

5 Principles of Multimedia Learning

5.1 Multimedia Learning: Expectations and Reality 

5.2 Cognitive Theory of Multimedia Learning

5.3 Mayer's Principles of Multimedia Learning

5.4 Further Theories of Multimedia Learning

References:

Kentaro Toyama: There Are No Technology Shortcuts to Good Education,
Educational Technology Debate, Jan. 2011

[http://edutechdebate.org/ict-in-schools/
there-are-no-technology-shortcuts-to-good-education/](http://edutechdebate.org/ict-in-schools/there-are-no-technology-shortcuts-to-good-education/)

Richard E. Mayer (ed.): The Cambridge Handbook of Multimedia Learning,
Cambridge University Press 2005

100 Years of Technology in Education

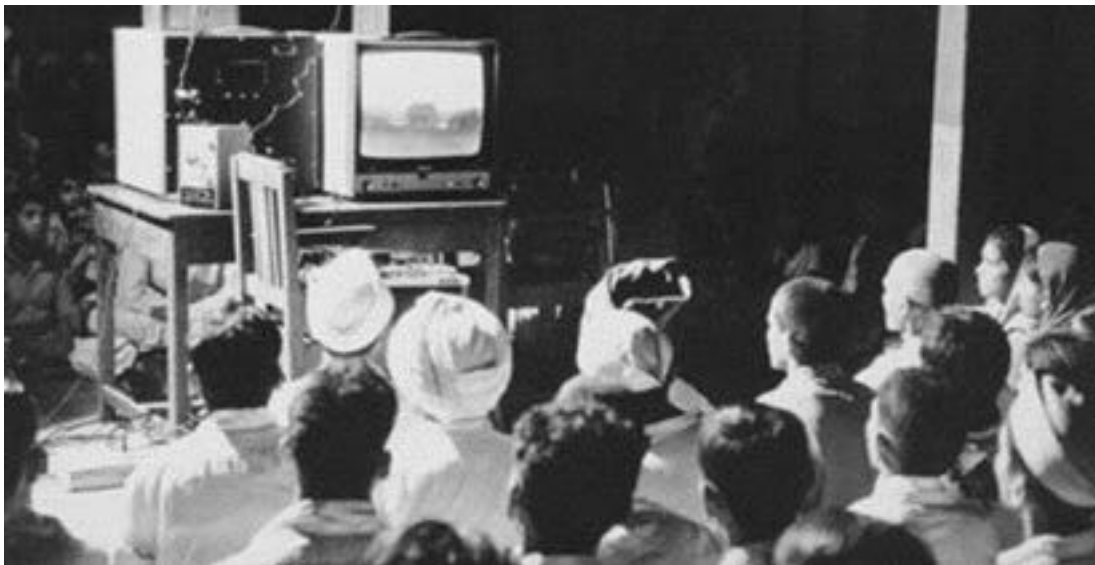
- **Edison 1922:**

“The motion picture is destined to revolutionize our educational system, and in a few years it will supplant largely, if not entirely, the use of textbooks”

- **William Levenson 1945:**

“A radio receiver will be as common in the classroom as the blackboard”,
“Radio instruction will be integrated into our school life”

Larry Cuban: Teachers and Machines: The Classroom Use of Technology since 1920.
Teachers College Press 1986



- **Wilbur Schramm 1964:**

“What if the full power and vividness of television teaching were to be used to help the schools develop a country’s new educational pattern?”

Experiment in American Samoa, mid-1960s: “education” of 80% of students based on educational TV.

Computer Technology in Education

Patrick Suppes: The Uses of Computers in Education. Scientific American, 215(3):207-220, 1966

[Computers can] “adapt mechanical teaching routines to the needs and the past performance of the individual student.”

Mark Warschauer: Laptops and Literacy: Learning in the Wireless Classroom. Teachers College Press 2006

“placing computers and Internet connections in low-[income] schools, in and of itself, does little to address the serious educational challenges faced by these schools. ... can in fact be counterproductive.”



Study on a Peruvian One Laptop Per Child (OLPC) project:
After three months, no significant gains in academic achievement.
Usage decreases after initial interest.

<http://www.iadb.org/document.cfm?id=35370099>

Claimed Benefits of Multimedia

- From <http://http-server.carleton.ca/~shick/mypage/benefit.html>:

- **Improves Learning**

Numerous studies over the years have shown that interactive multimedia learning takes less time, is enjoyed more and increases learning. In a review of numerous meta-analysis studies Najjar (1996:30) found that "learning was higher when information was presented via computer-based multimedia systems than traditional classroom lectures".

- **Interactive**

Interactivity is mutual action between the learner, the learning system, and the learning material. Numerous studies have found that interactivity has a strong positive effect on learning (Bosco, 1986, Fletcher, 1989, 1990, Stanford, 1990). For example, Bosco (1986) reviewed 75 learning studies and found that learners learn faster, and have better attitudes toward learning when using interactive multimedia.

Properties of Multimedia Which May Enhance Learning

(Partially based on <http://http-server.carleton.ca/~shick/mypage/benefit.html>!)

- **Immersive:** Uses a large part of the human cognitive system
- **Flexible & modular:** Adaptable to the individual situation
- **Demanding & consistent:**
Forces teachers to work out the material in good structure
- **Realistic:**
Can represent real-life situations, to support problem-based learning
- **Timely:** Can be used at the time when needed
- **Engaging:** Keeps learners interested and reinforces skills
- **Cost-effective**

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Günter Daniel Rey: E-Learning, Huber 2009 (Kap. 2)

Richard E. Mayer (ed.): The Cambridge Handbook of Multimedia Learning, Cambridge University Press 2005

Assumptions for a Cognitive Theory of Multimedia

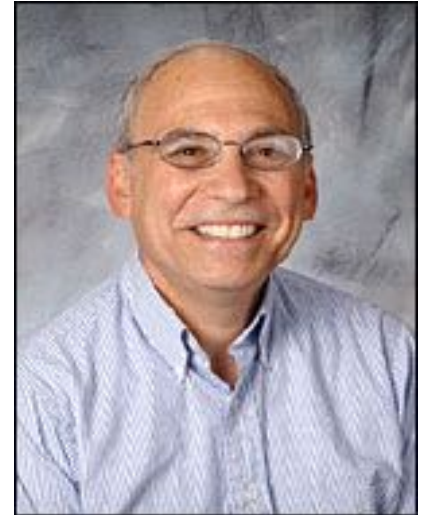
- Dual channels assumption
 - Separate information processing channels
 - » Visual/pictorial channel
 - » Auditory/verbal channel
 - Sensory *modalities* (eyes/ears): two input channels
 - *Coding* as picture/word: two storage forms
 - Cross-channel representations are possible (e.g. reading, narration)
- Limited capacity assumption
 - Limits for the amount of information that can be processed in each channel at one time
 - Short-term memory: approx. seven chunks
 - Allocation of resources by central memory control processes
- Active processing assumption
 - Learners are active processors, not passive recorders

Cognitive Load Theory

- Sweller et al. 1998
- Cognitive Load (Kognitive Belastung)
 - Intrinsic cognitive load
 - » Teaching materials and interrelationships between elements
 - » High intrinsic load requires many elements to be processed simultaneously
 - » Presentation (multimedia) only relevant when intrinsic c.l. is high
 - Extrinsic cognitive load
 - » Dependent on way of presentation
 - » Shall be reduced by design of presentation
 - Germane cognitive load
 - » Dependent on learning task
 - » Spent for construction of schemata in long-term memory
 - » Shall be maximized

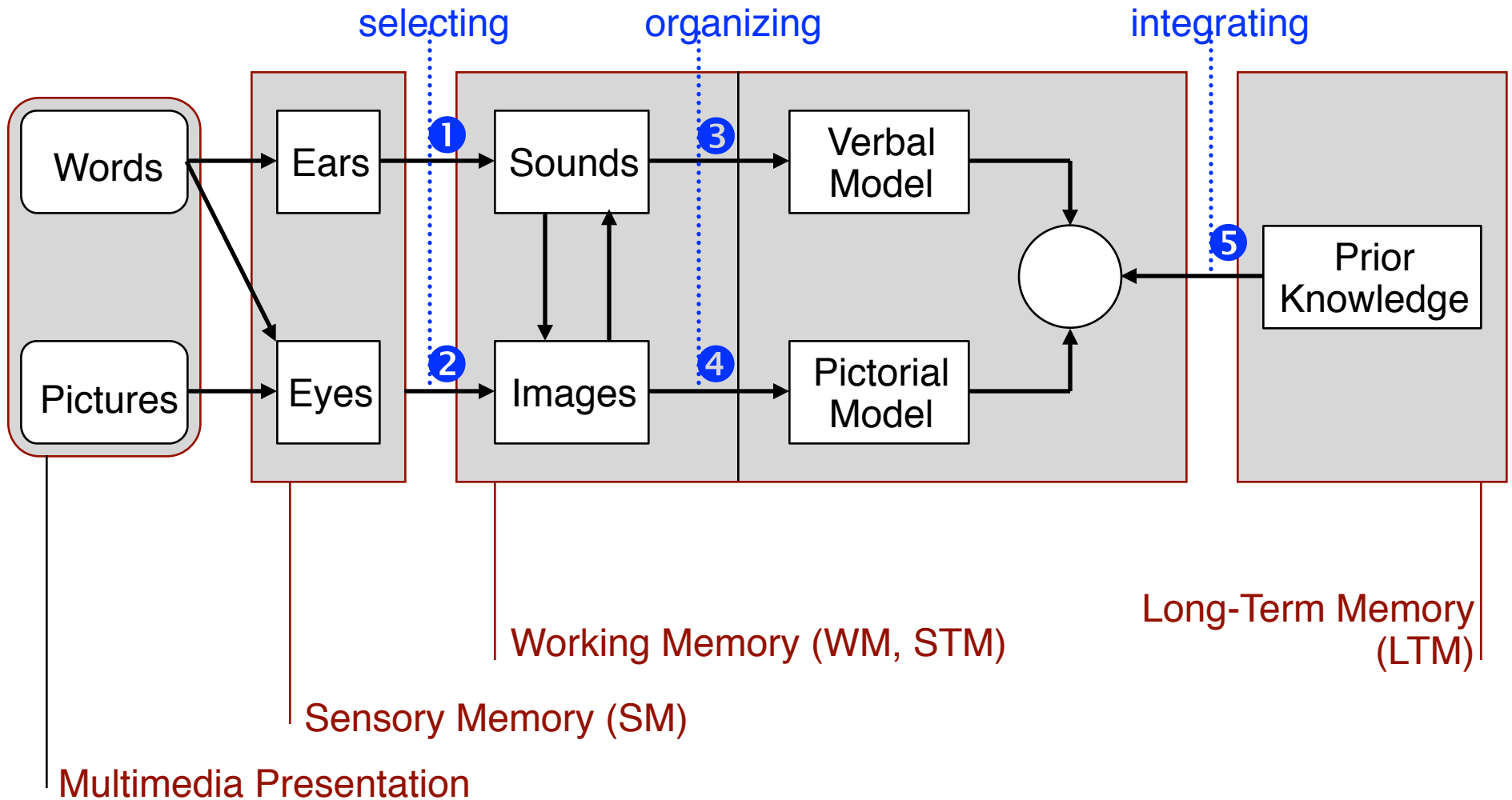
Principle of Cognitive Load-Based Theories

- Define a model of human cognition
 - Including tests for measuring values
- Carry out empirical studies
 - Comparing different designs of learning materials
- Give recommendations
 - For design of learning materials
- Several theories of this type:
 - Sweller's cognitive load theory
 - **Richard Mayer's Cognitive Theory of Multimedia Learning (CTML)**
 - » By far the most prominent and most widely known theory
 - Refinements and variants of CTML
- Following material based on **CTML**
- For alternative approaches see later



Richard E. Mayer

Cognitive Model of Multimedia Learning

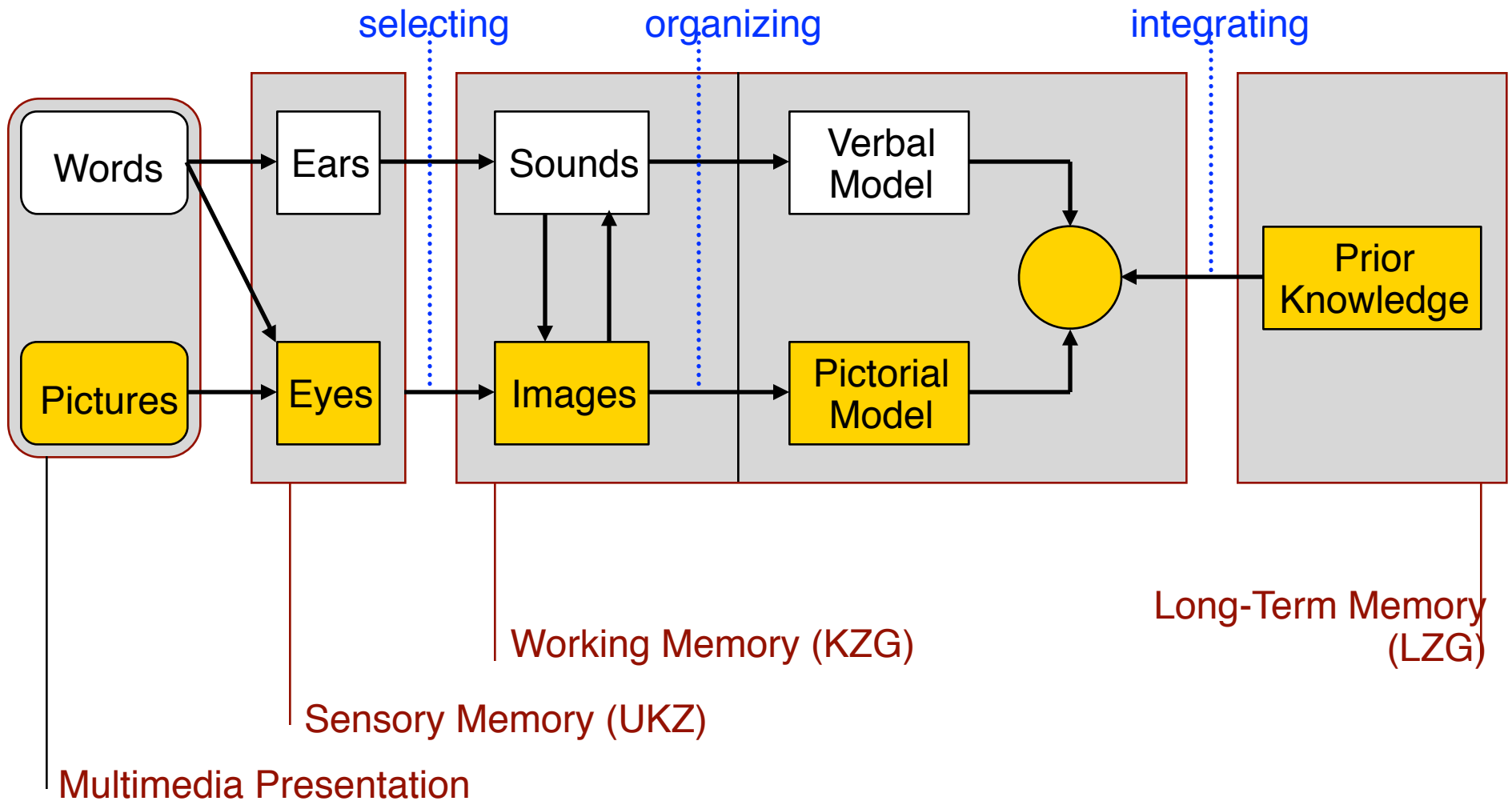


Five Steps of Understanding

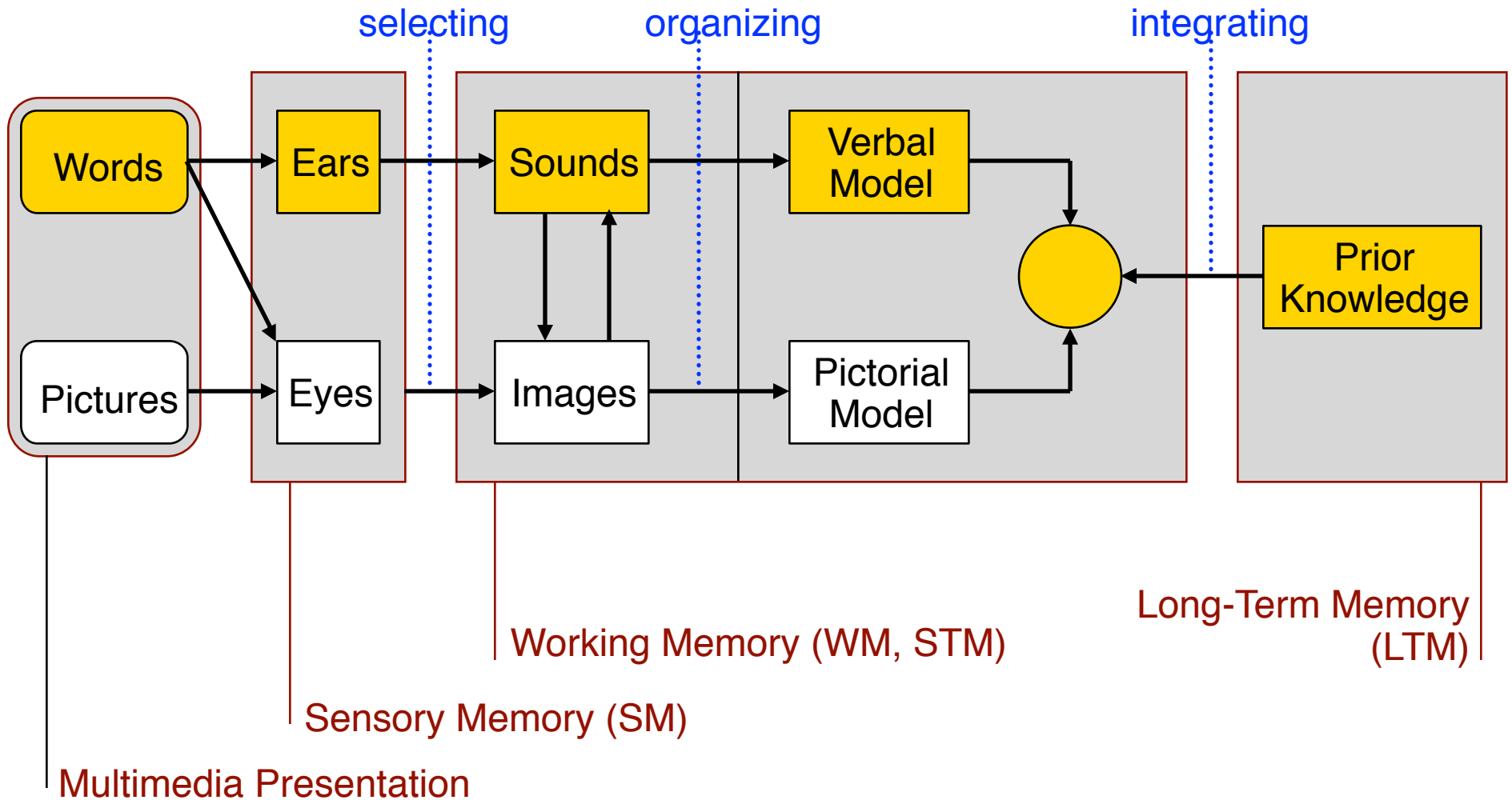
Basic processes, not necessarily in this order (arbitrary moves)

1. Selecting relevant words
 - Paying attention to *some of* the presented words
2. Selecting relevant images
 - Paying attention to *part of* the illustrations and animations presented
3. Organizing selected words
 - Building connections amongst words, e.g. cause-effect chains
4. Organizing selected images
 - Building structures that make sense to the learner, e.g. cause-effect-chains
5. Integrating word-based and image-based representations
 - Making connections between word-bases and image-based representations
 - Most relevant for *multimedia*
 - Extremely demanding process: "sense making"
 - Carried out only segment by segment for larger presentations

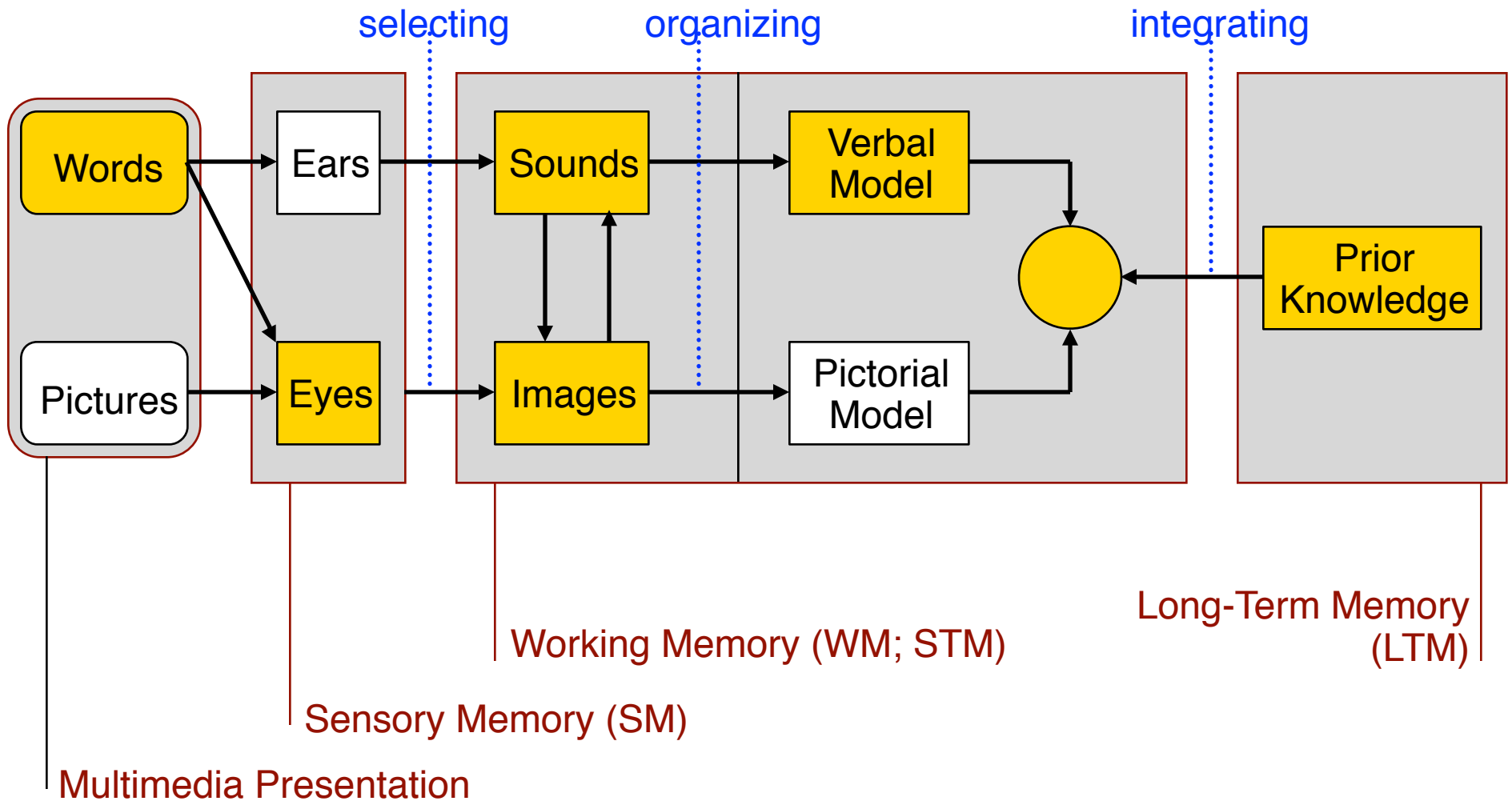
Example: Processing of Pictures



Example: Processing of Spoken Words



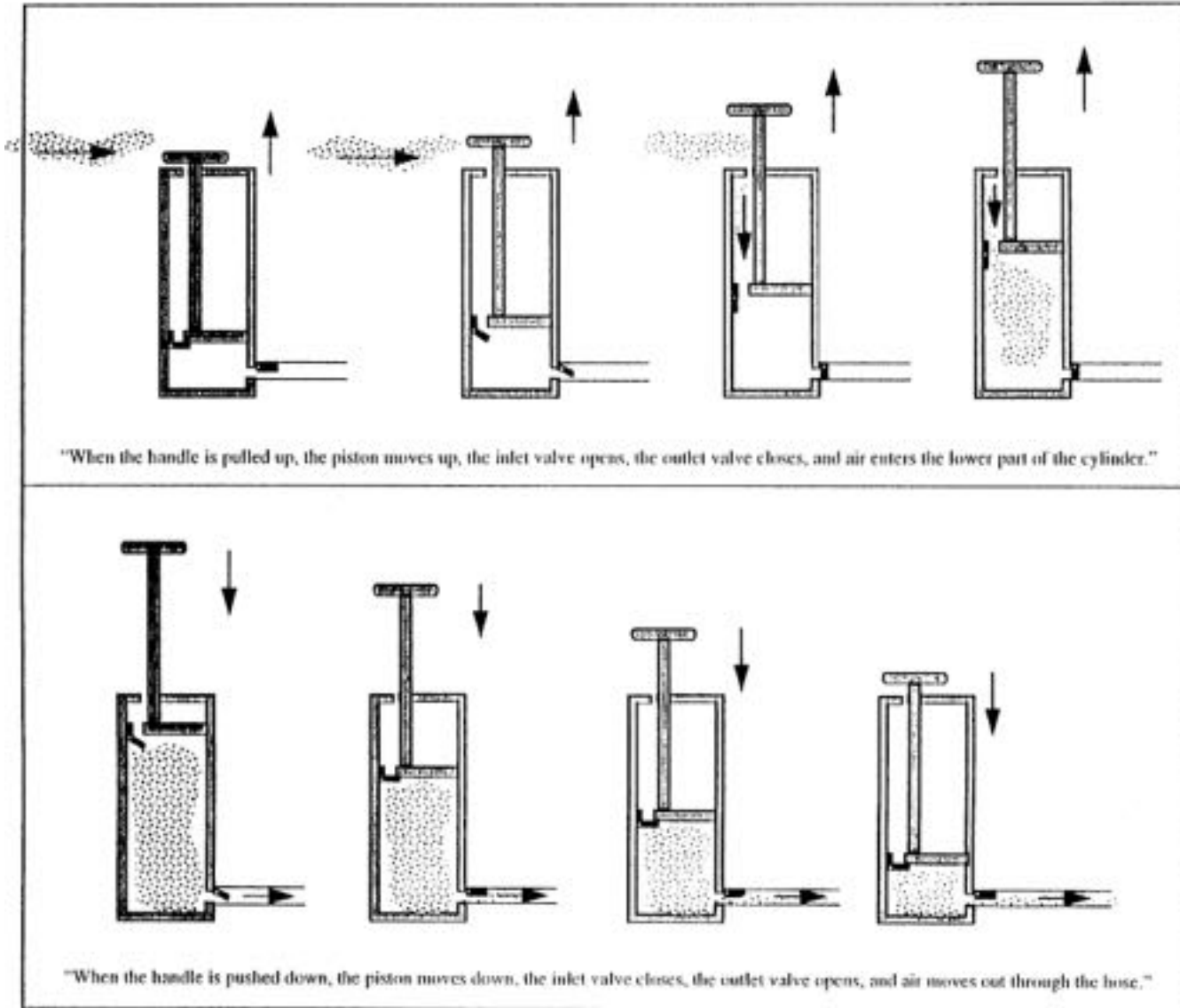
Example: Processing of Printed Words



Goals of Multimedia Learning

- Two different effects of learning can be measured:
- *Retention*
 - Remembering
 - Ability to reproduce or recognize presented material
 - Example test:
“Write down all you can remember from the passage you just read”
- *Transfer*
 - Understanding
 - Ability to use presented material in new situations
 - Example test:
“List some ways to improve the reliability of the device you just read about”

Example: “Multimedia” Instructional Message



Example: Retention and Transfer Tests

- Retention Test:
 - “Please write down an explanation of how a bicycle tire pump works. Pretend that you are writing to someone who does not know much about pumps.”
- Transfer Test:
 1. “What could be done to make a pump more reliable – that is, to make sure it would not fail?”
 2. “What could be done to make a pump more effective – that is, to make it move more air more rapidly?”
 3. “Suppose you push down and pull up the handle of a pump several times but no air comes out. What could have gone wrong?”
 4. “Why does air enter a pump? Why does air exit from a pump?”

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<https://sites.google.com/site/cognitivetheorymmllearning/>
(Northern State University)

Are Pictures Different from Words?

What do you think?

Is there a special quality to presenting an information in pictures instead of words?

Is it better to use words, pictures or a combination of them?

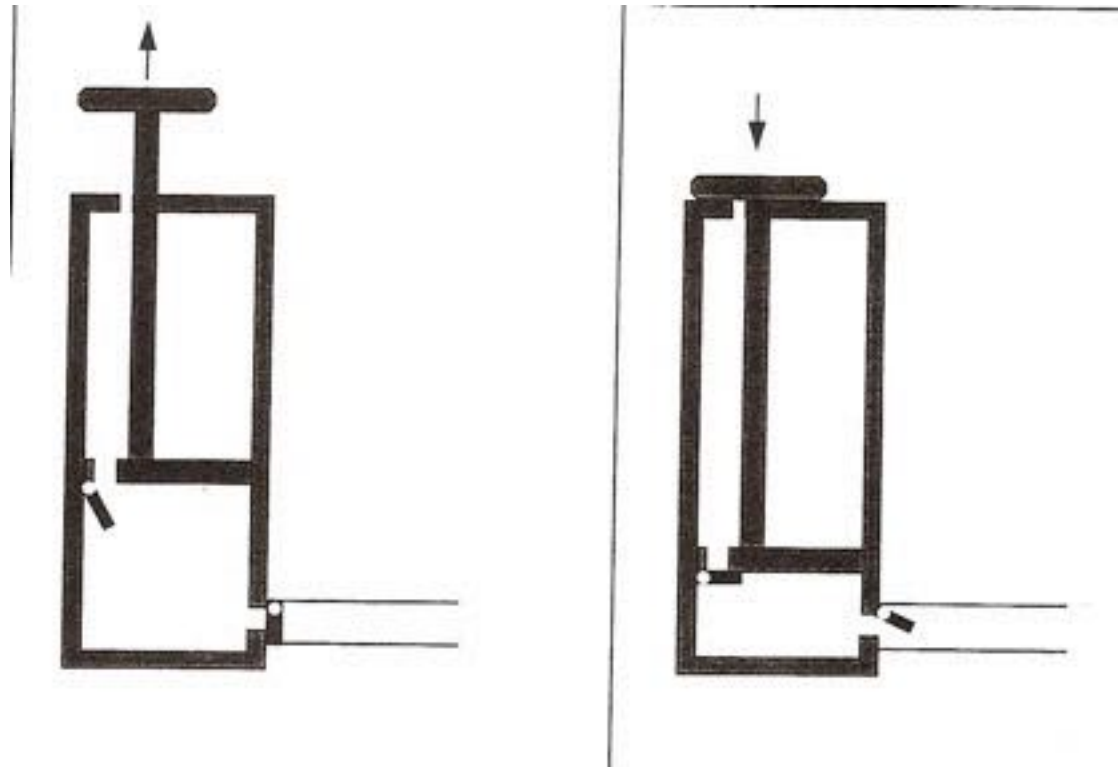
How can we find out?

Multimedia Design Principles of CTML

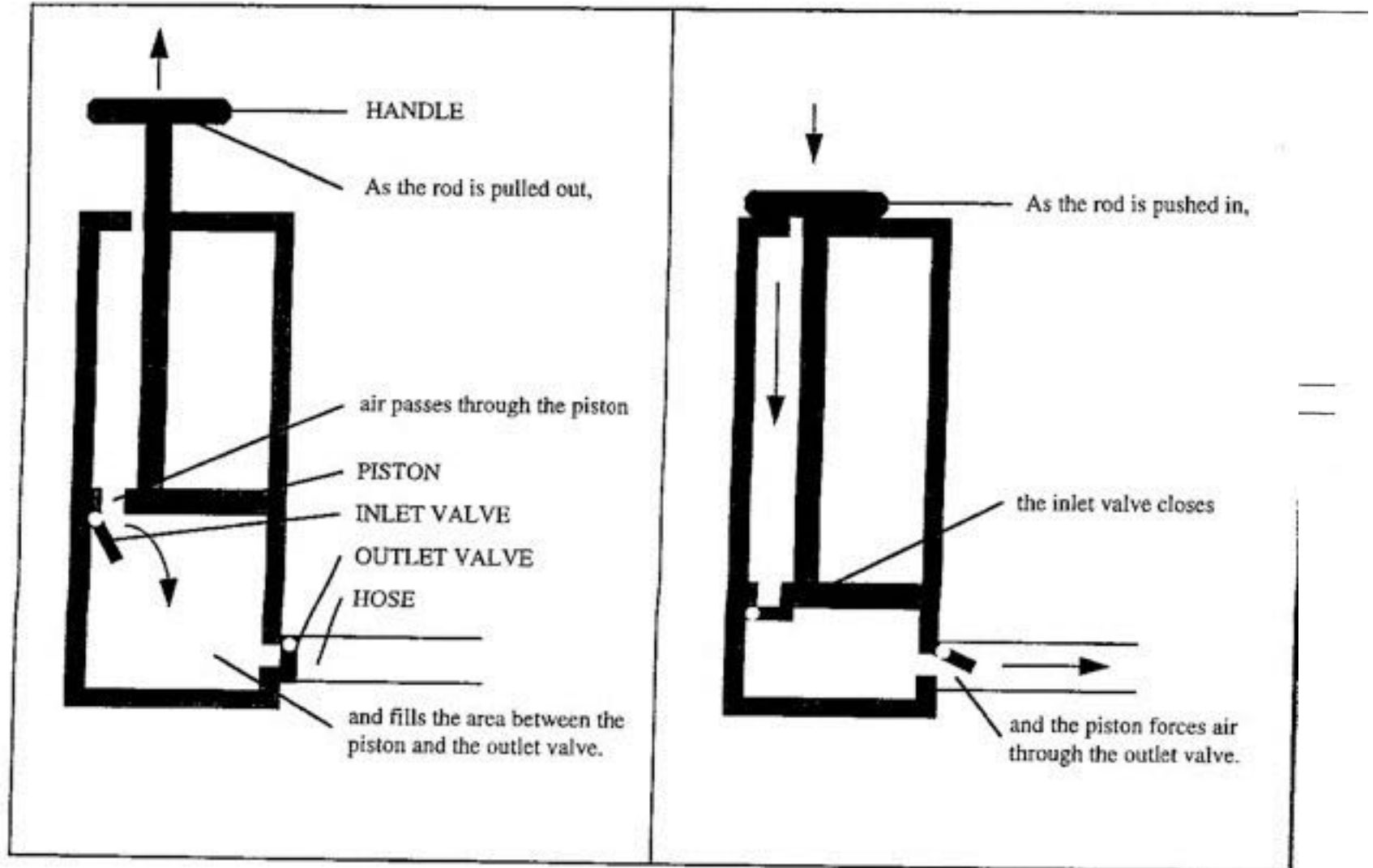
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Contiguity Principles (Spatial contiguity, temporal contiguity, segmenting)	To keep related material closely together helps in learning.
Modality Principle	Multi- <i>modality</i> (e.g. speech and pictures) can help for learning.
Coherence Principle	Superfluous material hurts in learning.
Redundancy Principle	Presenting the same material in several modalities hurts in learning.
Presentation Style Principles (Personalization, Voice, Image)	Details of presentation style matter.
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Words & Pictures & ...

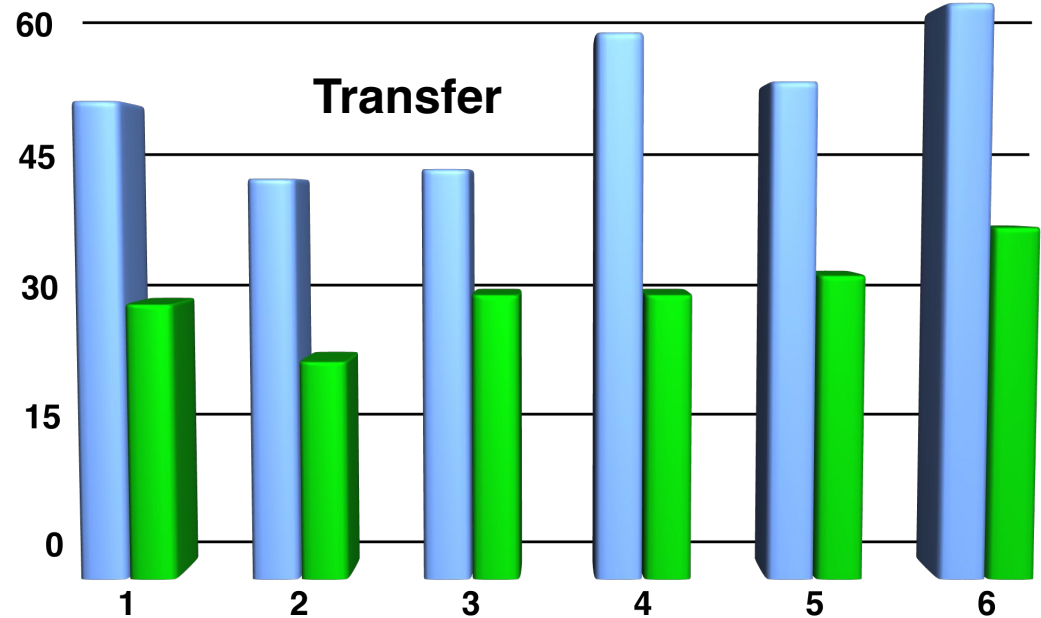
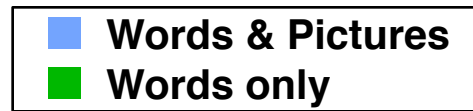
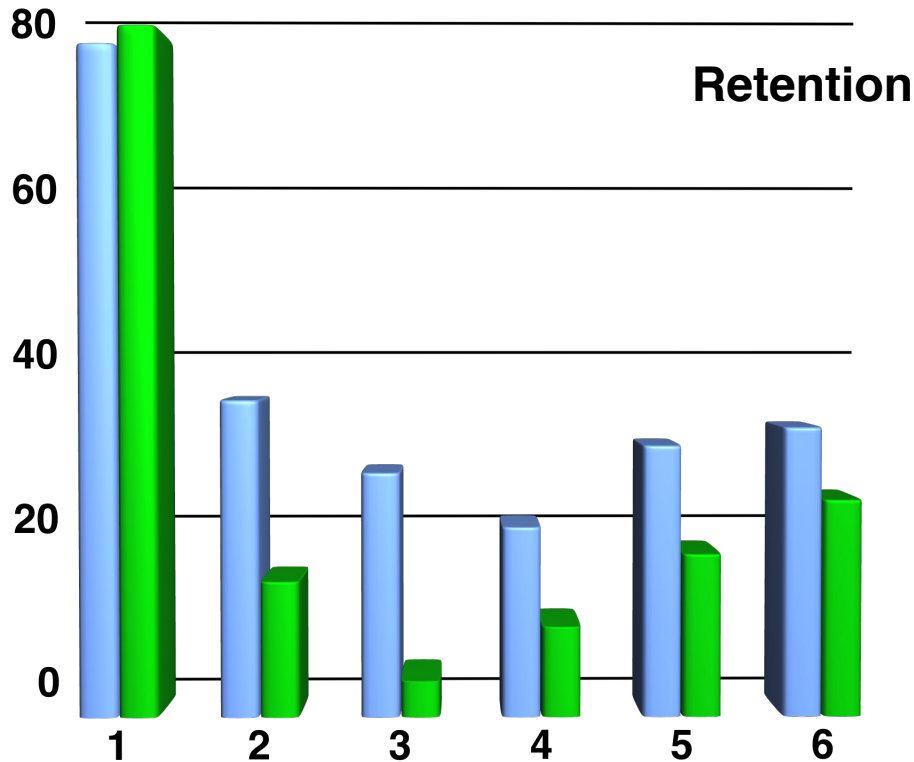
As the rod is pulled out, air passes through the piston and fills the area between the piston and the outlet valve. As the rod is pushed in, the inlet valve closes and the piston forces air through the outlet valve.



Words & Pictures & Combination

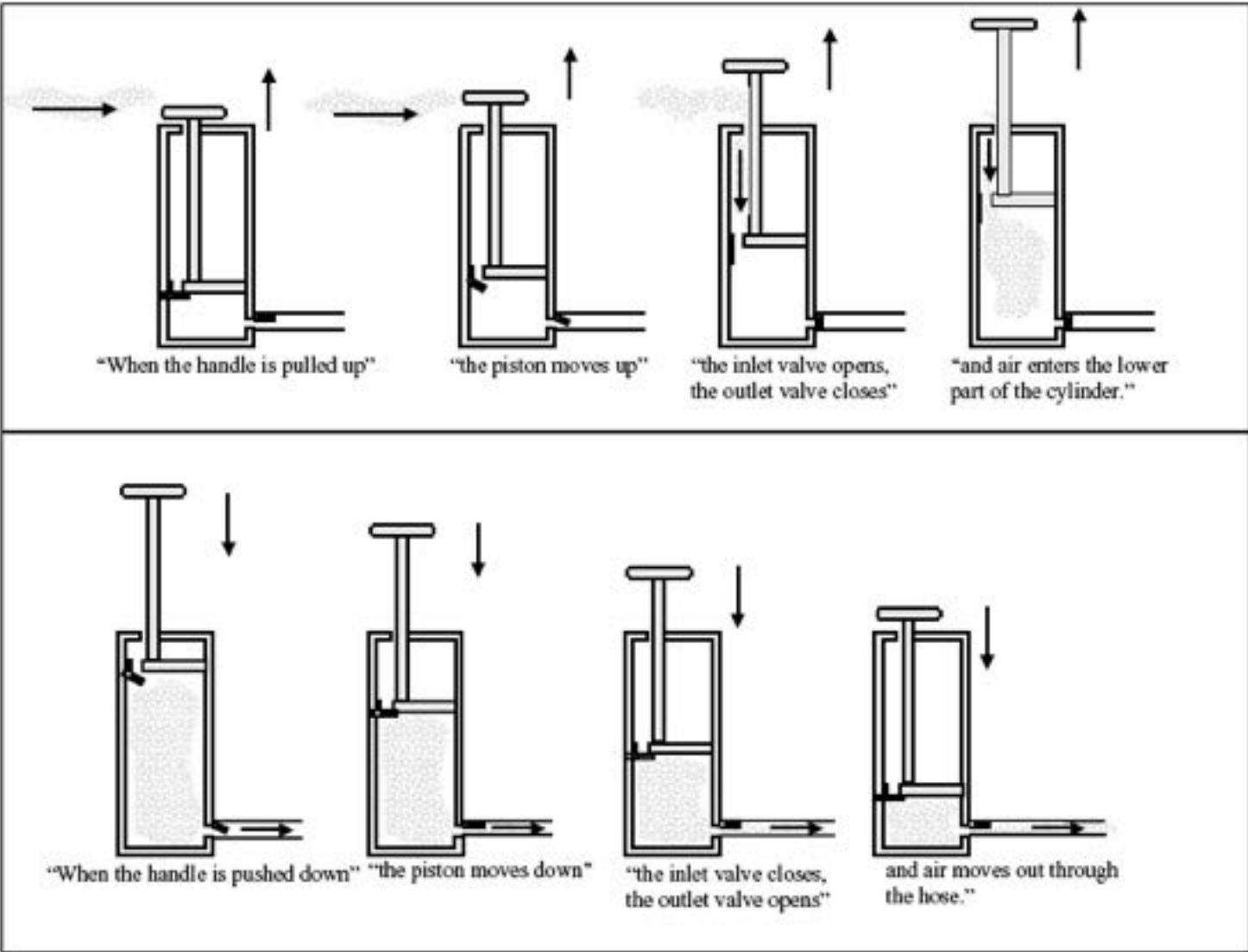


Experimental Results on Multimedia Principle

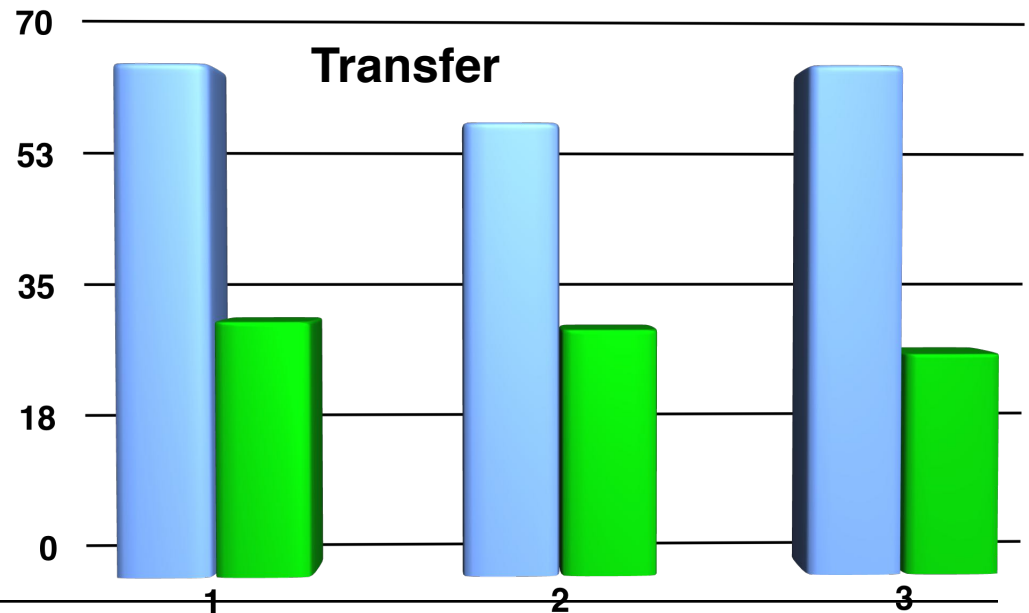
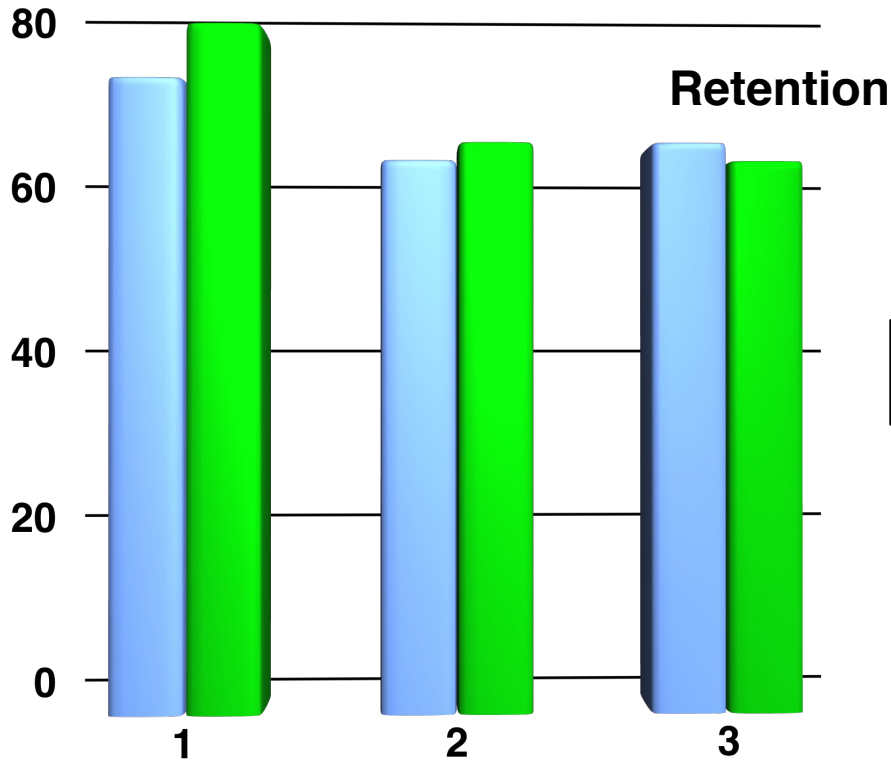


Mayer & Anderson 1991

Narrated Animation

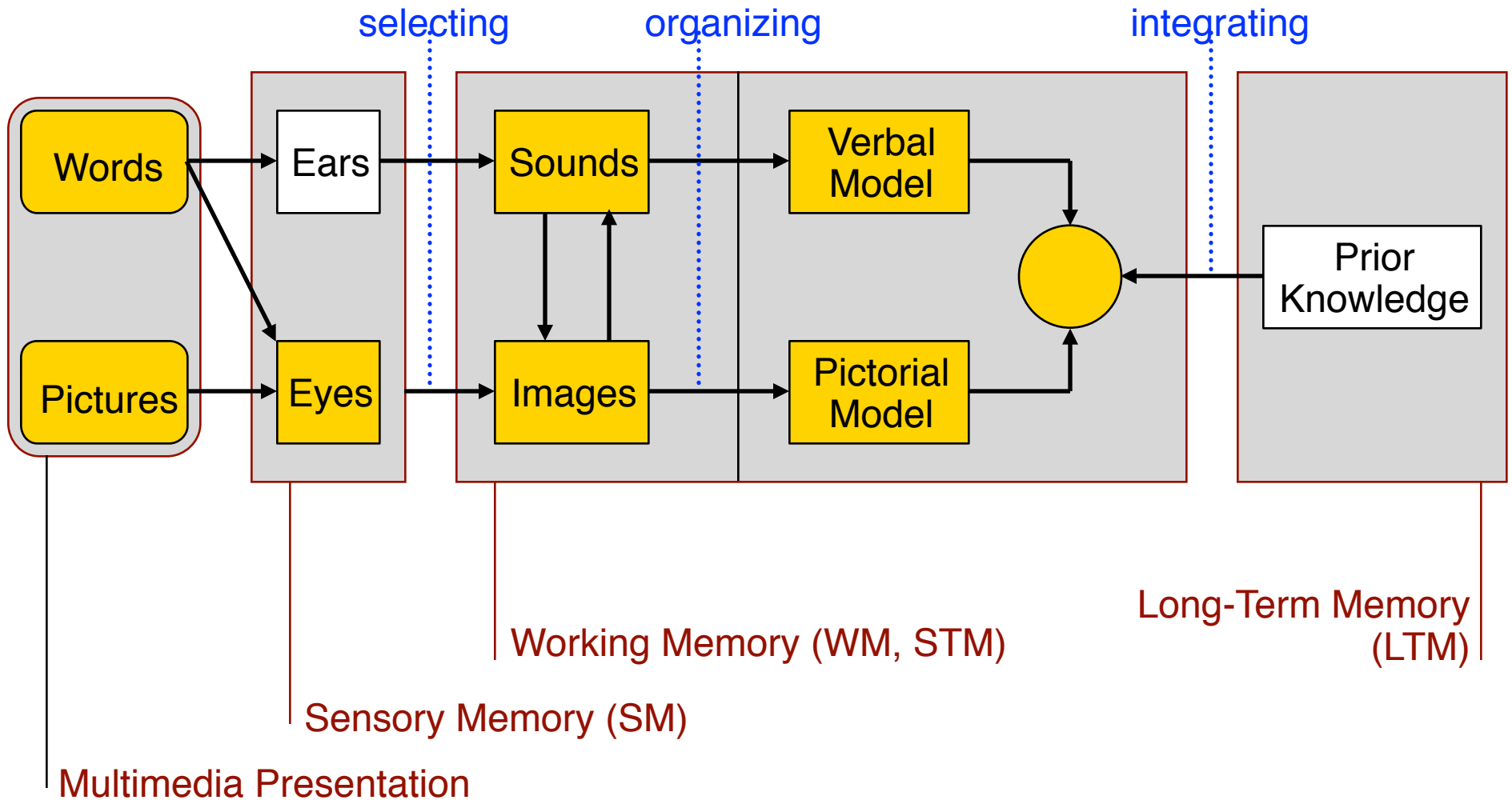


Experimental Results on Multimedia Principle (2)



Mayer & Anderson 1991

Easing Integration of Mental Images



Multimedia Principle

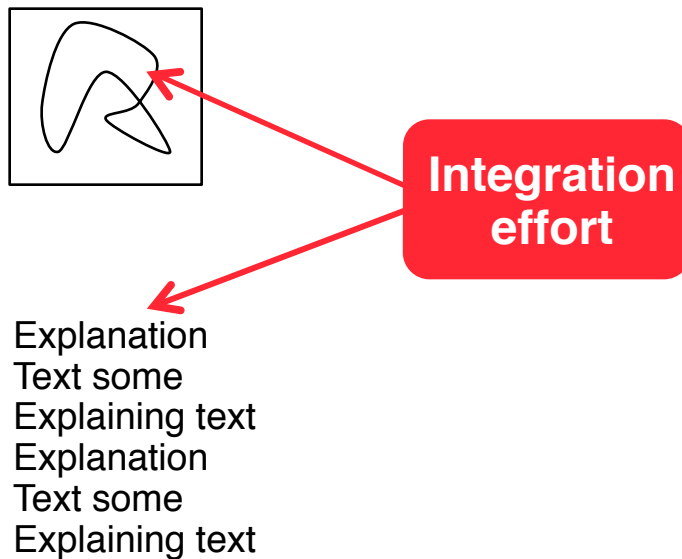
Students learn better from words and pictures than from words alone.

- Mayer et al. 1991
- Empirical evidence exists
- Cognitive model can predict the effect
- Applicable only under limitations!
 - Under some conditions adding pictures is harmful ...

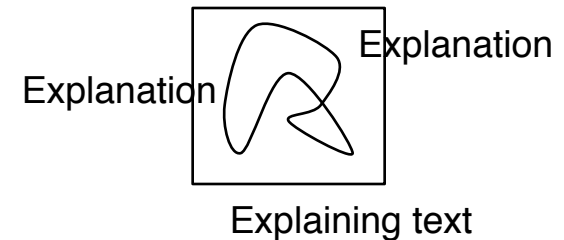
Instructional Split-Attention

- Tarmizi, Sweller 1988:
 - Effectiveness of presenting geometry examples is dependent on the format of the presentation !

Split presentation



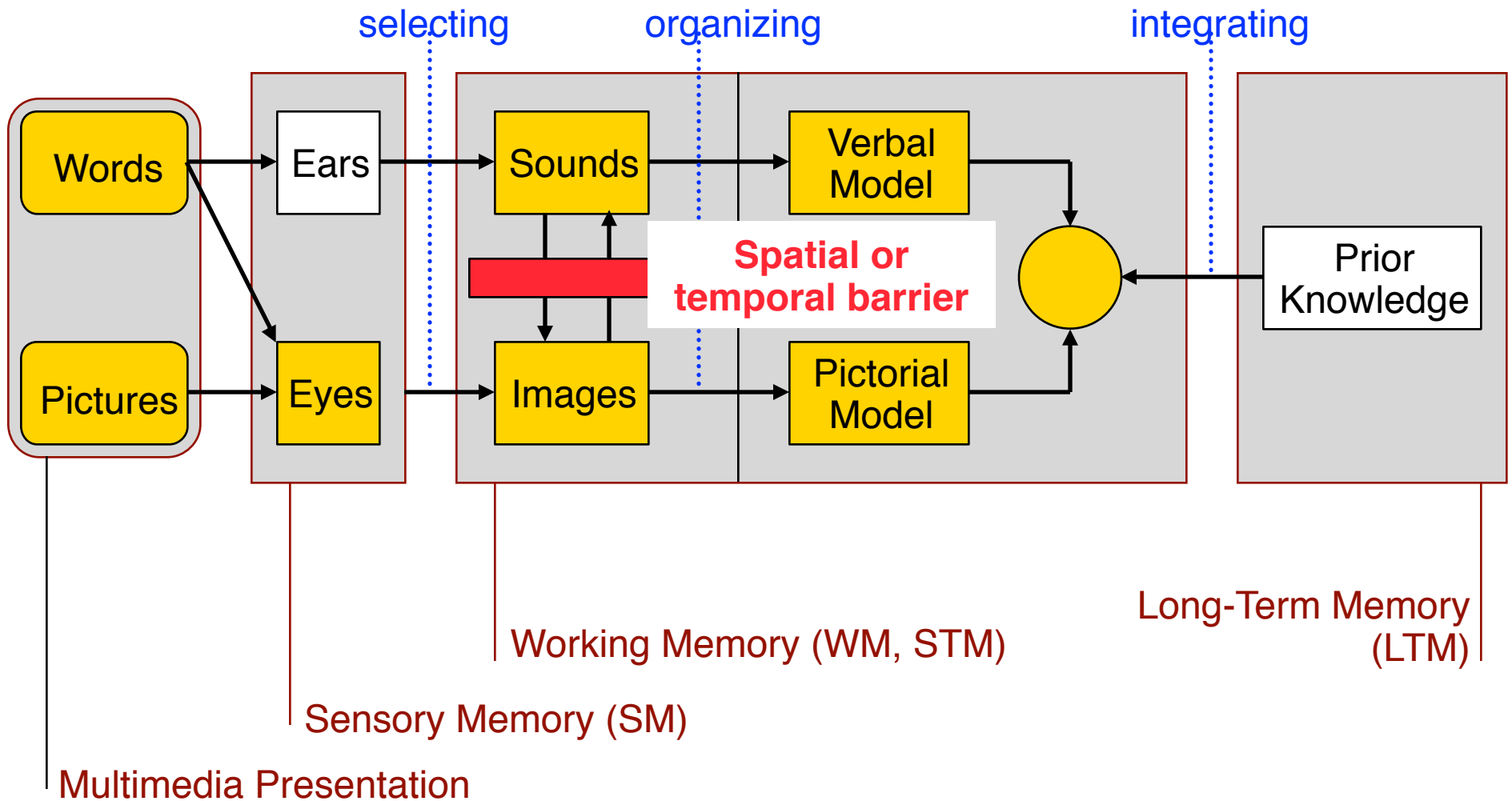
Integrated presentation



Multimedia Design Principles of CTML

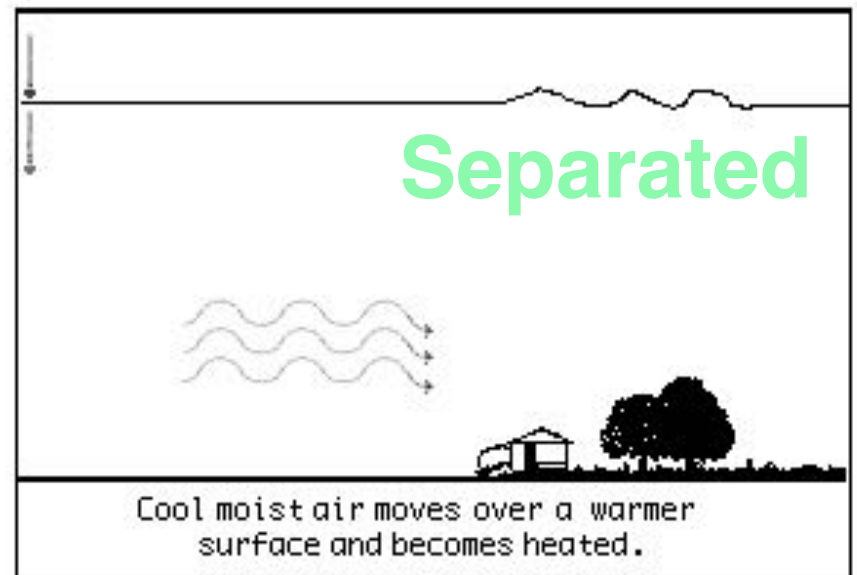
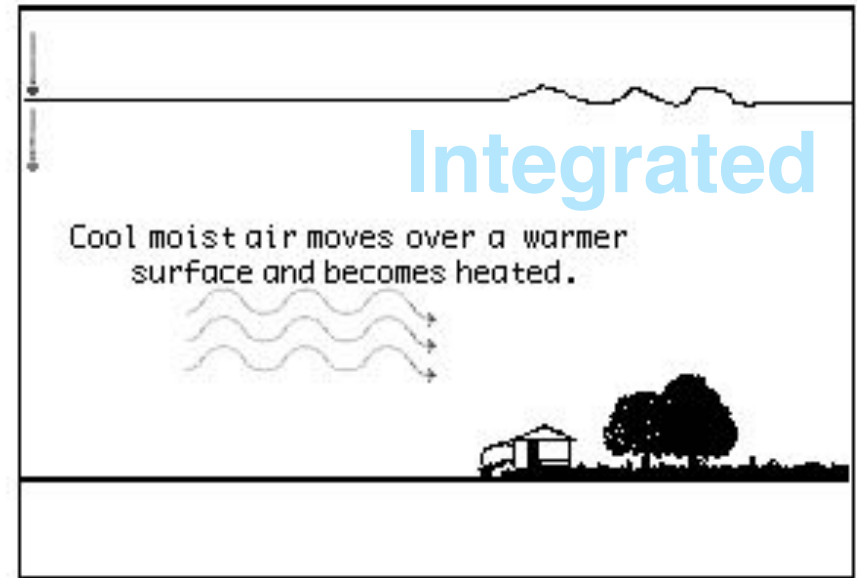
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Integration of Mental Images



Spatial Contiguity Principle

- **Students learn better when corresponding words and pictures are presented near each other than far from each other on the page or screen.**
- Mayer et al. 1989 – 1995
- Comparison of
 - "integrated" text/animation
 - "separated" text & animation
- Retention and transfer results consistently better for integrated presentation

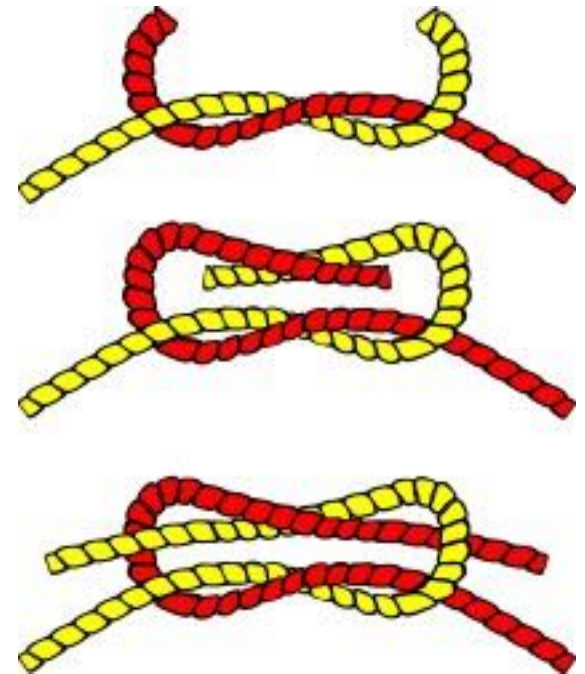


Temporal Contiguity Principle

- **Students learn better when corresponding words and pictures are presented simultaneously rather than successively.**
- Mayer et al. 1991– 1999
- Experiment:
 - 16-sentences narration followed by a pictorial animation vs.
 - Animation in parallel with narration
- Results:
 - Retention: Parallel version only slightly superior (3 out of 5)
 - » Sequential version =
Better preparation for purely verbal reproduction of information?
 - Transfer: Parallel version consistently and significantly superior
- Variation:
 - 16 small segments of narration followed by small step of animation
 - » Effect almost equivalent to parallel presentation

Segmenting Principle

- **Students learn better from a multimedia lesson is presented in user-paced segments rather than as a continuous unit.**
- Meyer, Dow, Mayer 2003
- Giving the user control over the advancement of presentation is helpful
- Proven valid for animations
- Traditional principle for textual and pictorial instructions



Picture: <https://sites.google.com/site/cognitivetheorymlearning/>

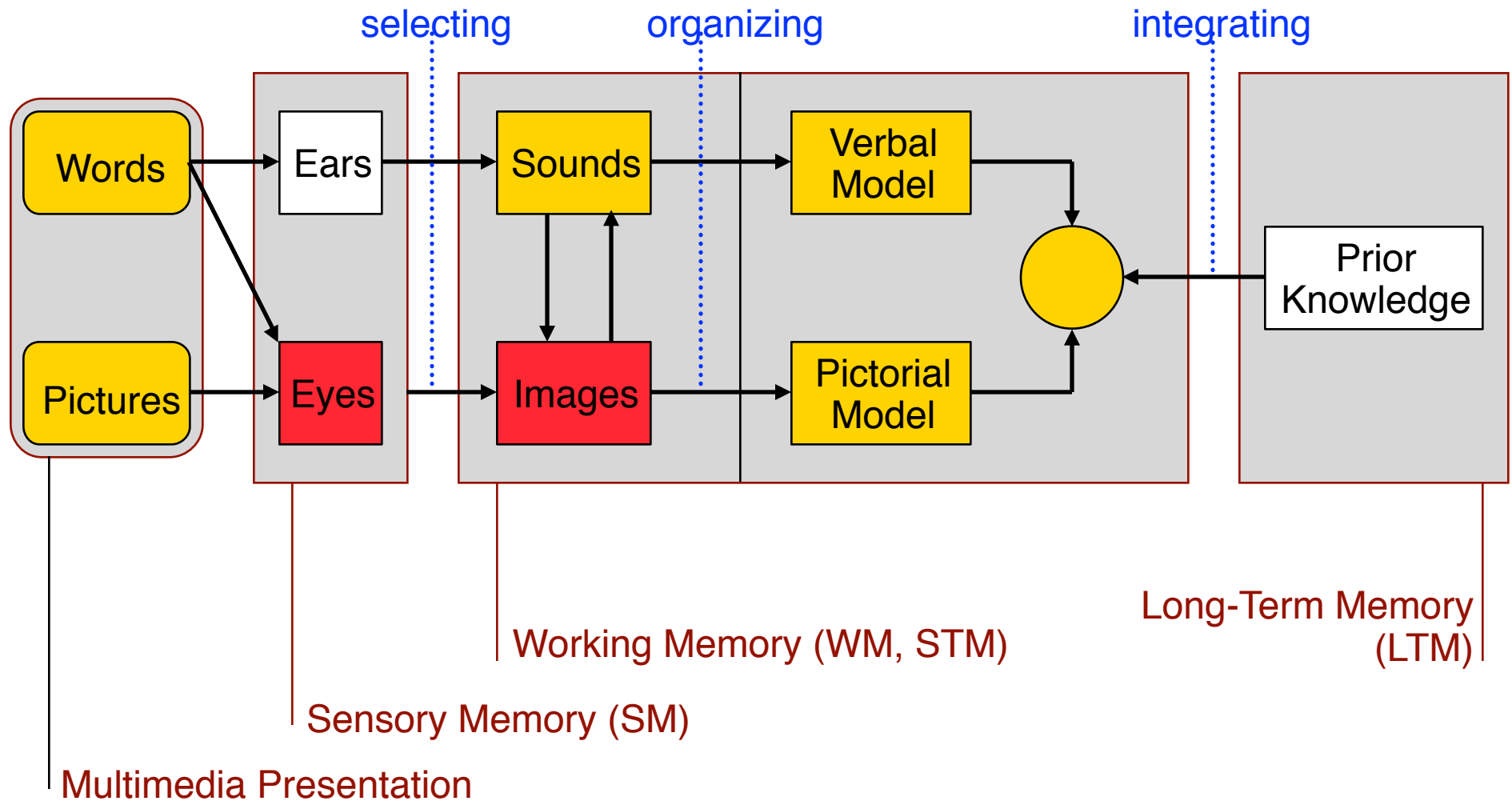
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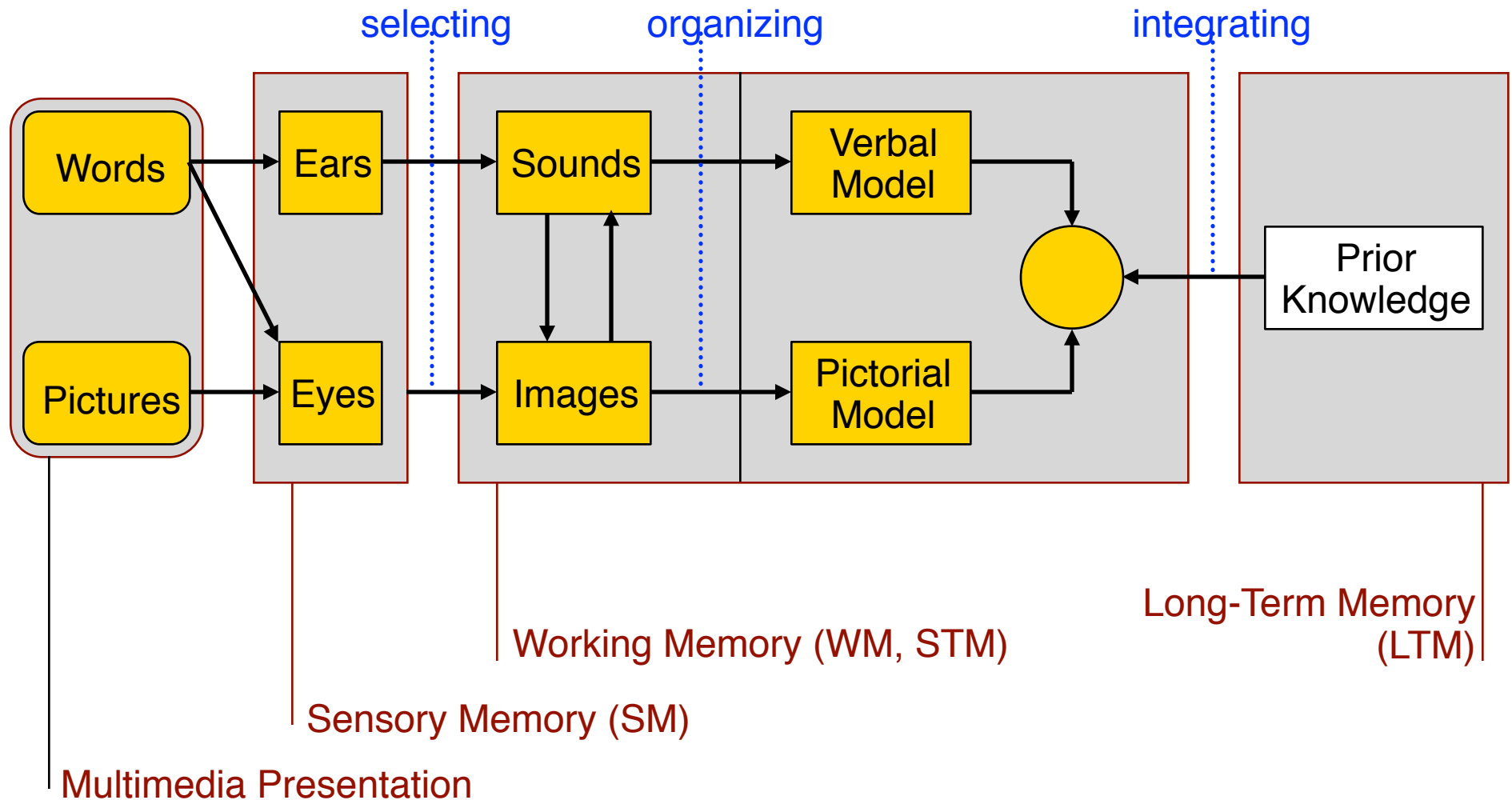
Modality Principle

- **Students learn better from animation and narration than from animation and on-screen text.**
 - Students learn better when words in a multimedia message are presented as spoken text rather than printed text.
- Mayer et al. 1998 – 2001
- Experiment:
 - Animation accompanied with text
 - » As on-screen (separated) text, small segments, vs.
 - » As audio narration
- Results:
 - Consistent and clear superiority for narration, in retention and transfer

Cognitive Overload by Monomodal Presentation



Less Cognitive Load by Multimodal Presentation



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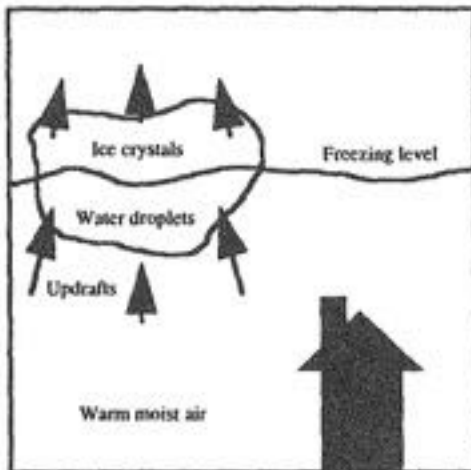
Coherence Principle, Type 1 (Visual)

- **Students learn better when extraneous material is excluded rather than included.**
 - Version 1: Student learning is *hurt* when interesting but irrelevant **words and pictures** are added to a multimedia presentation
- Harp & Mayer 1998
 - "seductive text", "seductive illustrations":
 - Topically relevant, entertaining and interesting for learners
 - Cognitive load is consumed by extraneous material
- Arguments *pro* addition of seductive details:
 - Arousal theory: Students are emotionally aroused and therefore learn better
- Arguments *contra* addition of seductive details:
 - Dewey (1913): "When things have to be made interesting, it is because interest itself is wanting."
 - Cognitive interest (enjoying to understand) is better than "surface" interest

Example: Interesting but Irrelevant Additions

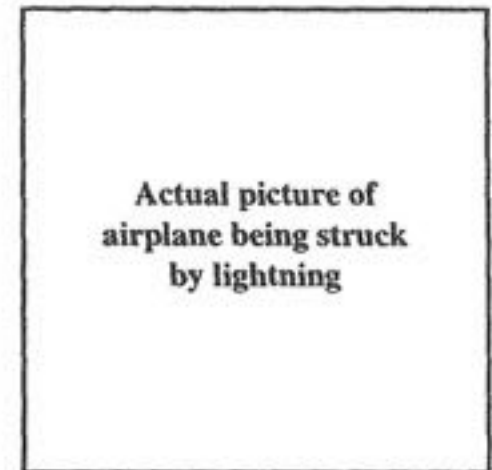


Picture: huffingtonpost.com



Warm moist air rises, water vapor condenses and forms a cloud.

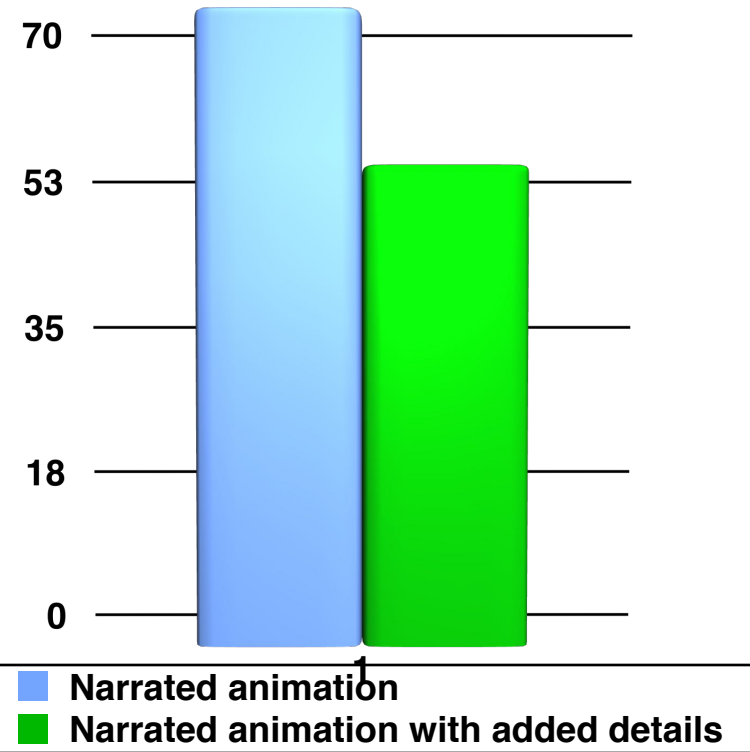
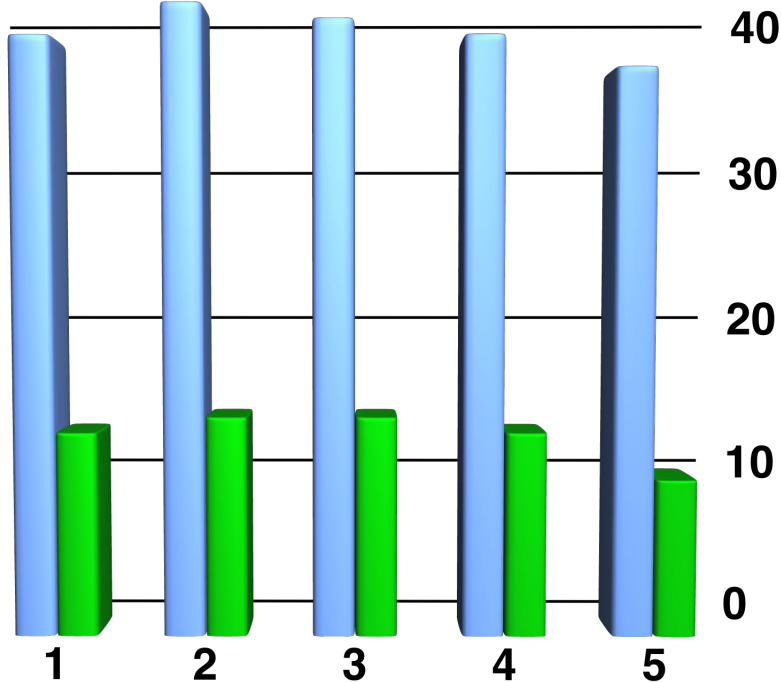
When the surface of the earth is warm, moist air near the earth's surface becomes heated and rises rapidly, producing an updraft. As the air in these updrafts cools, water vapor condenses into water droplets and forms a cloud. When flying through updrafts, an airplane ride can become bumpy. Metal airplanes conduct lightning very well, but they sustain little damage because the bolt, meeting no resistance, passes right through. The cloud's top extends above the freezing level. At this altitude, the air temperature is well below freezing, so the upper portion of the cloud is composed of tiny ice crystals.



Metal airplanes conduct lightning, but sustain little damage.

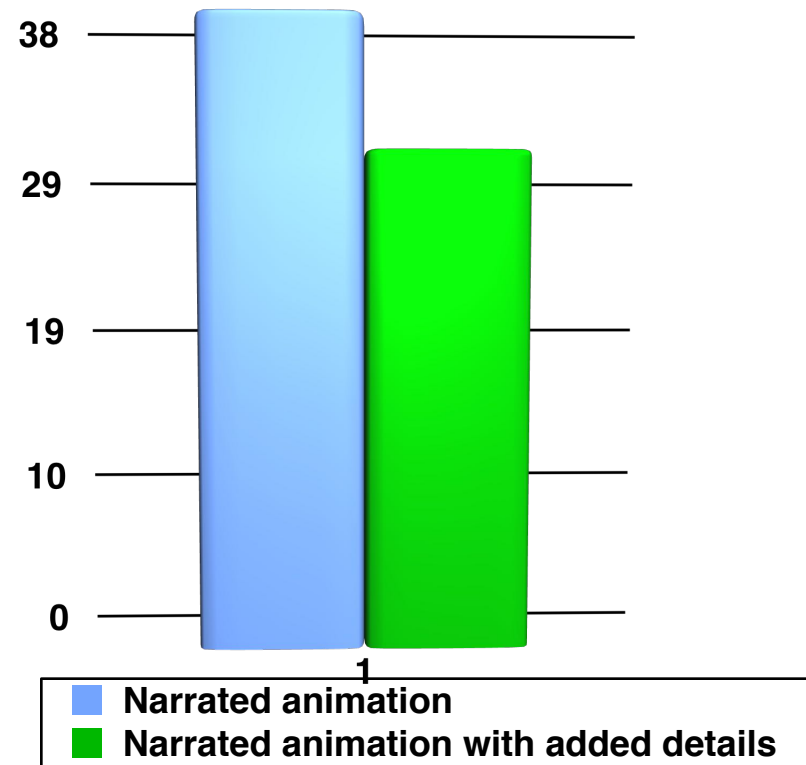
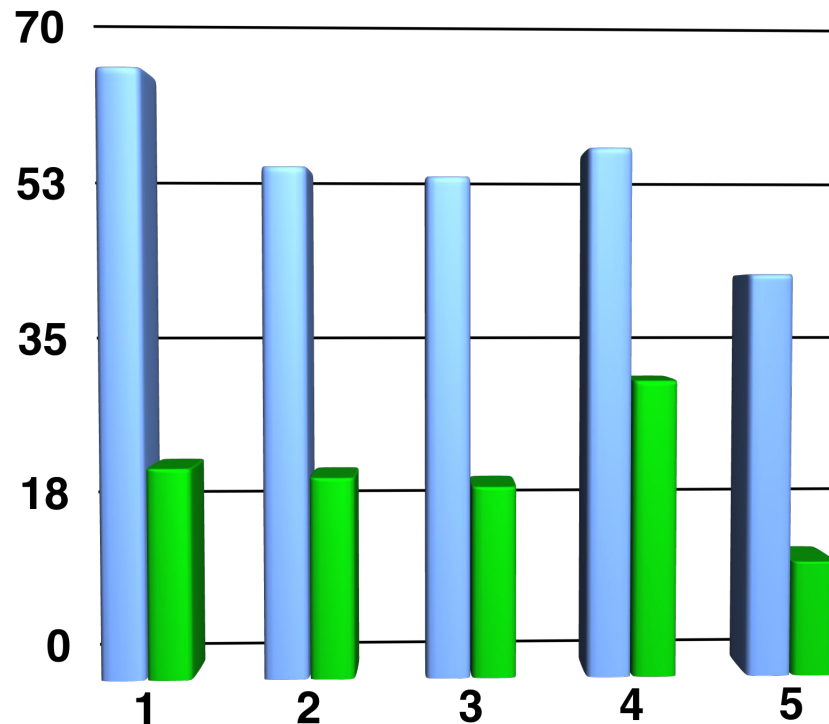
Experimental Results on Coherence Principle (1)

Retention



Experimental Results on Coherence Principle (2)

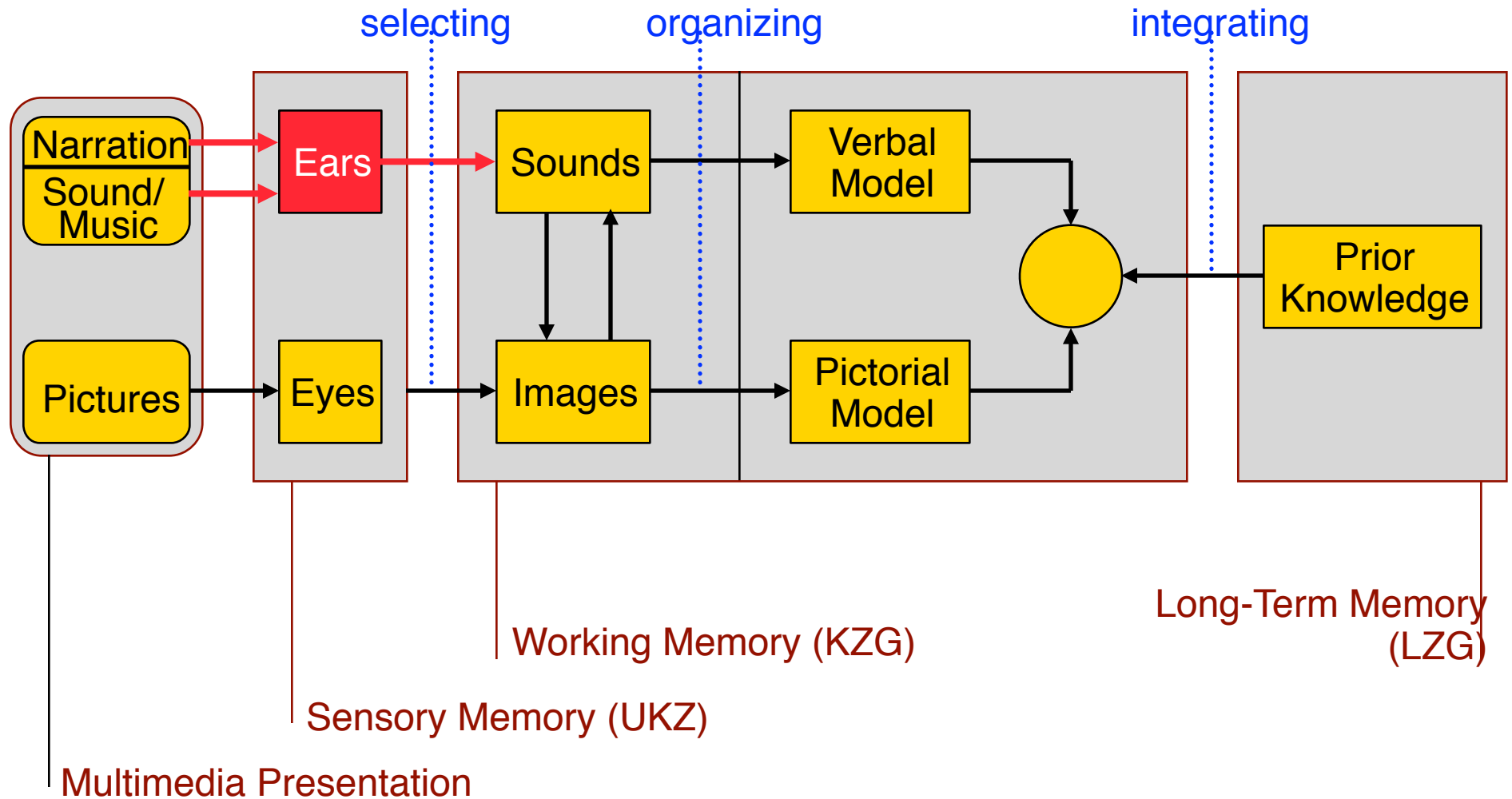
Transfer



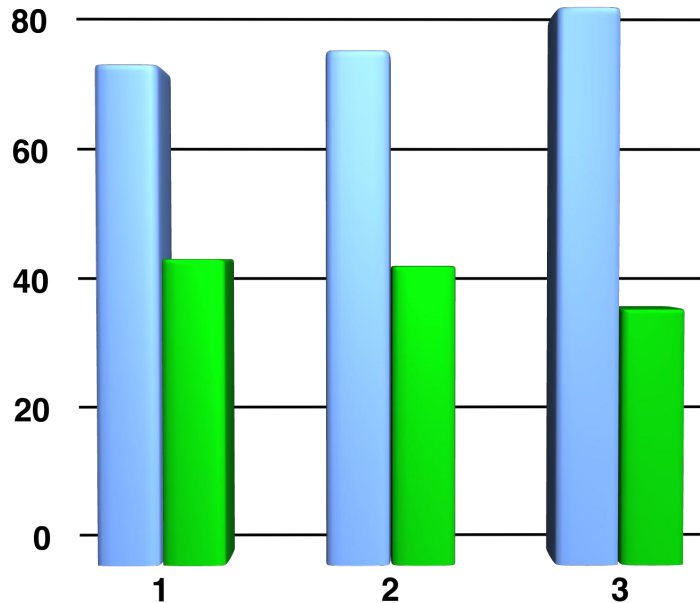
Coherence Principle, Type 2 (Visual-Auditive)

- **Students learn better when extraneous material is excluded rather than included.**
 - Version 2: Student learning is *hurt* when interesting but irrelevant **sounds and music** are added to a multimedia presentation
- Harp & Mayer 2000
 - Using a presentation with picture animation and *narrated text*
 - Add gentle background music loop
 - Add environmental sounds (e.g. blowing wind, crackling ice cubes)
- Arguments *pro* extraneous sound additions:
 - Arousal theory (fun, playful elements), relaxation
- Arguments *contra* extraneous sound additions:
 - Limited capacity in auditory processing channel
 - Extraneous sound competes with narration for processing capacity
- Experimental Results:
 - Clearly better retention & transfer when additional sounds omitted

Cognitive Analysis of Coherence Principle Type 2



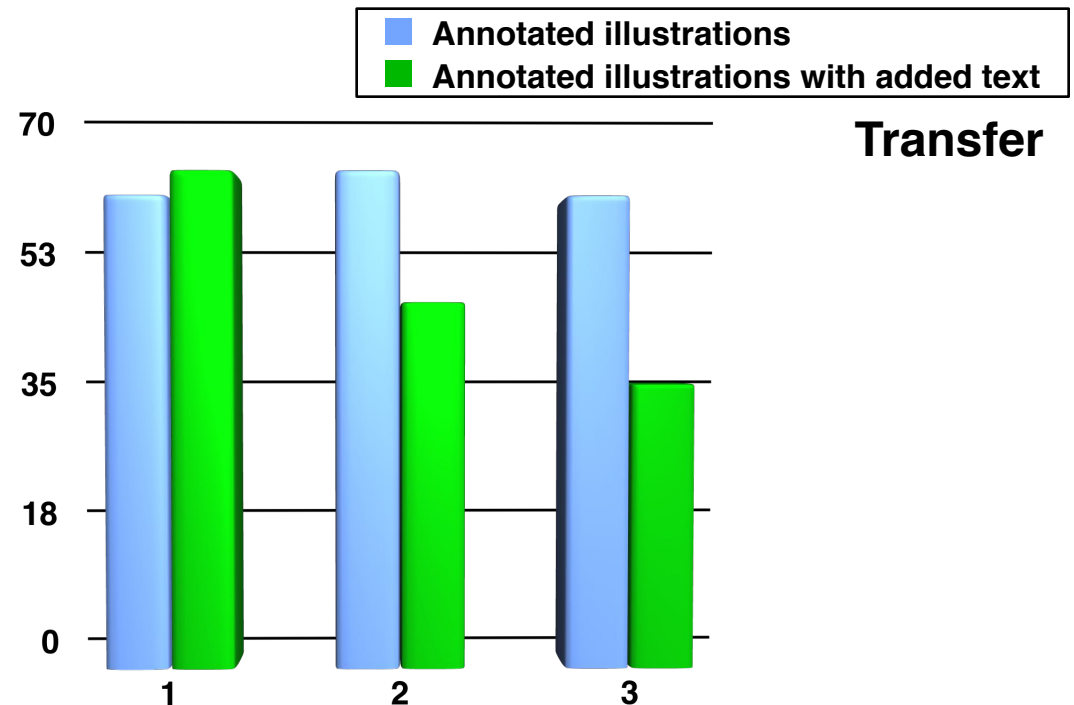
Experimental Results on Coherence Principle (3)



Retention



"... shows that the coherence effect sizes are consistent and moderate, with a median of .70, and students who received the summary version ... generated a median of 28% more creative solutions than did students who received the full version."
(Mayer 2001, p.131)



Transfer



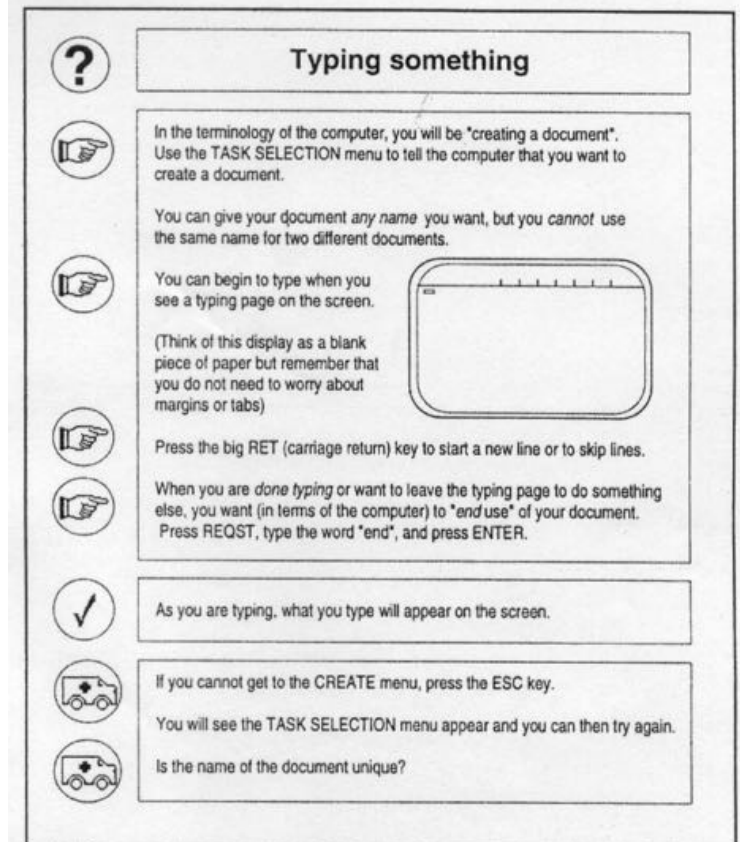
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History of the Redundancy Principle



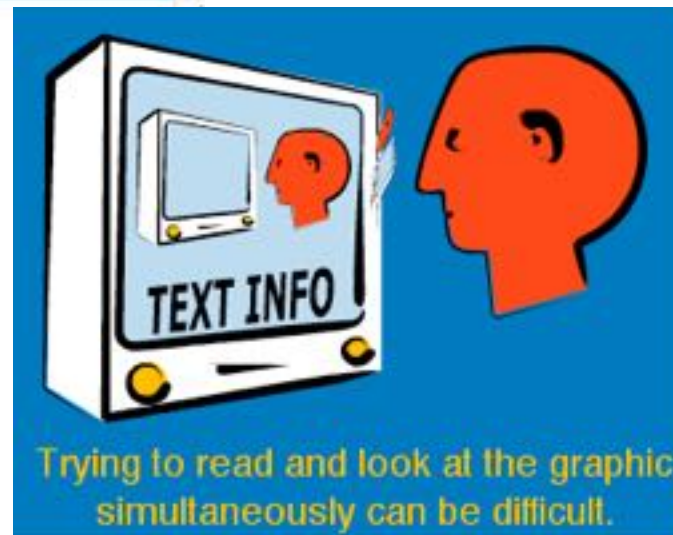
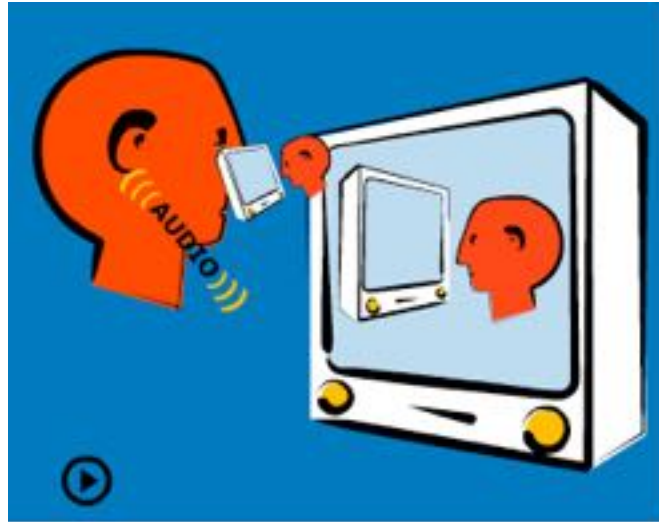
- Miller (1937)
 - Word "cow" spoken and read
 - Word "cow" spoken, read and picture shown
 - Reading test was always better for teaching *without* pictures!
- Reder, Anderson (1980-82):
 - Full text of textbook chapters (geography, linguistics, economy etc.)
 - Summaries of the text (20% length)
 - "To our surprise, all ... experiments indicated that subjects learn information better when they read an abridged or summarized version of the original text than when they read the original chapter."
- Carroll et al. (1990):
 - "The minimal manual"



Redundancy Principle

- Formulation of the Redundancy Principle in Mayer (2001):
 - **Students learn better from animation and narration than from animation, narration, and text.**
- Redundancy principle in Multimedia Learning according to Sweller (2005):
 - More general:
 - » **"Redundant material interferes with rather than facilitates learning."**
 - » "Redundancy effect occurs when additional information presented to learners results in learning decrements..."
 - Identical information presented in two or more different forms or media is not helpful for learning
 - Criticism: Multiple Representations Theories – see next lecture

Multimedia Redundancy Effect



- Audio narration plus video animation
 - Balanced combination
 - Load distributed between auditory and visual channels
- Audio narration plus video animation plus on-screen text
 - Animation and text compete for the visual channel
 - Overall effect **worse** than for a subset of the presentation forms

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Presentation Style Principles

- Personalization Principle:
Students learn better from multimedia lessons when words are in conversational style rather than formal style.
- Voice Principle:
Students learn better when the narration in multimedia lessons is spoken in a friendly human voice rather than a machine voice.
- Image Principle:
People do not necessarily learn better from a multimedia lesson when the speaker's image is added to the screen.

Adapted from

http://hartford.edu/academics/faculty/fcl/d/data/documentation/technology/presentation/powerpoint/12_principles_multimedia.pdf