Text Modality, Cognitive Load, and Desirable Difficulties

Ralf Rummer

University of Erfurt

9th International Cognitive Load Theory Conference 2016
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, Rümer, & Schweppe (2013)
  - An (elementary) multimedia study: Rümer, Schweppe, Scheiter, & Zindler (2011)
- **Excursus. Desirable difficulties:** short-term and long-term effects
  - **Testing effect:** Rümer, Schweppe, Gerst, & Wagner (under revision)
- **Modality effect (part 2):** long-term effect
  - Schweppe & Rümer (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).
Cognitive Theory of Multimedia Learning (CTML)

Mayer (2001, 2009)
The Modality Effect (ME)

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

DV$s$: 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)
Illustration of the Visuo-Spatial Load Hypothesis Based on Baddeley & Hitch’s Working Memory Model (1974)
Cognitive Theory of Multimedia Learning (CTML)

Mayer (2001, 2009)

- Pictures
- Auditory Text
- Written Text
Mayer (2001, 2009)

Cognitive Theory of Multimedia Learning (CTML)

- Pictures
- Auditory Text
- Written Text
Perspective 1
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, hH
    Example 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, Della Sala, Wynn & Baddeley (2000, QJEP)
Logie et al. (2000, Exp. 4)
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, hH
  Example 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, Della Sala, Wynn & Baddeley (2000, QJEP)
Forstenberg, Rummer & Schwepppe (2013, Memory)
Perspective 2

The sensory store is a temporary storage area for sensory input. The input is initially processed in the sensory region before being stored in the sensory store. The sensory store retains information for a short period of time, allowing for further processing and analysis.

VSSP (Visual Sensory System) → Sensory Store

Sensory Store → CE (Cognitive Engine)

CE → PL (Perceptual Layer)
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.)
Logie, Della Sala, Wynn & Baddeley (2000, QJEP)
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.

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

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

Rummer et al. (2011, JEP: Applied)
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

Rummer et al. (2011, JEP: Applied)
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 beträgt 16 Mag. Wie heißt das Sternbild?
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.

Wie heißt das Sternbild?

...
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.

Wie heißt das Sternbild?
Picture Recognition

Rummer et al. (2011, JEP: Applied)
Anwers to Text-related Questions

Rummer et al. (2011, JEP: Applied)
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.

Rummer et al. (2011, JEP: Applied)
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

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

Schweppe & Rummer (2016, CHB, Exp. 1)
Mayer & Moreno’s (1998) lightning materials (animations)

Figure 1. Selected frames from a multimedia lesson on the formation of lightning.
Anwers to the Transfer Questions

Schweppe & Rummer (2016, CHB, Exp. 1)
Anwers to the Transfer Questions

Schweppe & Rummer (2016, CHB, Exp. 1)
Replication Study

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

Schweppe & Rummer (2016, CHB, Exp. 2)
Retention

Schweppe & Rummer (2016, CHB, Exp. 2)
Transfer

Schwepp & Rumber (2016, CHB, Exp. 2)
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

Immediate Test
- Auditory
- Visual

Delayed Test
- Auditory
- Visual

$p<.05$  $p<.05$
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

Schweppue, Eitel, & Rummer (2015, L&I, Exp. 2)
Retention Transfer

Schweppe, Eitel, & Rummer (2015, *L&I*, Exp. 2)
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

• (Preregistered) 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 ...

Schweppen & Rummer (2014, 2016, EPR)
Thank you for your attention!
References

Rummer, R., Schweppe, J., Wagner, S. & Gerst, K. (under revision). Is testing a more effective learning strategy than note-taking?


