# Multimedia Learning
## Principles of instruction

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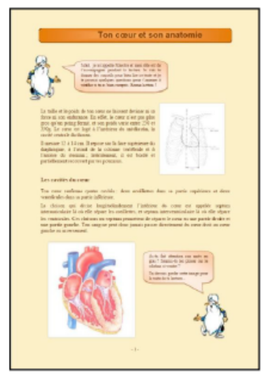
## Multimedia learning

- Combines words and pictures (Mayer 2014)
- **Words**: written, spoken
- **Pictures**: illustrations, graphs, animations…
- Traditional:
  - textbooks, slides, animations, videos
- Interactive:
  - simulations, video games, tutoring systems, conversational agents

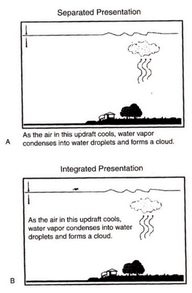



(Andery et al., 2016, SIG2)

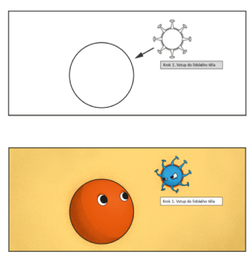
## Research Questions

- Making the experiments simple

changes to the materials → + cognitive processes → + learning outcomes

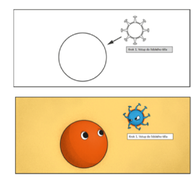



(Mayer & Moreno, 1998, J Edu Psy)



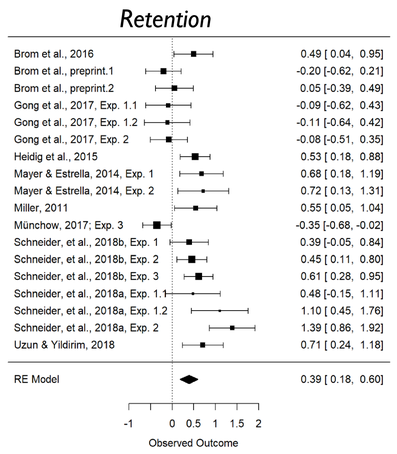
(Starkova et al., submitted)

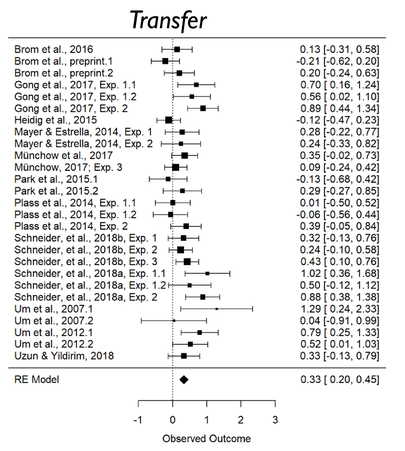
## Meta-analyses



95% confidence interval for *d*

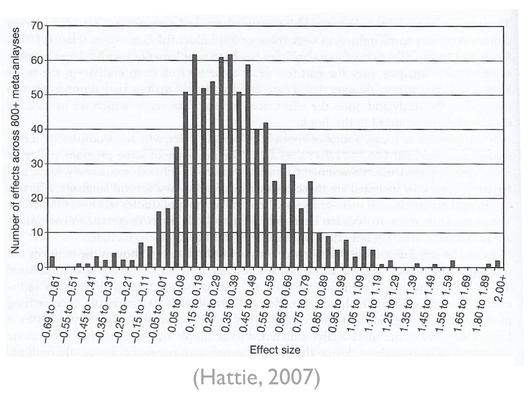
- Retention: *d* = **0.39** [0.18 – 0.60]
- Transfer: *d* = **0.33** [0.20 – 0.45] (Brom et al., 2018 Edu Res Rev)




## Effect sizes in educational sciences
(Cohen, 1988)

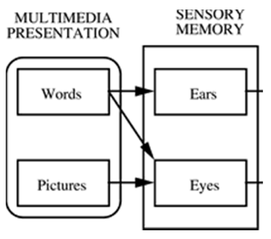
- 0.2 ~ small
- 0.5 ~ medium
  - ~ 0.4 (Hattie, 2007)
- 0.8 ~ large




(Hattie, 2007)

## Theoretical model

- Cognitive theory of multimedia learning (Mayer, 2009; based on Miller, 1956; Baddeley, 1986; Paivio, 1986; Sweller, 1999)
  - dual-channel
  - limited capacity
  - active learning, knowledge construction
  - selecting, organizing, integrating



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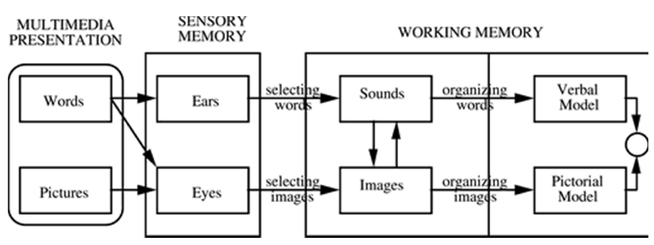


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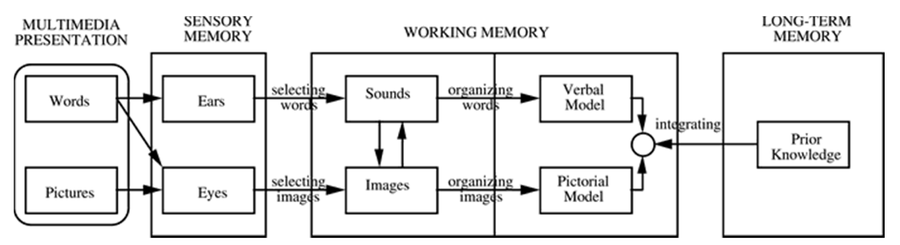


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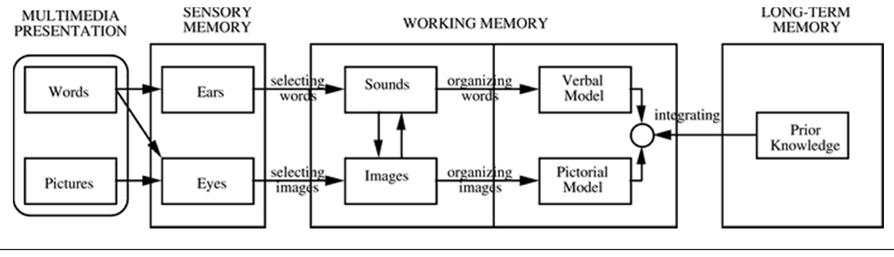


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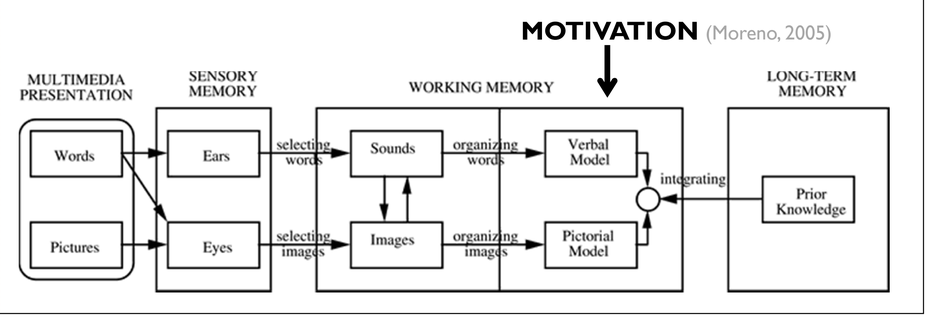
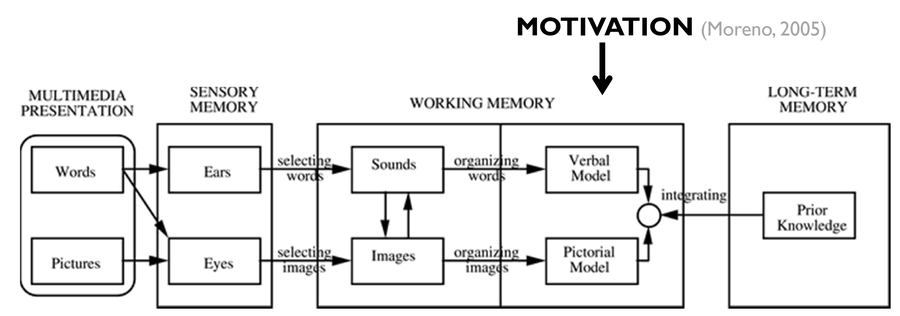



# Theoretical model

- Cognitive load theory (Sweller et al., 2011; de Jong, 2010)
  - **intrinsic** load
  - **extraneous** load
  - ~~germane load~~

# Question

- **How to support… ?**
  - selecting
  - organizing
  - integrating




(Mayer 2009)

# Principles – categories

- Low level vs. high level
- Processes
  - extraneous none
  - essential selecting, partly organizing
  - generative partly organizing, integrating

# Principles

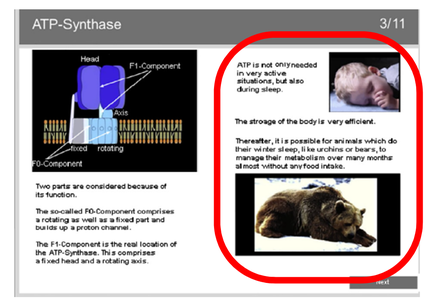
- Multimedia
- Seductive details
- Signaling/cueing
- Spatial and temporal contiguity/split attention
- Redundancy
- Modality
- Realism
- Segmenting & pre-training
- Animation
- Summarizing
- Self-testing
- Choice
- Assisted discovery

# Multimedia principle

- Do this: **"using words + pictures rather than just words"**
  - probably simplifies all processes
- *k* = 11, Median *d* = **1.39** (Mayer 2009)
- Boundary conditions (Mayer 2009)
  - less strong for high prior knowledge learners (expertise reversal)
  - instructional quality of the graphics
- Note: Orbis Pictus (Comenius)

# Seductive details principle

- Interesting
  - but not central
- Text, sound, image
- Do not: **"include seductive details"**
  - extraneous processing



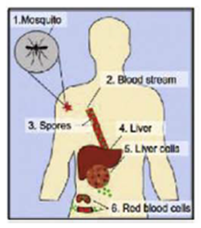

(Park et al. 2015 Comp Hum Beh)

- Retention: *d* = **-0.30** [-0.39 – -0.20]
- Transfer: *d* = **-0.48** [-0.34 – -0.61]

(Rey 2012 Edu Res Rev)

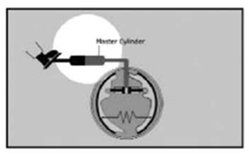
# Signaling principle
## Cueing

- Do this: **"highlight key information"**
  - simplifies selecting




(McTigue 2009 Cogn Instr)

- *k* = 145, *N* = 12,201 (Schneider et al 2018 Edu Res Re
  - Retention: *k* = 139, *g* = **0.53** [0.42 – 0.64]
  - Transfer: *k* = 70, *g* = **0.33** [0.22 – 0.43]



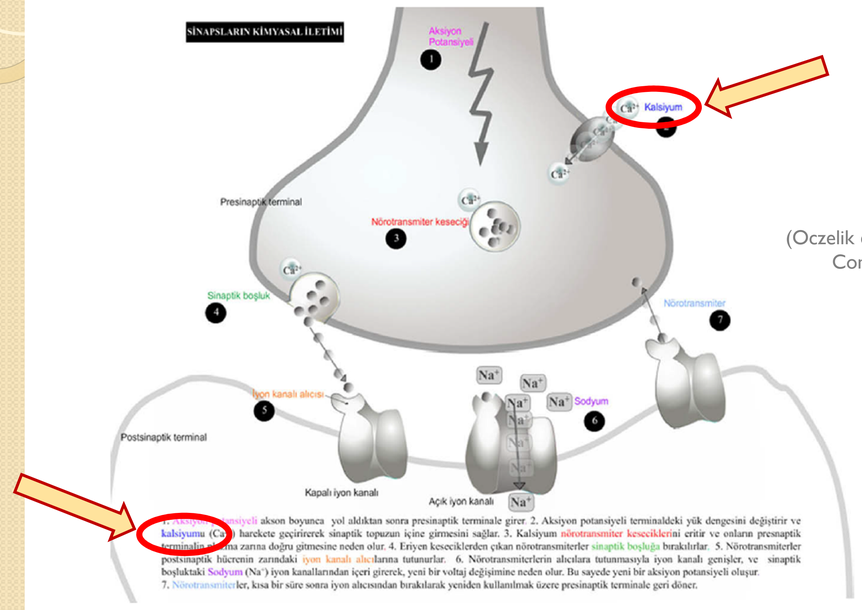

(Doolittle & Alstaedter 2009 J Res Innov Teach)

- Boundary conditions (Schneider et al 2018 Edu Res Rev)
  - Flashing: k = 3, *g* = **-0.56**, n.s.
  - Prior knowledge not confirmed

*Now heat the product to 75 DEGREES Centigrade. This is the temperature at which enzymes BEST CONVERT starches into sugars. There are also more complex methods of brewing that allow for better tasting beer.*

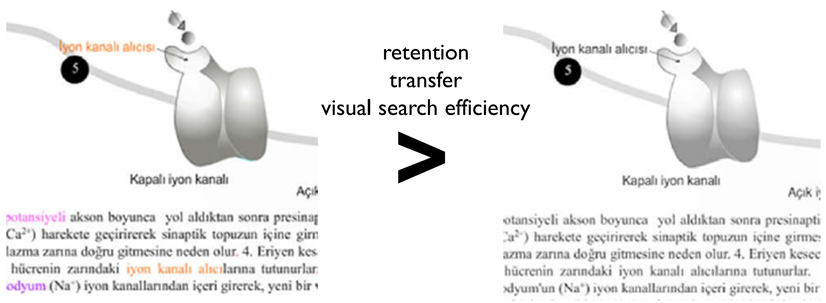
(Brom et al. 2014 Comp & Edu)

# Example: Color coding




(Oczelik et al. 2009 Comp & Edu)

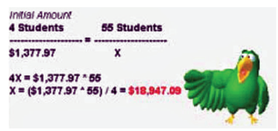
# Example: color coding




retention
transfer
visual search efficiency
>

(Oczelik et al. 2009 Comp & Edu)

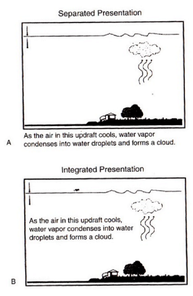
# Embodiment principle




(Lusk & Atkinson, 2007, Appl Cog Psy)

- Do this: **"use agents with gaze and gesture rather than static/talking images of agents"**
  - signaling principle?
- Agents vs. no agent (Schroeder et al., 2013, J Edu Comp Res)
  - $k$ = 43, $N$ = 3088, $g$ = **0.19** [0.12, 0.27]
- Low embodied agent vs. no agent
  - $k$ = 14, Median $d$ = **0.20** (Mayer 2014, Handbook ML, p. 359)
- Boundary conditions
  - Low embodied vs. high embodied agent: $k$ = 11, Median $d$ = 0.36 (Mayer 2014, Handbook ML, p. 361)
  - note: Schneider et al. 2018 includes cueing agents

# Spatial and temporal contiguity
## Split-attention




(Mayer & Moreno, 1998, J Edu Psy)

- Do this: **"put related bits of information close together"**
  - manages essential processing
- $k$ = 50; $N$ = 2375 (Ginns, 2006, Ln Instr)
  - Transfer: $k$ = 29, $d$ = **0.80** [0.67 – 0.92]
  - Spatial: $k$ = 37, $d$ = **0.72** [0.61 – 0.82]
  - Temporal: $k$ = 13, $d$ = **0.78** [0.63 – 0.92]
  - note: similar results for spatial, $g$ = 0.63: (Schroeder & Cenki 2018 Educ Psy Rev)
- Boundary conditions (Mayer, 2009)
  - high prior knowledge (expertise reversal effect possible) or simple material
  - temporal: short segments (e.g. ~10s)

# Redundancy principle

- Do this: **"using pictures + narration rather than pictures + narration + text"**
  - reduces extraneous processing
- $k$ = 5, Median $d$ = **0.72** (Mayer 2009)
- Boundaries: short captions, interspersed, no graphics (Mayer 2009)

(Adesope & Nesbit 2012 J Edu Psy)

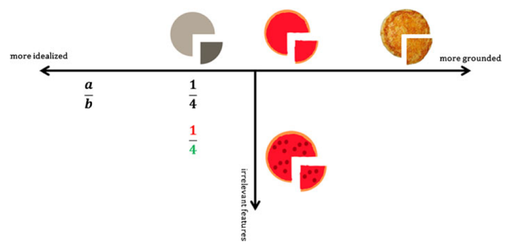
spoken–written better

| Variable | $N$ | $k$ | $g+$ | $SE$ | 95% CI |
|---|---|---|---|---|---|
| All | 3,452 | 57 | 0.15* | 0.03 | [0.08, 0.22] |
| Comparison treatment | | | | | |
| Text (on-screen) only | 1,480 | 23 | −0.04 | 0.05 | [−0.14, 0.06] |
| Speech (audio) only | 1,972 | 34 | 0.29* | 0.05 | [0.20, 0.39] |
| Images included in material? | | | | | |
| No | 541 | 12 | 0.45* | 0.09 | [0.28, 0.63] |
| Yes | 1,248 | 21 | 0.06 | 0.06 | [−0.05, 0.17] |
| Animation included in materi | 1,216 | 21 | 0.24* | 0.06 | [0.12, 0.35] |
| No | 573 | 12 | 0.06 | 0.08 | [−0.10, 0.23] |
| Yes | | | | | |

# Modality principle

- Do this: **"present words aurally"**
  - manages essential processing
- $k$ = 39; $N$ = 1887 (Ginns, 2005, Ln Instr)
  - Transfer: $k$ = 25, $d$ = **0.76** [0.64 – 0.88]
- k = 61 (Mayer, 2014, Handbook ML, p. 494)
  - Median $d$ = **0.76**
- Boundary conditions
  - lengthy/complex/unfamiliar words (Low & Sweller, 2014, Handbook ML, p. 239)

# Realism




- Narrative review
  - grounded relevant improves retention and interest
  - idealized improves transfer (Belenky & Schalk 2014 Educ Psychol Rev)
- My view
  - open issue
  - concreteness fading (Fyfe et al. 2014 Educ Psychol Rev)

# Segmenting and pre-training

- Do this: **"using words + pictures rather than just words"**
  - helps with organizing / essential processing
- Mayer (Mayer 2014 Handbook ML)
  - segmenting: *k* = 10, Median *d* = **0.79**
  - pre-training: *k* = 16, Median *d* = **0.75**
- Boundary conditions (Mayer 2009)
  - strongest for complex, fast-paced materials

# Animation

- Do this: **"use animation rather than static graphics"**
  - can improve selecting and organizing
  - but can increase extraneous processing
- *k* = 140; *N* = 7036 (Berney & Betrancourt 2016, Comp Edu)
  - Factual: *k* = 32, *g* = **0.34** [0.13 – 0.54]
  - Conceptual: *k* = 93, *g* = **0.16** [0.05 – 0.28]
  - Procedural : *k* = 13, *g* = **0.39** [-0.15 – 0.92]
- Boundary conditions (Berney & Betrancourt 2016, Comp Edu)
  - abstract (*g* = 0.01) vs. iconic (*g* = 0.24) representation
  - written (*g* = 0.11) vs. narrated (*g* = 0.32) words vs. no text (*g* = 0.89)
  - visualizers vs. verbalizers: unclear (e.g., Kirschner 2017 Comp Edu)
  - low spatial ability: animations especially better (Hoffler 2010 Educ Psychol Rev)

# Generative strategies

(Fiorella & Mayer 2014)

| Learning strategy | Description | Comparisons (positive) | Effect size (median) | Strongest when |
|---|---|---|---|---|
| Summarizing | Create a written or oral summary of the material | 26 of 30 | 0.50 | Learners are trained; lessons are short texts |
| Mapping | Create a concept map | 23 of 25 | 0.62 | Learners are inexperienced; learners receive guidance |
| | Create a knowledge map | 5 of 6 | 0.43 | |
| | Create a matrix organizer | 8 of 8 | 1.07 | |
| Drawing | Create a drawing that depicts the text | 26 of 28 | 0.40 | Learners are trained; learners receive scaffolding and support |
| Imagining | Imagine a drawing that depicts the text | 16 of 22 | 0.65 | Learners are experienced; materials are well designed |
| Self-testing | Give yourself a practice test on the material | 70 of 76 | 0.57 | Learners receive feedback; practice test matches final test |
| Self-explaining | Create a written or oral explanation of confusing parts of the material | 44 of 54 | 0.61 | Learners are inexperienced; prompting is focused |
| Teaching | Explain the material to others | 17 of 19 | 0.77 | Learners expect to teach |
| Enacting | Move objects to act out the material | 36 of 49 | 0.51 | Learners are experienced; learners are trained |

# Assisted discovery

- Do this: **"using guided discovery rather than pure discovery"** (Alfieri et al. 2011 J Edu Psy)
  - reduces extraneous processing, facilitates essential processing, possibly fosters motivation
  - note: guided play (Skolnick Weisberg et al 2016 Curr Dir Psych Sci)
- Unassisted discovery vs. explicit instruction (e.g., direct teaching, feedback, worked examples…)
  - *k* = 580, *d* = **-0.38** [0.44 – 0.31]
- Assisted discovery vs. other types (e.g., direct teaching, worked examples, unassisted discovery…)
  - *k* = 360, *d* = **0.30** [0.23 – 0.36]
  - generation (*d* = -0.15), elicited explanation (*d* = 0.36), guided discovery (*d* = 0.50)

# Choice

*Results of Analyses Examining the Overall Effect of Choice on All Outcomes*

| Outcome | *k* | *d* | 95% confidence interval: Low estimate | 95% confidence interval: High estimate | *Q* |
|---|---|---|---|---|---|
| Intrinsic motivation | 46 | 0.30**(0.36)** | 0.25(0.27) | 0.35(0.46) | 146.30** |
| Effort | 13 | 0.22**(0.28)* | 0.08(0.01) | 0.35(0.56) | 48.06** |
| Task performance | 13 | 0.32**(0.36)** | 0.17(0.09) | 0.47(0.63) | 38.73** |
| Subsequent learning | 14 | 0.10(0.10) | −0.02(−0.02) | 0.21(0.21) | 13.37 |
| Perceived competence | 8 | 0.59**(0.59)** | 0.42(0.34) | 0.76(0.84) | 14.34* |
| Preference for challenge | 3 | 0.71*(0.74) | 0.34(−0.59) | 10.07(2.07) | 26.35** |
| Pressure or tension | 3 | −0.03(−0.08) | −0.33(−0.60) | 0.27(0.45) | 5.63 |
| Creativity | 2 | 0.17(0.48) | −0.11(−0.51) | 0.45(1.47) | 5.58* |
| Satisfaction | 1 | 0.08(0.08) | −0.32(−0.32) | 0.48(0.48) | 0.00 |

*Note.* Fixed-effects estimates are presented outside parentheses and random-effects estimates are within parentheses. On the basis of these overall results, only intrinsic motivation was examined for moderator effects. Although the effect of choice demonstrated a significant amount of heterogeneity (*Q*) for other outcomes as well, moderator analyses were not conducted for those outcomes with fewer than 15 samples contributing to the composite effect.
*$p < .05$. **$p < .01$.

(Patall et al. 2008 Psych Bull)

- Note:
  - also non-non learning situations
  - intrinsic motivation needed to be included (i.e., subsequent learning possibly skewed)

# END

- todo experise reversal effect
- relevance (keller)
- hattie
- book vs e-book
- sezame street
- feedback
- worked examples