Multimedia Learning
Meta-analyzes

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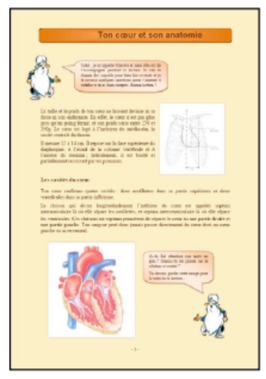
Multimedia learning

- 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

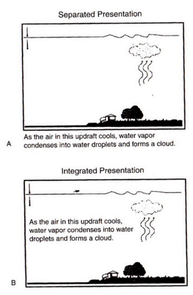


(Andery et al., 2016, SIG2)

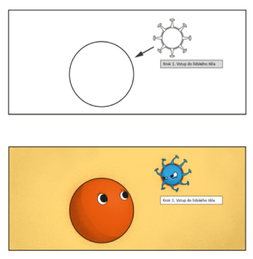
Research Questions

- Making the experiments simple

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



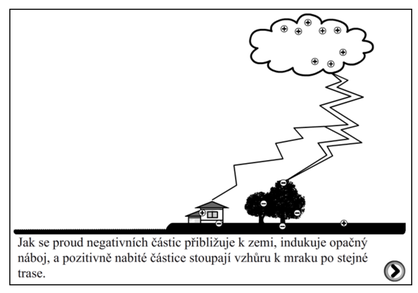
(Mayer & Moreno, 1998, J Edu Psy)



(Starkova et al., submitted)

Knowledge

- **Mental models**
  (e.g., Jones et al.,2011, Ecol Soc)
- Retention
- Transfer



(Moreno & Mayer, 2000, J Edu Psy)

Table 2.1. Retention and Transfer Questions for the Lightning Lesson

Retention Test
Please write down an explanation of how lightning works.
Transfer Test
What could you do to decrease the intensity of lightning?
Suppose you see clouds in the sky, but no lightning. Why not?
What does air temperature have to do with lightning?
What causes lightning?

(Mayer 2009)

Knowledge

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Table 2.1. Retention and Transfer Questions for the Lightning Lesson

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What causes lightning?

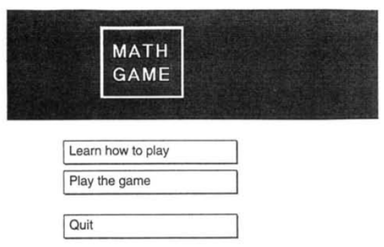
(Mayer 2009)

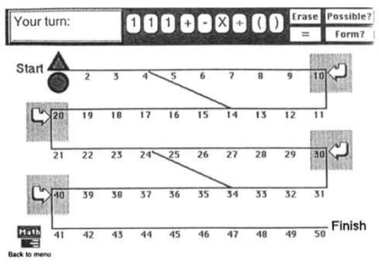
Effect sizes in educational sciences
(Cohen, 1988)

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

Cordova & Lepper

- Participants: 10.49 y; *N* = 72; 3 x 30 min
- Topic: Math game, move forward by computing a task
- Design: Abstract game vs. story + choice + customization (1 + 2 x 2)

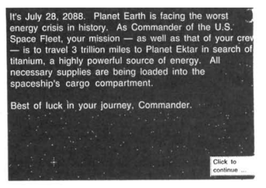




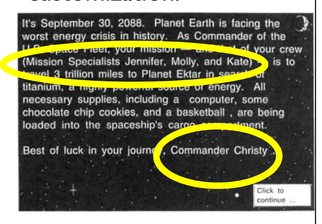
(Cordova & Lepper 1996 Jn Edu Psy)

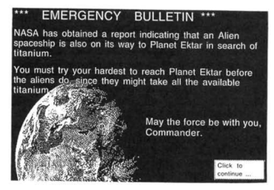
Cordova & Lepper

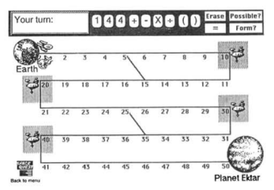
- Abstract game vs. story + choice + customization



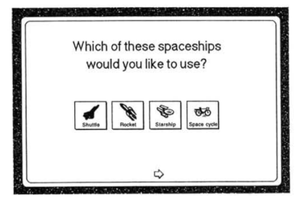
customization:







choice:



Cordova & Lepper

learning / motivation

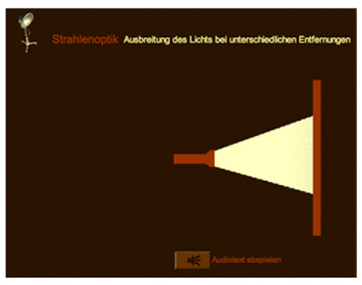
- Abstract game vs. story: *d* ~ **0,6** / **0,3**
- Choice vs. no-choice: *d* ~ **0,4** / **0,8**
- Customization vs. no cust. : *d* ~ **1,3 / 0,7**
- Abstract game vs. full game: *d* ~ **2,5** / **3,3**

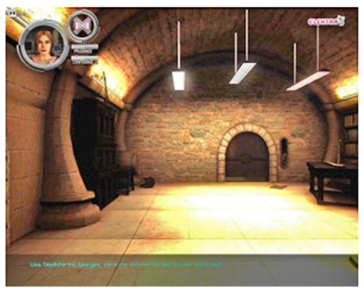
Schrader & Bastiens 2012

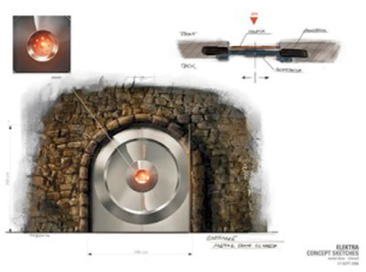
- Participants: 13.4 y; *N* = 84; 3 x 30 min
- Topic: Light refraction, magnetism, air resistance
- Design: 1 + 1
  - 3D virtual reality adventure game (narrative)
  - Hypertext environment with the same tasks & 2D pictures and animations

(Schrader & Bastiens, 2012, Comp Hum Beh)

Schrader & Bastiens 2012







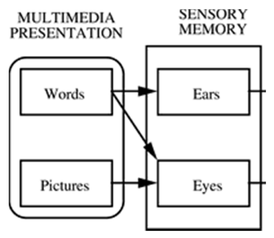
Schrader & Bastiens 2012

	Experimental condition (Exp) High-immersive educational computer game (*n* = 42) *M* (*SD*)	Control condition (Ctrl) Low-immersive educational computer application (*n* = 42) *M* (*SD*)
Virtual presence	3.65 (*.87*)	3.24 (*.66*)
Involvement and control	3.70 (*.97*)	3.14 (*.86*)
Distraction	3.53 (*.18*)	2.79 (*.18*)
Cognitive load	2.66 (*.54*)	2.55 (*.82*)
Learning outcomes		
Retention	1.26 (*.21*)	2.33 (*.31*)
Comprehension	1.00 (*.24*)	1.83 (*.21*)
Near transfer	2.11 (*.19*)	2.76 (*.48*)
Far transfer	.69 (*.24*)	1.38 (*.32*)
Game knowledge	4.21 (*1.45*)	

Explanations?

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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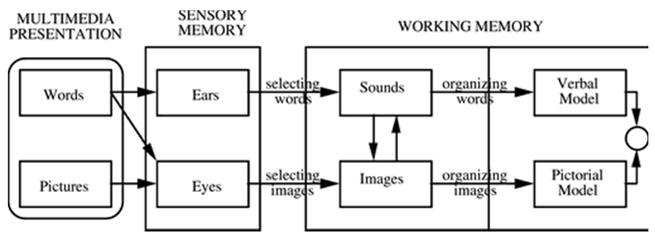

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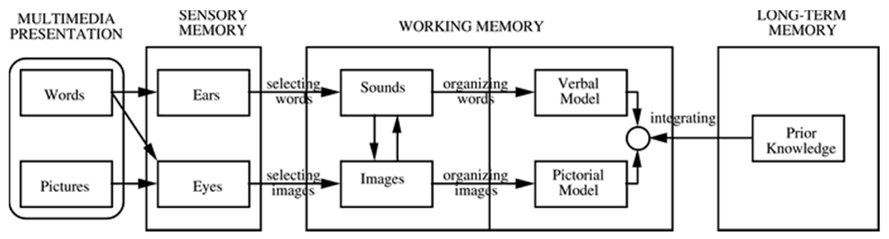


Where is motivation?

Theoretical model I.

- Cognitive theory of multimedia learning

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

Theoretical model II.

"nice"

- Cognitive-affective theory of learning from media (Moreno 2005)

Theoretical model II.

"nice" —+→ affective-motivational incentives

- positive affect
- enjoyment
- flow
- …

- Cognitive-affective theory of learning from media (Moreno 2005)

Theoretical model II.

"nice" —+→ affective-motivational incentives —+→ cognitive processes

- higher cognitive engagement
- improved self-regulation
- …

- Cognitive-affective theory of learning from media (Moreno 2005)

Theoretical model II.

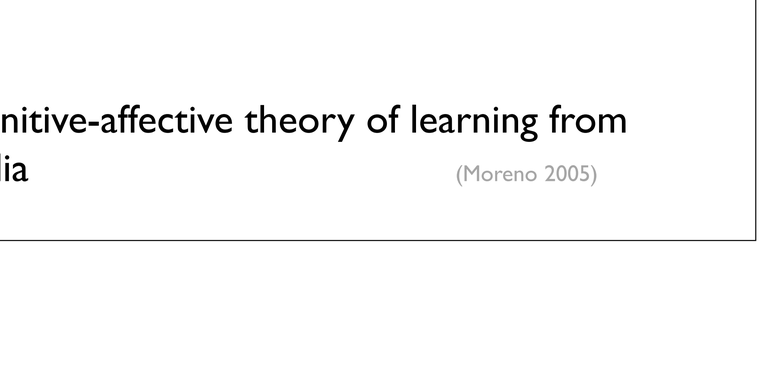
"nice" —+→ affective-motivational incentives —+→ cognitive processes —+→ learning outcomes

- better

- Cognitive-affective theory of learning from media (Moreno 2005)

Theoretical model II.

"nice" —+→ affective-motivational incentives —+→ cognitive processes —+→ learning outcomes



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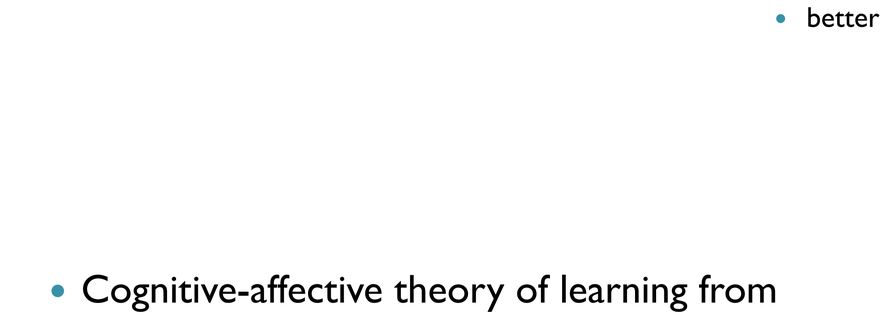
Theoretical model II.



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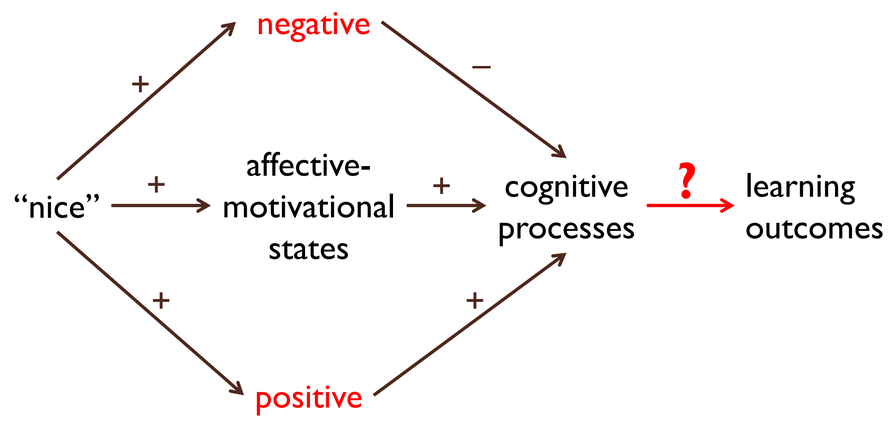

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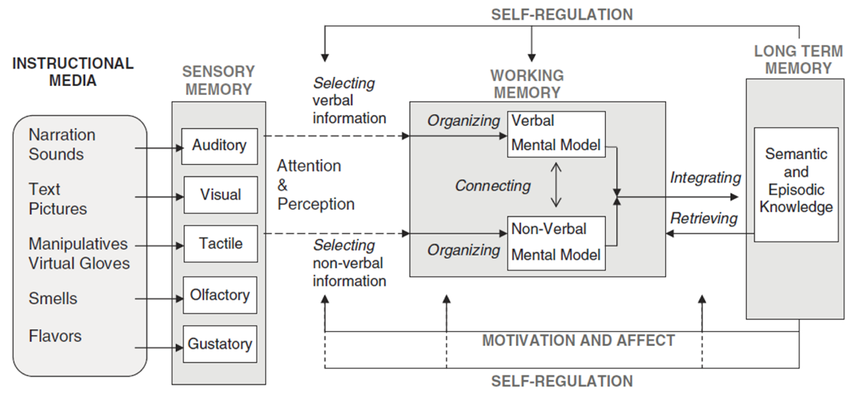

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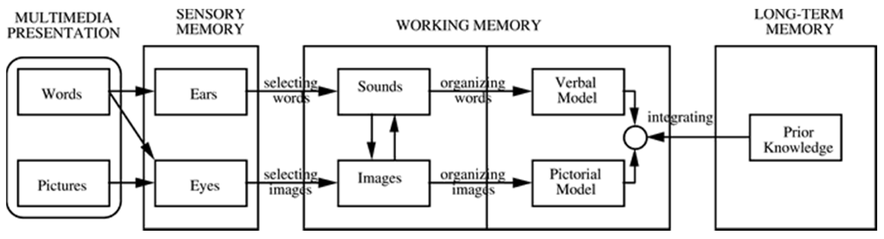


Narrative

(Echevaría et al. 2012 Comp Edu)

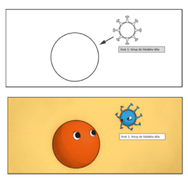
learning/ motivation

- Cordova & Lepper: 10-11 yr; no-story vs. story: **0,6** / **0,3**
- Jimenéz: grade 4; no-story vs. weak story vs. story: **0,5** (0,25) / ---
- McQuiggan et al. : 13-14 yr; light vs. strong story: **-0,3** / ---
- Schrader & Bastiens: 13-14 yr; no-story&2D vs. story&3D: **-2,5** / ---
- Echevaría et al., 16-18 yr; no-story vs. story&graphics: **-0,1** / **-0,9**
- Johnson-Glenberg et al.: college; no-story vs. cut-scenes: **-0,1** / **-0,1**
- Adams et al.: college; no-story vs. story: **0,2** / ---
- Koening et al.: college; no-story vs. story: **0,3** / **0,4**
- Huk & Ludwigs: 16-18 yr; no-story vs. story&grounding: **0,4** / ---

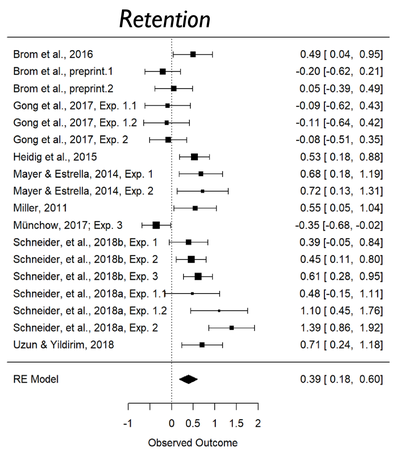
- Topper et al.: college; video vs. video&backstory: **0,5** (0,3) / **0,1**
  week later: **0** (0,4) / **0**

Meta-analyses

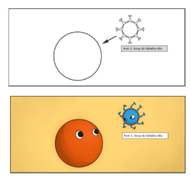
95% confidence interval for *d*



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

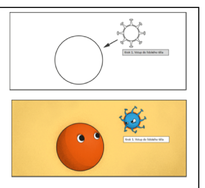


Meta-analyses: properties



- Search process
  - replicable
- Selecting studies
  - replicable
- Coding variables
  - replicable
- Statistical analysis
  - replicable

Search criteria



- Google Scholar, PsychINFO, ERIC, ScienceDirect
  - ("learning gains" OR "learning gain" OR "posttest" OR "post-test" OR "learning outcome" OR "learning outcomes") AND
  - ("**emotional design**") OR
  - (("**anthropomorphisms**" OR "anthropomorphism") AND "multimedia learning") OR
  - (("**pleasant colors**" OR "pleasant color" OR "aesthetic colors" OR "aesthetic color") AND "multimedia learning")
- 1990 – March 2018

Inclusion criteria

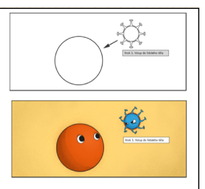
- (Quasi-)experiment
- Positive-activating emotions
  - not: negative
- Learning outcomes
- Statistics for computing effect sizes
- Pleasant colors, anthropomorphisms, both
  - not: color of surrounding context (e.g., walls)
  - not (explicitly): cueing
  - not: random color manipulations (e.g., monochrome versus colorful instructional film)
  - not: appearance of pedagogical agents

excluded:

(Kumar 2016, PhD thesis)

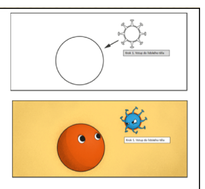
(Domagk 2010, J Media Psy)

Sample



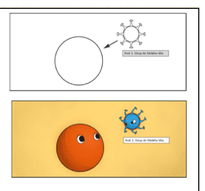
- 20 manuscripts
- *k* = 33 independent samples
- *N* = 2924

Dependent variables



- Learning outcomes
  - retention
  - comprehension
  - transfer
- Affective-motivational
  - generalized positive affect
  - liking/enjoyment
  - intrinsic motivation
- Learning perception
  - perceived effort
  - perceived difficulty
  - perceived learning

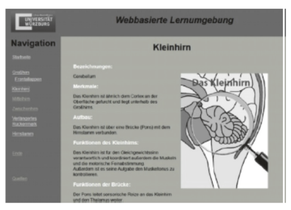
Study variables



- Experimental contrast
  - color
  - anthropomorphisms
  - both (color + anthro)
  - combined

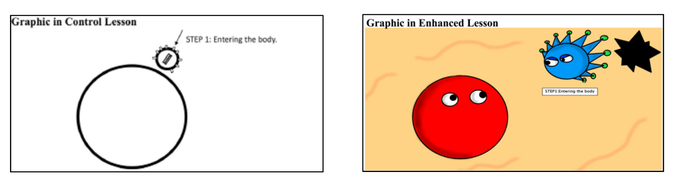
Experimental contrast

- "Color"



(Münchow et al., 2017, Edu Res Int)

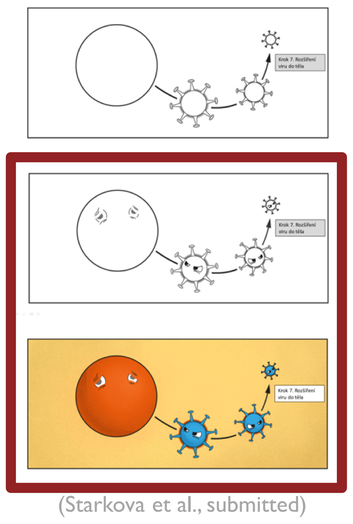
- "Both"



(Mayer & Estrella, 2014, Ln Instr)

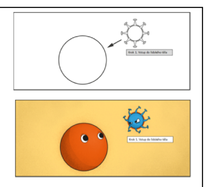
Experimental contrast

- "Combined"



(Starkova et al., submitted)

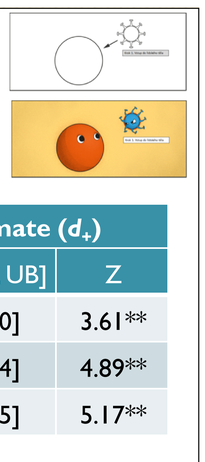
Results



	Sample		Meta-analytic estimate (d_+)		
Measure	*k*	*n*	Estimate (SE)	95% CI [LB, UB]	Z
Retention	18	1759	**0.39** (0.11)	[0.18, 0.60]	3.61**
Comprehension	14	1404	**0.32** (0.07)	[0.19, 0.44]	4.89**
Transfer	27	2281	**0.33** (0.06)	[0.20, 0.45]	5.17**

+ $p < .1$ * $p < .05$ ** $p < .01$

Results



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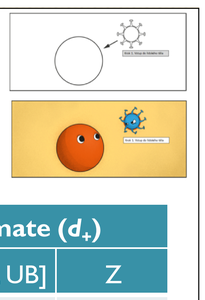
Liking/Enjoyment	20	1474	**0.11** (0.05)	[0.01, 0.21]	2.06*
Positive affect	15	1407	0.11 (0.06)	[-0.01, 0.23]	1.88†
Intrin. motivation	23	2023	**0.26** (0.09)	[0.09, 0.42]	2.95**

+ $p < .1$ * $p < .05$ ** $p < .01$

Results



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Intrin. motivation	23	2023	**0.26** (0.09)	[0.09, 0.42]	2.95**
Perceived effort	20	1215	0.05 (0.14)	[-0.23, 0.33]	0.36
Perc. difficulty	14	967	**-0.21** (0.07)	[-0.35, -0.06]	-2.80**
Perc. learning	11	739	0.10 (0.08)	[-0.06, 0.25]	1.21

+ $p < .1$ * $p < .05$ ** $p < .01$

Moderation

- Example: Narrative
  - what if the effect is caused 3D graphics?
  - what if the effect is caused by age of participants?

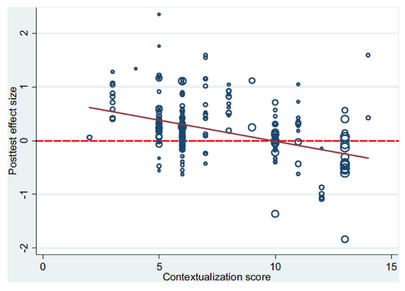
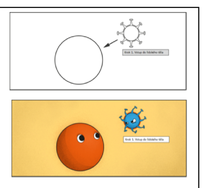


FIGURE 2. *Scatter plot of pretest-adjusted posttest effect sizes and overall contextualization aggregate score for digital game versus nongame conditions (media comparisons).*
Note. Each effect size shown proportionate to its weight in the meta-analysis. Slope coefficient from meta-regression with robust variance estimation $b = -0.07$ ($p = .01$, 95% CI [−0.12, −0.01]).

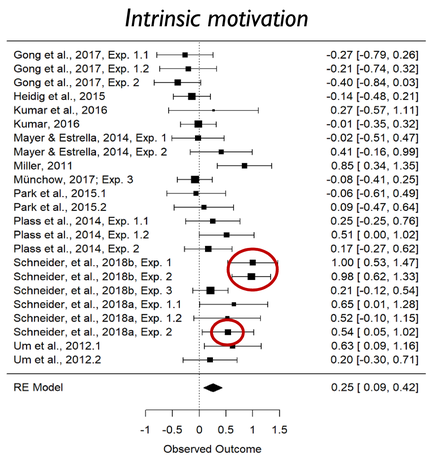
- view point (3rd person … 1st person)
- visual realism (schematic … realistic)
- anthropomorphisms (low … high)
- story relevance (none … relevant)
- story depth (thin … thick)

(Clark et al. 2016 Rev Edu Res)

Moderation: example



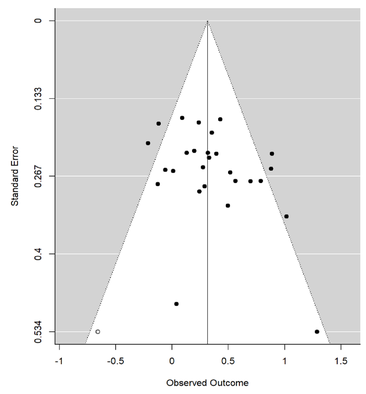
- Heterogeneous
  - age moderates the effect on intrinsic motivation



Publication bias

- **What is it?**

- Funnel plot & trim-and-fill analysis
- Moderation by publ. type



Digital learning games vs. "traditional" teaching

(Wouters et al. 2013 J Edu Psy)

- Learning outcomes immediate:
  - k = 77, N = 5547
  - d = **0.29** [0.17, 0.42]
- Learning outcomes delayed:
  - k = 16, N = 499
  - d = **0.36** [0.07, 0.68]
- Motivational outcomes:
  - k = 31, N = 2,216
  - d = **0.26** [-0.03, 0.56]

- **Reasons?**

Technology-enhanced learning

(Tamim et al. 2011 Rev Edu Res)

- Technology vs. no technology

- Meta-meta-analysis
  - 25 meta-analyzes
  - 1055 primary studies
  - ~109 700 participants
- d = 0.32

Active learning

(Freeman et al. 2014 PNAS)

- STEM "active learning" vs. "lecture"
- Performance
  - k = 158
  - N = ??
  - d = 0.47
- Failure rate
  - k = 67
  - N = 29300
  - 1.5 more likely to fail in "lecture" (21.8% vs. 33.8%)

Active learning

(Freeman et al. 2014 PNAS)

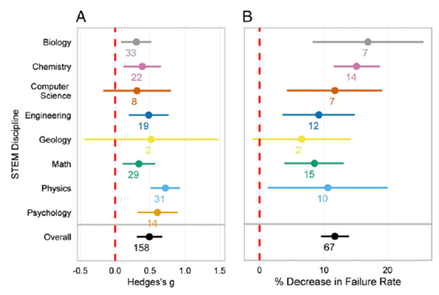


Fig. 2. Effect sizes by discipline. (*A*) Data on examination scores, concept inventories, or other assessments. (*B*) Data on failure rates. Numbers below data points indicate the number of independent studies; horizontal lines are 95% confidence intervals.

heterogeneous

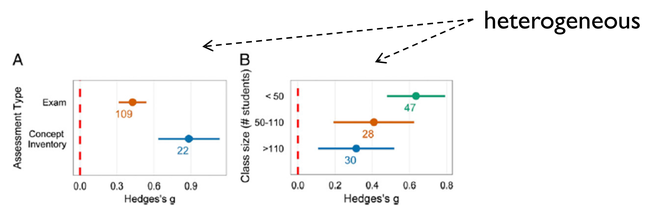


Fig. 3. Heterogeneity analyses for data on examination scores, concept inventories, or other assessments. (*A*) By assessment type—concept inventories versus examinations. (*B*) By class size. Numbers below data points indicate the number of independent studies; horizontal lines are 95% confidence intervals.

Active learning

(Freeman et al. 2014 PNAS)

Table 1. Comparing effect sizes estimated from well-controlled versus less-well-controlled studies

Type of control	*n*	Hedges's *g*	SE	95% confidence interval: Lower limit	95% confidence interval: Upper limit
For student equivalence					
Quasirandom—no data on student equivalence	39	0.467	0.102	0.268	0.666
Quasirandom—no statistical difference in prescores on assessment used for effect size	51	0.534	0.089	0.359	0.709
Quasirandom—no statistical difference on metrics of academic ability/preparedness	51	0.362	0.092	0.181	0.542
Randomized assignment or crossover design	16	0.514	0.098	0.322	0.706
For instructor equivalence					
No data, or different instructors	59	0.472	0.081	0.313	0.631
Identical instructor, randomized assignment, or ≥3 instructors in each treatment	99	0.492	0.071	0.347	0.580

Limitations

- Example: Active learning
  - Media comparison (what is what)
  - Missing "active learning" interventions, e.g., games
  - Is "passive" lecture passive?

Intervention type	*n*	Hedges' *g*	s.e.	95% C.I.: lower limit	95% C.I.: upper limit
Case studies	2	0.472	0.477	-0.463	1.408
Clickers	19	0.507	0.132	0.249	0.765
Interactive demonstrations	2	0.389	0.472	-0.536	1.313
Combination designs (multiple interventions)	18	0.702	0.144	0.420	0.985
Problem-based learning	9	0.156	0.189	-0.215	0.526
Quizzing	5	0.361	0.243	-0.115	0.837
Studio/workshop	9	0.772	0.172	0.435	1.109
Worksheets (cooperative group problem solving)	90	0.364	0.063	0.240	0.487

(Freeman et al. 2014 PNAS)

Note that *n*'s may not sum to 158, due to missing data.

Limitations

- **You have to read Methods and Supplements**

To create a working definition of active learning, we collected written definitions from 338 audience members, before biology departmental seminars on active learning, at universities throughout the United States and Canada. We then coded elements in the responses to create the following consensus definition:

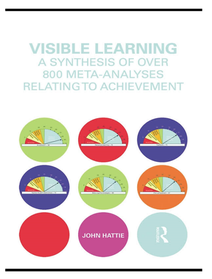
> Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work. (See also ref. 31, p. iii).

Following Bligh (32), we defined traditional lecturing as "...continuous exposition by the teacher." Under this definition, student activity was assumed to be limited to taking notes and/or asking occasional and unprompted questions of the instructor.

traditional vs. active, not differing in more than 30min/wk

Note that criterion *i* yielded papers representing a wide array of active learning activities, including vaguely defined "cooperative group activities in class," in-class worksheets, clickers, problem-based learning (PBL), and studio classrooms, with intensities ranging from 10% to 100% of class time (*SI Materials and Methods*). Thus, this study's intent was to evaluate the average effect of any active learning type and intensity contrasted with traditional lecturing.

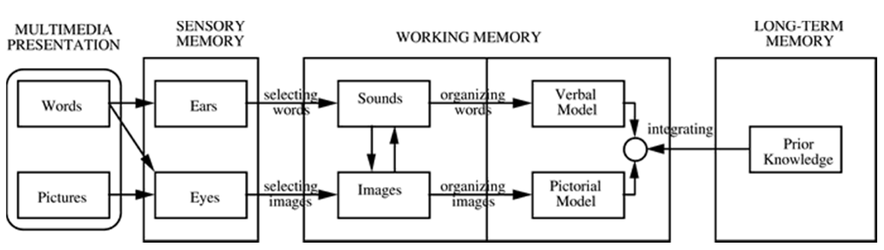
Summary



- Meta-analyses:
  - replicable
  - interpretable: garbage in, garbage out
  - the devil is in the detail
- Selecting, organizing, integrating
- Motivation
- Distraction

My homework

- **What could work for… ?**
  - selecting
  - organizing
  - integrating



(Mayer 2009)

Tereza's homework

Questions?