

Text Modality, Cognitive Load, and Desirable Difficulties

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What is this talk about ...?

- The CTML and the concept of working memory
- The cognitive basis of the **modality effect (part 1)**
 - A (very elementary) visual working memory experiment: Fürstenberg, Rummer, & Schweppe (2013)
 - An (elementary) multimedia study: Rummer, Schweppe, Scheiter, & Zindler (2011)
- Excursus. *Desirable difficulties*: short-term and long-term effects
 - *Testing effect*: Rummer, Schweppe, Gerst, & Wagner (under revision)
- **Modality effect (part 2)**: long-term effect
 - Schweppe & Rummer (2016)
 - Replication
- Conclusions

Original assumption of the Cognitive Load Theory:

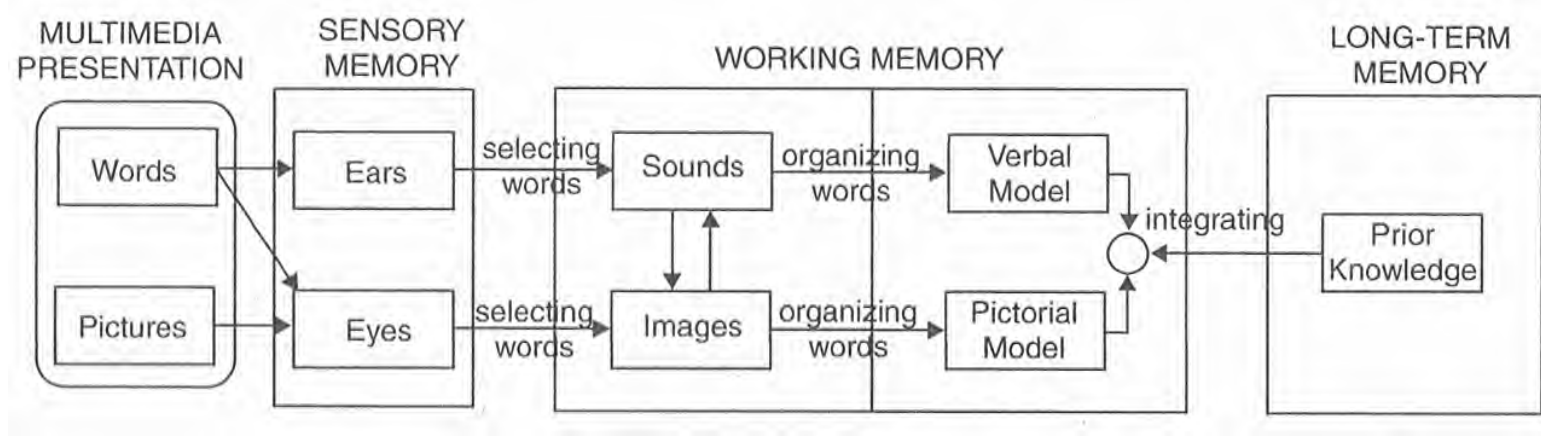
- Minimize extraneous cognitive load during the learning process to make learning more effective!
- Particularly when intrinsic cognitive load (in terms of element interactivity) is high!

Application of the CLT in Multimedia Research

- The Cognitive Theory of Multimedia Learning (CTML) is also based on the idea of capacity-limited working memory.
- Working memory is fractionated in separable subsystems.
- These subsystems represent different *modalities* (auditory vs. visual) and/or *codalities* (pictorial vs. verbal).

Mayer (2001, 2009)

Cognitive Theory of Multimedia Learning (CTML)



The Modality Effect (ME)

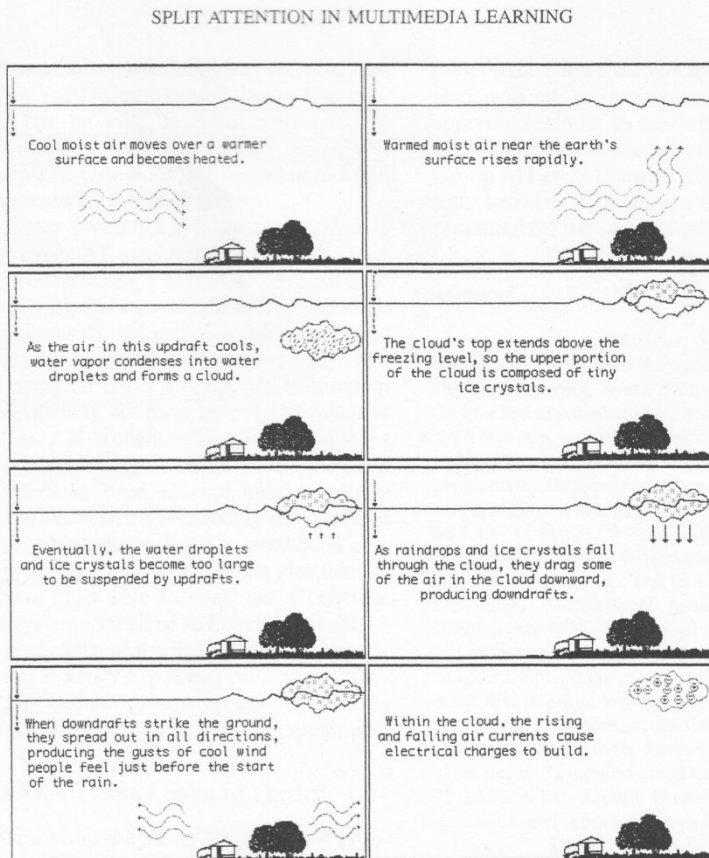
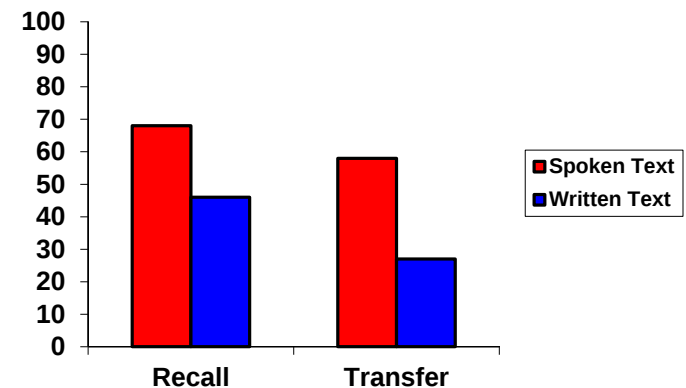


Figure 1. Selected frames from a multimedia lesson on the formation of lightning.

IV: Texts were either presented in a **spoken modality** or in a **visual modality**.

DVs: Free Recall; Transfer



Visuo-spatial load hypothesis: ME is attributed to an (extraneous) overload of the visual working memory system caused by the simultaneous processing and storage of written text and pictures/animations.

Illustration of the Visuo-Spatial Load Hypothesis Based on Baddeley & Hitch's Working Memory Model (1974)

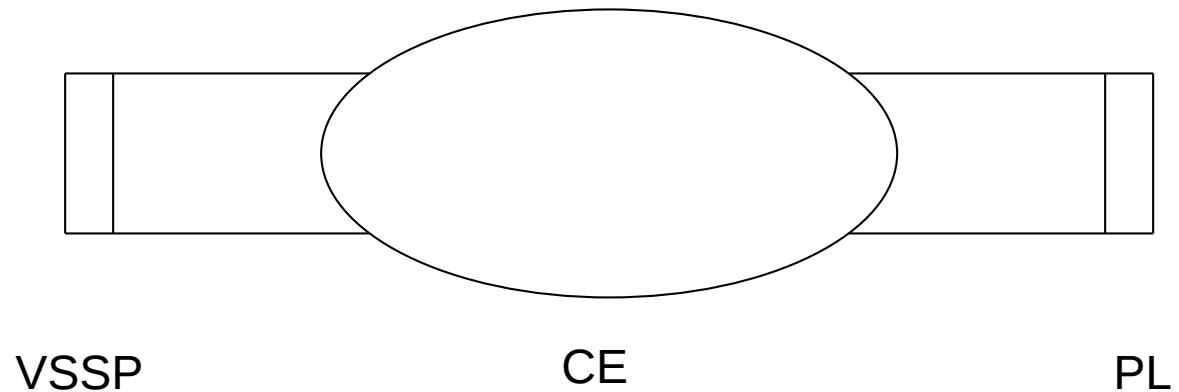
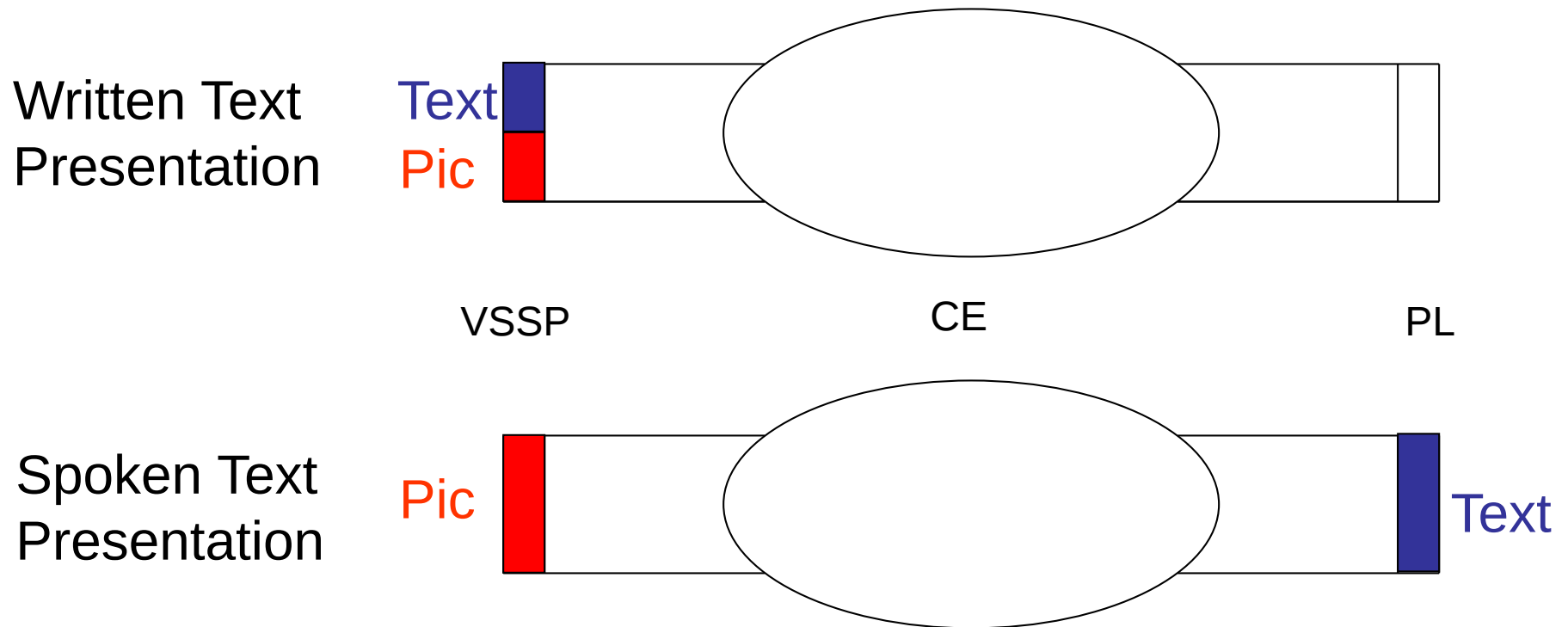


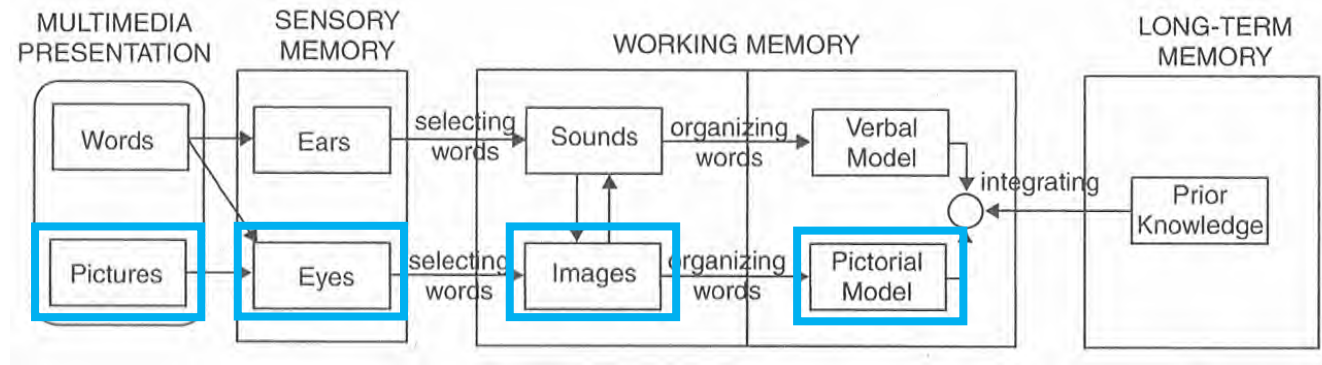
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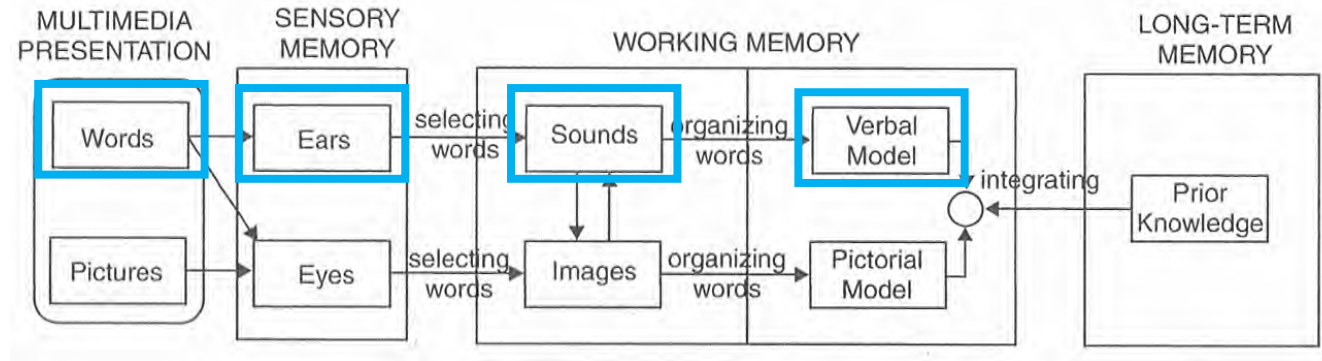
Mayer (2001, 2009)

Cognitive Theory of Multimedia Learning (CTML)

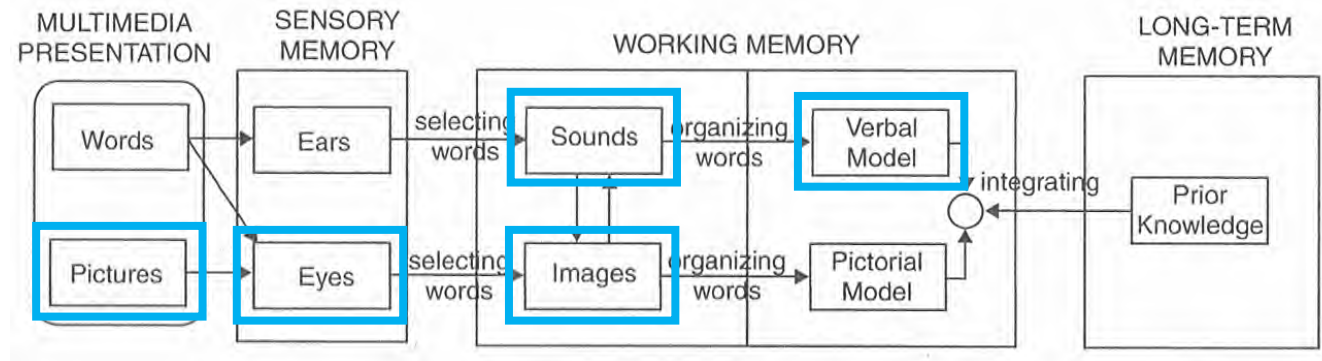
Pictures



Auditory Text

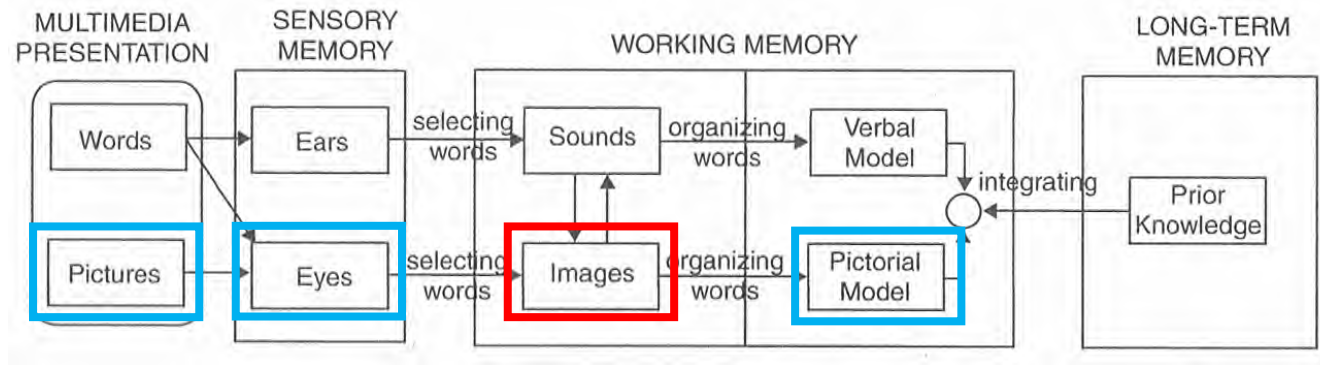


Written Text

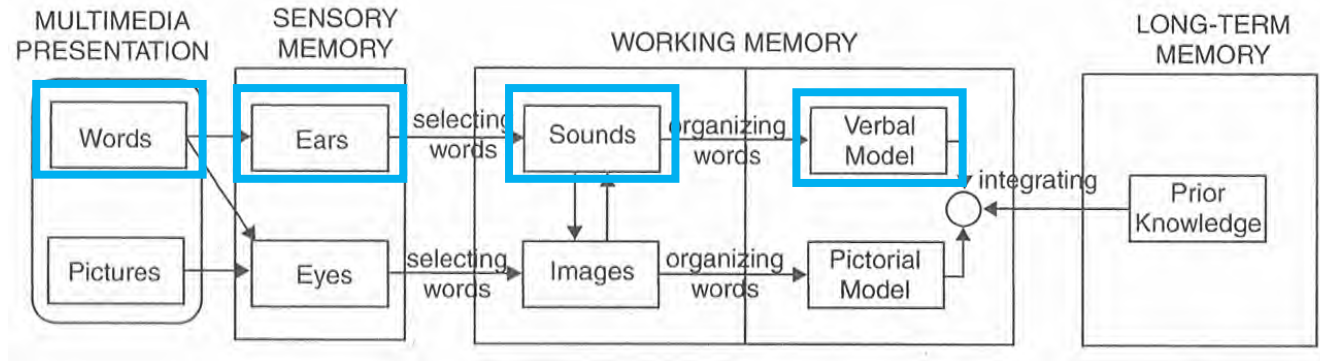


Cognitive Theory of Multimedia Learning (CTML)

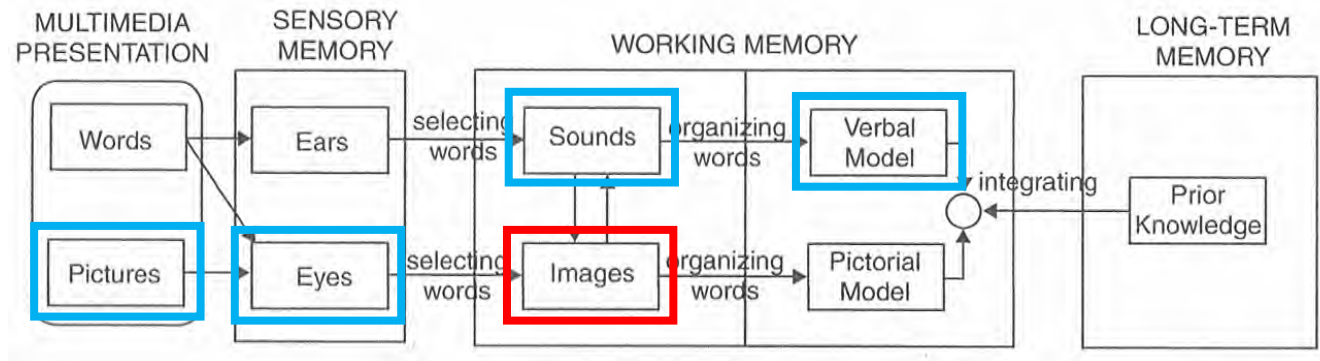
Pictures



Auditory Text



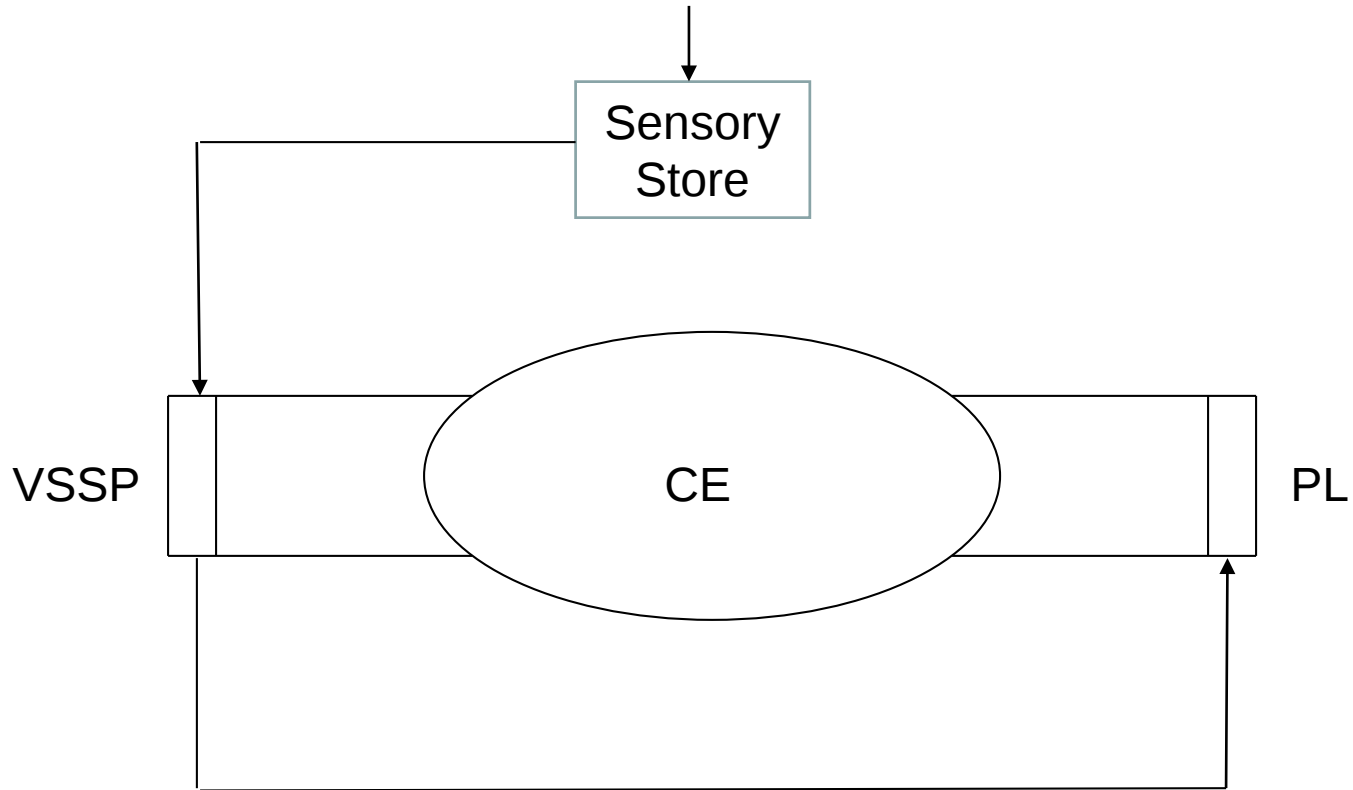
Written Text



Perspective 1

The pulley system

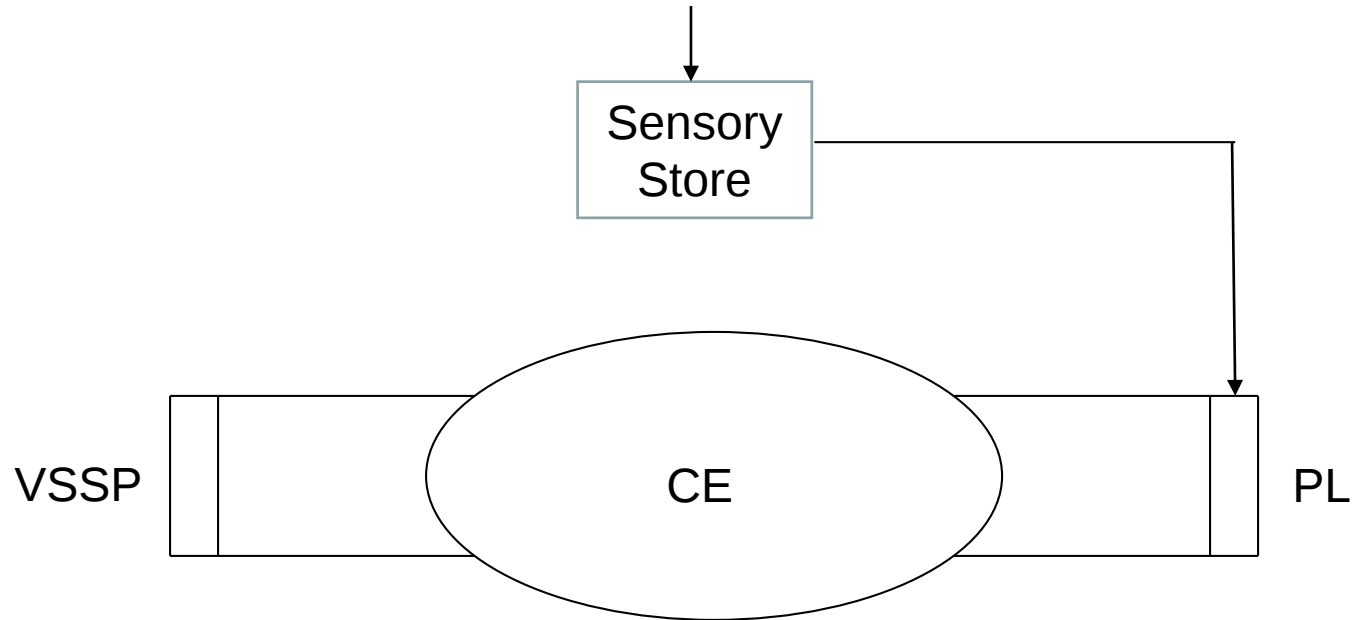
The pulley system consists of three pulleys, two ropes and one weight. The upper pulley is attached to the ceiling. Below the upper pulley is the middle pulley that is free to move up and down and is therefore called free pulley. The upper rope is attached to the ceiling at one end, goes under the middle pulley and over the upper pulley and is free at the other end. The lower pulley is free to move up and down, and is therefore called free pulley as well. The lower rope is attached to the ceiling at one end, it goes under the lower pulley and is attached to the middle pulley at the other end. The weight is suspended from the lower pulley. When the free end of the upper rope is pulled, the rope moves over the upper pulley and under the middle pulley and pulls up the middle pulley. This causes the lower rope to move under the lower pulley and to pull up both the lower pulley and the weight. For these types of pulley systems, each free pulley that is added to the system gives the force with which the weight has to be lifted or held. Each free pulley that is added to the system, however, also doubles the length of rope to be pulled.



Perspective 2

The pulley system

The pulley system consists of three pulleys, two ropes and one weight. The upper pulley is attached to the ceiling. Below the upper pulley is the middle pulley that is free to move up and down, and is therefore called free pulley. The upper rope is attached to the ceiling at one end, goes under the middle pulley and over the upper pulley, and is free at the other end. The lower pulley is free to move up and down, and is therefore called free pulley as well. The lower rope is attached to the ceiling at one end, it goes under the lower pulley and is attached to the middle pulley at the other end. The weight is suspended from the lower pulley. When the free end of the upper rope is pulled, the rope moves over the upper pulley and under the middle pulley and pulls up the middle pulley. This causes the lower rope to move under the lower pulley and to pull up both the lower pulley and the weight. For these types of pulley systems, each free pulley that is added to the system splits the force with which the weight has to be lifted or held. Each free pulley that is added to the system, however, also doubles the length of rope to be pulled.



Logie, Della Sala, Wynn & Baddeley (2000, Exp. 3 & 4)

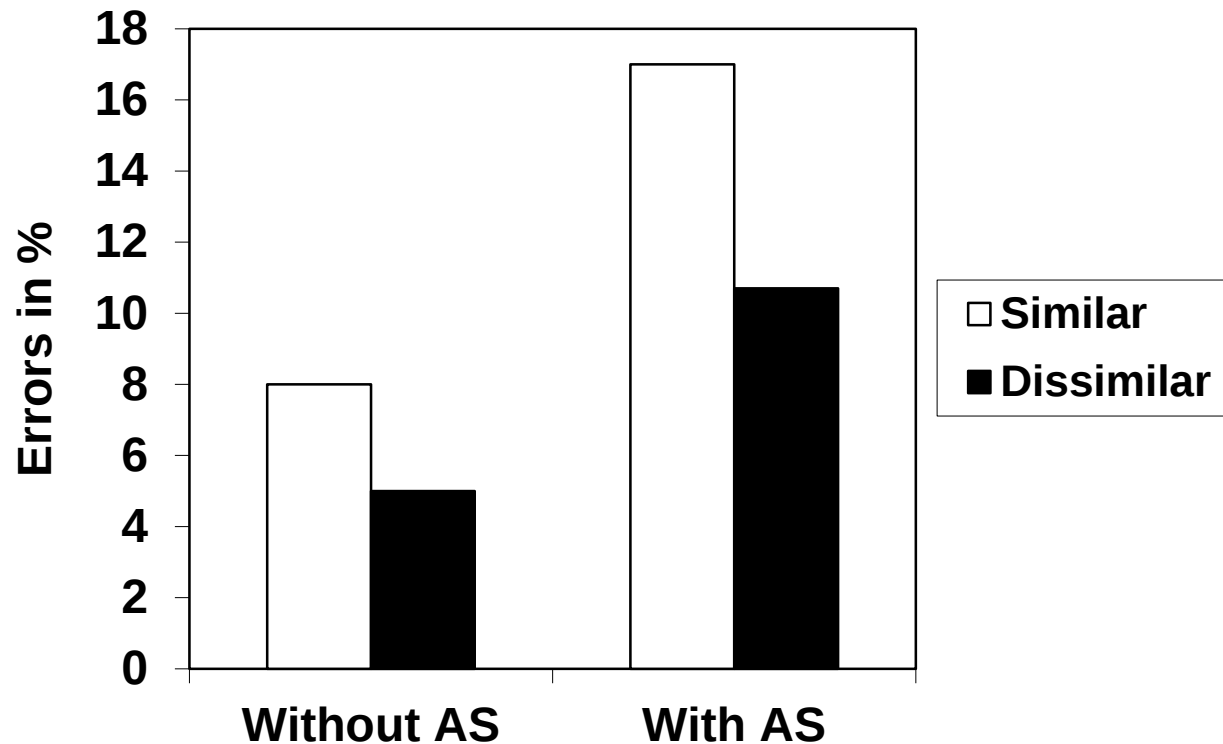
Mixed lists with four lower case or upper case letters (consonants) were presented. Participants had to serially recall these letters correctly (correct letter & correct case).

Design

2 x 2 (within subjects) design

- Visual similarity of the upper case and lower case letters
 - (a) similar letters: cC, sS, vV, wW
 - (b) dissimilar letters: lL, rR, qQ, hHExample for a similar list: "C v s W"
Example for a dissimilar list: "r Q L h"
- Articulatory suppression (AS)
 - (a) with AS („one - two - three - four - five - one- ...“)
 - (b) without AS

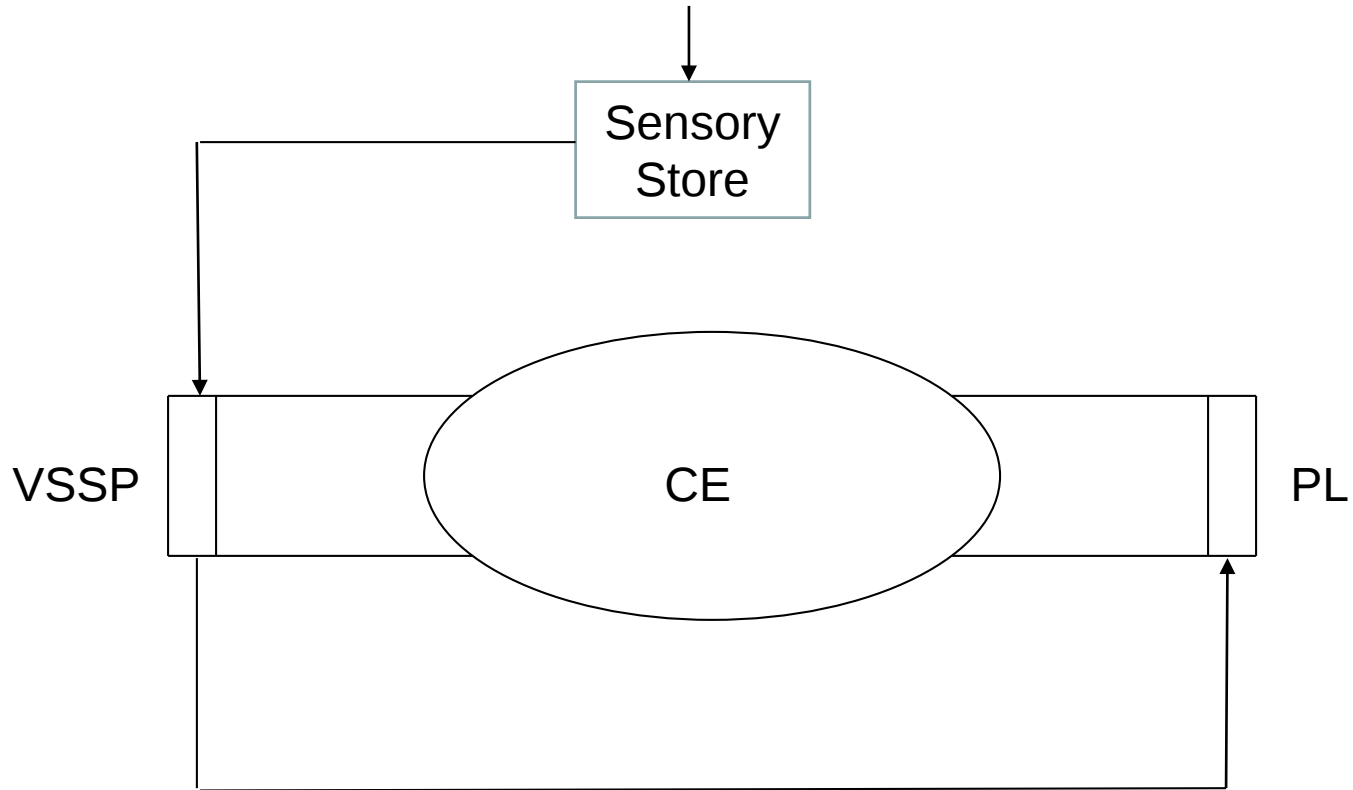
Logie et al. (2000, Exp. 4)



Perspective 1

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Example for a similar list: C v s **W**

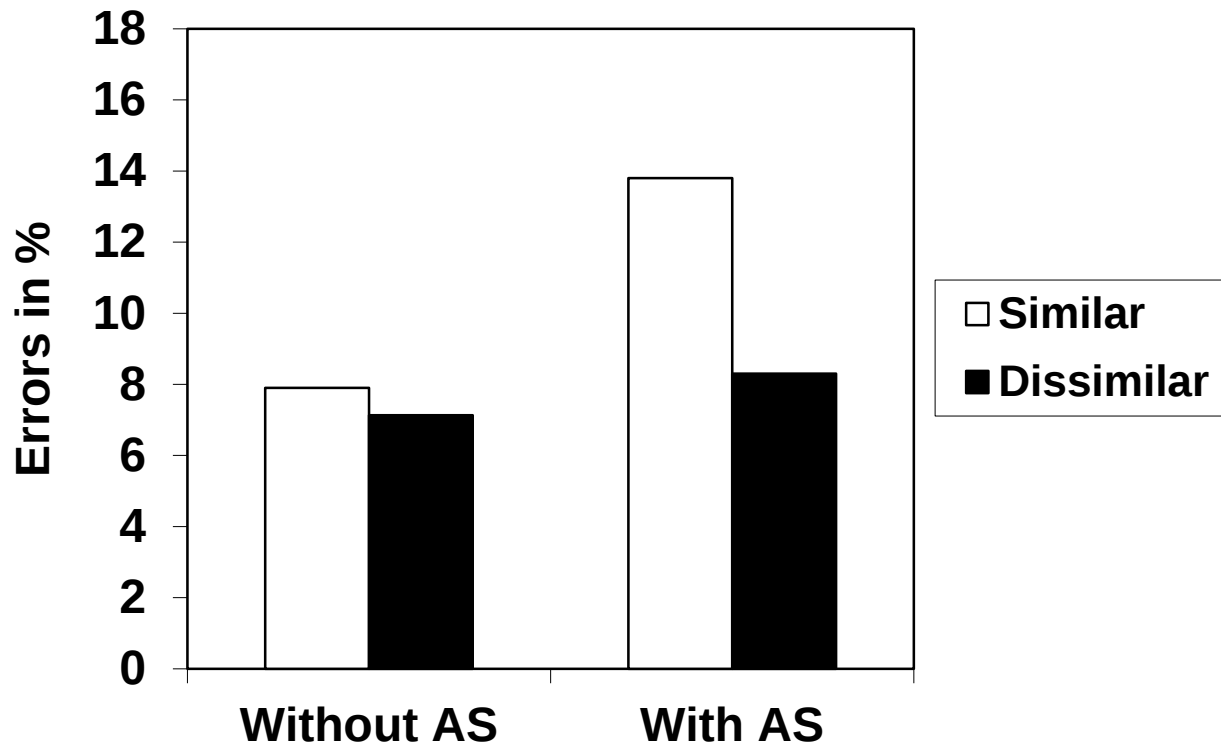
Example for a dissimilar list: r Q L h

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(b) without AS

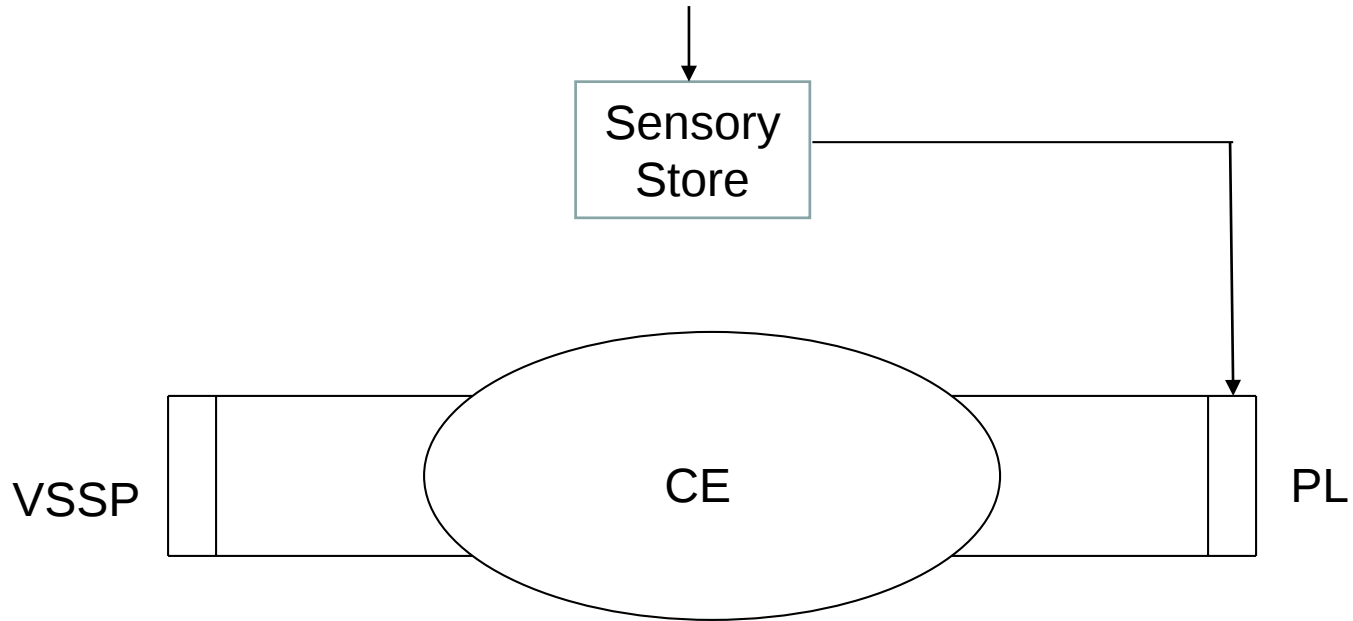
„Replication“ in German (/ve:/ instead of /'dʌblju:/)



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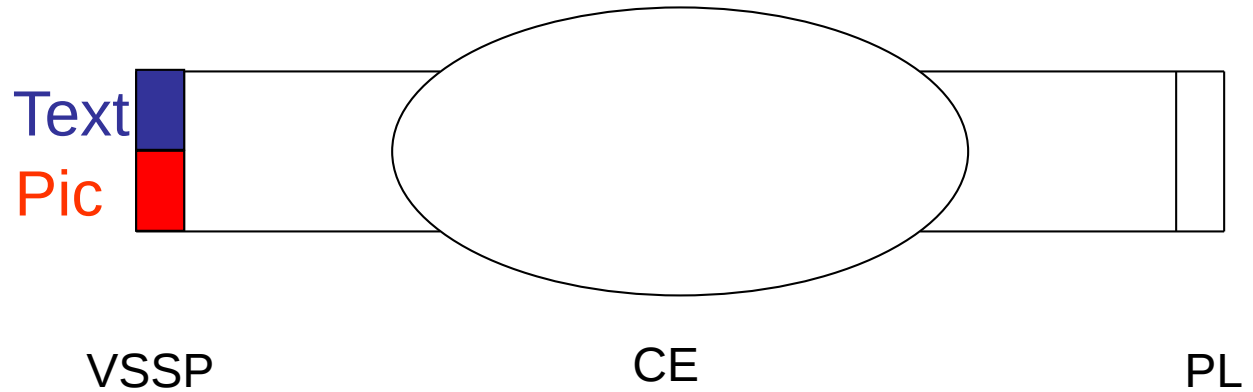


Conclusion

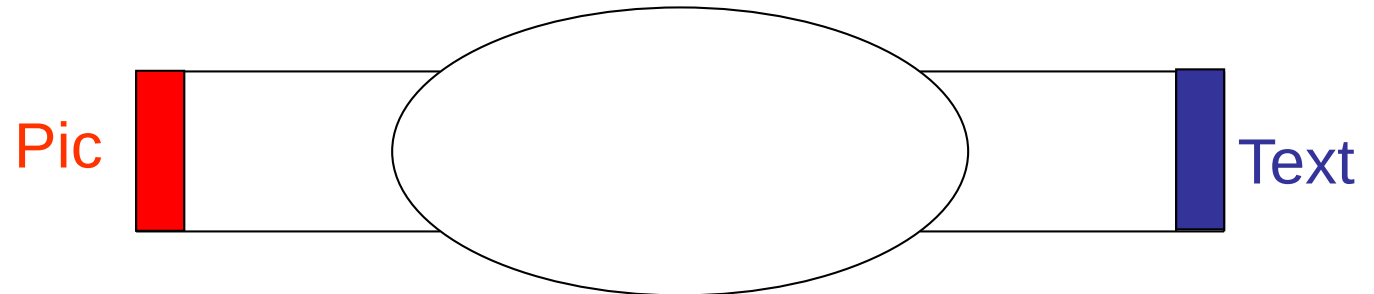
The visuo-spatial working memory system only contributes to the processing of letters (and written text) when phonological encoding is impossible (i.e., when the PL is blocked by another task)! (This is not the case when texts and pictures are processed simultaneously.)

Baddeley & Hitch (1974)

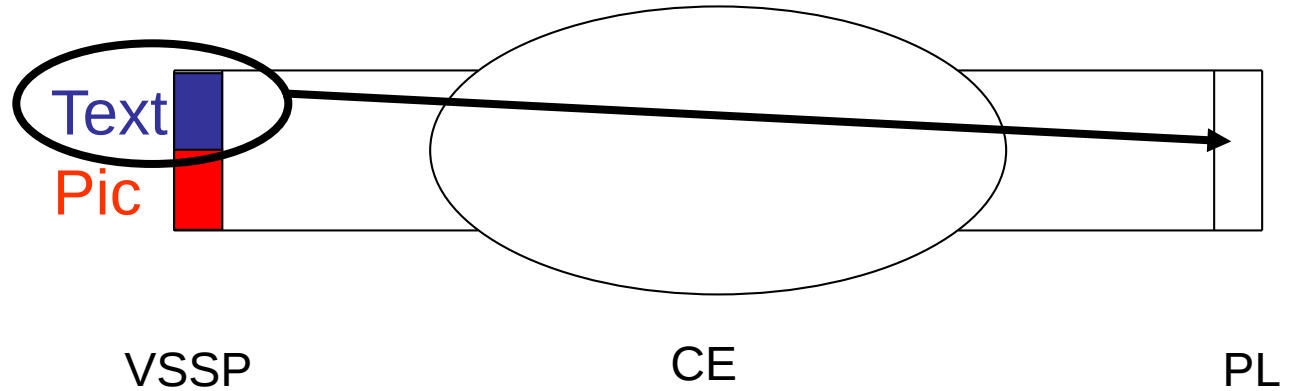
Written Text
Presentation



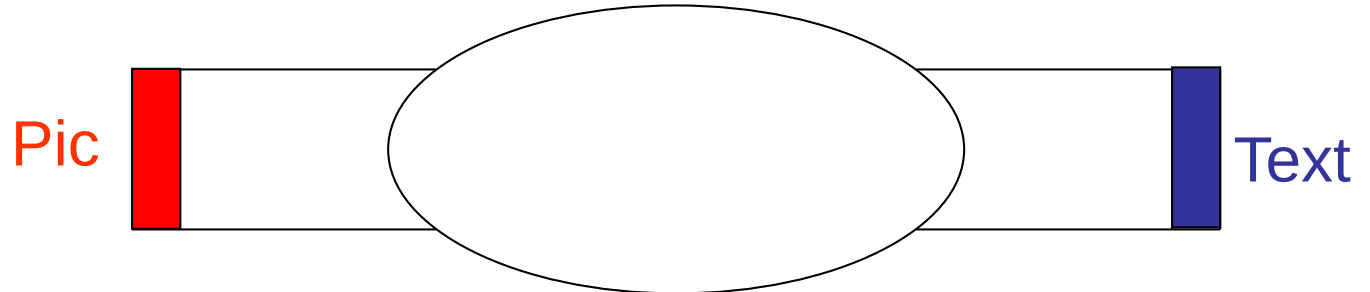
Spoken Text
Presentation



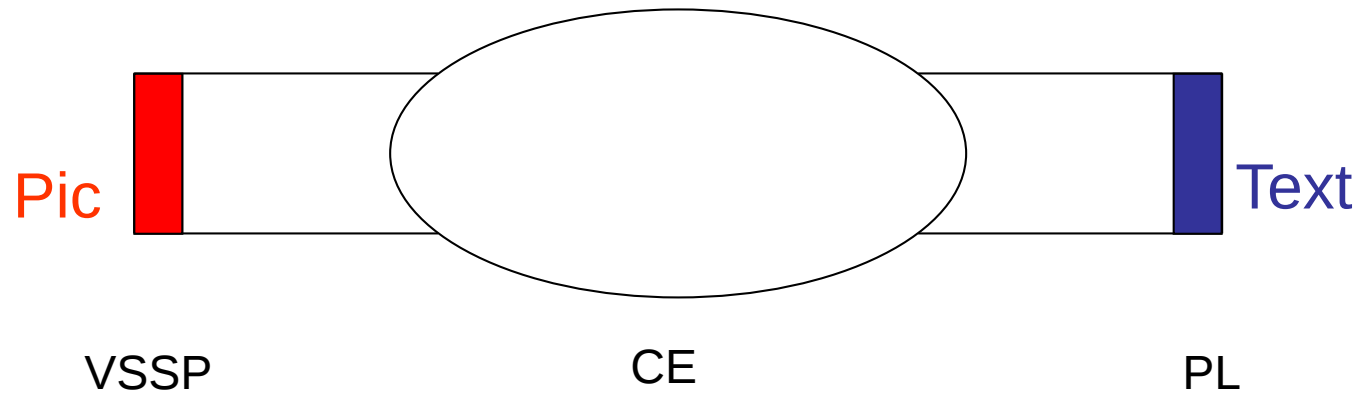
Written Text
Presentation



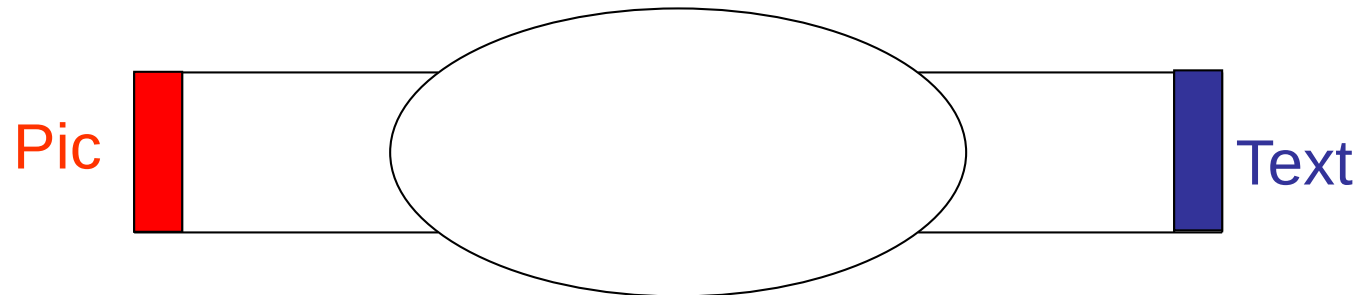
Spoken Text
Presentation



Written Text
Presentation

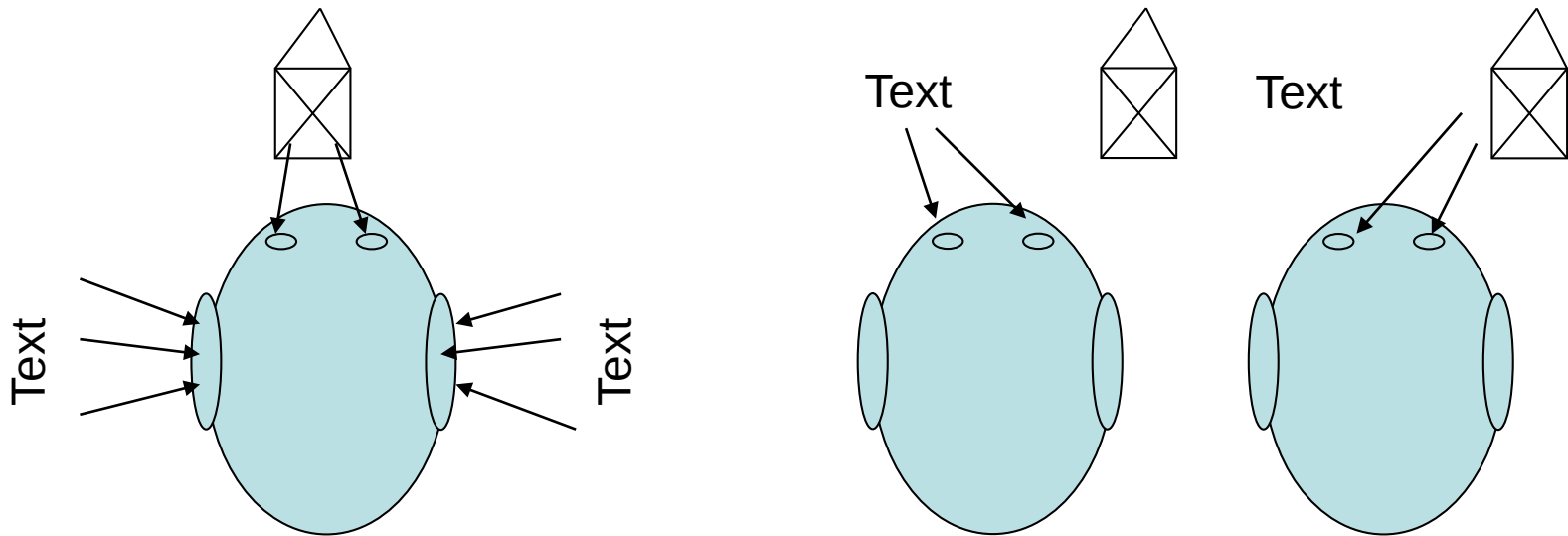


Spoken Text
Presentation

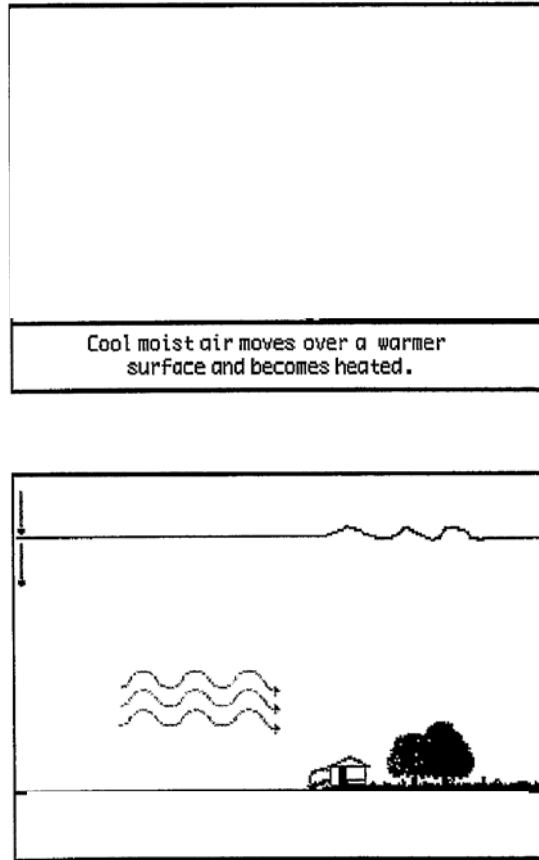


Remaining Explanation for the Modality Effect

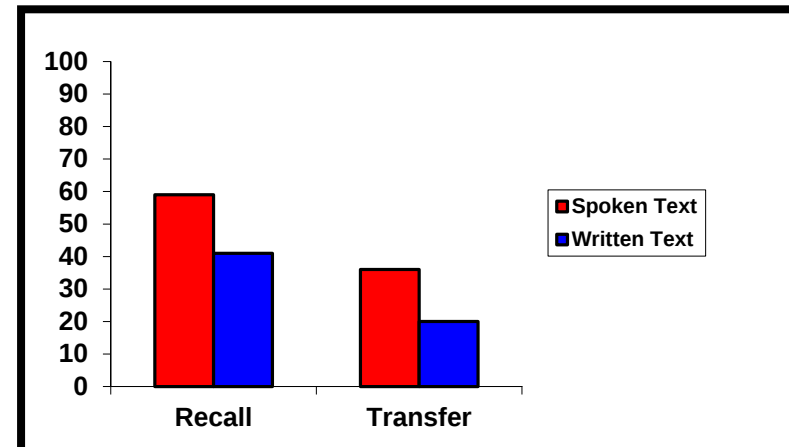
Split attention assumption (for the explanation of the modality effect with simultaneous presentation)



The Modality Effect with Sequential Presentation of Texts and Pictures



IV: Texts were either presented **auditorily** or **visually**.



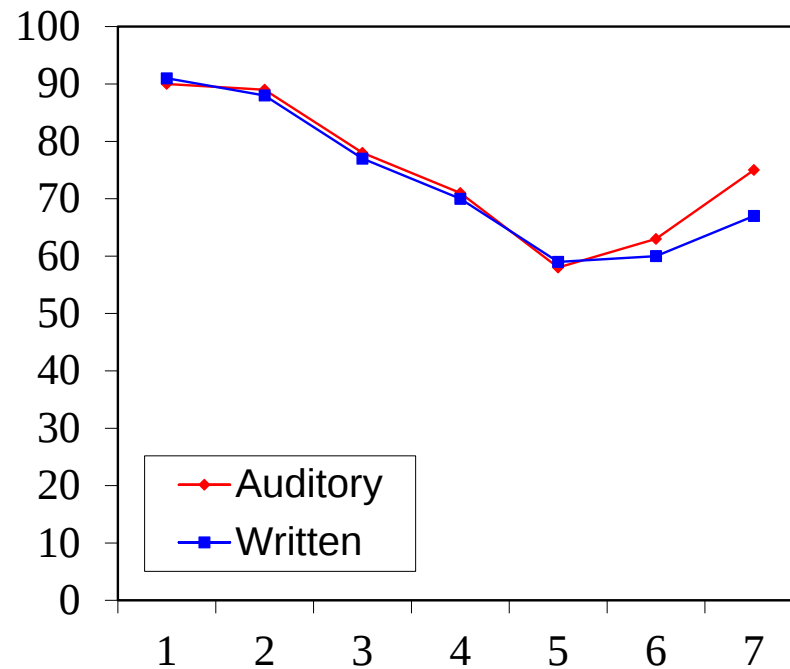
The modality effect can be observed with both simultaneous and **sequential** presentation (text – animation).

Moreno & Mayer (1999, *JEdP*, Exp. 2)

Question

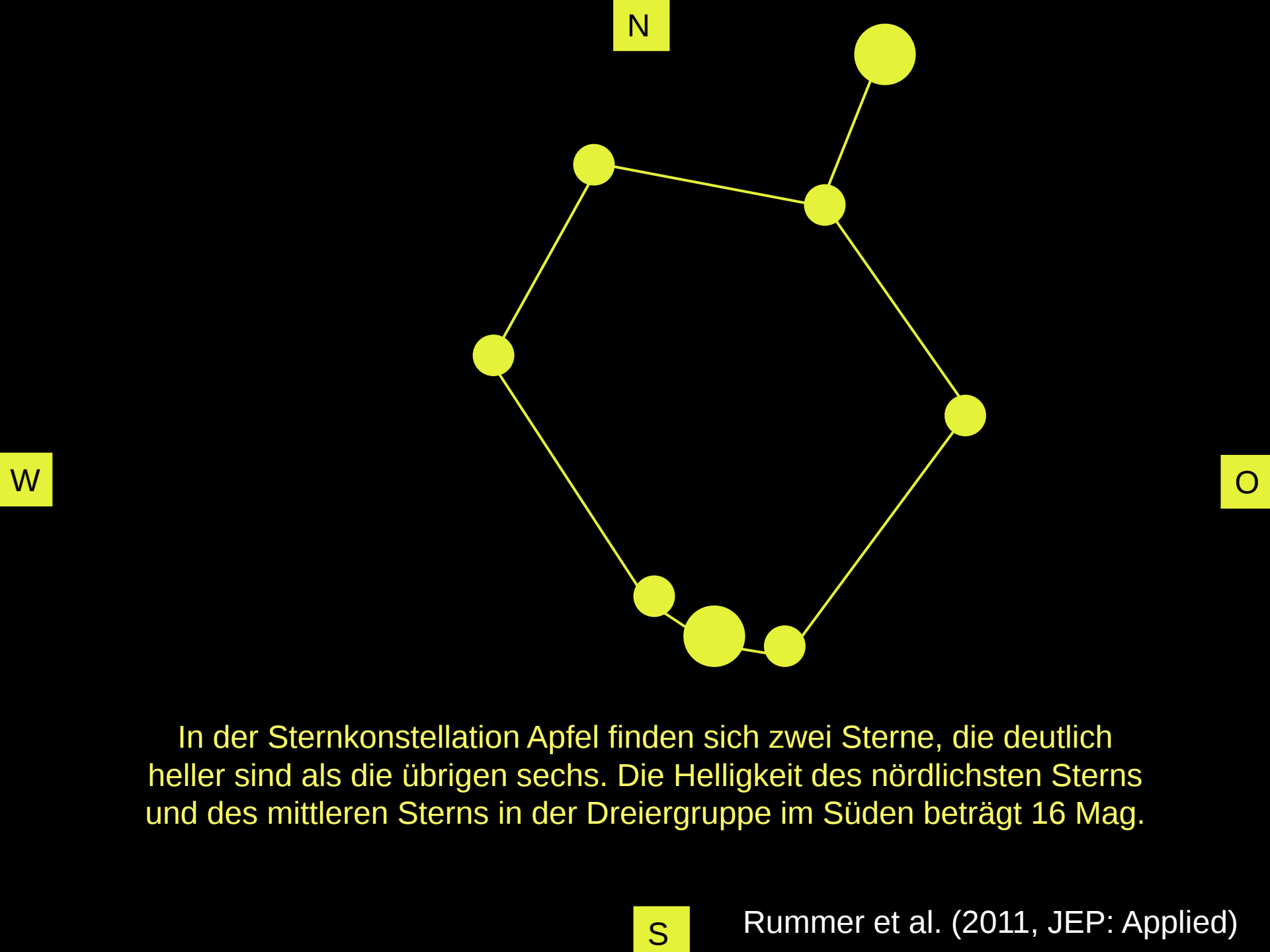
Why does the modality effect appear with sequential (as well as with simultaneous) presentation of multimedia materials?

Auditory Recency Effect



Assumptions

1. A multimedia effect occurs under split attention conditions, i.e., with simultaneous presentation of texts and pictures.
2. In addition, an auditory *recency* effect is observed.
 - Retention of the most recent piece of verbal information is better with spoken texts than with written texts.
 - This auditory recency effect is independent of whether or not the texts are accompanied by pictures.



In der Sternkonstellation Apfel finden sich zwei Sterne, die deutlich heller sind als die übrigen sechs. Die Helligkeit des nördlichsten Sterns und des mittleren Sterns in der Dreiergruppe im Süden beträgt 16 Mag.

Design

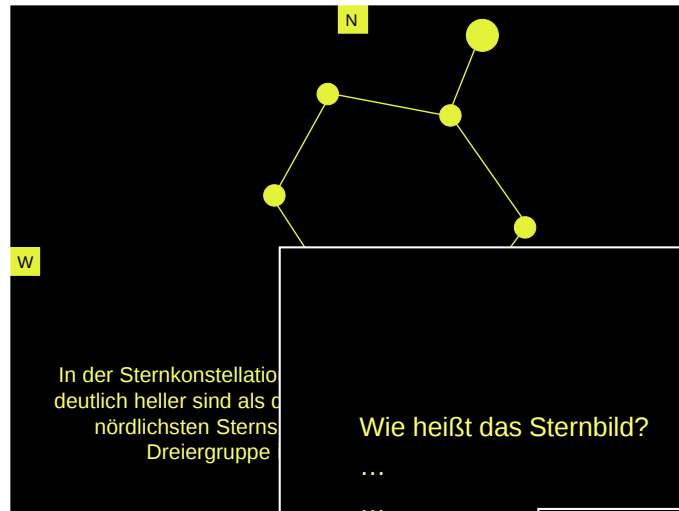
2 x 3 (between subjects) design

IV1: Text modality (spoken vs. written)

IV2: Presentation mode (text and picture simultaneous vs. text before picture vs. text only)

DV1: Picture recognition (*hits – false alarms*)

DV2: Correctness of answers to text-related questions



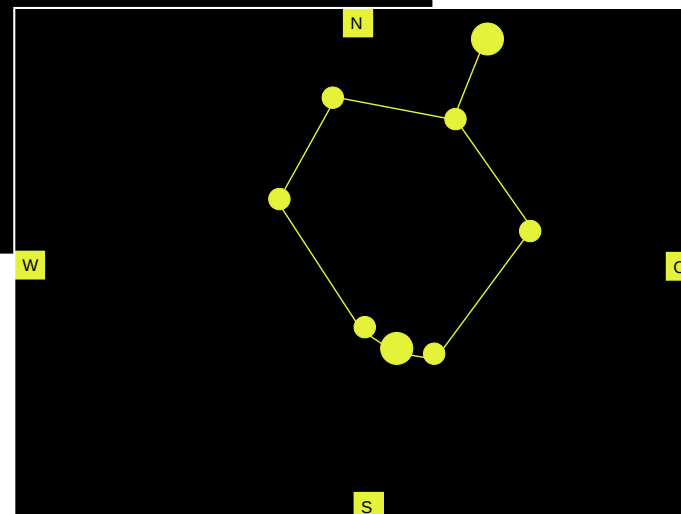
Wie heißt das Sternbild?

...

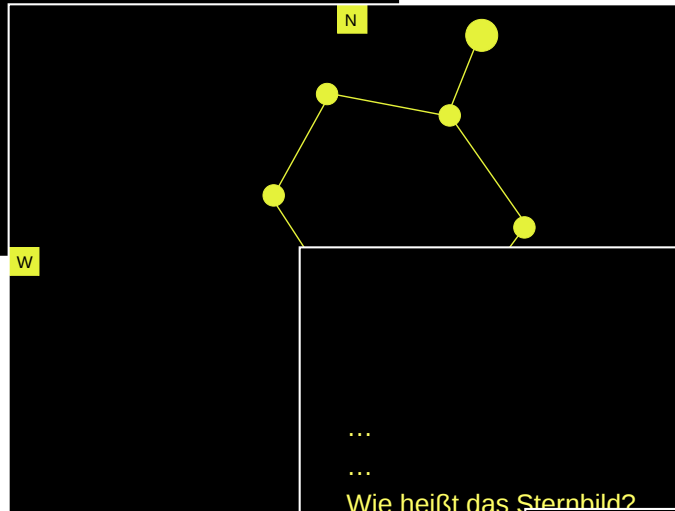
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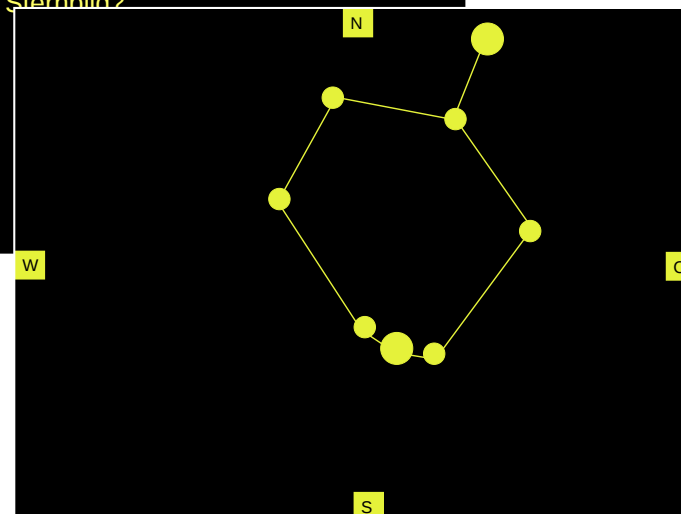
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...
...
Wie heißt das Sternbild?
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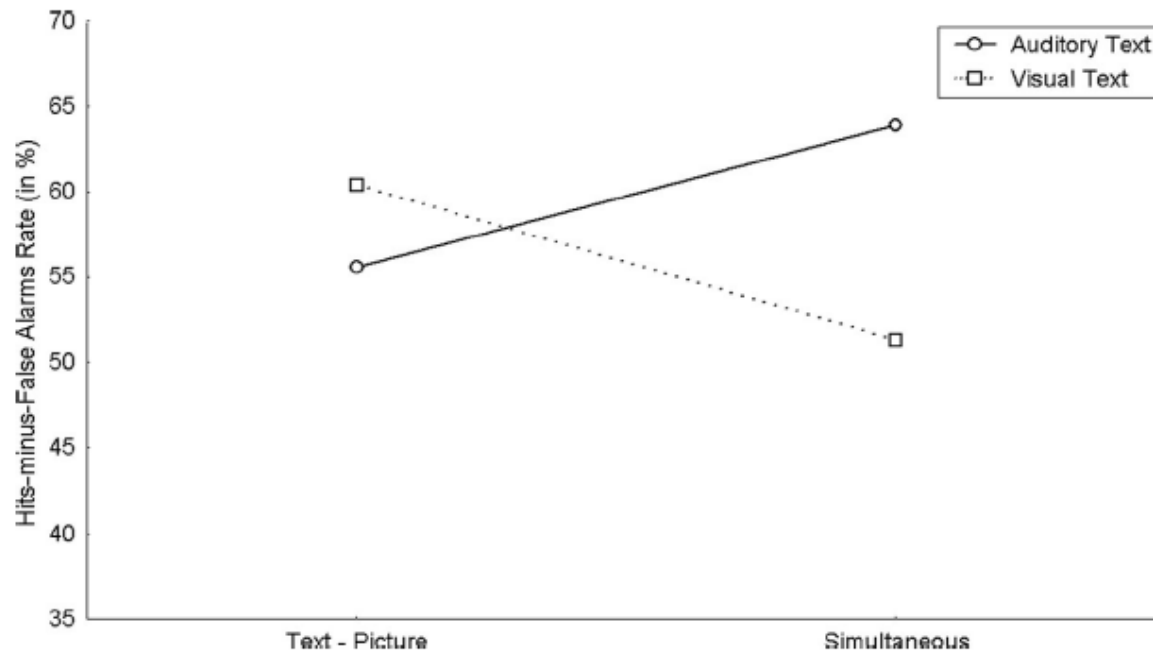


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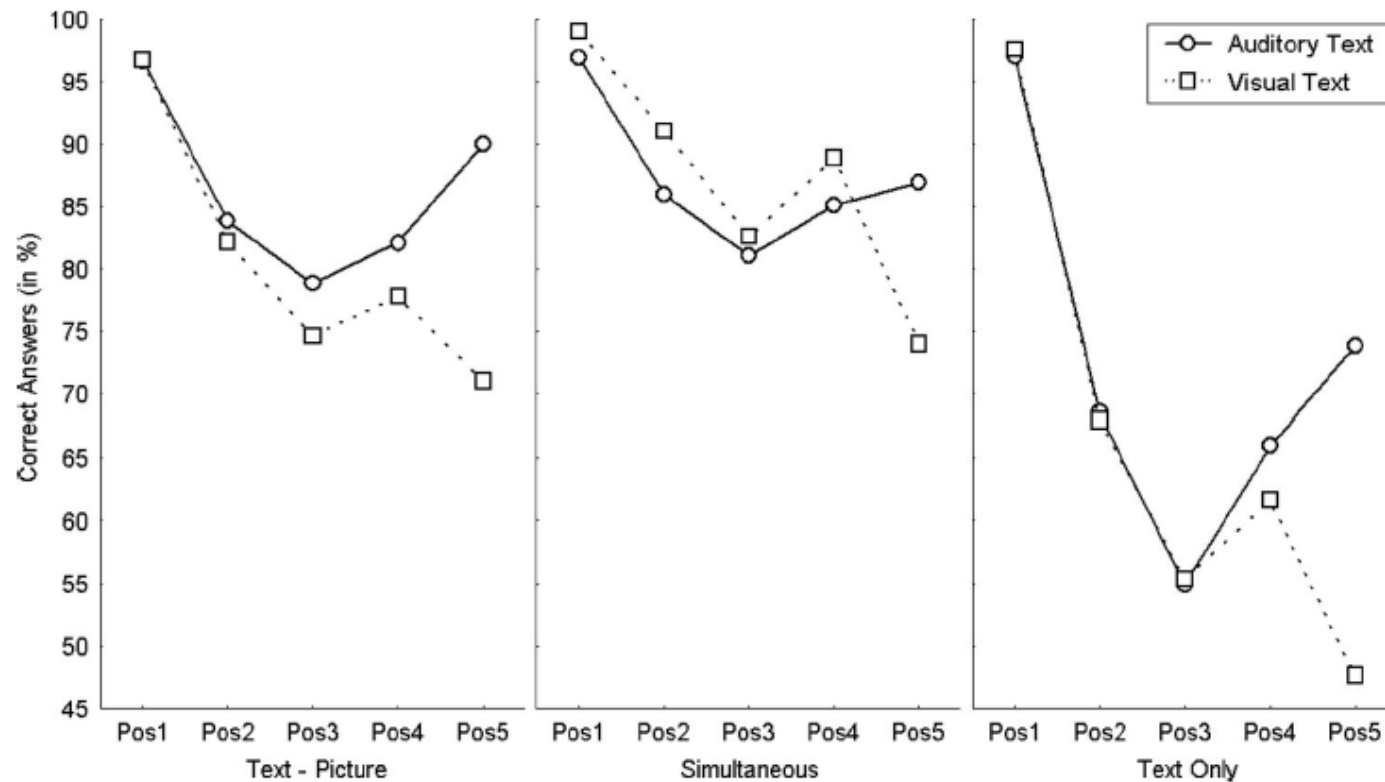
...

Wie heißt das Sternbild?

Picture Recognition



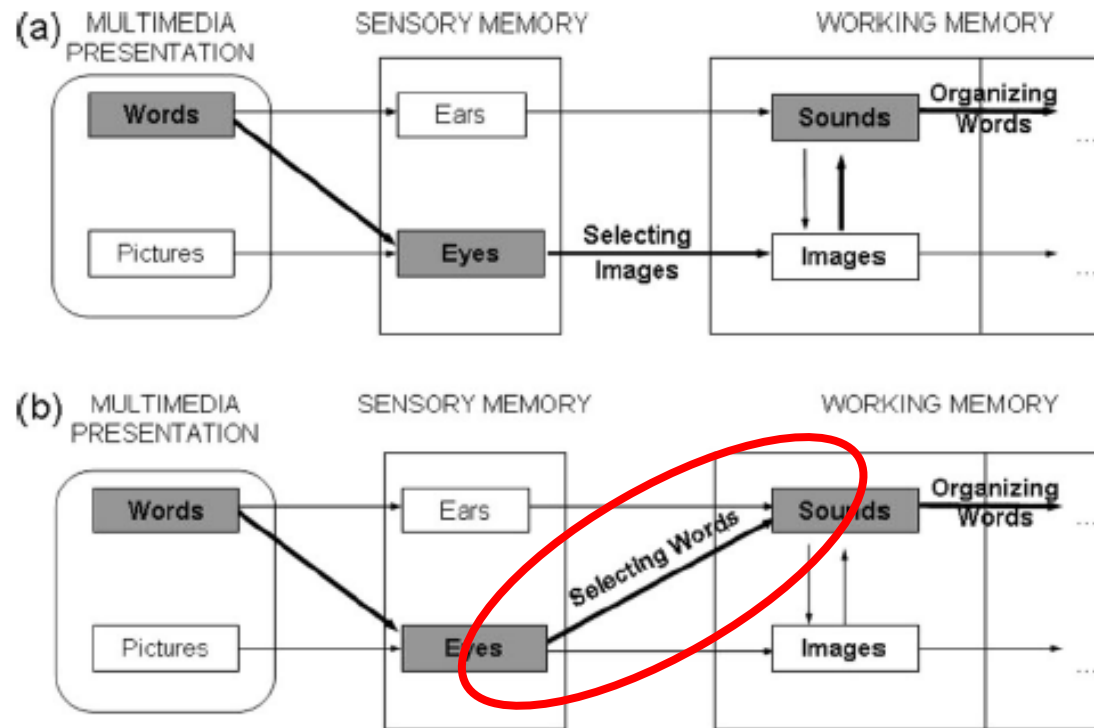
Answers to Text-related Questions



Discussion

1. Modality effect with picture recognition (split attention)
2. Questions for the most recent piece of verbal information are answered more accurately when presented in auditory rather than visual modality (auditory recency effect).
3. This auditory recency effect is not due to interference between written text and pictorial information.
4. **Conclusion: the *visuo-spatial load* hypothesis must be rejected.**

Modified Cognitive Theory of Multimedia Learning (Mayer, 2001, 2009)



Part 2

Sustainability of the Modality Effect

Hardly any existing study on multimedia principles tests short-term learning!

Might this be a problem?

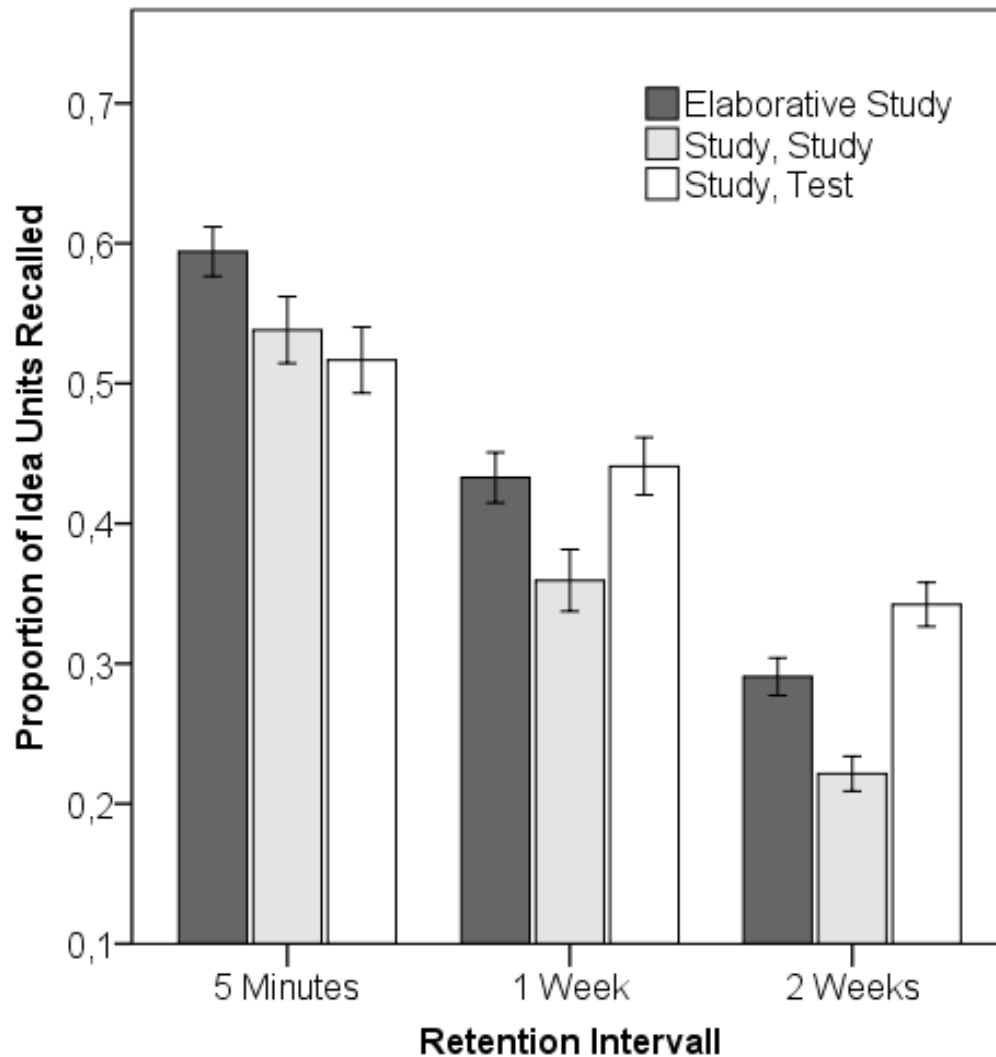
Desirable Difficulties

- Sometimes difficult (and cognitively demanding) learning materials can be more effective than materials that are easy to process (Bjork, Oppenheimer, Roediger, Karpicke, Pashler, etc.).
- Testing effect, spacing effect, etc.
- Interestingly, these advantages are not detectable immediately.
 - Example: *testing effect* (Rummer, Schweppe, Gerst & Wagner, under revision)

Testing Effect

- Material: German text about the honey badger
- 3 x 3 design (between subjects)
 - Learning condition
 - Note taking
 - Rereading
 - Testing (no feedback)
 - Final test delay
 - 5 minutes
 - 1 week
 - 2 weeks

Testing Effect



Rummer, Schweppe, Wagner, & Gerst (under revision, Exp. 1)

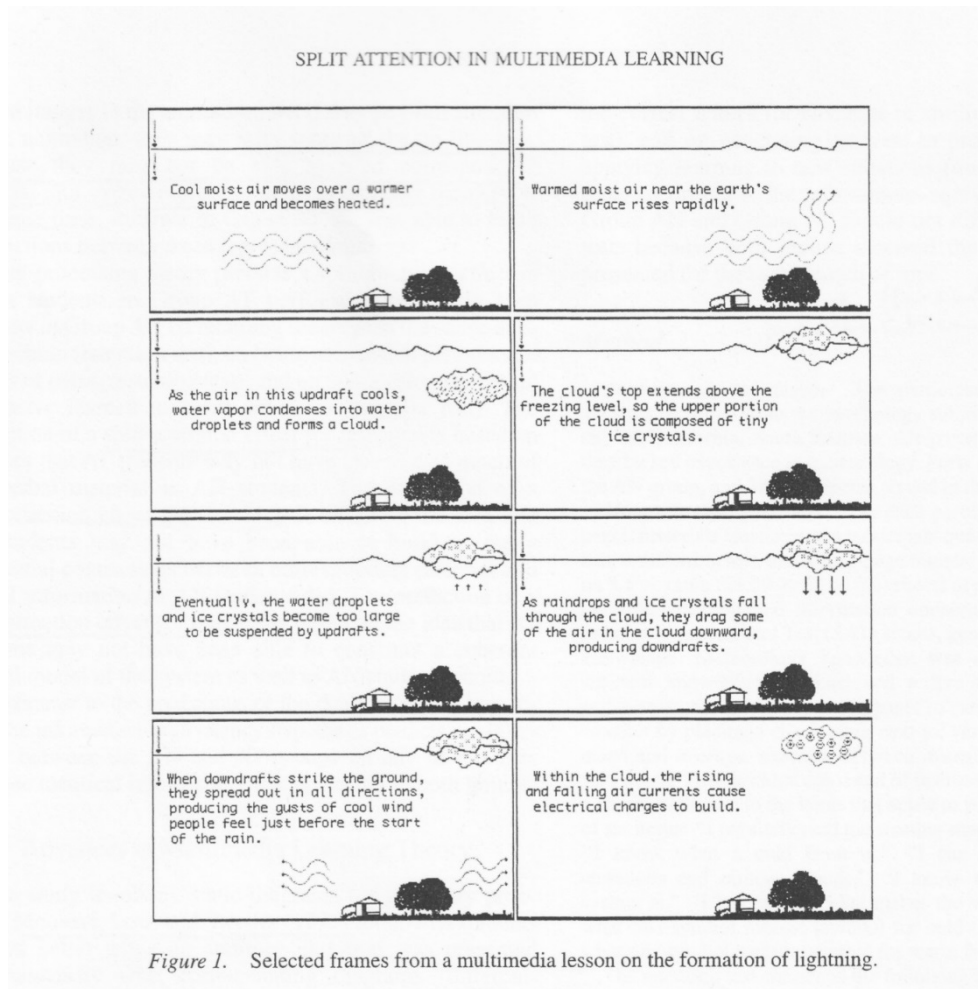
Maybe that learning with written text plus pictures is a desirable difficulty (just like testing) and in the long run, written text turns out to be more effective than spoken text!

Is there a "reversed" long-term modality effect?

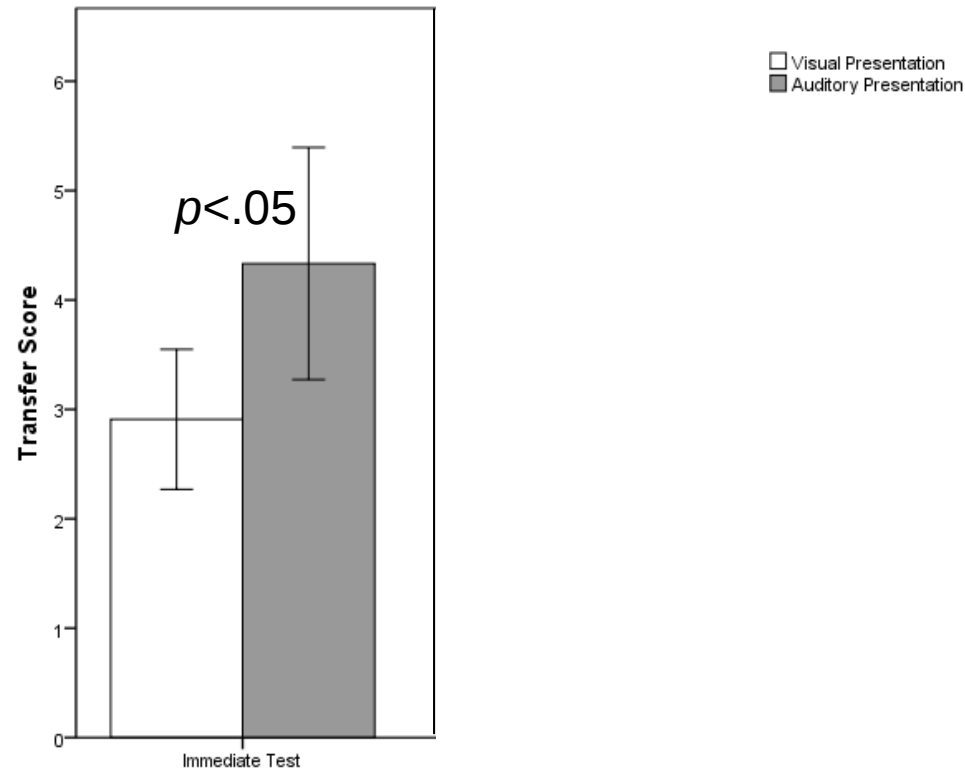
Experiment

- Design (classroom experiment, 4 different classes at University of Erfurt)
 - IV1: Spoken vs. written text presentation
 - IV2: Immediate test vs. test after one week
 - DV: Transfer test (+ retention)

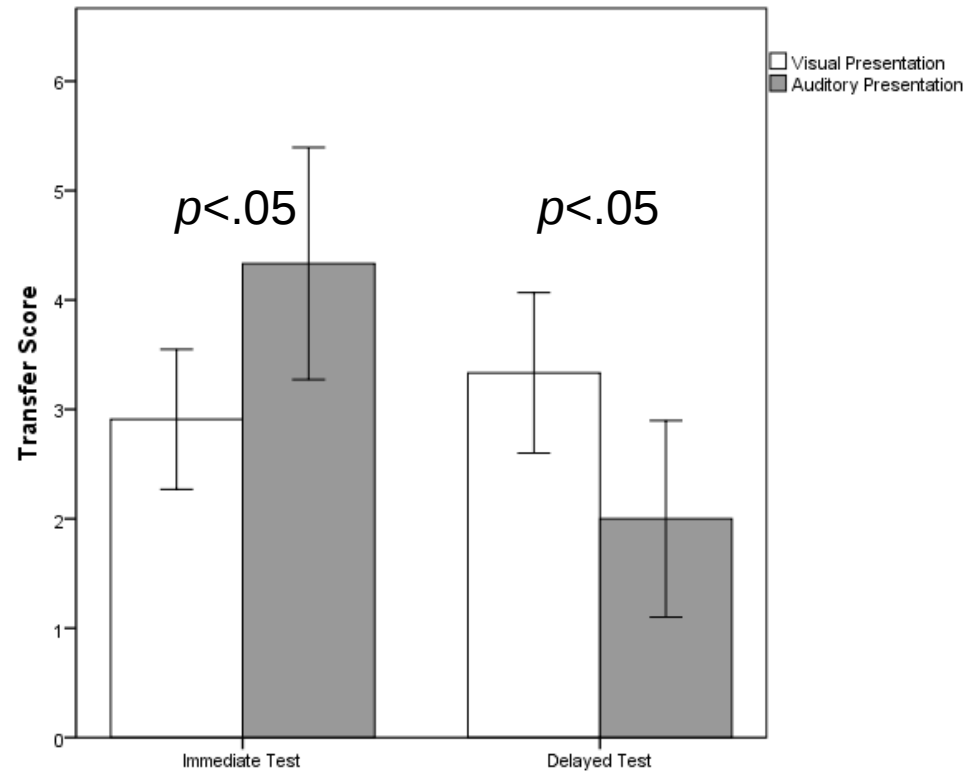
Mayer & Moreno's (1998) lightning materials (animations)



Answers to the Transfer Questions



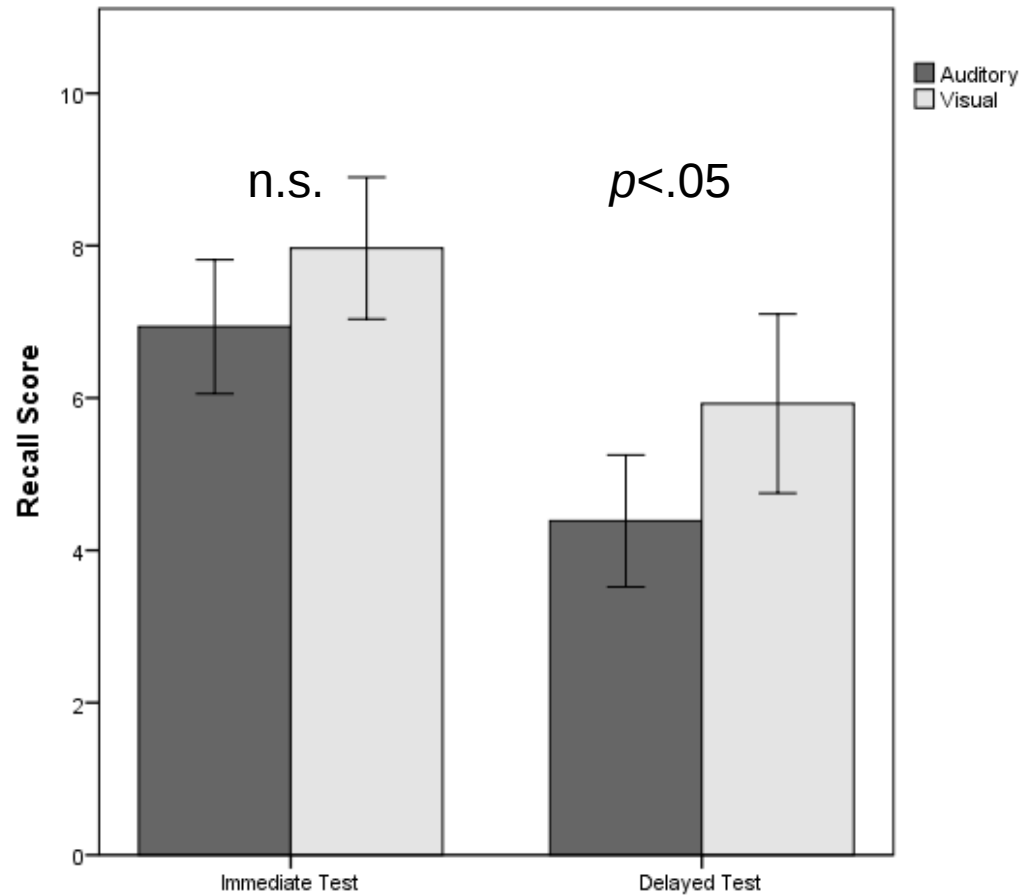
Answers to the Transfer Questions



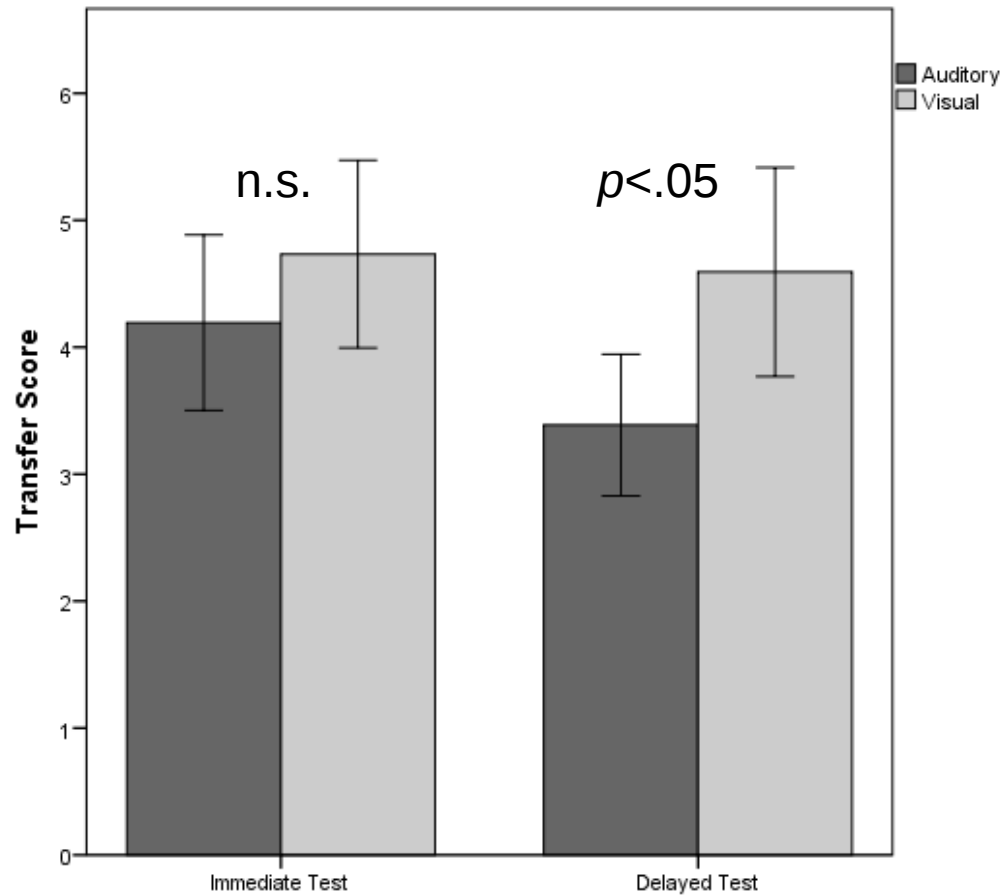
Replication Study

- Same materials
- Design (laboratory study)
 - IV1: Spoken vs. written text presentation
 - IV2: Immediate test vs. test after one week
 - DV: Retention, transfer

Retention



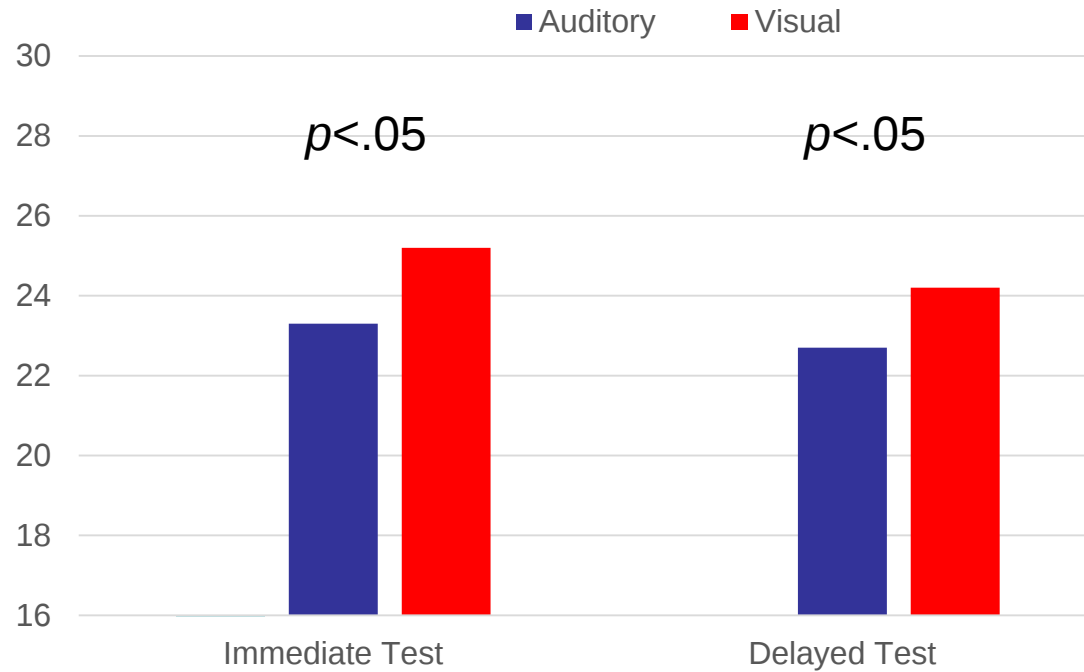
Transfer



Replication Study: Tornado Materials

- Schüler et al.'s (2012) materials (Tornado), but prolonged presentation rate (4:30 minutes instead of 3:00 minutes)
- Same design (laboratory study)
 - IV1: Spoken vs. written text presentation
 - IV2: Immediate test vs. test after one week
 - DV: Retention (multiple choice items + verification task)

Preliminary Results: Retention



Discussion

- The modality effect is not as **robust** as expected!
- **In the long run**, learning with written texts + pictures is more effective than learning with spoken texts + pictures! → **Reverse modality effect** (cf. Segers et al., 2008; Wittemann & Segers, 2010)
- Reading seems to be a **desirable difficulty**!

What about other Design
Principles?

Multimedia Principle

- Presentation: monomedia (text only) vs. multimedia (text + picture)
- Test delay: immediate test, test after 1 week, test after 2 weeks

text only

The pulley system

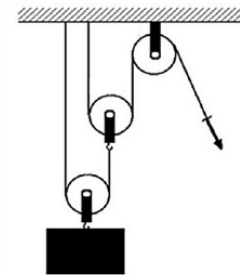
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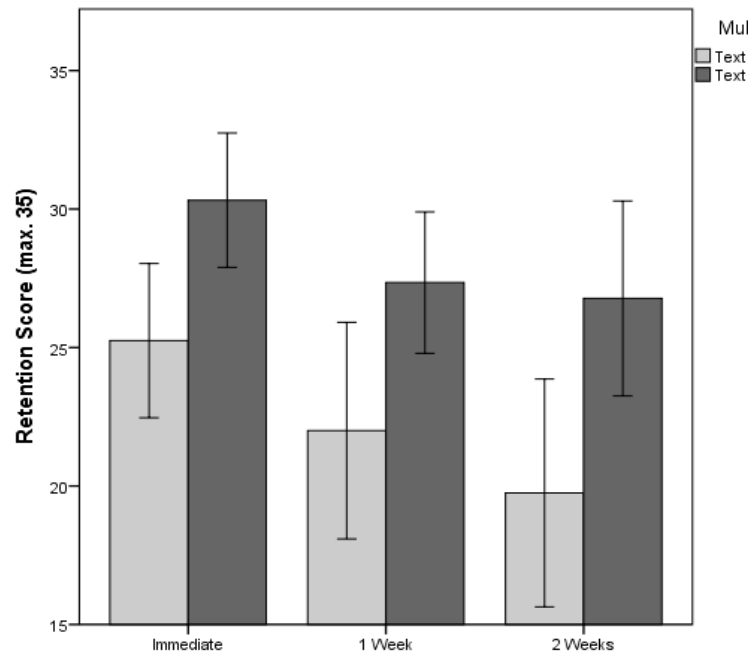
VS.

text and picture

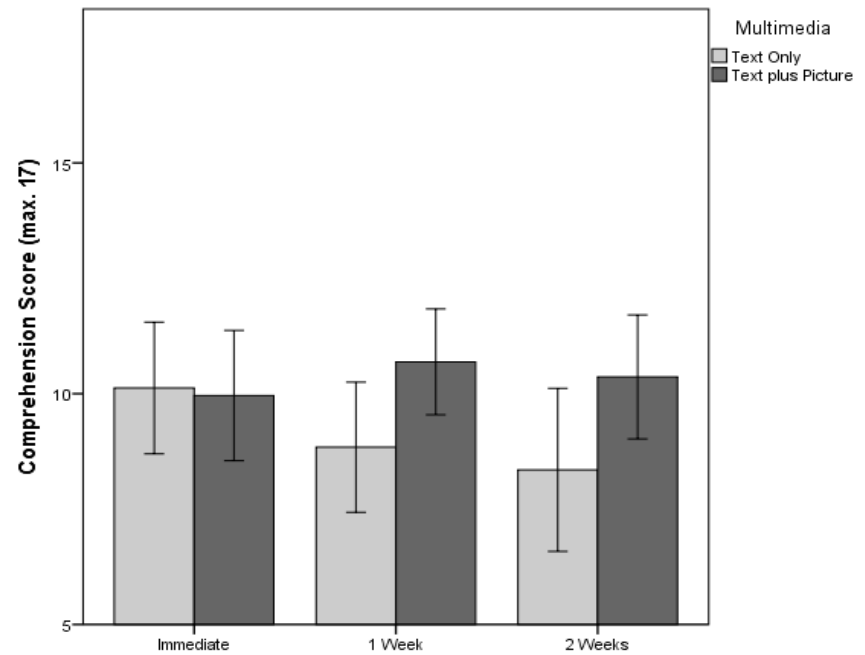
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Retention



Transfer

Should we Generally Make Learning Materials Difficult?

- No, when the difficulties are not desirable (like monomedia presentation)!
- No, when the materials are hard to understand (high element interactivity) and learners have a low working memory capacity!

Should we Generally Make Learning Materials Difficult?

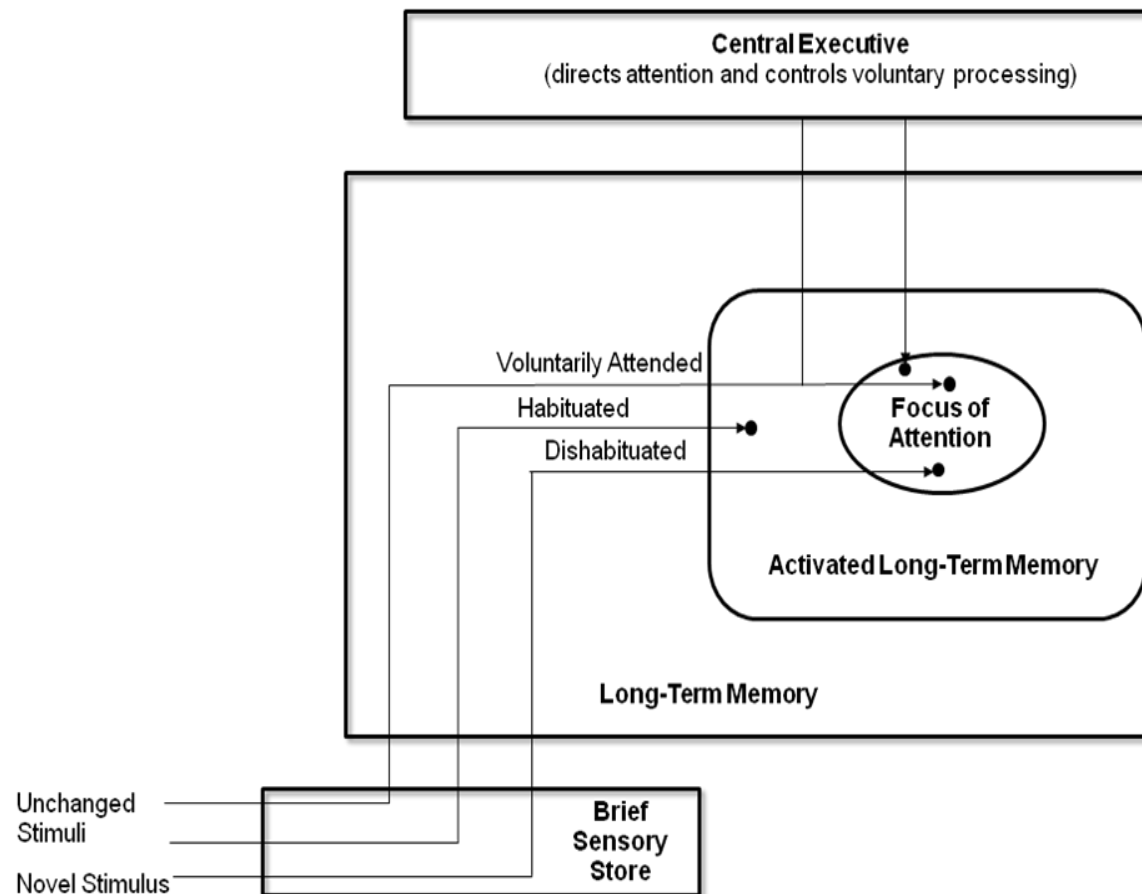
- Possibly, when the materials are of low complexity (low element interactivity).
 - Depends on whether the difficulties are desirable or not desirable!
 - Desirable difficulties: Testing, spacing, reading (rather than listening)
 - Undesirable difficulties: Monomedia (rather than multimedia) materials (Schweppe et al., 2015), etc.
 - Still unclear, but with a tendency to classify it as an undesirable difficulty: Perceptually disfluent materials (Rummer et al., 2016, but see Diemand-Yauman et al., 2011)?

Methodological Implications

- (Preregistrated) replications of basic learning principles to reject (publication) biased findings or get more information concerning their boundary conditions!
- Delayed tests of the most important design principles!
- Systematical variation of the complexity of learning materials!
- Theoretical development which focuses to those principles which are robust and durable ...

What is Needed in the Long run?

A model like this ...



Thank you for your attention!

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