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Theory-based Design Criteria for the Creation of Animations for Chemistry Lessons

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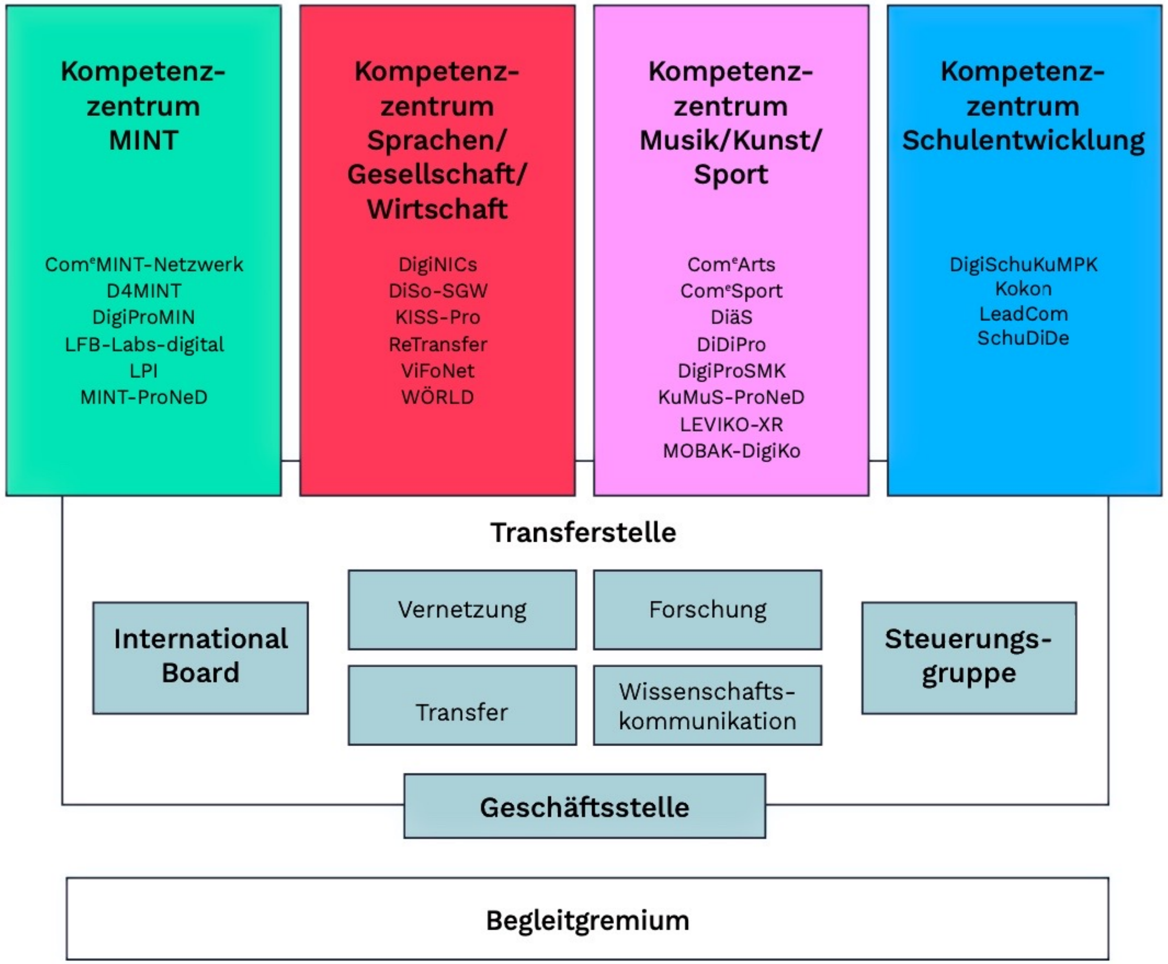
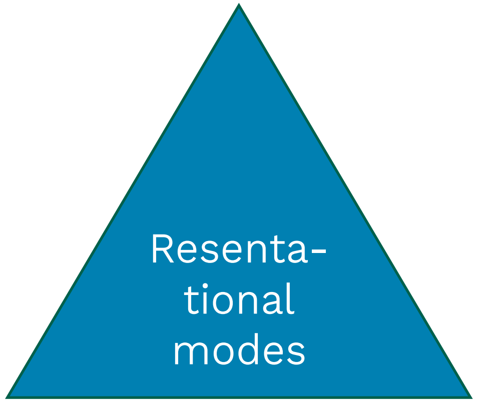
Competence network „lernen:digital“

Kompetenzverbund lernen:digital

- 500+ participants from university, state institutes and schools
- 200+ projects
- Competence center with focus on STEM, languages/economy, music/art/sports and school development
- Main goal: creation of teacher trainings for digital enhanced teaching
- https://lernen.digital



Triangle of chemistry teaching by Johnstone



by A. H. Johnstone (1993)

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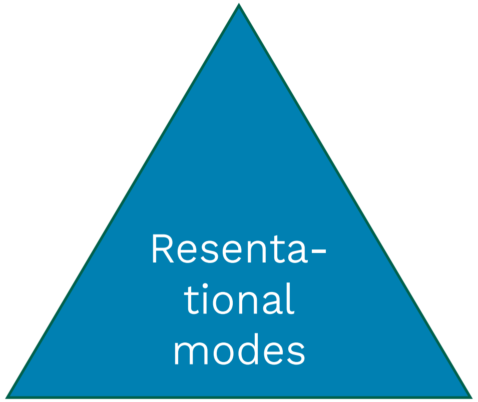

macroscopic

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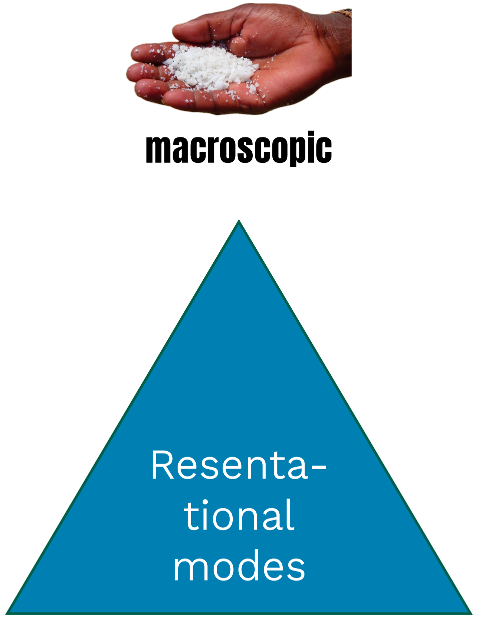

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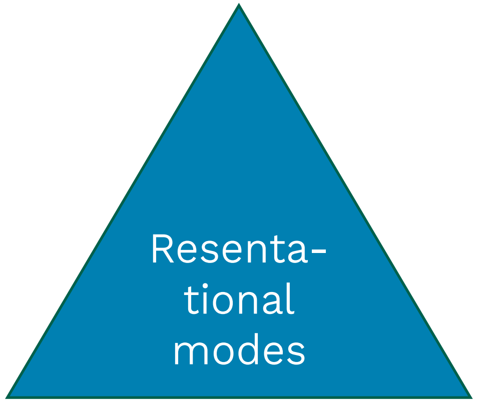
Triangle of chemistry teaching by Johnstone

macroscopic

symbolic

NaCl



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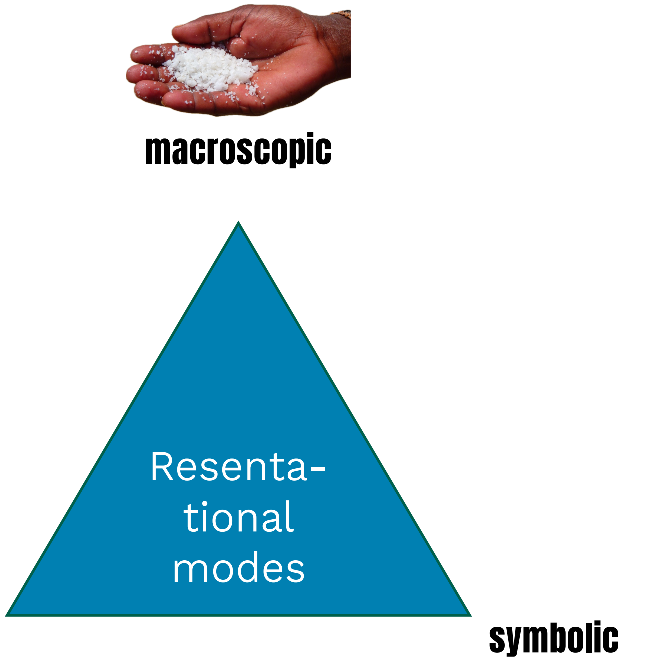

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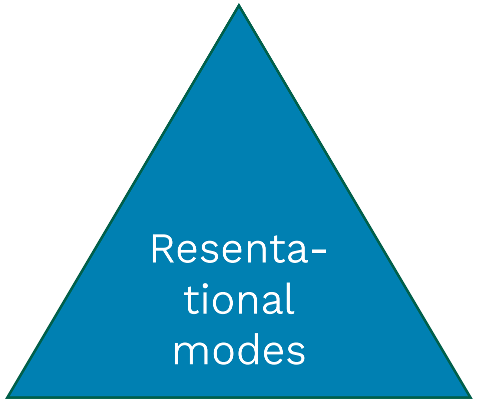
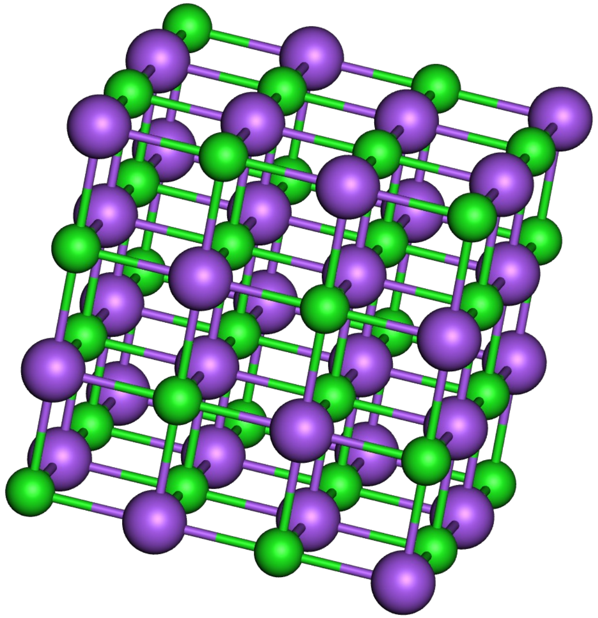


symbolic

NaCl

by A. H. Johnstone (1993)

submicroscopic



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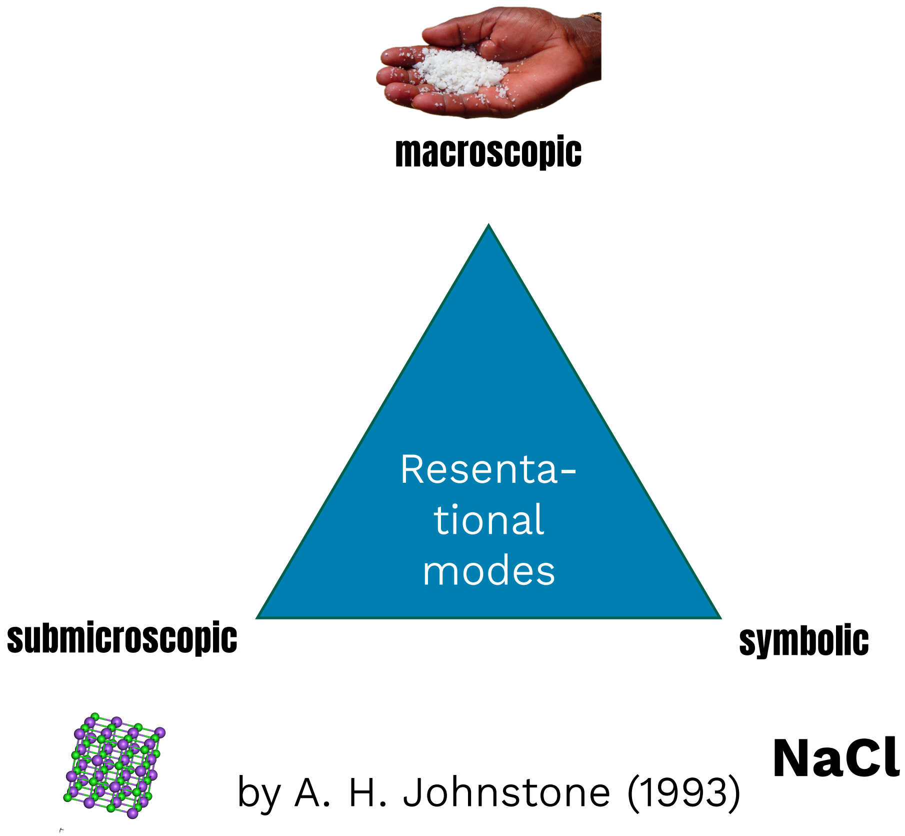

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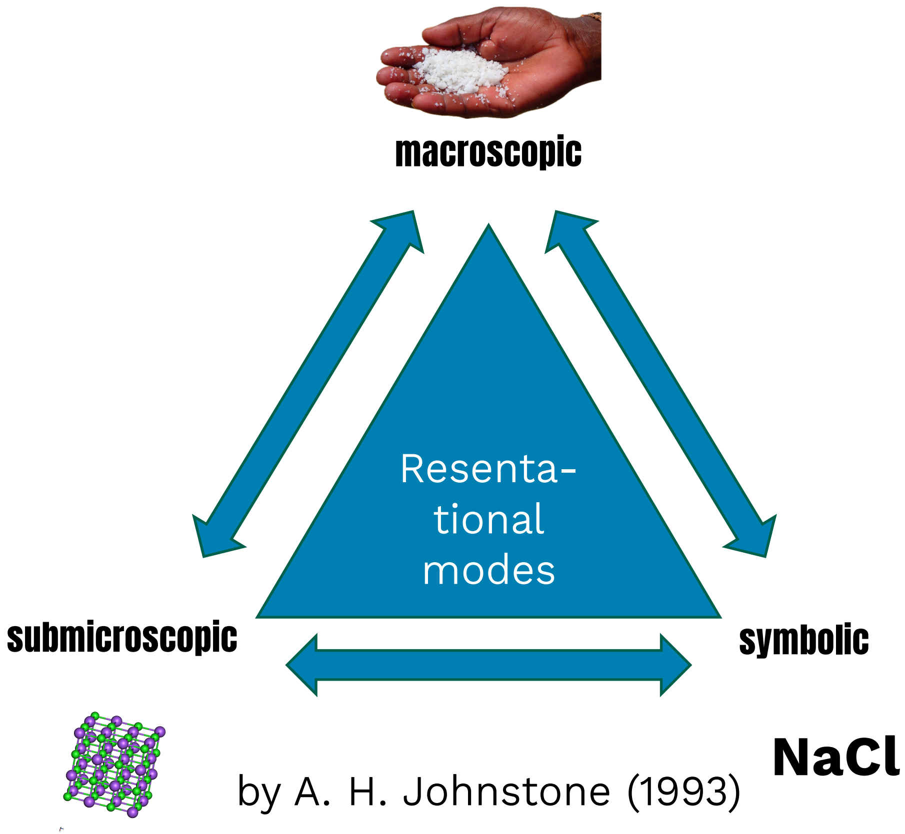
Triangle of chemistry teaching by Johnstone



by A. H. Johnstone (1993)

- „classic“ chemistry teaching: from macroscopic (e.g., experiment) to symbolic (e.g., chemical equation) → learning difficulties (vgl. H.-K. Wu und P. Shah (2004))
- essential for chemical understanding: submicroscopic visualization + connecting with other resentational modes (vgl. H.-K. Wu und P. Shah (2004))
- **Animations** show the dynamic nature of chemical reactions on a submicroscopic level

1. Research questions

How can animations be designed?

Criteria for other media

example:

Criteria for learning videos (e.g. Kulgemeyer (2020)) → *adaption to animation in chemistry lessons*

Criteria for other animations

example:

Animation for physics lessons → adaption to animation in chemistry lessons

1. Research questions

1. To what extent can animations be constructed based on theory in such a way that they can be optimally perceived by students?

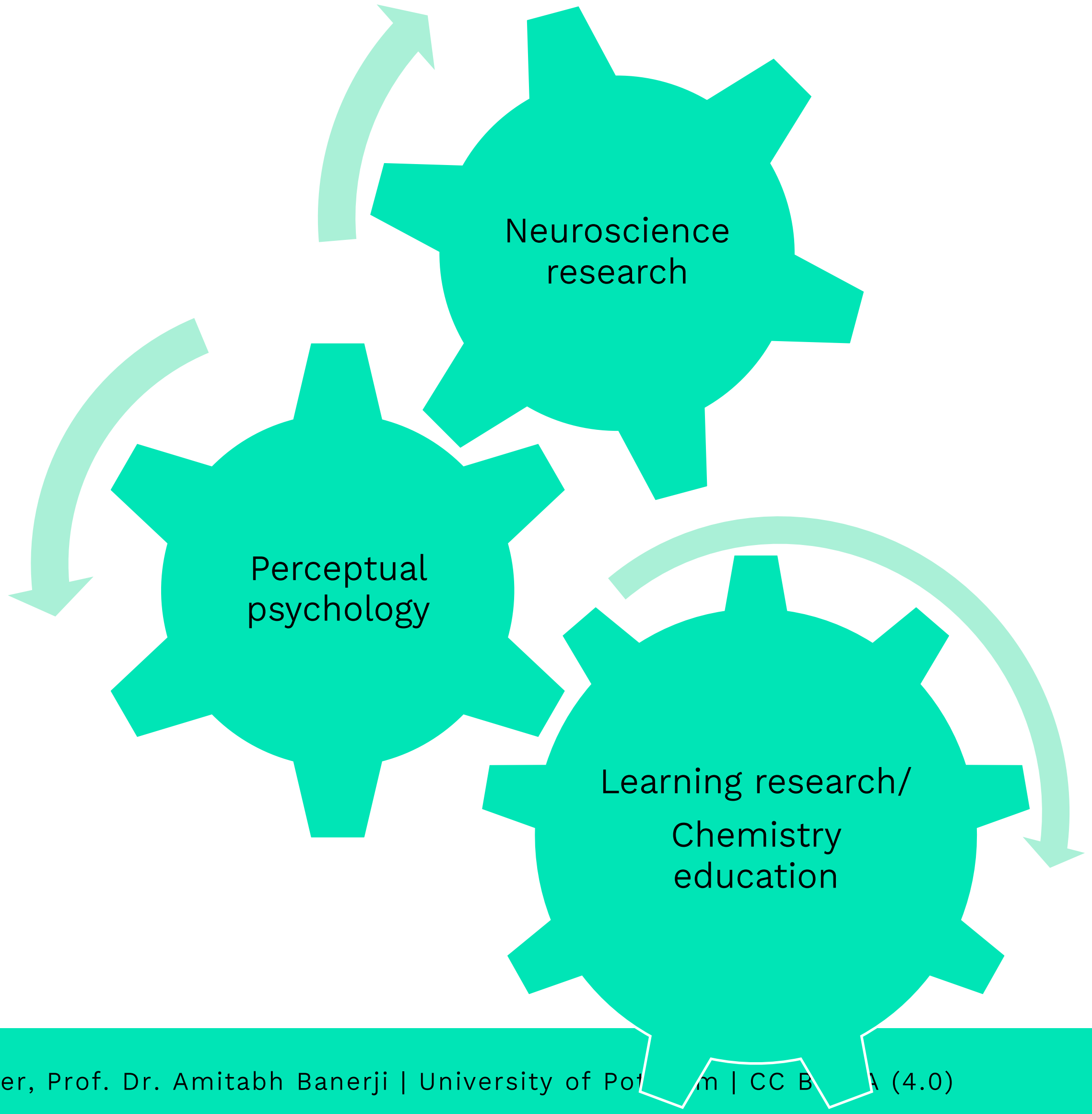
2. Can design criteria be derived from higher-level disciplines for chemistry lessons?

3. What aspects do teachers need to consider when using animation in chemistry lessons?

Structure

1. Research questions
2. scientific background for the criteria catalog
3. Structure of the criteria catalog
4. Exemplary presentation of some criteria
5. Limits and potentials
6. Discussion

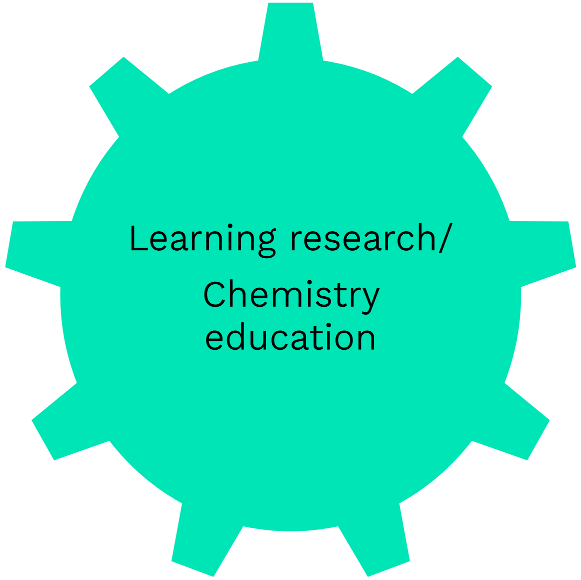
2. scientific background for the criteria catalog



2. scientific background for the criteria catalog

Key aspects:

- scientifically correct and appropriate selection of content for the learning group
- Analyzing different teaching situation for the use of animation
- Embedding digital media in a lesson
- Misconceptions about chemical processes
- Sample literature: H.-D. Barke et al., 2017; F. Paas and J. Sweller, 2014



2. scientific background for the criteria catalog

Perceptual psychology

Key aspects:

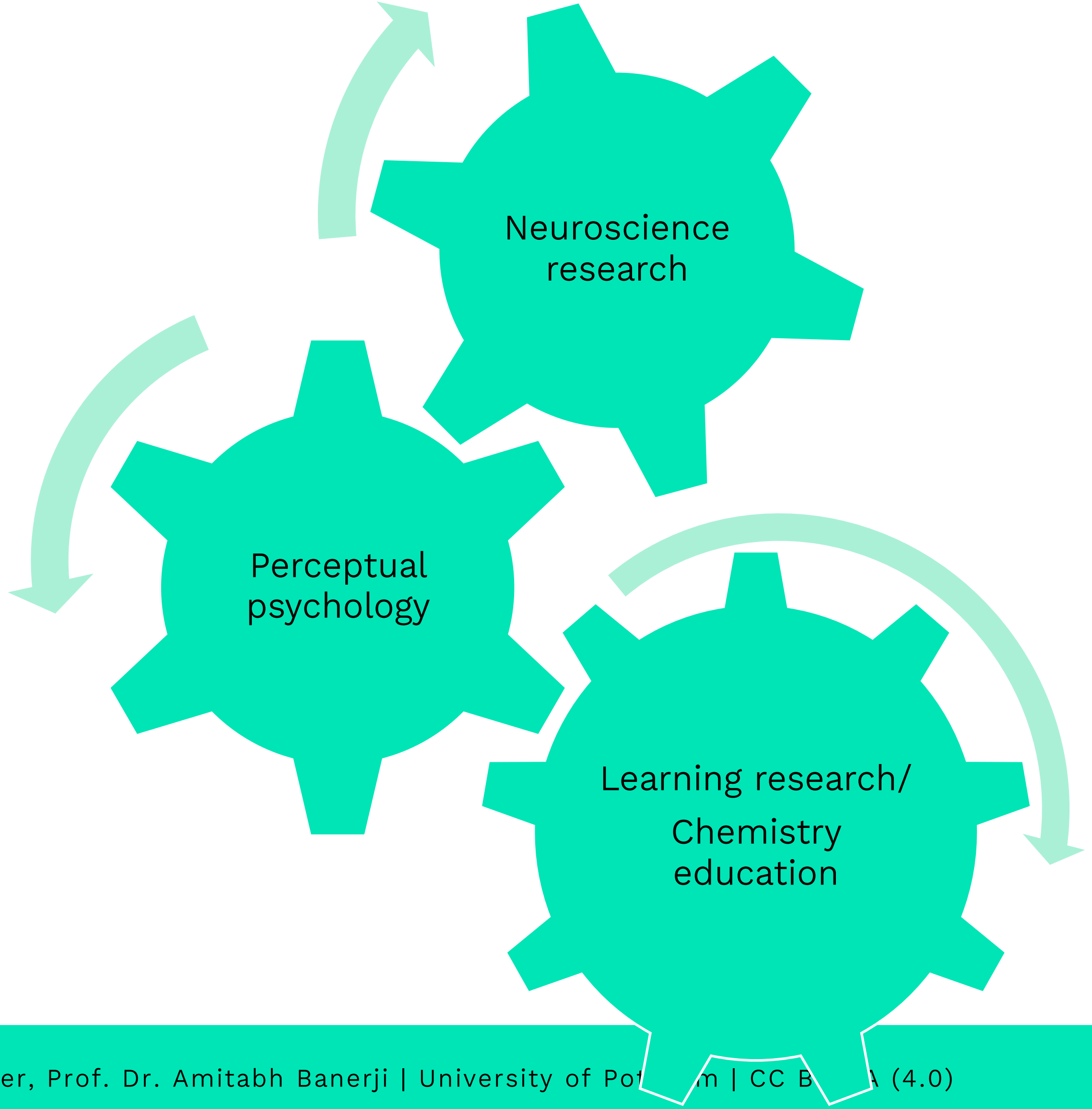
- Laws of perception and design
- Problems and limits of perception
- Empirically proven principles and models
- Sample literature: J. Müsseler and M. Rieger, 2017

2. scientific background for the criteria catalog

Key aspects:

- Structure of the brain and sensory organs
- Cortical processing pathways
- Physiological requirements for stimulus processing
- Sample literature: M. F. Bear, B. W. Connors and M. A. Paradiso, 2018

2. scientific background for the criteria catalog



2. scientific background for the criteria catalog

- 64 publications reviewed with focus on creating animations
- Identified a total of 19 different criteria from 10 publications
- These 19 criteria form the raw version of the criteria catalog
- 1 expert interview with university professor (chemistry education), more to come
- Feedback from teachers

3. Structure of the criteria catalog

- Tabular structure
- Table header with:
  - main focus (chemical aspects, learning/teaching aspects, design aspects)
  - Design criteria
  - Feature of the animation to check the criterion
  - Explanation
  - Literature source
- Sorted by focus and importance for the animation

3. Structure of the criteria catalog

Chemical aspects

1. The subject-related content in the animation is scientifically consistent.
2. The animation is adapted to the learners' prior knowledge and cognitive level of development.
3. The animation is divided into sections (micro chunks).
4. The limitations of the used models are addressed.
5. Coloring of particles (atoms, molecules etc.) should be different from the color of the represented material.

learning/teaching aspects

6. Only show one animated chemical content at a time.
7. The animation is didactically embedded in the lesson by means of a task.
8. Interaction is possible, such as forwarding, rewinding and pausing.
9. The animation allows to link the symbolic, macroscopic and submicroscopic information in a meaningful way.

Design aspects

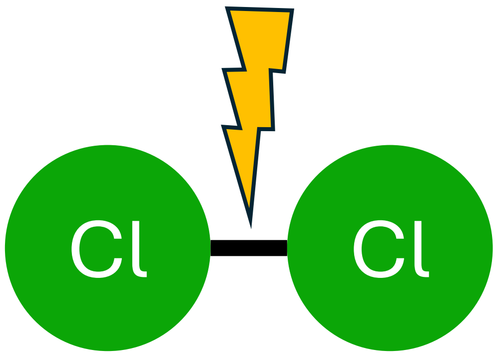
10. Linear or predictable movements were used.
11. The design was realized with simplified lines, rectangles and circles.
12. Perception was directed to relevant aspects of the animation.
13. No text overlays and movement were used at the same time.
14. The animated objects should stand out clearly from the background.
15. The animation shows temporal sequences as well as causal relationships.
16. Perception of detail and perception of movement are differentiated from each other.
17. The amount of dynamics are used appropriately.
18. Different objects are clearly distinguished from one another in terms of direction of movement, position, orientation and color.
19. Consistent design conventions are used.

4. Exemplary presentation of some criteria

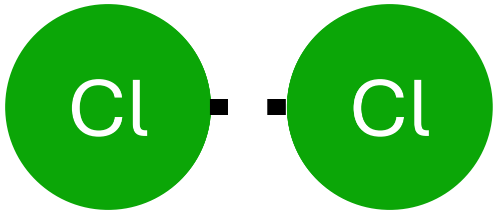
3. The animation is divided into sections (micro chunks).

Negative and positive example

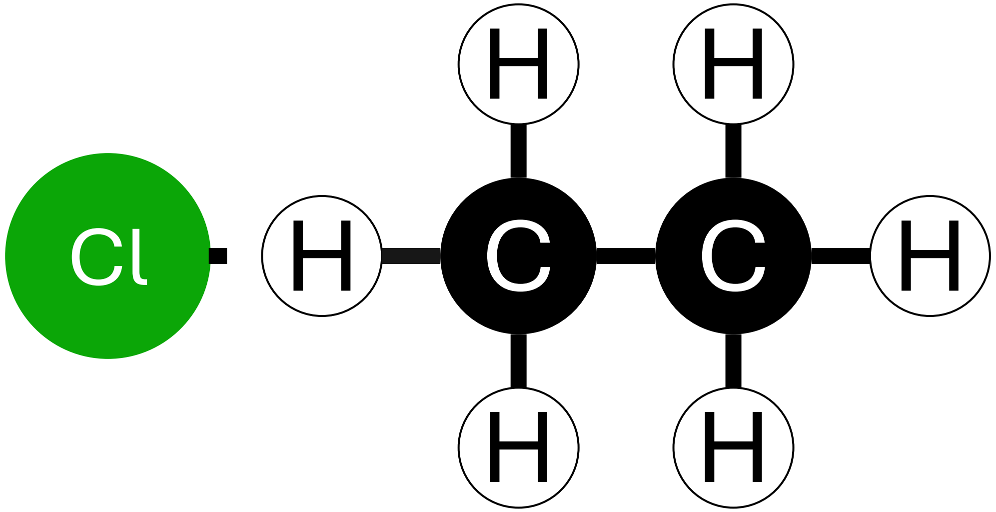
Negative example



Negative example



Negative example



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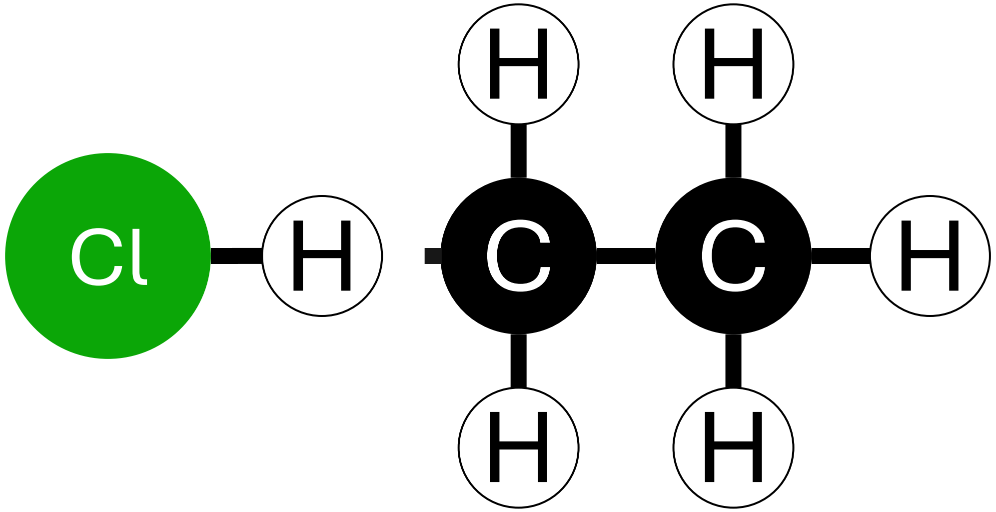
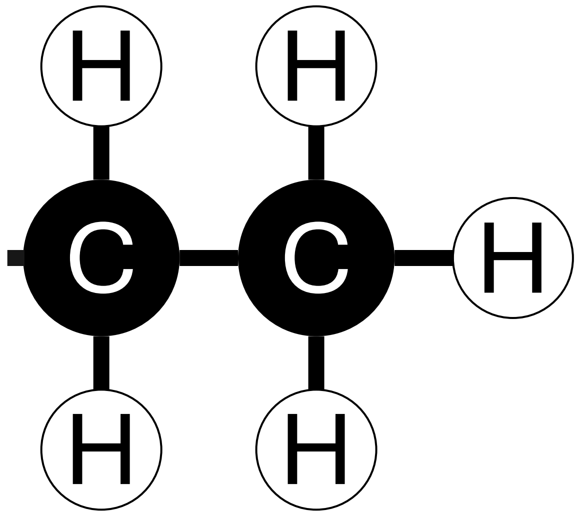
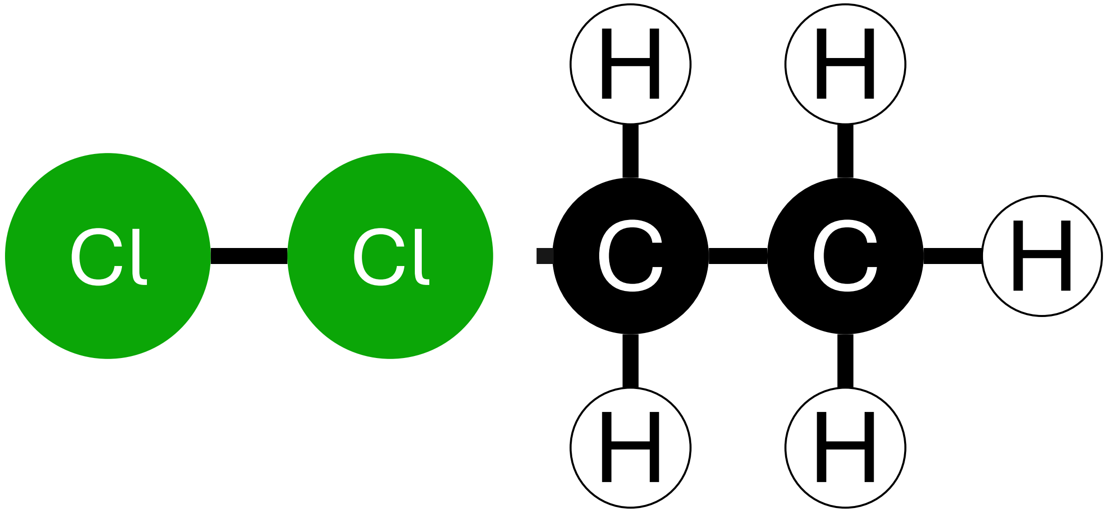


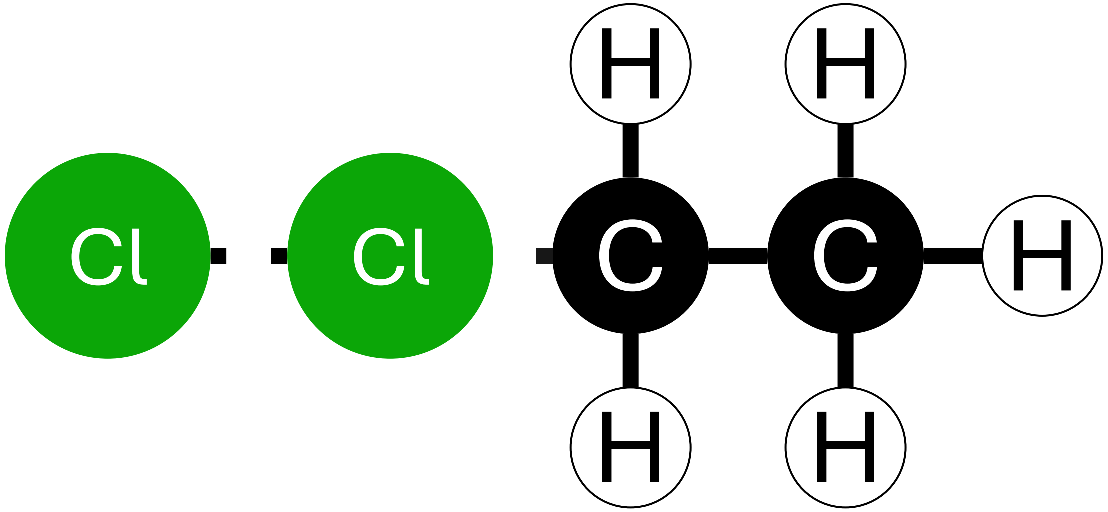
Negative example



Positive example



Positive example



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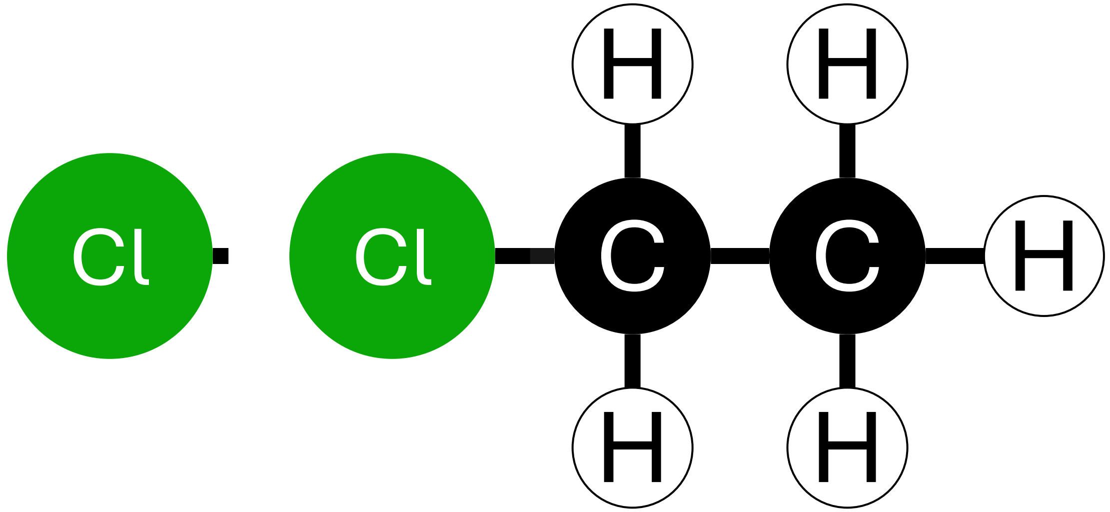

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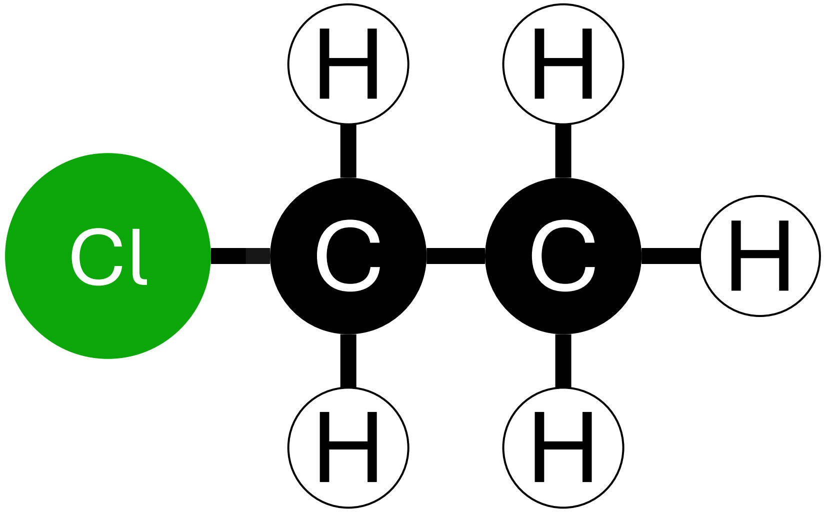
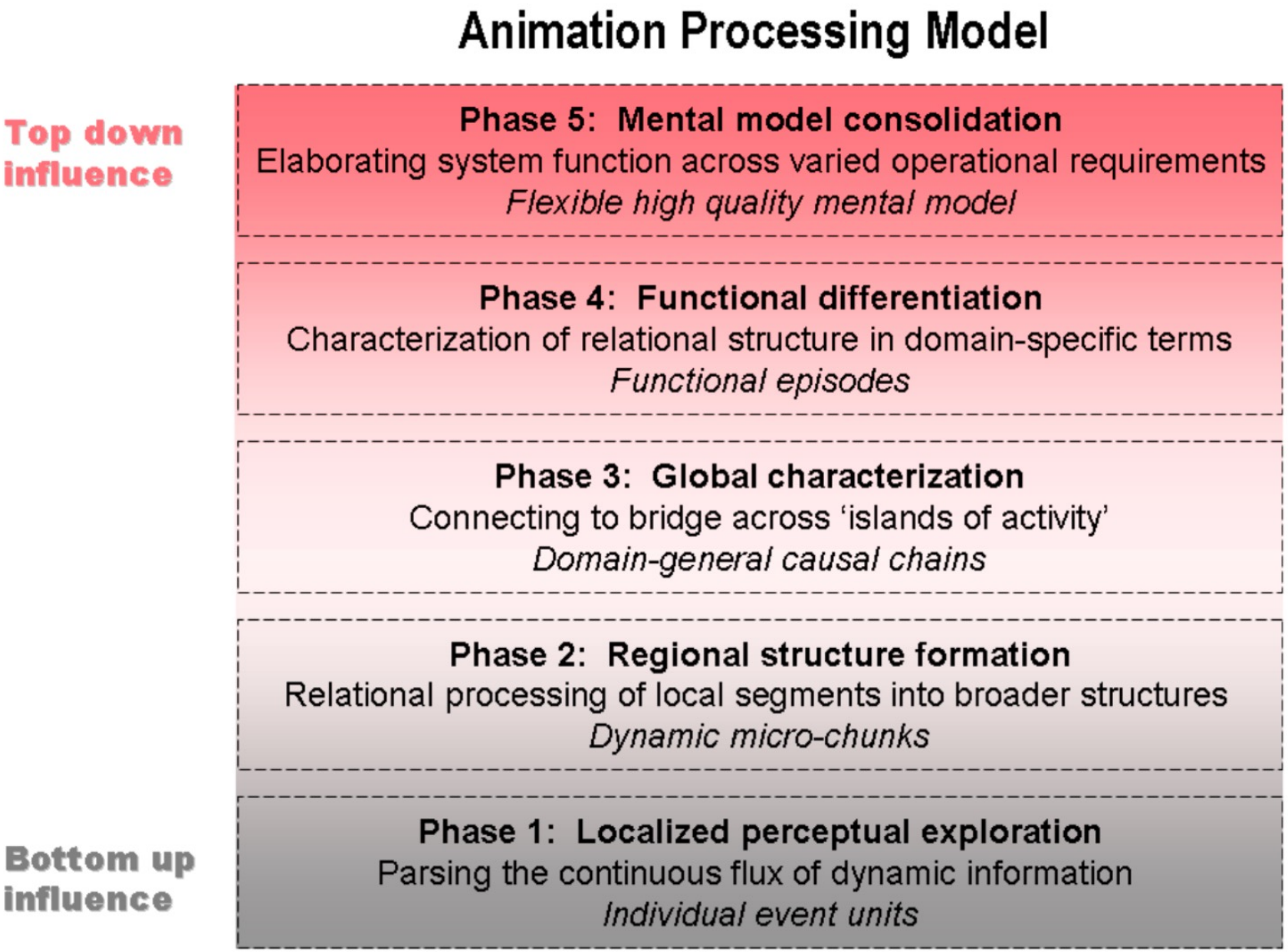
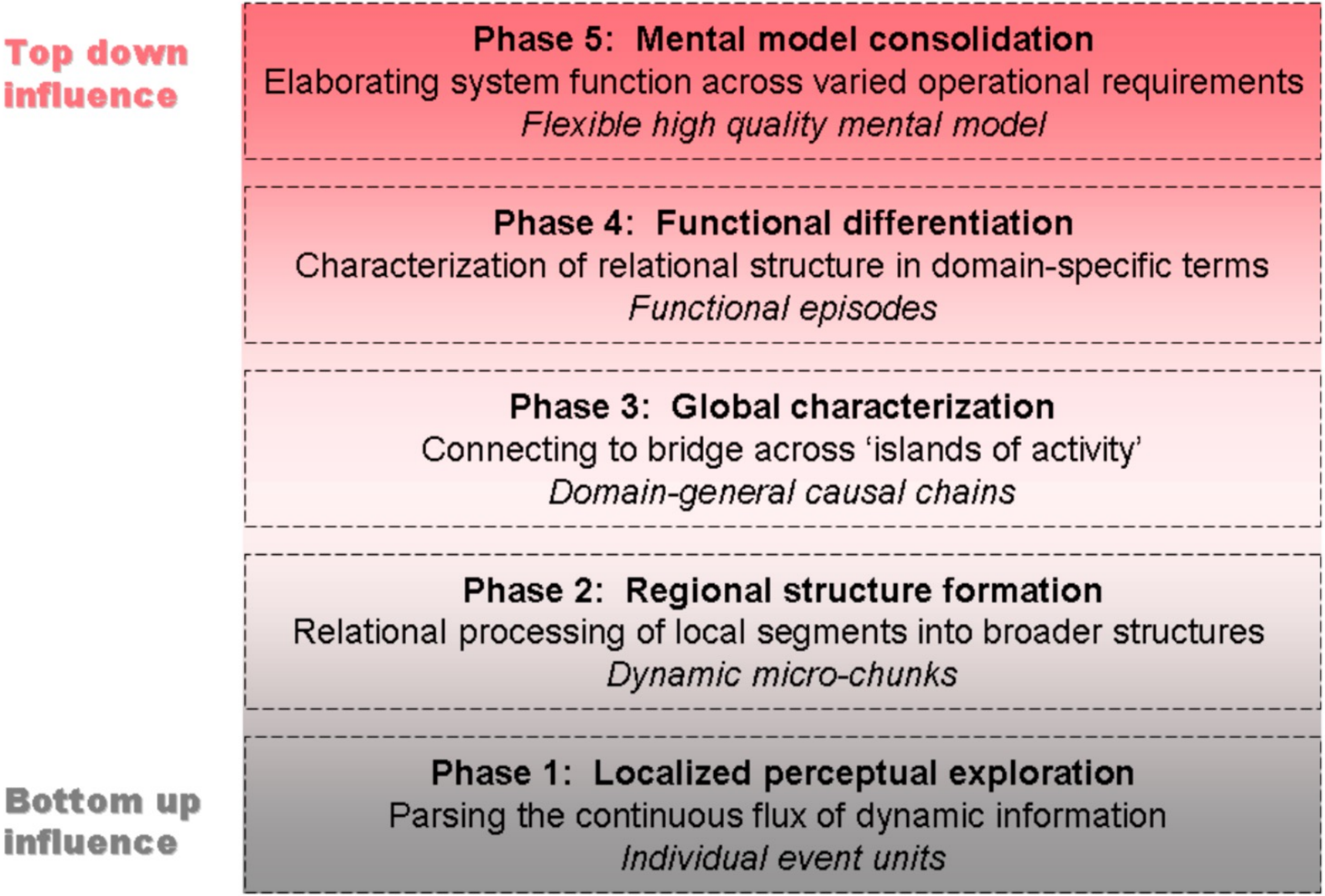


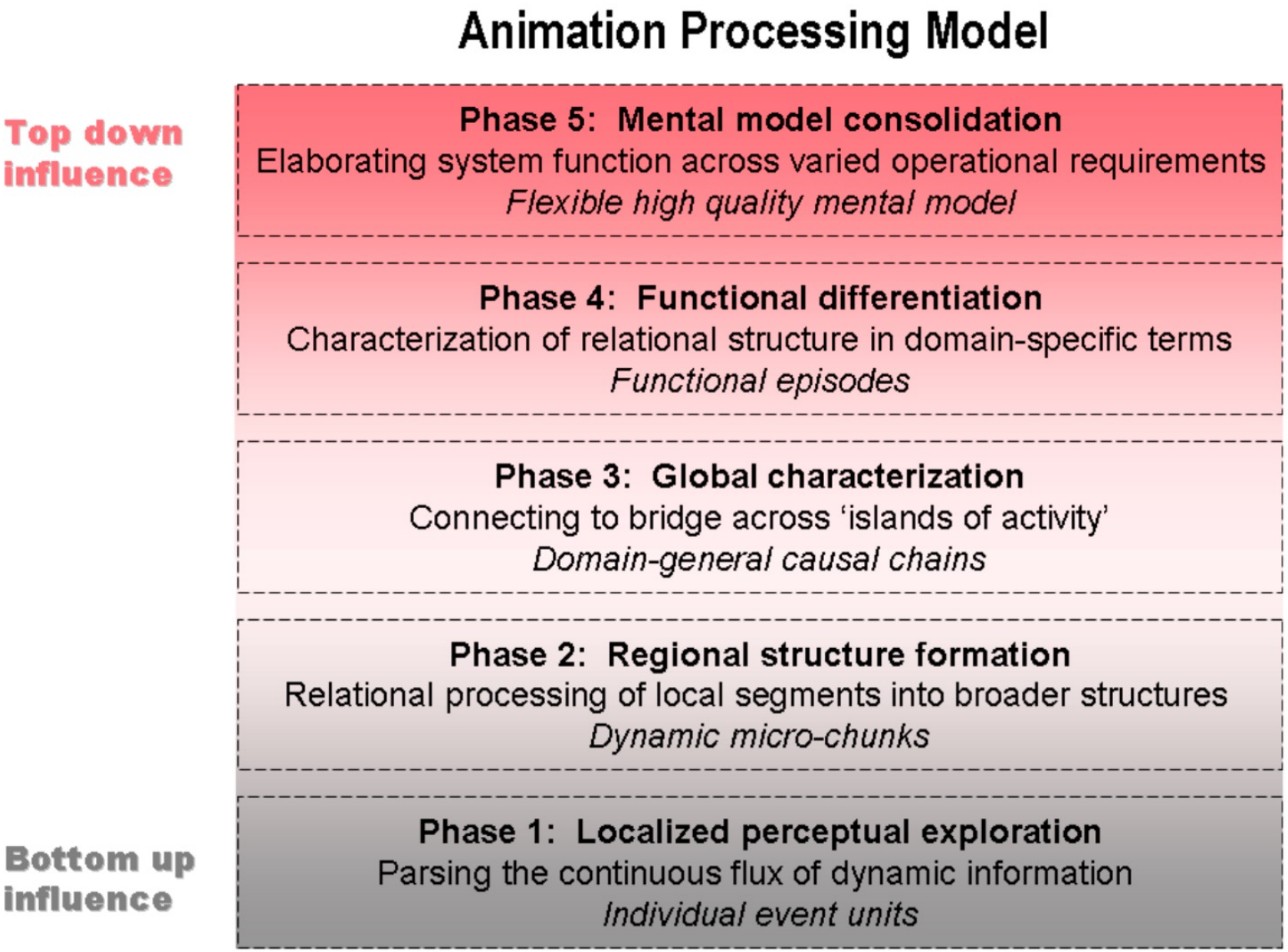
4. Exemplary presentation of some criteria



R. K. Lowe und W. Schnotz (2014)


Top down influence
Phase 5: Mental model consolidation
Elaborating system function across varied operational requirements
Flexible high quality mental model
Phase 4: Functional differentiation
Characterization of relational structure in domain-specific terms
Functional episodes
Phase 3: Global characterization
Connecting to bridge across 'islands of activity'
Domain-general causal chains
Phase 2: Regional structure formation
Relational processing of local segments into broader structures
Dynamic micro-chunks
Phase 1: Localized perceptual exploration
Parsing the continuous flux of dynamic information
Individual event units
Bottom up influence

4. Exemplary presentation of some criteria



R. K. Lowe und W. Schnotz (2014)

4. Exemplary presentation of some criteria

3. The animation is divided into sections (micro chunks).

- supports learners in phase 1 (decomposition of the continuous flux of information) of the Animation Processing (R. K. Lowe und W. Schnotz (2014))

→ reduction of cognitive load (R. K. Lowe und J.-M. Boucheix (2016))

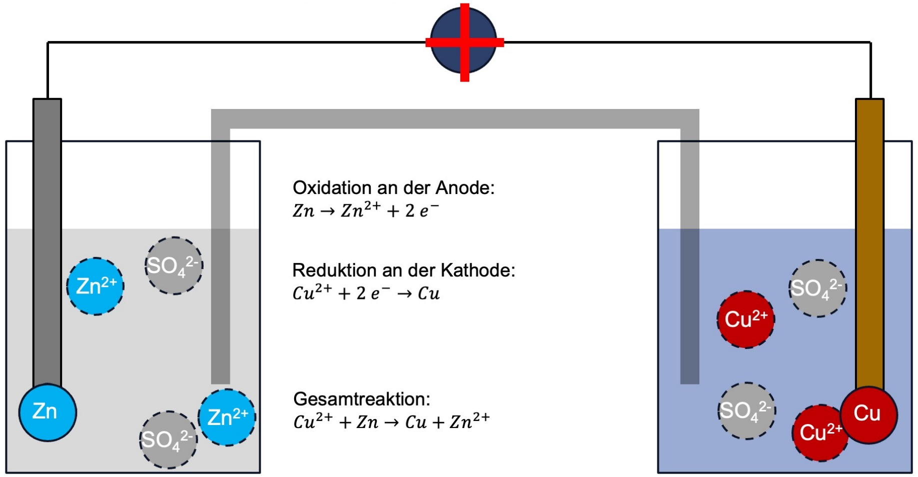
→ scenes involving electron transfers and submicroscopic movement should be separated by short breaks

4. Exemplary presentation of some criteria

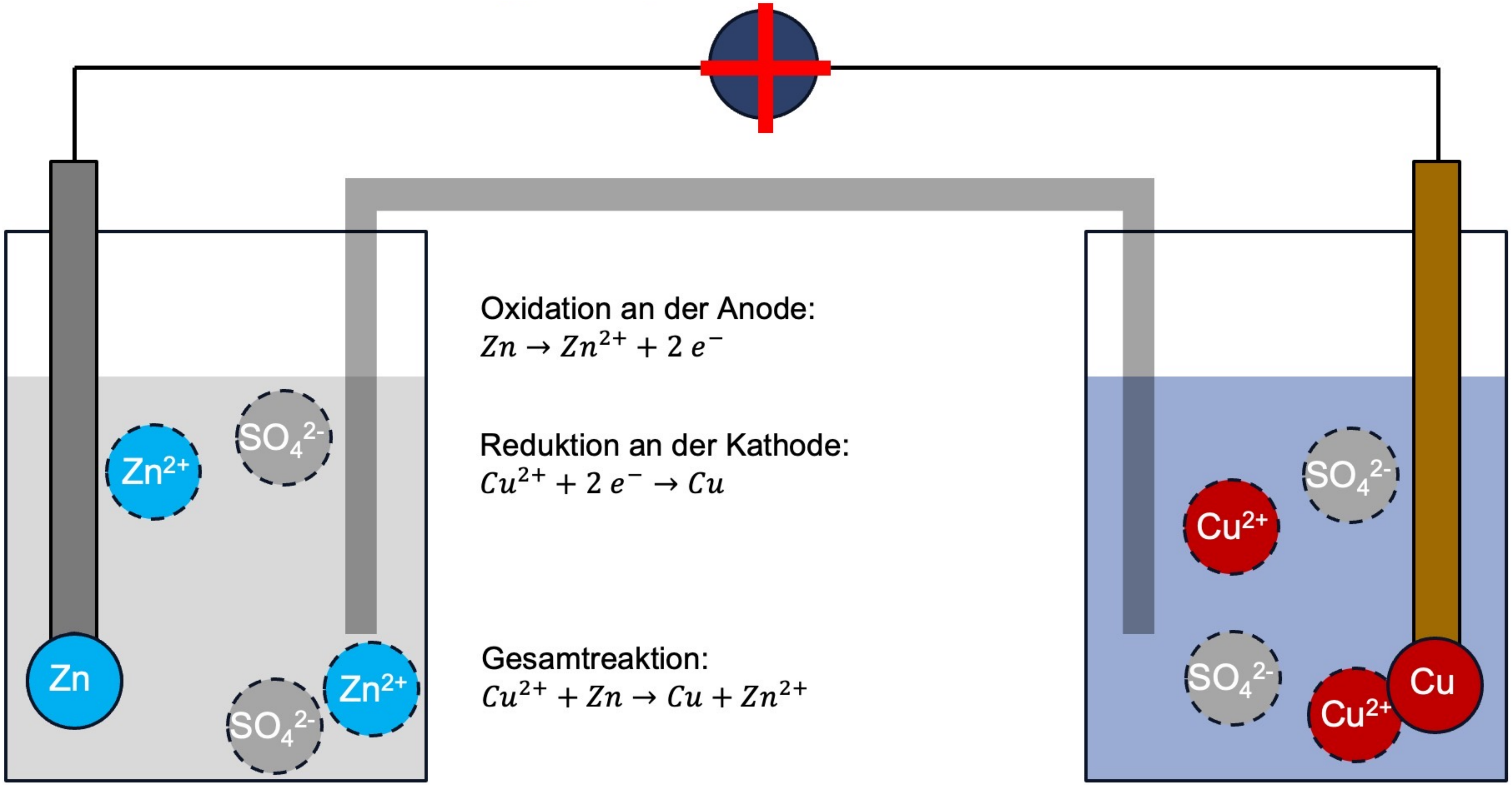
9. The animation allows to link the symbolic, macroscopic and submicroscopic information in a meaningful way.

positve: link animations with real experiments and tasks about symbolic information (e.g. reaction equation) (vgl. H.-K. Wu und P. Shah, 2004)

negative:



4. Exemplary presentation of some criteria



4. Exemplary presentation of some criteria

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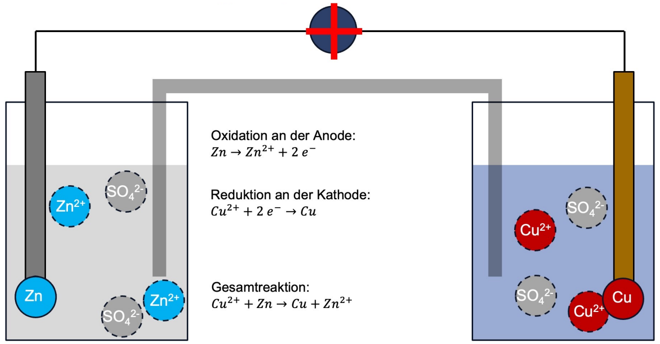
positve: link animations with real experiments and tasks about symbolic information (e.g. reaction equation) (vgl. H.-K. Wu und P. Shah, 2004)

negative: mixing resentational modes → misconceptions about the size of atoms/molecules, particle carry properties of substances, ...
(H.-D. Barke, et al., 2018)



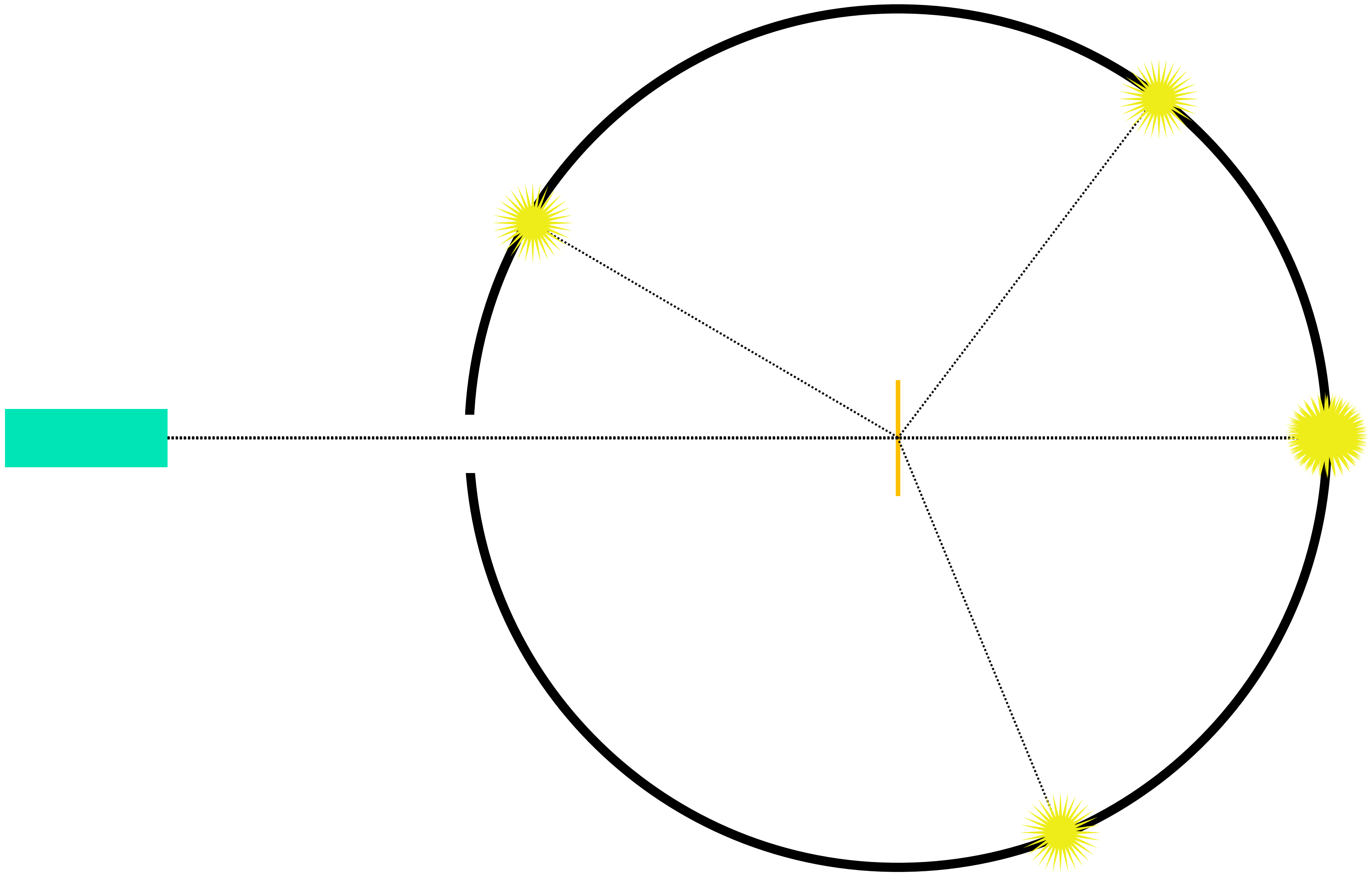
4. Exemplary presentation of some criteria

10. Linear or predictable movements were used.

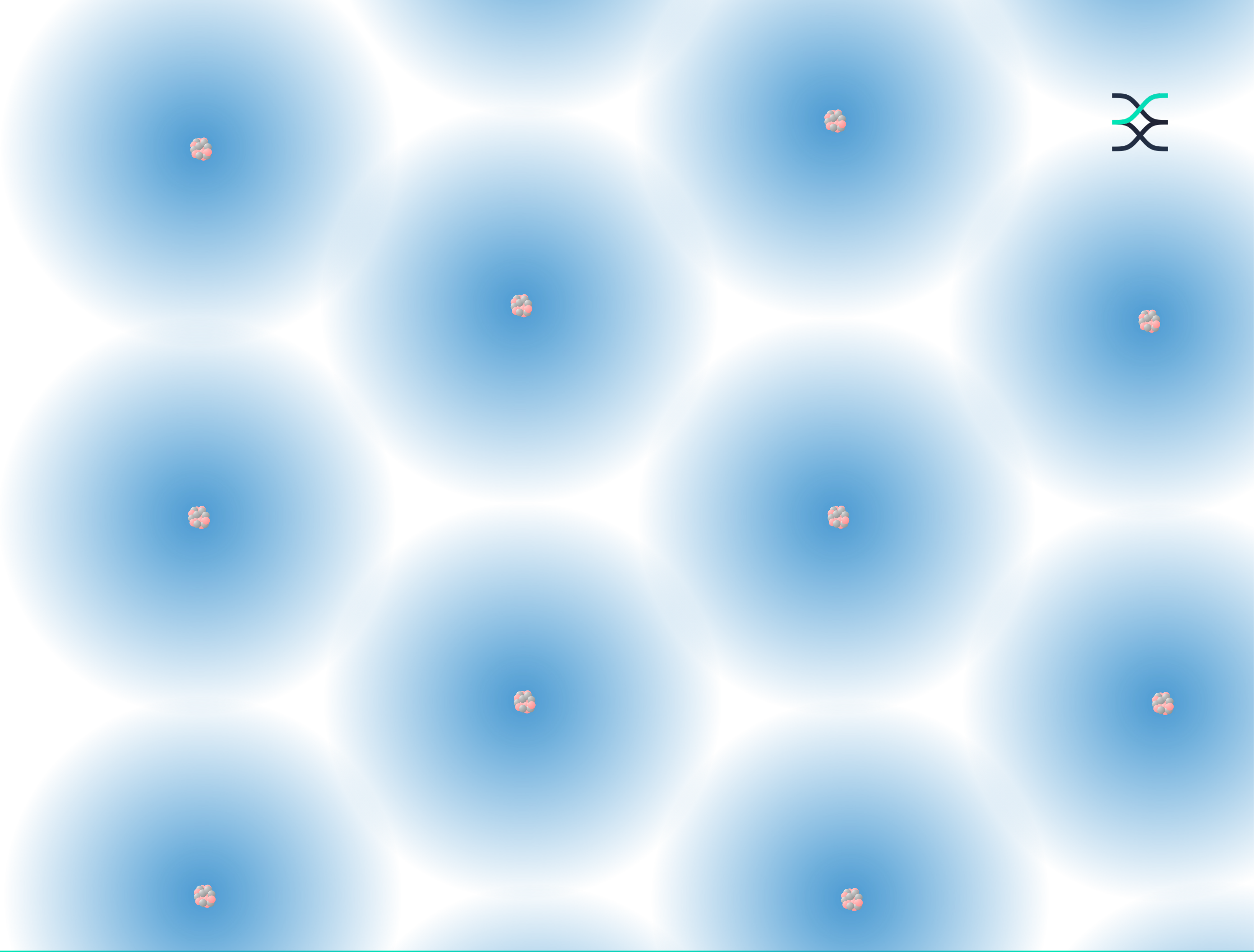
A sensory stimulus preactivates surrounding ganglion cells (M. J. Berry et al. 1999) on the retina and corresponding cortical cells (W. Erlhagen et al. 1999) according to a linear activation pattern

- Preactivation ensures faster stimulus perception if the stimulus actually hits these sensory cells (J. Müsseler und M. Rieger, 2017)
- If a change in direction occurs object is not observed for tenths of a second due to localization error (flash-lag effect) (J. Müsseler und M. Rieger, 2017)
- Critical view on specific animations (e.g. Rutherford scattering)

Macroscopic level



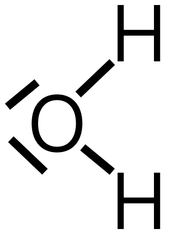
Submicroscopic level

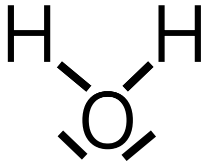


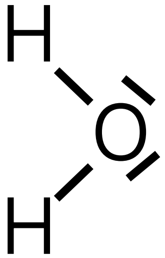
4. Exemplary presentation of some criteria

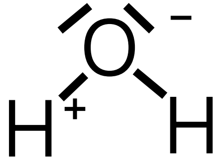
12. Perception was directed to relevant aspects of the animation.

Negative example:





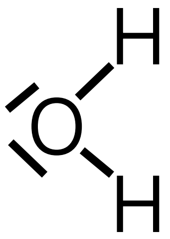


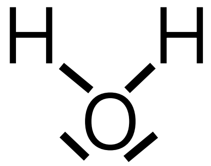


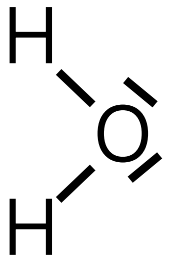
4. Exemplary presentation of some criteria

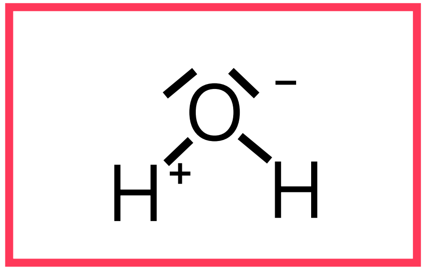
12. Perception was directed to relevant aspects of the animation.

Positive example:









4. Exemplary presentation of some criteria

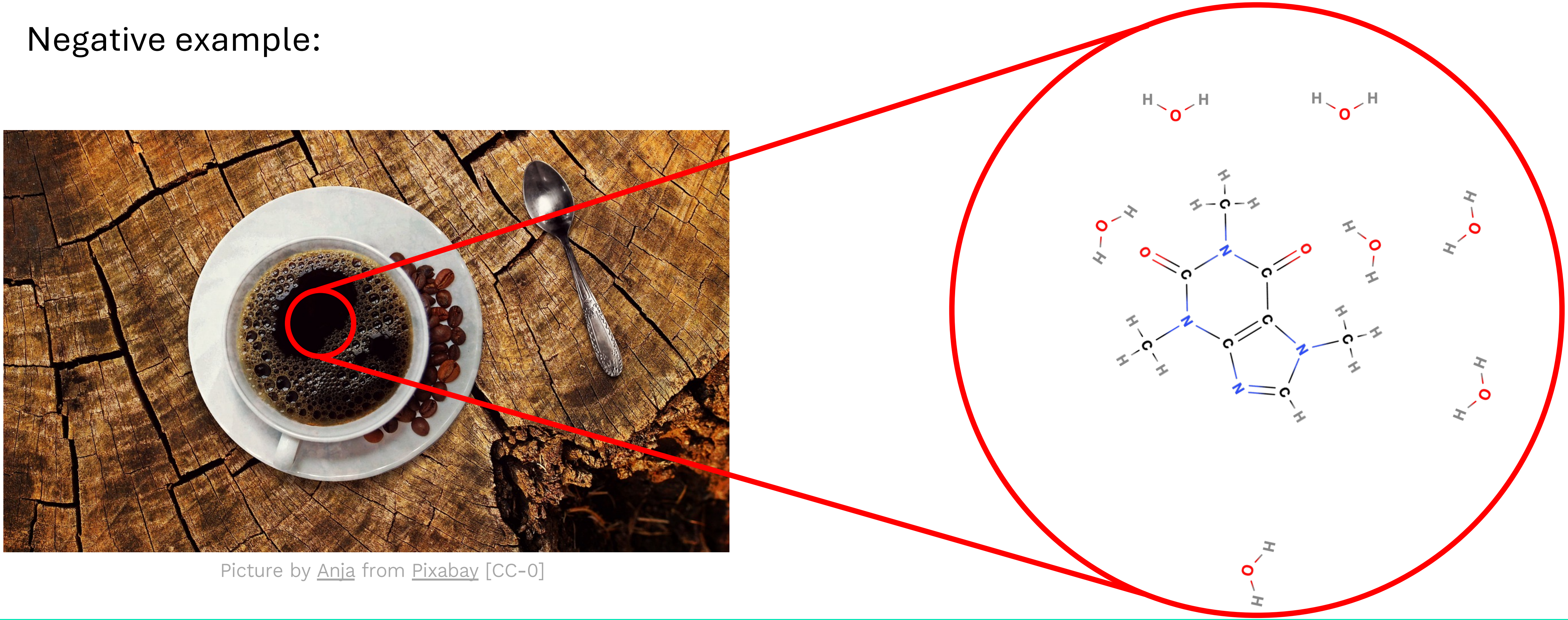
12. Perception was directed to relevant aspects of the animation.

- supports learners in phase 1 (highlight the most relevant information) of the Animation Processing Models (R. K. Lowe und W. Schnotz (2014))
- Adaptation to an animation outside the current field of view can take a few tenths of a second → Parts of the animation are missed (J. Müsseler und M. Rieger, 2017)

4. Exemplary presentation of some criteria

16. Perception of detail and perception of movement are differentiated from each other.

Negative example:



Picture by Anja from Pixabay [CC-0]

4. Exemplary presentation of some criteria

16. Perception of detail and perception of movement are differentiated from each other.

- P-type ganglion cells (Fig. a): small receptive fields → Differentiation of fine differences in color and brightness, respond only slowly (detailed perception)
- M-type ganglion cells (Fig. b): large receptive fields → Differentiation of big differences in color and brightness, respond quickly (motion perception)
- There are two separate transmission paths in the brain, which are processed in different areas of the brain (posterior parietal cortex and infero-temporal cortex)
- → Only static objects can be perceived in detail → Do not animate texts or detailed objects

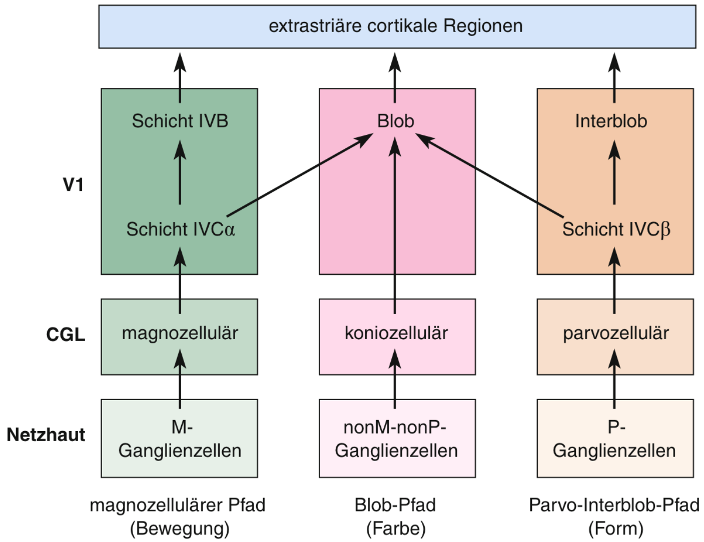
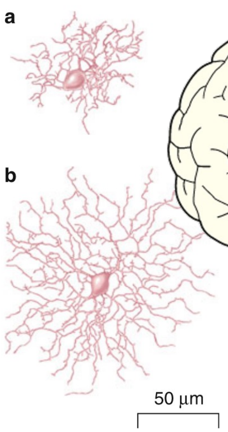


Fig.: M. F. Bear, B. W. Connors und M. A. Paradiso, 2018



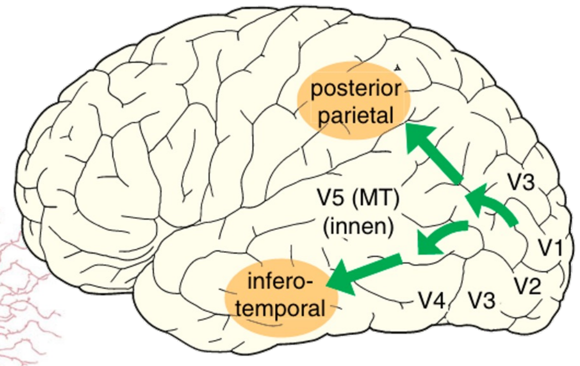


Fig.: J. Müsseler und M. Rieger, 2017

AFig: M. F. Bear, B. W. Connors und M. A. Paradiso, 2018

5. Limits and potentials

Potential:

- Basis Guidance for teachers to create high-quality animations that are supposedly better adapted to the learning group
- Measuring instrument for assessing the quality of animations
- Can also be transferred to other subject areas (especially physics and biology)
- Interdisciplinary collaboration to validate the criteria
- Explorative approach: Teachers (N=18) and students (N=32) used a simplified, reduced form of the design criteria in the discussion about animation creation
- Criteria enable theory-based creation of animations

5. Limits and potentials

Limits:

- No verification of whether meeting with the criteria increases the quality of animations
- No information on whether the criteria catalog is valid as a measuring instrument
- More detailed studies needed on the acceptance of these criteria by teachers
- Only few animations fulfill all design criteria or intentionally violate them (example: Rutherford's scatter experiment)

Research questions

1. To what extent can animations be constructed based on theory in such a way that they can be optimally perceived by students?

2. Can design criteria be derived from higher-level disciplines for chemistry lessons?

3. What aspects do teachers need to consider when using animation in chemistry lessons?

Literature

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