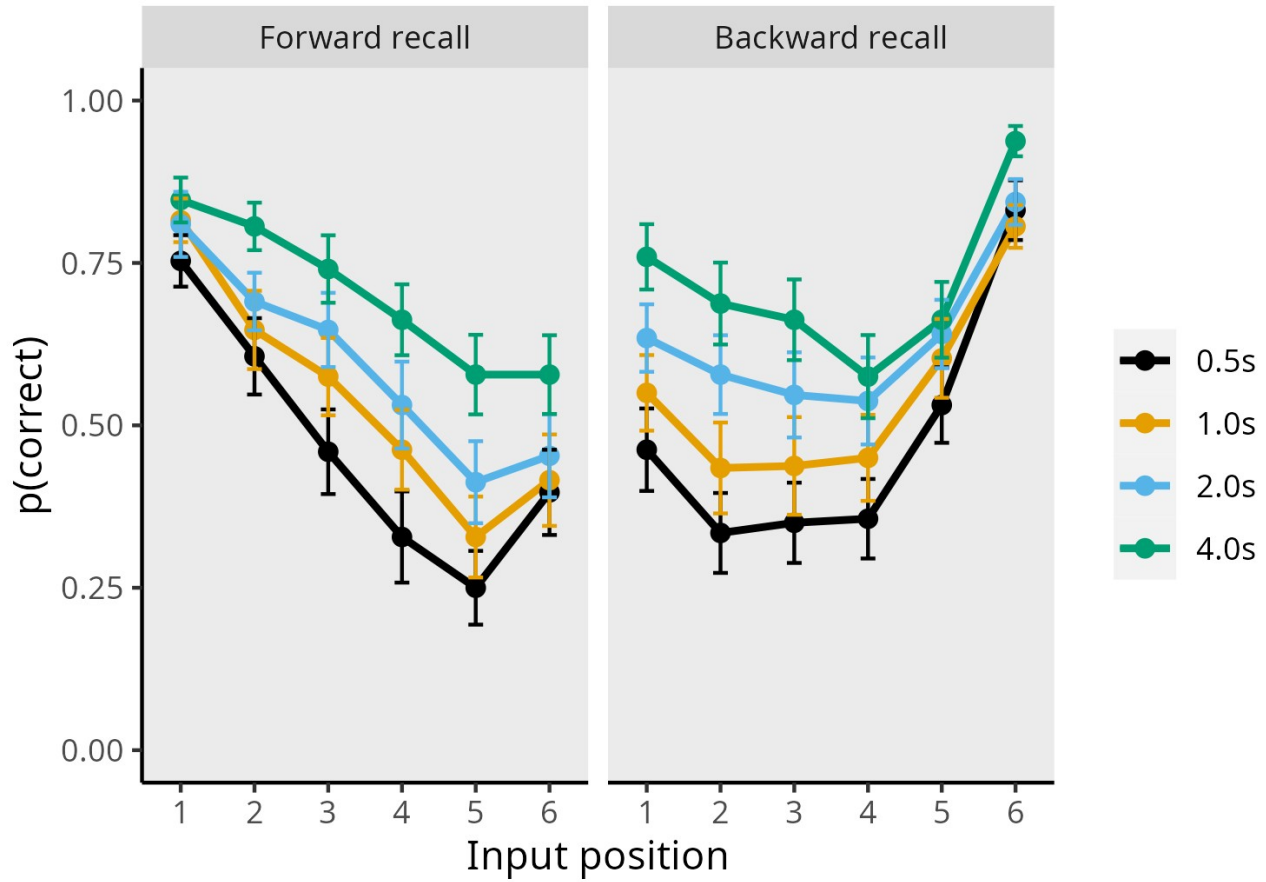
50%: **Forward** serial recall

50%: **Backward** serial recall

# Predictions



# Results



# Results

## **Encoding resource:**

The fanning-out effect depends on **encoding**

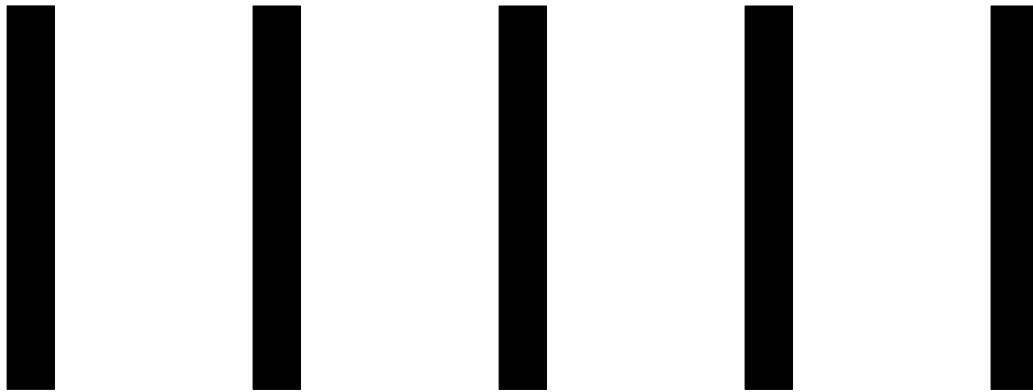
## **Resistance to output interference:**

The fanning-out effect depends on the **direction** of retrieval

# A different model: TBRS\*

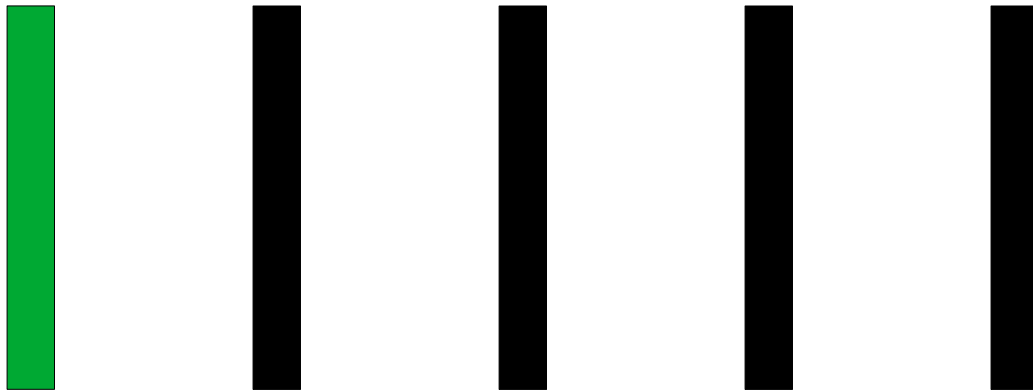
Computational implementation of the Time-  
Based Resource Sharing (TBRS) theory

# A different model: TBRS\*





# A different model: TBRS\*



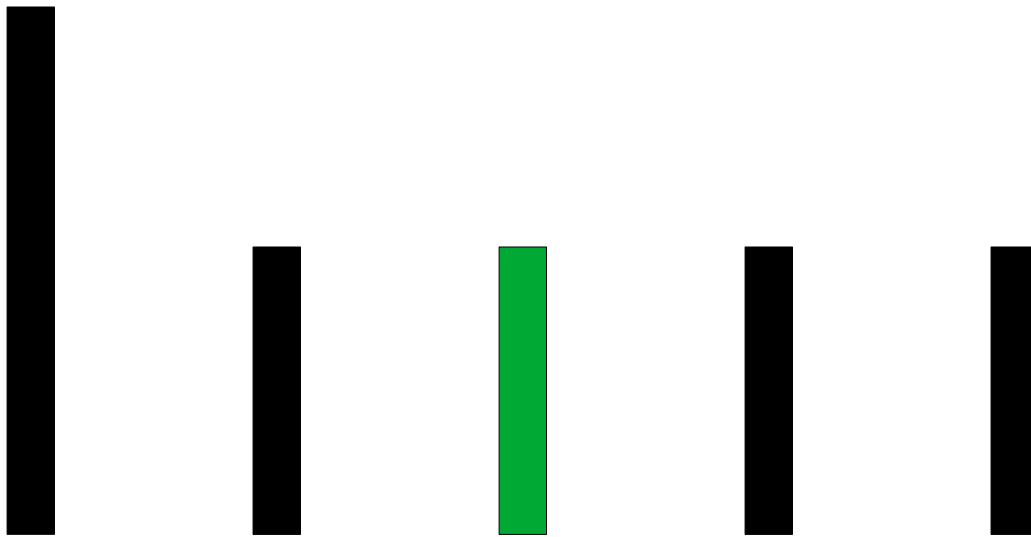
# A different model: TBRS\*



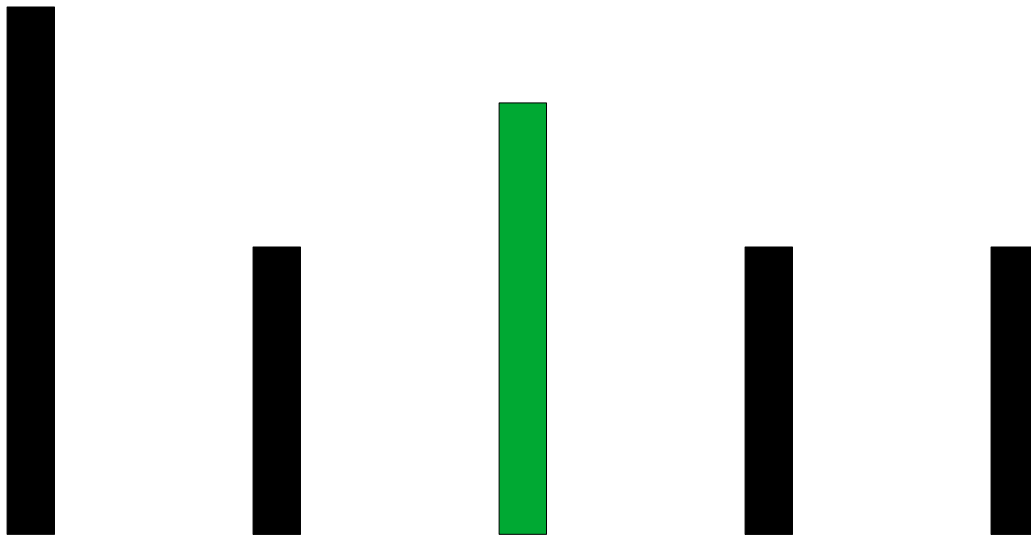
# A different model: TBRS\*



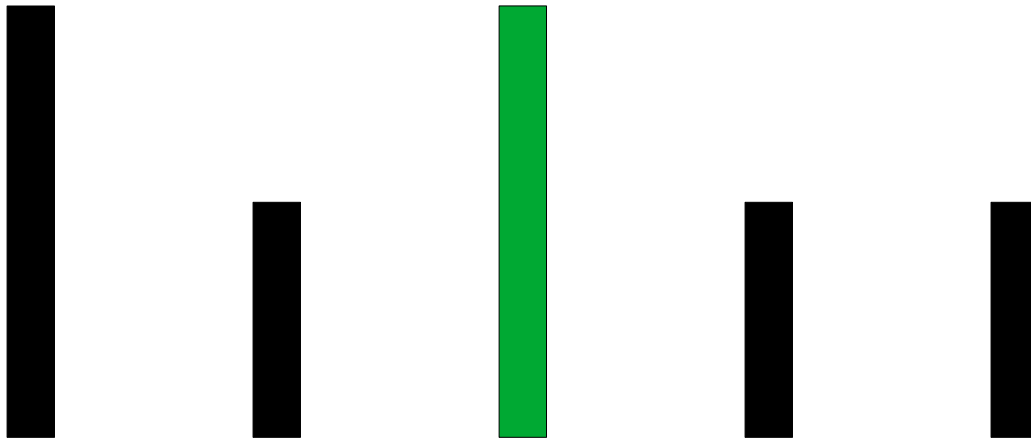
# A different model: TBRS\*



# A different model: TBRS\*



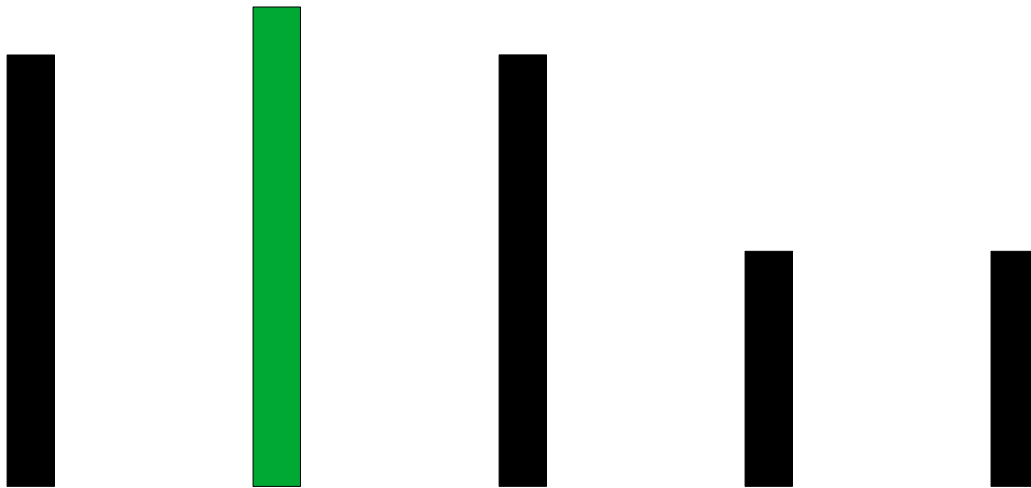
# A different model: TBRS\*



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# A different model: TBRS\*

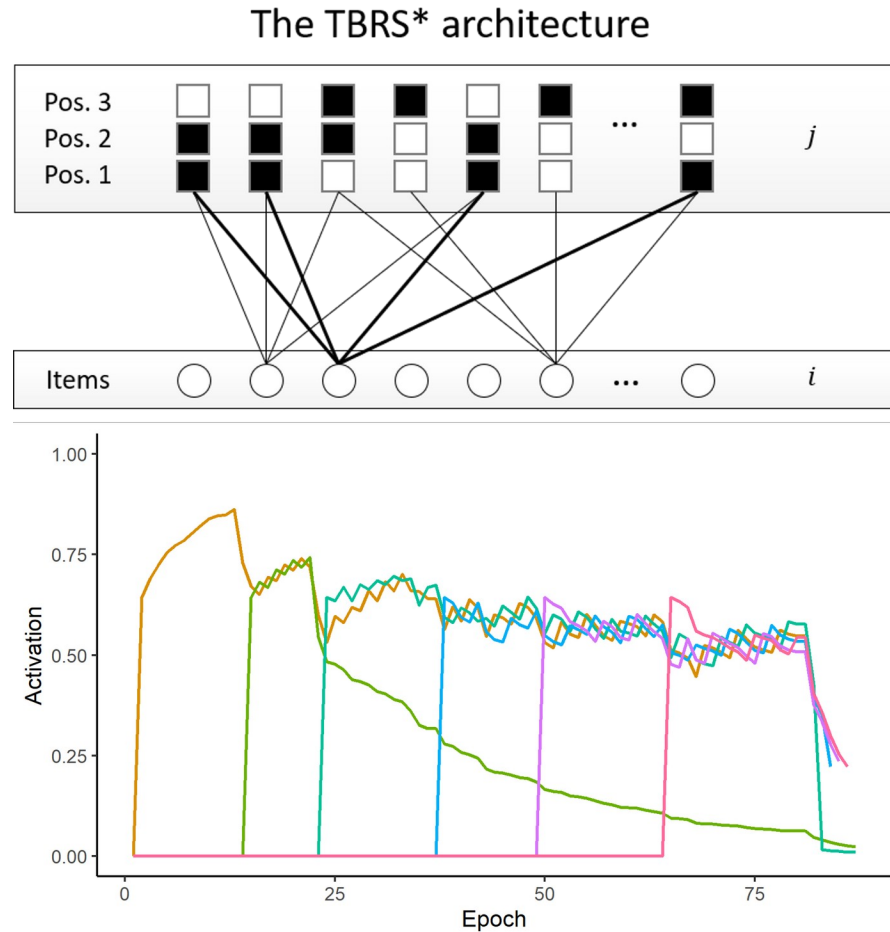




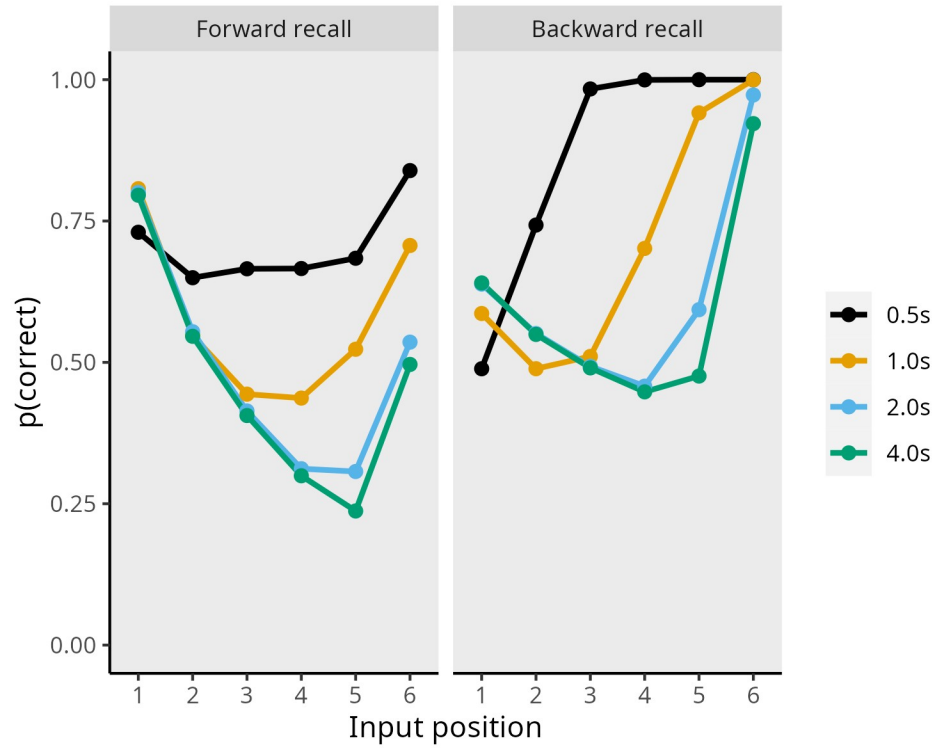
# A different model: TBRS\*



# A different model: TBRs\*



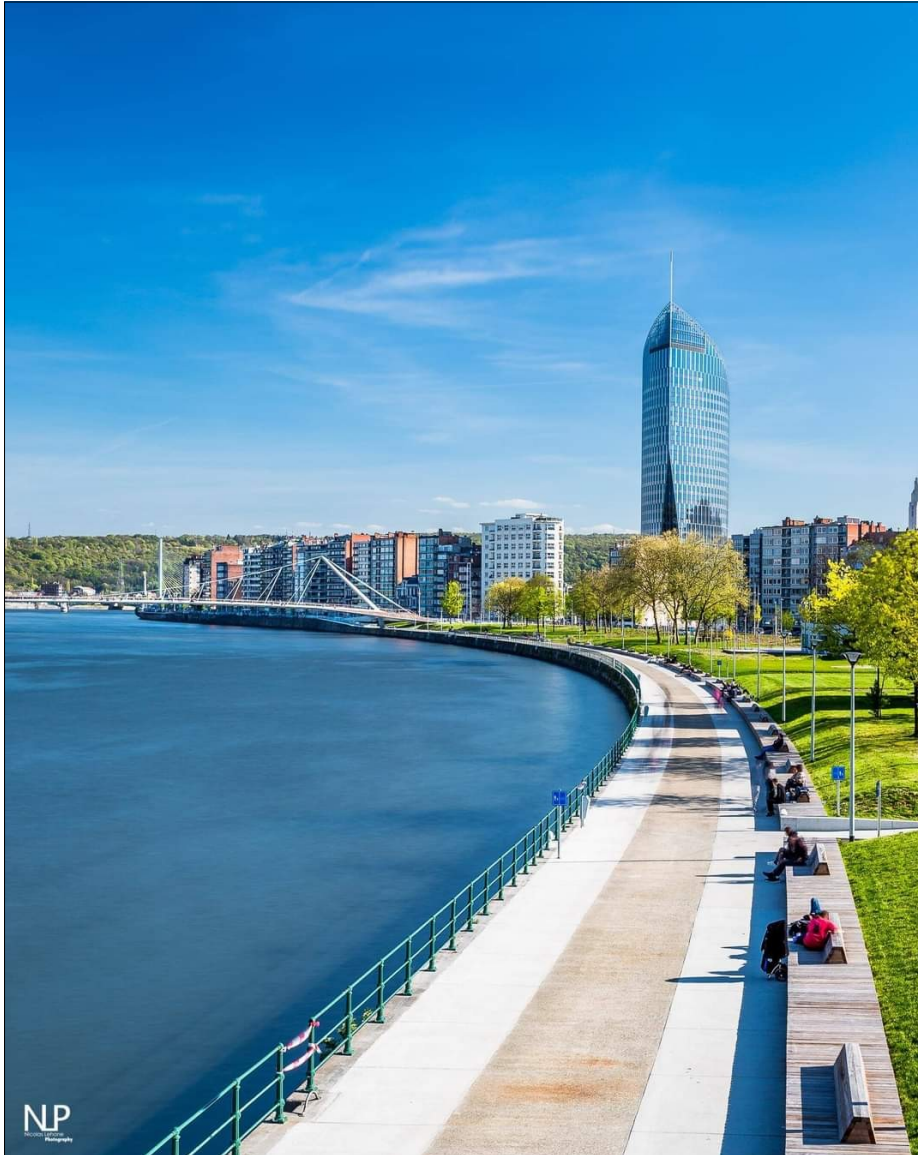
# A different model: TBRS\*



## A different model: TBRS\*

The fast presentation rate can compensate  
for the deleterious effect of decay.

The free-time benefit is best explained by a form of consolidation through which items resist more strongly to output interference.



NP  
Niederösterreich  
Naturpark

Danke schön  
Merci  
Dank u wel