Multimedia Learning
Variables

Cyril Brom, Tereza Hannemann
Charles University
Faculty of Mathematics and Physics
Advanced Multimedia Learning Laboratory

brom@ksvi.mff.cuni.cz
hannemann@ksvi.mff.cuni.cz
ksvi.mff.cuni.cz/amulab

Type of variables I.

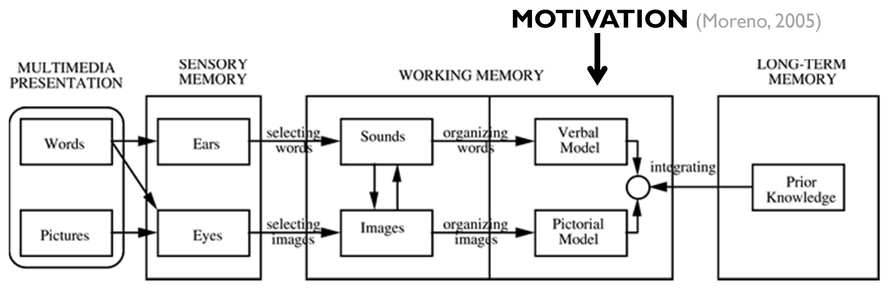
- Manipulated variable
- Dependent (outcome) variable
- Control variable
- Manipulation check variable
- Mediating variable
- Moderating variable

Type of variables II.

- Objective
  - knowledge outcomes
  - biofeedback
  - eye tracking
  - …
- Subjective
  - self-reports
  - think-aloud
  - retrospective judgement
  - …

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



A hypothetical affective-motivational design principle

- Do this […miracle…] and learners' affective-motivational states and **consequently** learning outcomes will be enhanced

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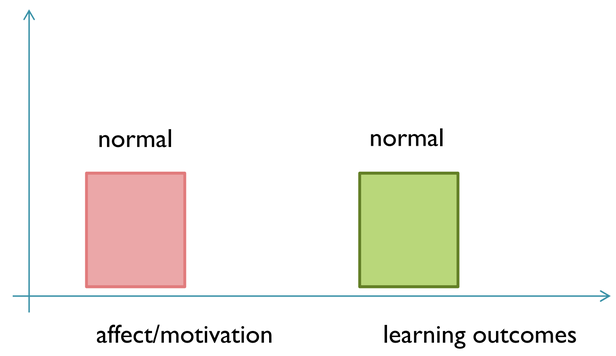

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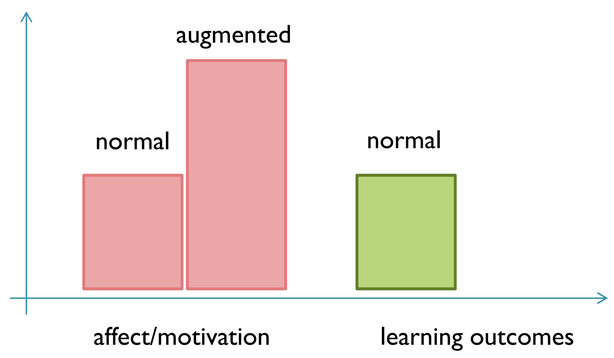

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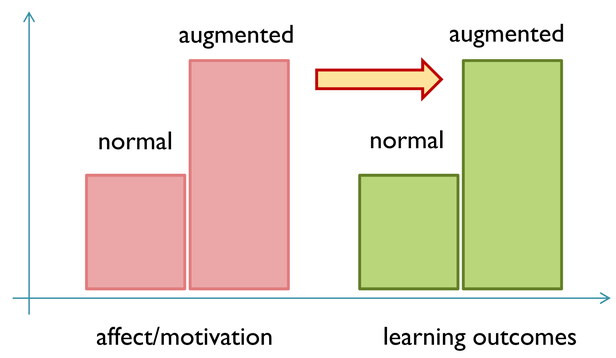

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- Cognitive-Affective Theory of Learning from Media [Moreno, 2005]
- Cognitive Load Theory [Sweller et al., 2011; Kalyuga, 2011]
  - intrinsic vs. extraneous load

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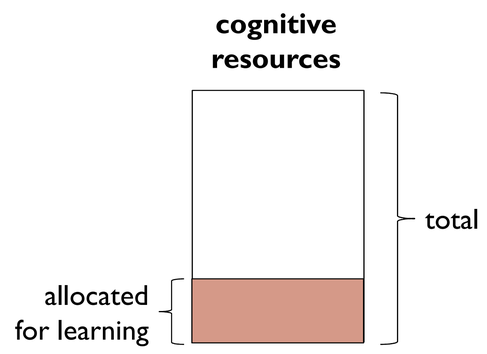

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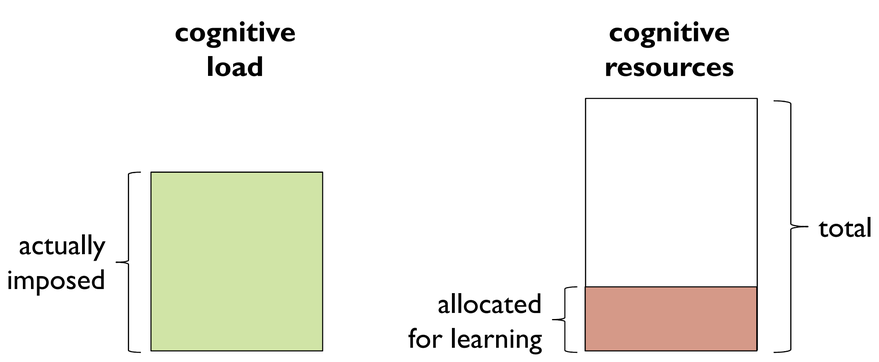

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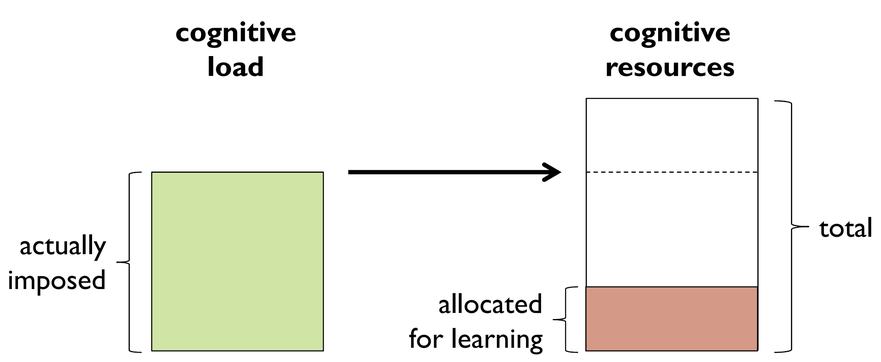

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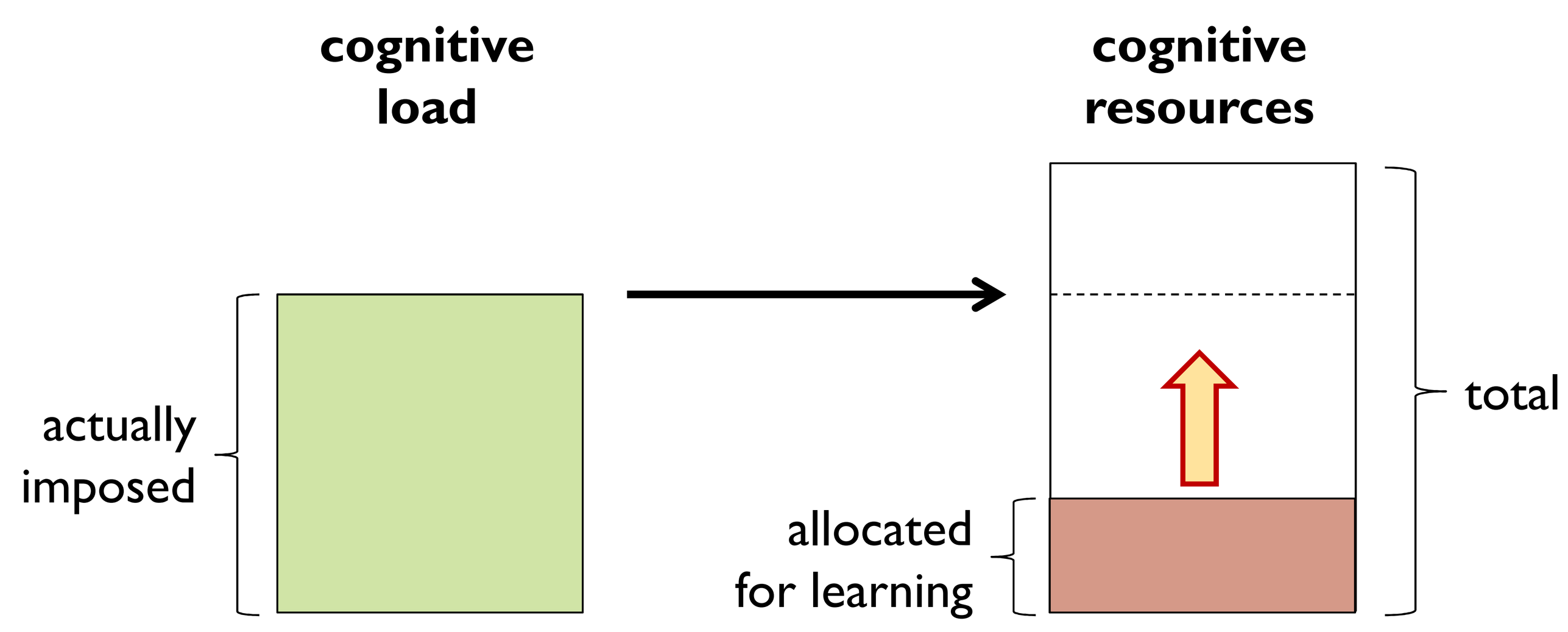

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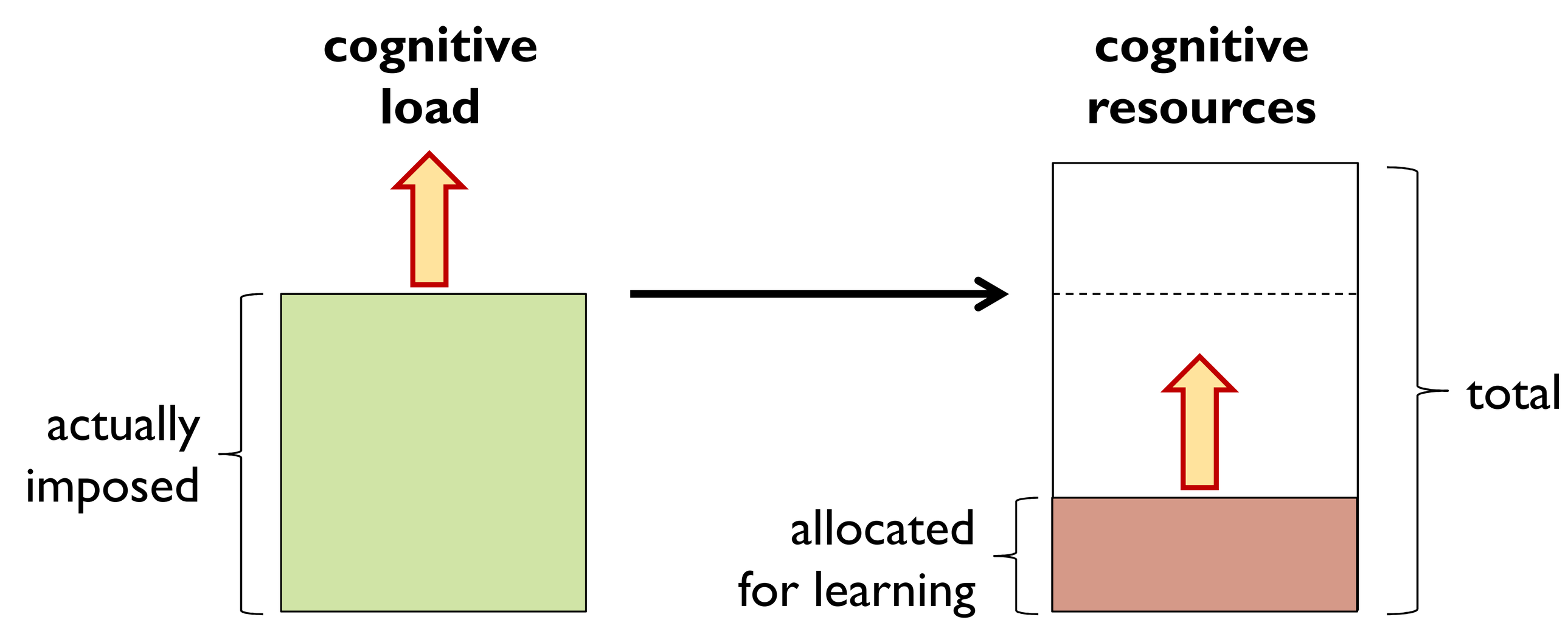

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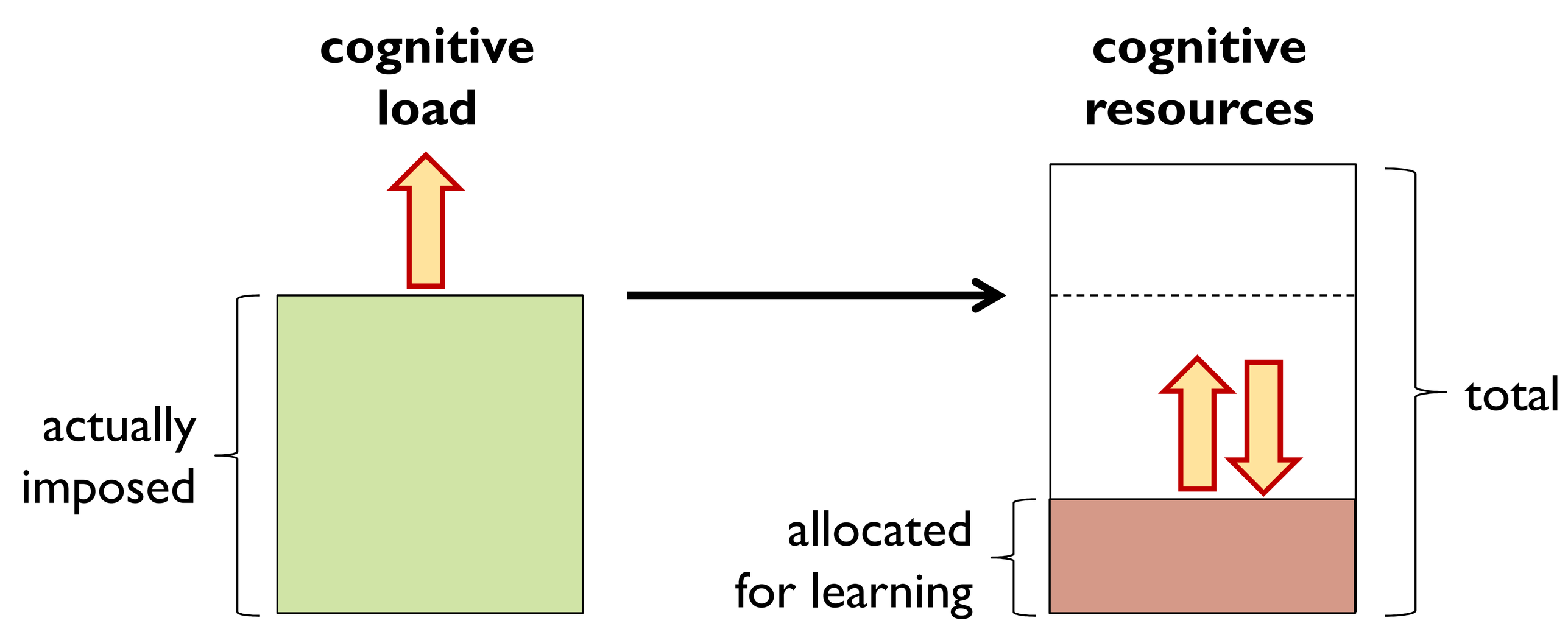

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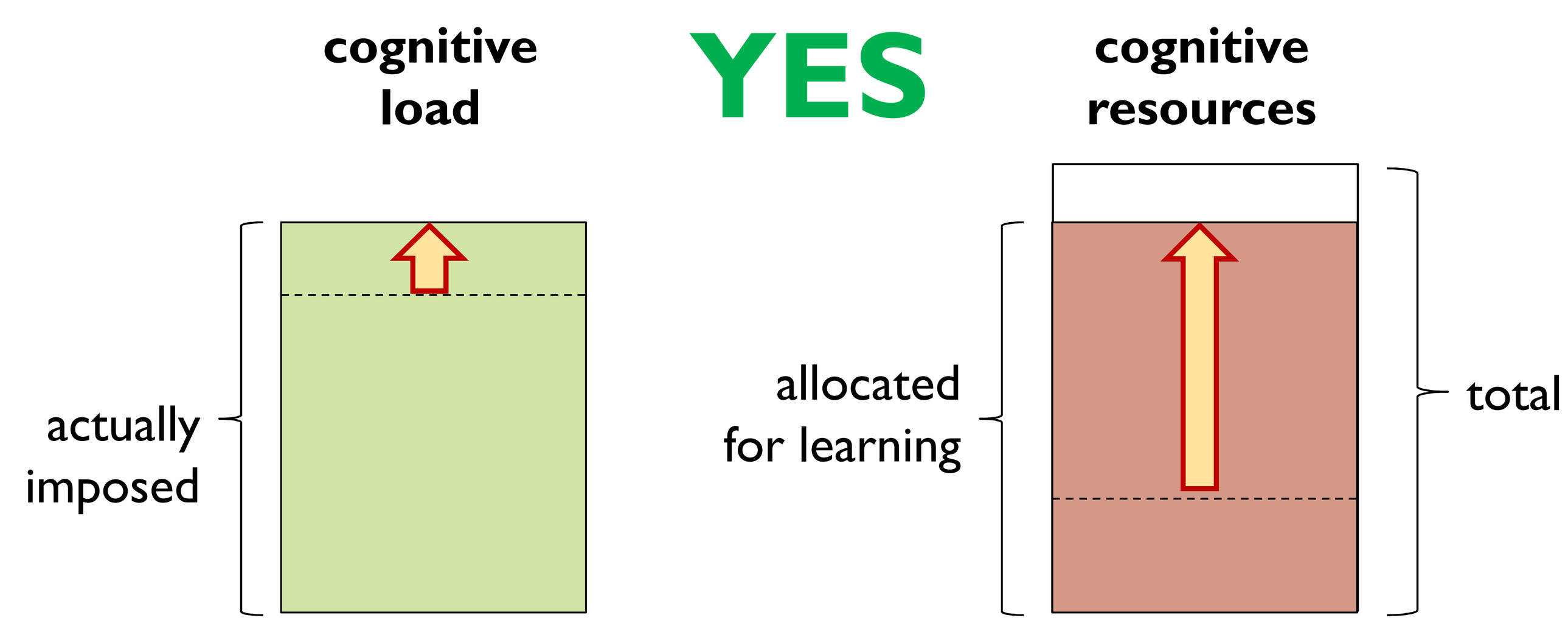

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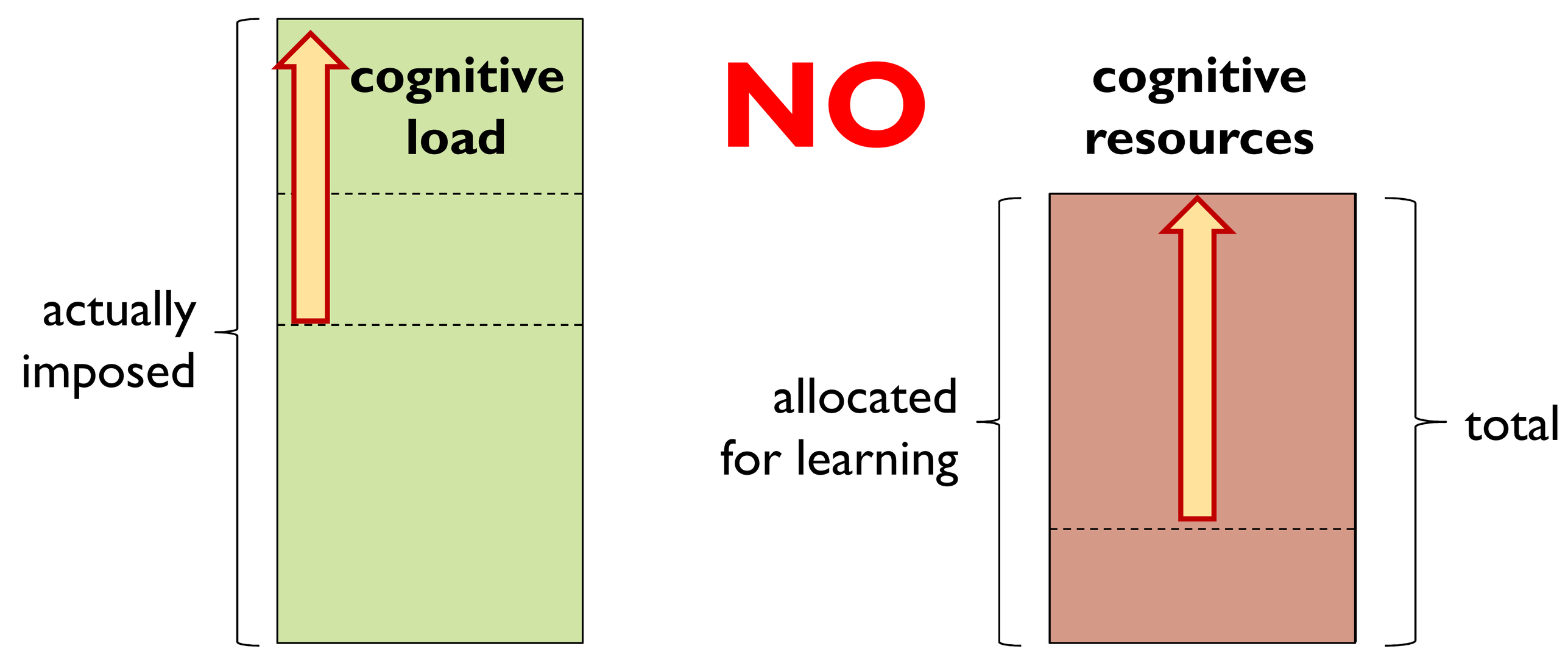
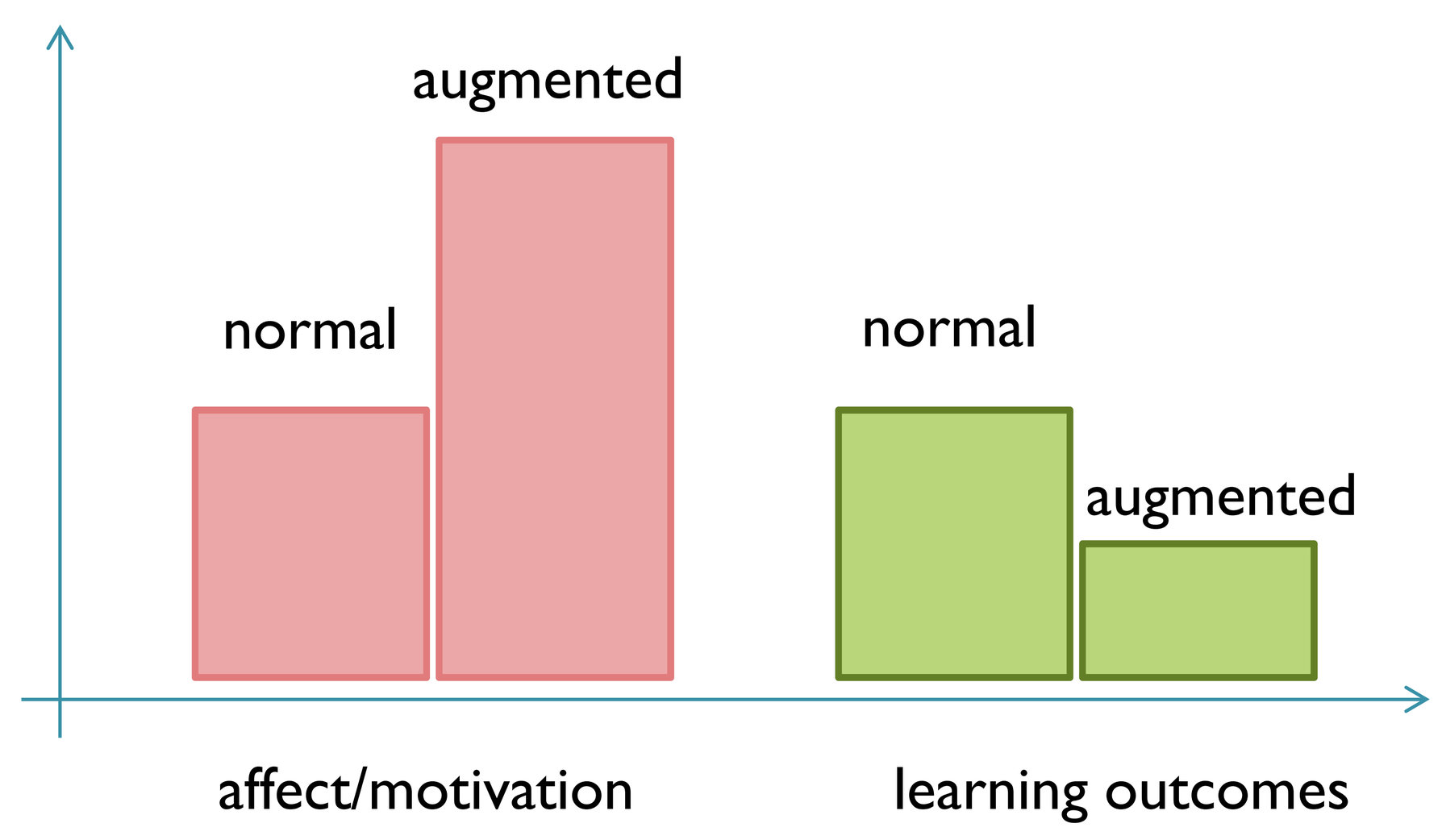


Possible principles

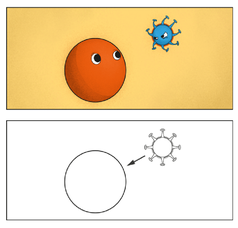
…and by the way, Edison was a kind of patent troll…

- Extraneous details [Garner et al., 1992; Rey, 2012]



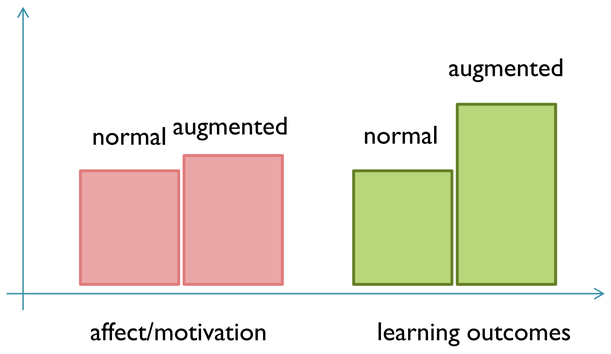
Possible principles

[Mayer & Estrella, 2014; Stárková et al., in prep.]



- Anthropomorphisms, color
  [Um et al., 2012; Münchow,et al., 2017; Plass & Kaplan, 2015]
- Personalization principle
  [Ginns et al., 2013]

…as raindrops and ice crystals fall through [your] ~~the~~ cloud, they…



Possible principles

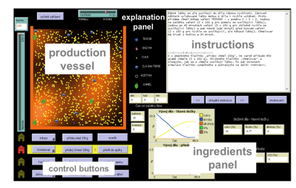
- Narrative
- Tutor/agent image
- Prosody
- Competition
- …

not enough data
mixed results

Problem statement

- "Affective-motivational" miracles unknown
- No approach consistently elevates **both positive affective-motivational factors** and **learning outcomes**
- Difficult to investigate affective-motivational mediation

Pretended topic manipulation



- 90-min long instructional simulation
- Beer vs. Citrate substrate (i.e., a bacterial growth medium)

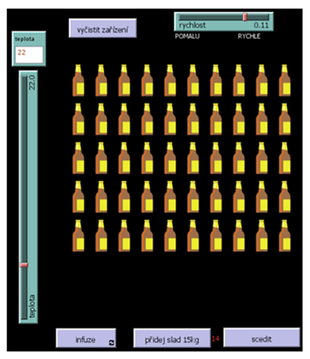
[Brom et al., 2017, CAE]

Manipulation

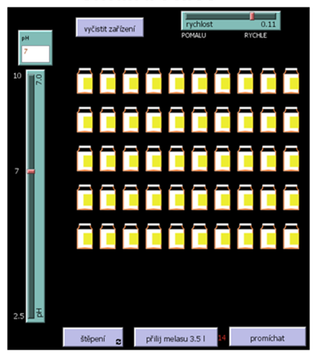
- Minimalistic change
  - The same learning process
  - ~25 word/short phrases replacements
    - yeast → fungal culture
    - acetone → toxin
  - Two superficial changes to graphics

Manipulation – graphics

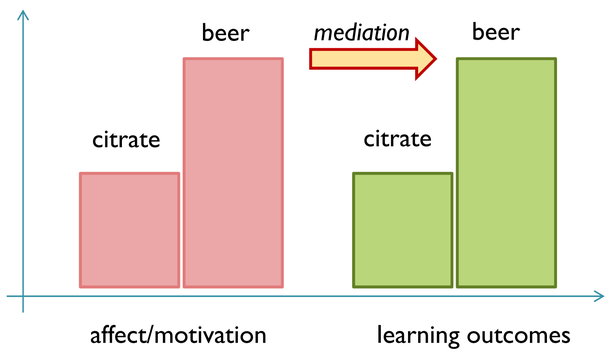
final product: beer in bottles



final product: substrate in small bottles



Hypotheses



Participants

- University (age ~ 24 years)
- Psychology, computer science, new media
- *N* = 30 + 35
- Low prior knowledge learners

Variables

Topic: beer brewing vs. citrate substrate

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Manipulation checks: → Perceived value

Variables

Topic: beer brewing vs. citrate substrate

Manipulation checks: → Perceived value (*d* = 1.13)

Variables

Topic: beer brewing vs. citrate substrate

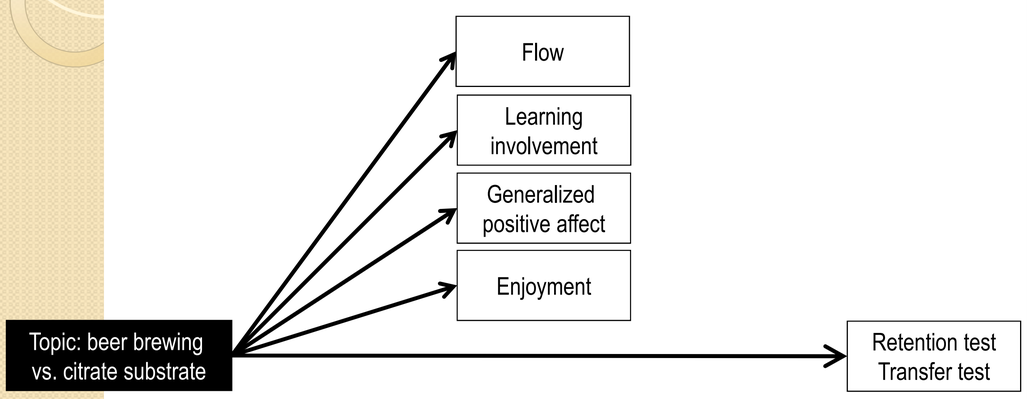
→ Flow (10 items) [Rheinberg & al., 2003]

→ Learning involvement (8 items)

→ Generalized positive affect (10 items) [Watson et al., 1988]

→ Enjoyment (3 items)

Variables



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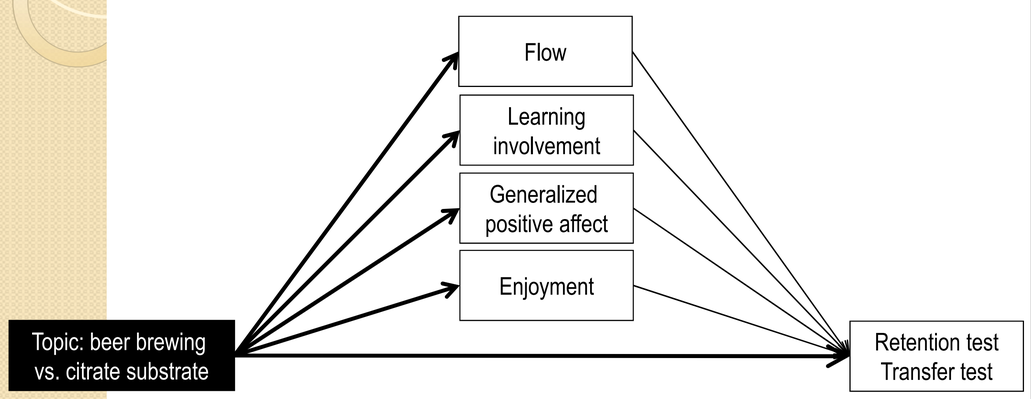

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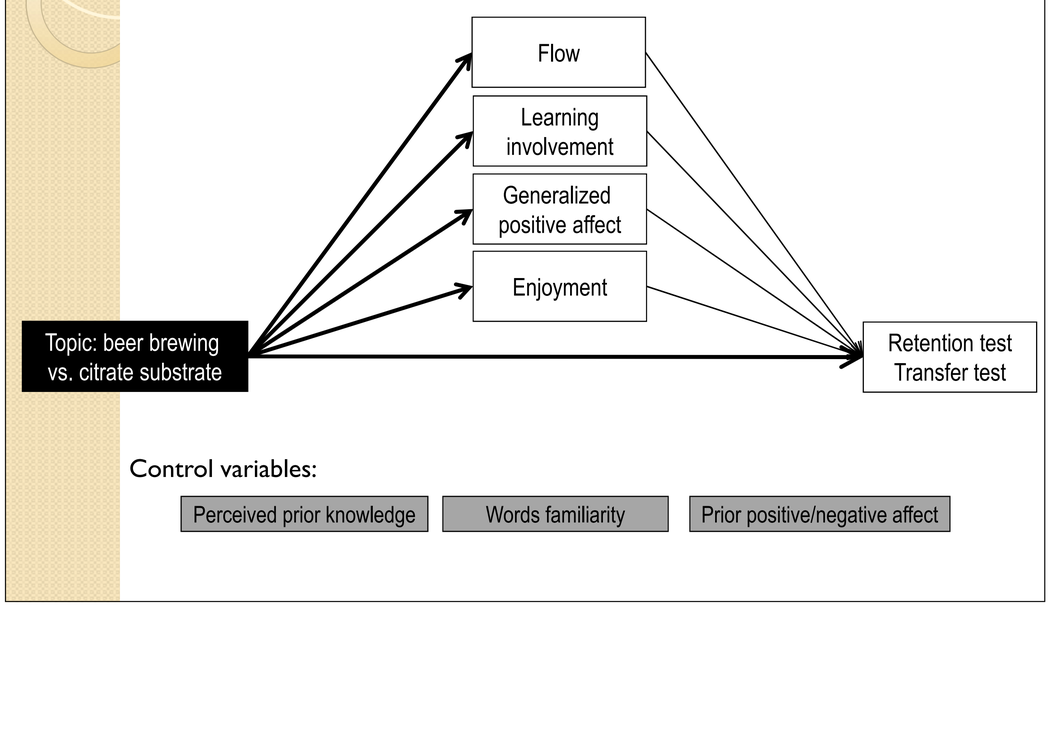


Results

Variable	Citrate substrate	Beer brewing	d
positive affect [10 – 50]	28.7 (7.21)	32.1 (6.48)	**0.44+**
flow [21 – 74]	53.4 (6.83)	57.3 (7.86)	**0.55***
learning involvement [8 – 56]	42.1 (6.88)	46.9 (5.32)	**0.70****
enjoyment [1 – 6]	4.83 (0.69)	5.40 (0.50)	**0.87****
retention immediate [0 – 31]	22.8 (5.05)	24.9 (3.99)	**0.48+**
retention delayed [0 – 31]	13.4 (6.08)	18.0 (6.71)	**0.66***
transfer immediate [Z-scores]	0.17 (0.93)	0.67 (0.84)	**0.46+**
transfer delayed [Z-scores]	-0.70 (0.86)	-0.08 (0.87)	**0.62***

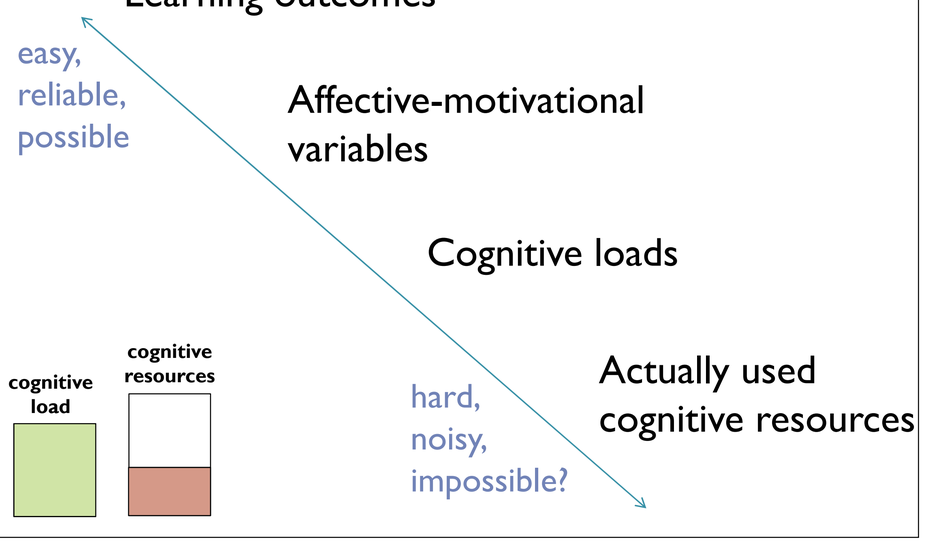
+ $p < .1$ * $p < .05$ ** $p < .01$

Results – mediation

- Immediate test scores
  - **Yes:**
    - Learning involvement ($p < .01$)
    - Flow ($p \sim .05$)
  - **No:**
    - Positive affect
    - Enjoyment
- Delayed test scores
  - The same immediate test scores
  - But after covarying out initial learning
    - **No** mediation detected

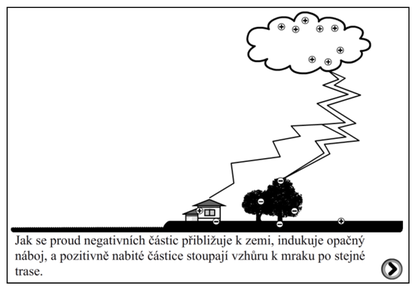
Easy to measure with self-reports?

[disclaimer: my experience]



Knowledge

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



(Moreno & Mayer, 2000, J Edu Psy)

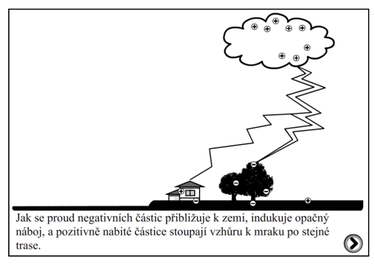
Table 2.1. Retention and Transfer Questions for the Lightning Lesson

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)

Types of transfer test questions

- Redesign
- Troubleshooting
- Prediction
- Conceptual
  (Mayer 2009)



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Grading

- Retention
  - contains key ideas (e.g., 1 pt ~ 1 screen)
  - sentences need not be word-for-word
  - terminologie must be exact
- Transfer
  - no terminology needed
  - contains „idea units“
    - pre-studies

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Transfer: idea units

- What does air temperature has to do with lightning? Write down **all possibilities** that occur to you.
  - cold wind before the storm
  - air gets warm and starts to rise
  - in colder temperatures, water vapor condenses into water droplets and forms a cloud
  - when the cloud's top extends above the freezing level, ice crystals starts to form
  - when temperature is below zero, it'll be snowing (and no lightning)
  - ...

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Checks

- Pre-studies
  - ~50 % correct answers (Mean); SD ~ 10 %
- 2 raters, agreement ~90%
- Item analysis
- Internal consistency, Cronbach's alpha
  - but mind complex systems (alpha can be low)

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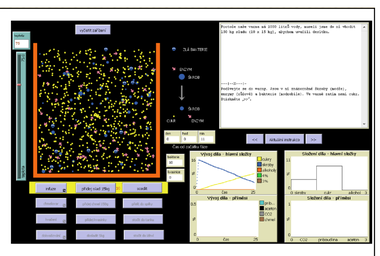
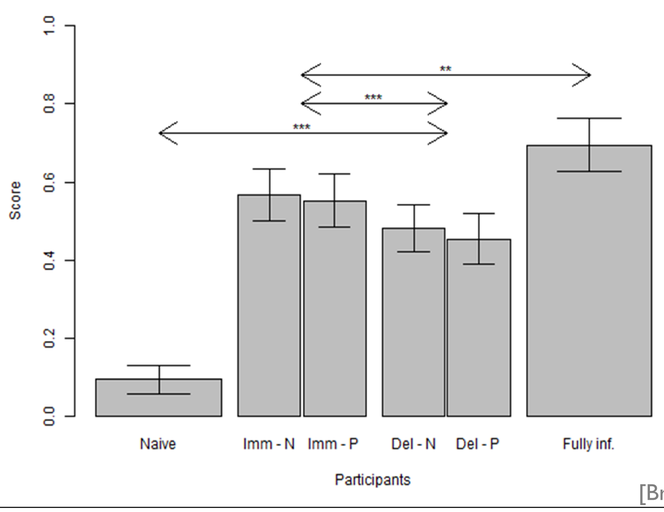
External validity





[Brom et al., 2014, CAE]

Pre-tests - issues

- Cueing
- Testing effect
- Self-assesses prior knowledge
  - low correlation with post-tests
  - self-confidence etc.

- Solomon design
- Zero prior knowledge
- Randomization

Positive-activating activity-realted affective-motivational states

Object focus	Positive[a] Activating	Positive[a] Deactivating	Negative[b] Activating	Negative[b] Deactivating
Activity	Enjoyment	Relaxation	Anger Frustration	Boredom
Outcome/ Prospective	Hope Joy[c]	Relief[c]	Anxiety	Hopelessness
Outcome/ Retrospective	Joy Pride Gratitude	Contentment Relief	Shame Anger	Sadness Disappointment

[a]Positive = pleasant emotion
[b]Negative = unpleasant emotion
[c]Anticipatory joy/relief

(Pekrun & Linnenbrink & Garcia, 2012)

Situation interest

Phases of interest development

Phase 1: Triggered situational	*Phase 2: Maintained situational*	*Phase 3: Emerging individual*	*Phase 4: Well-developed individual*

(Hidi & Renninger 2006 Educ Psych)

- This object/activity was:
  - feeling related
    - exciting
    - entertaining
    - boring (reverse-coded)
  - value related
    - useful
    - worthless
    - unimportant (Schiefelle, 1990)

Enjoyment

- I enjoyed doing this activity
- I thought this was a boring activity
- I would describe this activity as very interesting

Intrinsic motivation

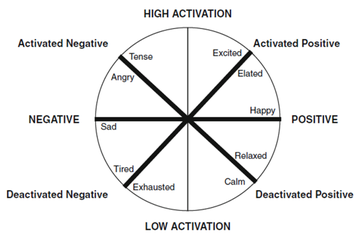
- I enjoyed doing this activity very much
- This activity was fun to do.
- This activity did not hold my attention at all (reverse-coded)
- I would describe this activity as very interesting.
- While I was doing this activity, I was thinking about how much I enjoyed it.

(McAuley, Duncan & Tammem, 1989)

Positive affect

- I feel right now/have felt [time period]:
  - interested
  - excited
  - strong
  - enthusiastic
  - proud
  - alert
  - inspired
  - determined
  - attentive
  - active

(Watson, Clark & Tellegen, 1988)



(Barrett & Russell, 1998;
Pekrun & Linnenbrink & Garcia, 2012)

- Negative affect
  - distressed
  - upset
  - guilty
  - scared
  - hostile
  - irritable
  - ashamed
  - nervous
  - jittery
  - afraid

Flow

- I feel just the right amount of challenge.
- My thoughts/activities run fluidly and smoothly.
- I don't notice time passing.
- I have no difficulty concentrating.
- My mind is completely clear.
- I am totally absorbed in what I am doing.
- The right thoughts/movements occur of their own accord.
- I know what I have to do each step of the way.
- I feel that I have everything under control.
- I am completely lost in thought.

(Rheinberg, Vollmeyer, & Engesser, 2003)

Learning involvement

- So far, I'm enjoying [topic]
- I was always sure what I was supposed to do next
- I always knew how to complete the assigned tasks
- I'm tired
- I'm looking forward to the next part
- I focused on the [topic's] activity
- I think I am doing well so far
- I was careful and conscientious when completing the tasks.

(Brom et al., 2017, CAE)

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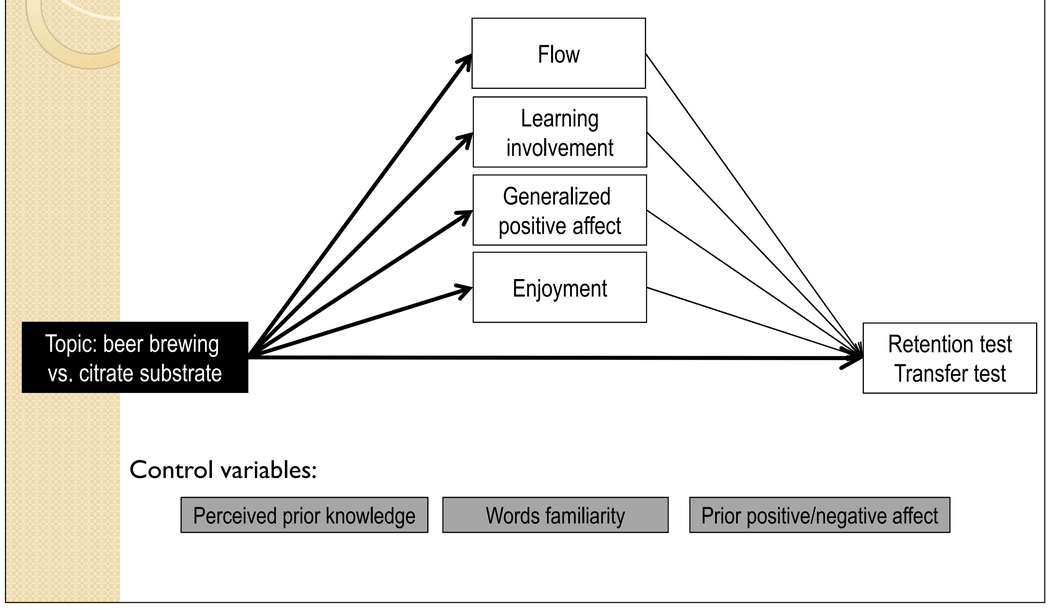


"Validation"

Experiment	Characteristics	*n*	Age group	Generalized positive affect [10-50]	Flow [21-74]	Generalized negative affect [10-50]
Beer Brewing	2-hour simulation, personalized version	36	university	32.89 (6.73)	55.43 (7.06)	14.24 (4.00)
(Brom, Bromová, et al., 2014)	2-hour simulation, direct version	39	university	31.26 (7.28)	55.71 (8.12)	13.86 (3.89)
Europe 2045	5-hour digital game	103	high school + university	30.95 (6.34)	50.86 (8.28)	17.86 (6.11)
(Brom, Šisler, et al., 2016)	5-hour non-digital game	96	high school + university	30.84 (7.21)	49.65 (8.36)	18.00 (6.57)
	5-hour discussion without gaming elements	126	high school + university	26.00 (6.77)	46.18 (7.77)	18.06 (6.15)
Beer Brewing – Gamified	2-hour simulation, gamified	31	university	32.26 (7.49)	57.23 (7.33)	13.45 (4.22)
(Brom et al., 2019)	2-hour simulation, personalized version	34	university	32.82 (7.03)	56.27 (8.28)	14.53 (5.28)
	2-hour simulation, direct version	33	university	30.20 (5.88)	54.11 (8.28)	13.71 (3.76)
Wastewater	6-minute animation, personalized version	37	university	31.86 (7.42)	57.32 (6.22)	12.30 (2.92)
(Brom, Hannemann et al., 2017)	6-minute animation, direct version	37	university	30.49 (6.03)	55.32 (8.21)	12.19 (3.69)
	6-minute animation, personalized version	37	high school	30.91 (7.15)	55.26 (8.17)	13.33 (3.33)
	6-minute animation, direct version	37	high school	30.89 (6.48)	54.47 (8.02)	14.59 (5.96)
Beer vs. Citrate	90-minute simulation, direct version, citrate substrate production	35	university	28.71 (7.21)	53.43 (6.83)	13.51 (3.91)
(Brom, Děchtěrenko et al., 2017)	90-minute simulation, direct version, beer brewing	30	university	32.10 (6.48)	57.28 (7.86)	12.87 (3.46)
First-aid training course; actors	15-minute life action training simulation; actors	12	young adults	34.08 (8.74)	58.58 (7.39)	14.25 (4.96)
(Brom, Buchtová, et al., 2014)						
Filling in of questionnaires at a delayed testing session	At the beginning a 30-minute long testing session	165	adults 18-34 years of age	23.27 (6.74)	-	13.89 (4.81)
(preliminary data)	At the end of a 30-minute long testing session	165	adults 18-34 years of age	22.19 (7.17)	-	13.41 (5.04)
Beginning of an experiment	6-minute animation (Wastewater, both conditions)	37+37	high school	28.60 (6.14)	-	16.97 (5.63)
(Brom et al., 2017)	6-minute animation (Wastewater, both conditions)	37+37	university	27.74 (6.28)	-	14.55 (3.69)

Cognitive load

(Pass, 1992; de Jong, 2010; Leppink et al.,2014)

- Difficulty:
  - How difficult was today's lesson on [topic] for you?
- Effort:
  - How much effort did you invest to learn today's topic?
- Intrinsic load:

  [1] The content of this activity was very complex.
  [2] The problem/s covered in this activity was/were very complex.
  [3] In this activity, very complex terms were mentioned.
  [4] I invested a very high mental effort in the complexity of this activity.

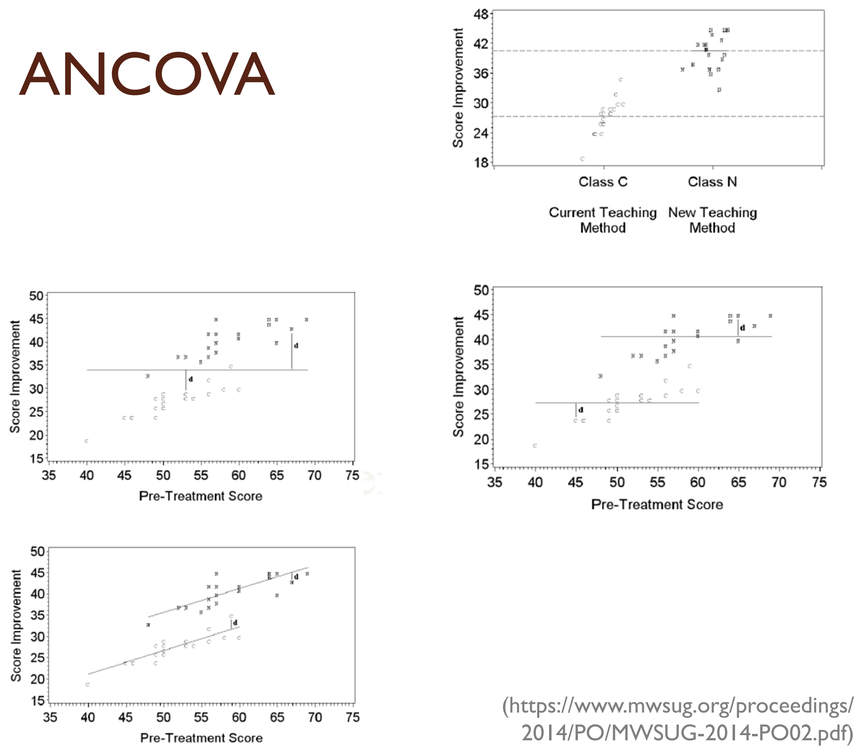
- Extraneous load:

  [5] The explanations and instructions in this activity were very unclear.
  [6] The explanations and instructions in this activity were full of unclear language.
  [7] The explanations and instructions in this activity were, in terms of learning, very ineffective.
  [8] I invested a very high mental effort in unclear and ineffective explanations and instructions in this activity.

Control variables

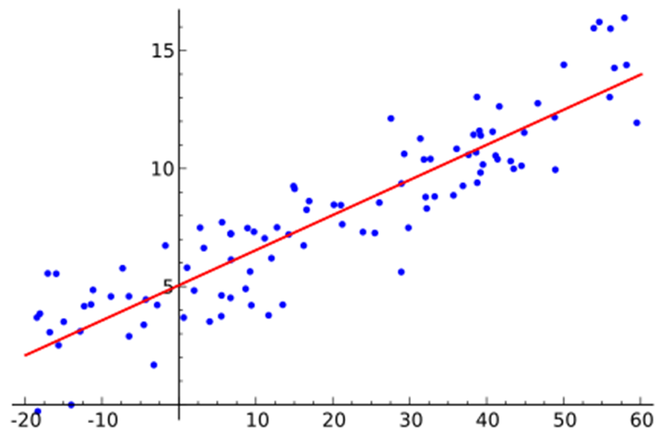
- Perceived math/ICT knowledge:
  - Check one of the following to indicate your knowledge of …
- Ability to acquire mental models:
  - Imagine you will be examined in the history of shipping traffic in the 19th century. A week before the exam, the examiner proposes that you can learn just one of the following two things: a) the names of British steamboats form the second half of the 19th century, including their displacement and their propeller type, or b) how these steamboats' propellers work. There are over sixty steamboats and five functionally distinct propeller types. What would you prefer to learn?
- Prior tiredness:
  - How alert do you feel right now?
  - How do you feel overall right now?

ANCOVA



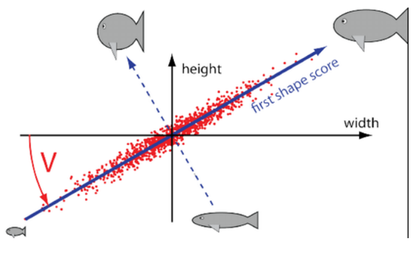
(https://www.mwsug.org/proceedings/2014/PO/MWSUG-2014-PO02.pdf)

ANCOVA and residuals

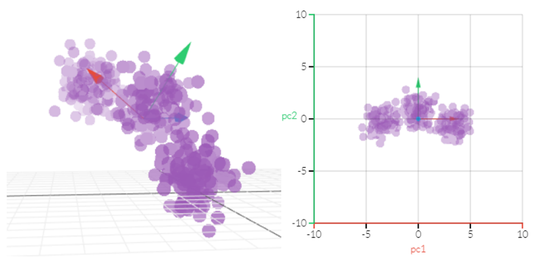


(Wikipedia, Goodness of fit)

Principal component analysis



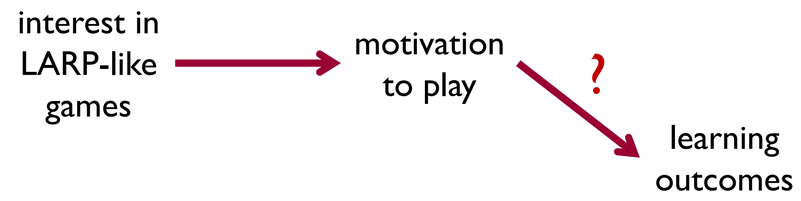
(Werner et al., 2014, PLOS)



(http://setosa.io/ev/principal-component-analysis/)

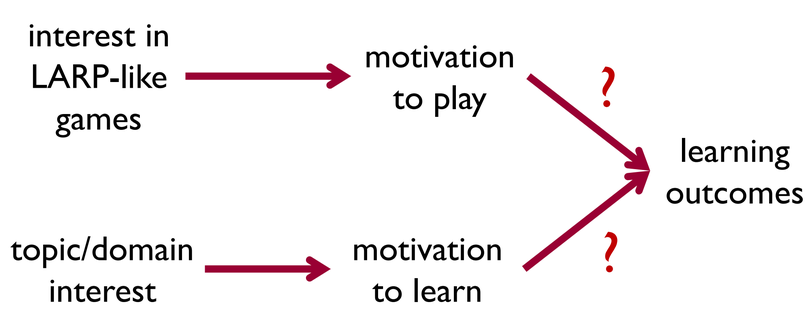
Example: Motivation to play vs. motivation to learn within edu-LARP

- Team role-play motivates (Brom et al., 2016, Int J Comp-Sup Collab Learn)
  - edu-LARP: Live Action Role Play



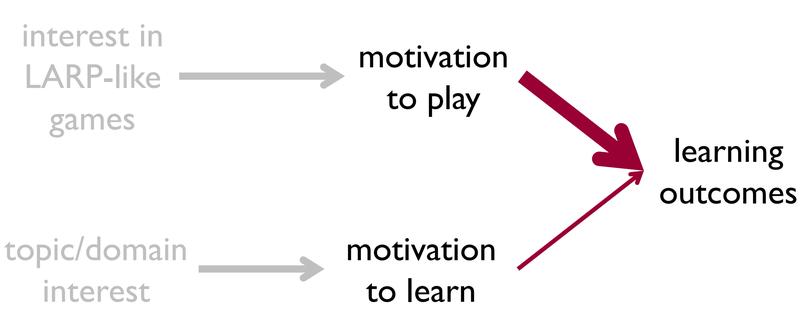
Example: Motivation to play vs. motivation to learn within edu-LARP

- Domain/topic interest
  - key role in motivational theories
  - as checked in the context of simulation-based learning (Brom et al., 2017, Comp & Edu)



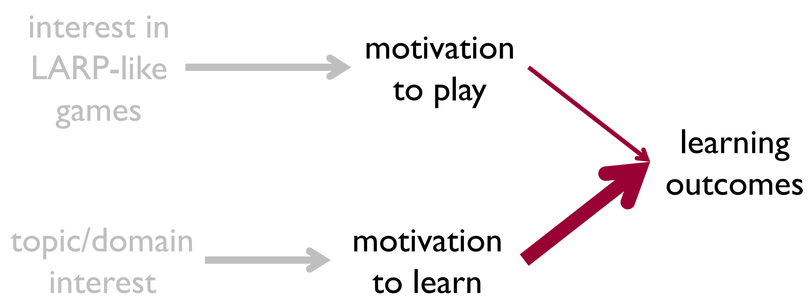
Key question

- Motivation to play
  or
  Motivation to learn? ← baseline



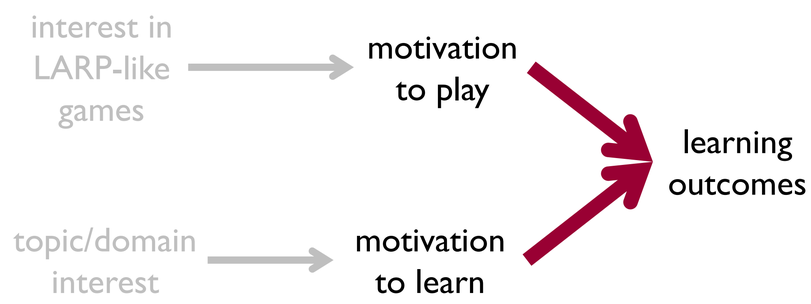
Key question

- Motivation to play
  or
  Motivation to learn? ← baseline



Key question

- Motivation to play
  or
  Motivation to learn? ← baseline

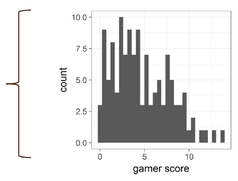


Self-determination theory

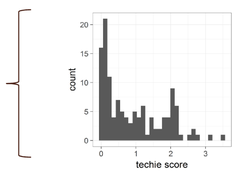
- Autonomous vs. controlled motivation (Deci & Ryan, 1985; Ryan et al., 2006; Vansteenkiste et al., 2009)
- Autonomous
  - needs for autonomy, competence, and relatedness
  - intrinsic motivation
  - identified regulation
    - idea: game-driven intrinsic motivation → learning-driven identified regulation
- Controlled
  - introjected regulation ("I don't want to be ashamed")
  - external regulation ("I want money")

Design

- Correlational study
- Within-subject comparison
- Heterogeneous sample (young adults; *N* = 128)
  - interest in LARP-like games

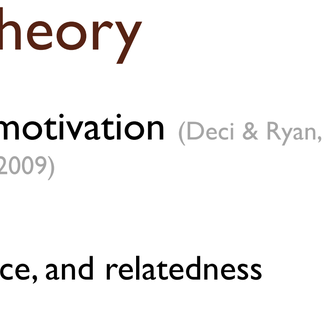


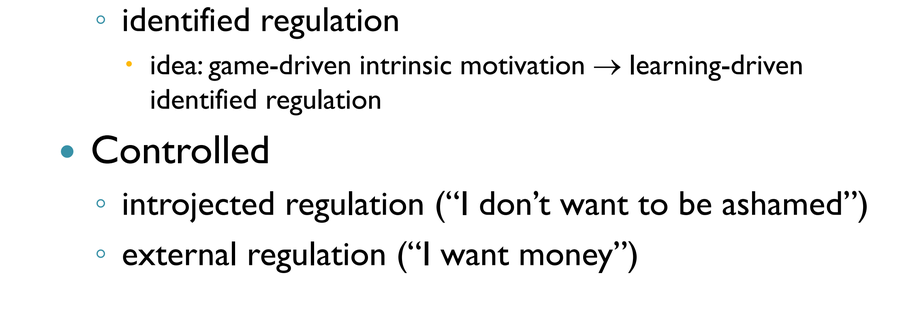
  - interest in electro-physics/ICT



Educational Live Action Role Play

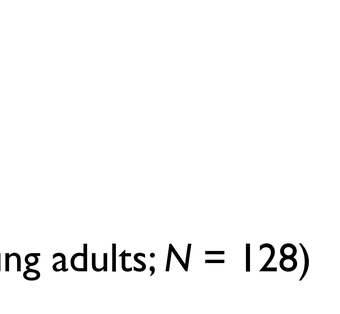
- 2 hours sci-fi edu-LARP
- 40 min learning
  - part of the story
  - lecture & hands-on





The device

- Controlling motors on a generation spaceship
- Game motivation: needed for winning the game
- Fictitious
- Each learner own device



Exploratory factor analysis & PA/flow residua

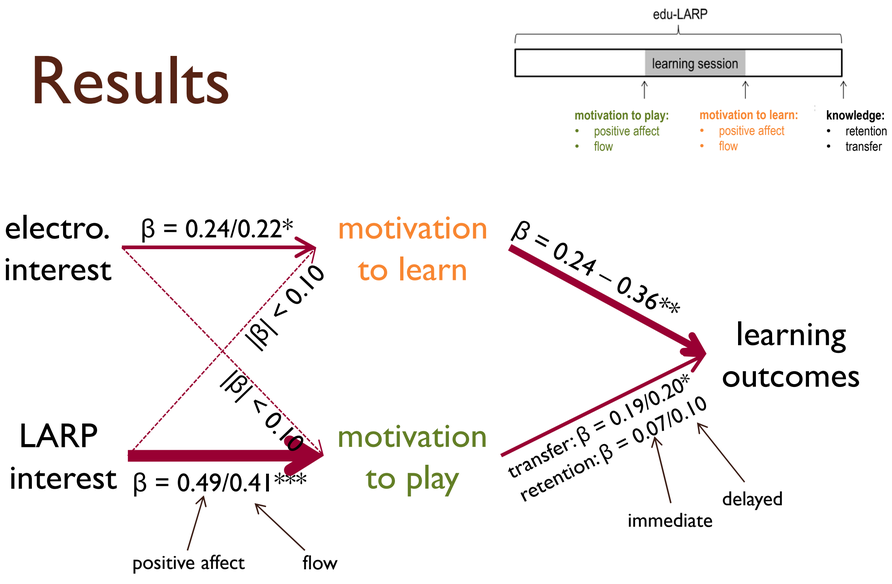
Loadings for three-factor solution with communalities shown in the last column (exploratory factor analysis)

Variable	Factors			Communalities
	Autonomous motivation to play	Autonomous motivation to learn	Cognitive load	
Game-induced PA	.08	**.86**	.03	.75
Game-induced flow	-.03	**.84**	-.19	.74
Learning-induced PA[a]	**.78**	-.06	-.15	.64
Learning-induced flow[a]	**.81**	.02	-.13	.68
Learning enjoyment	**.65**	.23	-.41	.64
Intrinsic load	-.27	-.06	**.52**	.34
Extraneous load	-.13	-.06	**.99**	1.00

Note: Loadings over .50 highlighted.

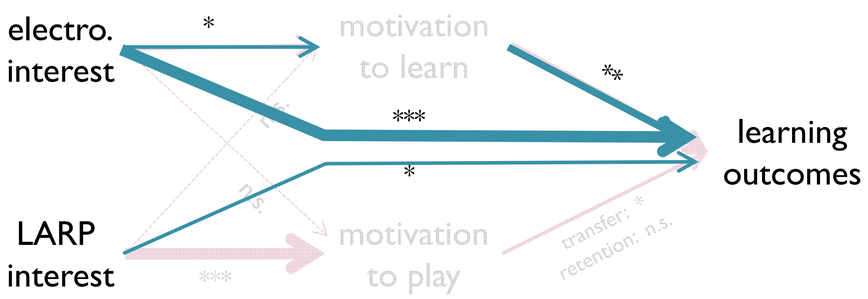
[a]Pre-/Post-learning residua.

Results



Note: cognitive load a bit like motivation to learn, but stronger effects.

Results



* $p < .05$ ** $p < .01$ *** $p < .001$

- Motivation to learn partly mediates the effect of "techies" on learning outcomes

Subjective/observational process measures

- Think-aloud
- Retrospective judgment
- Observations

Objective process measures

- Eye tracker
- Cognitive load:
  - dual-task paradigm
  - pupil dilatation (but!)
- Biofeedback sensors
- AI: Emotion detection

Eye tracking measures by Mayer

Name	Description	Cognitive process
Integrative transitions	Number of times the learner moves eye fixation from the text to the diagram or vice versa	Integrating: Attempts to integrate words and pictures
Text-to-diagram transitions	Number of times the learner moves eye fixation from the text to the diagram	Integrating: Attempts to integrate words and pictures
Corresponding transitions	Number of times the learner moves eye fixation from the text to the corresponding part of the diagram	Integrating: Successful integration of words and pictures
Proportion of corresponding transitions	Number of corresponding transitions divided by number of text-to-diagram transitions	Integrating: Successful integration of words and pictures
Proportion of fixations on diagram	Number of fixations on diagrams divided by total number of fixations	Selecting: Attentional focus on words or pictures
Proportion of fixations on text	Number of fixations on text divided by total number of fixations	Selecting: Attentional focus on words or pictures
Total fixation time on diagram (sec)	Total number of seconds learner looked at the diagram	Selecting: Attentional focus on words or pictures
Total fixation time on text (sec)	Total number of seconds learner looked at the text	Selecting: Attentional focus on words or pictures

(Johnson & Mayer, 2012, J Exp Psych Appl)

END