Managing Multiple Conceptions in Thermodynamics: A Comparison of Pluralist and Monist Teaching Approaches

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We now know preconceptions never disappear from our minds...
How should we teach scientific conceptions accordingly?

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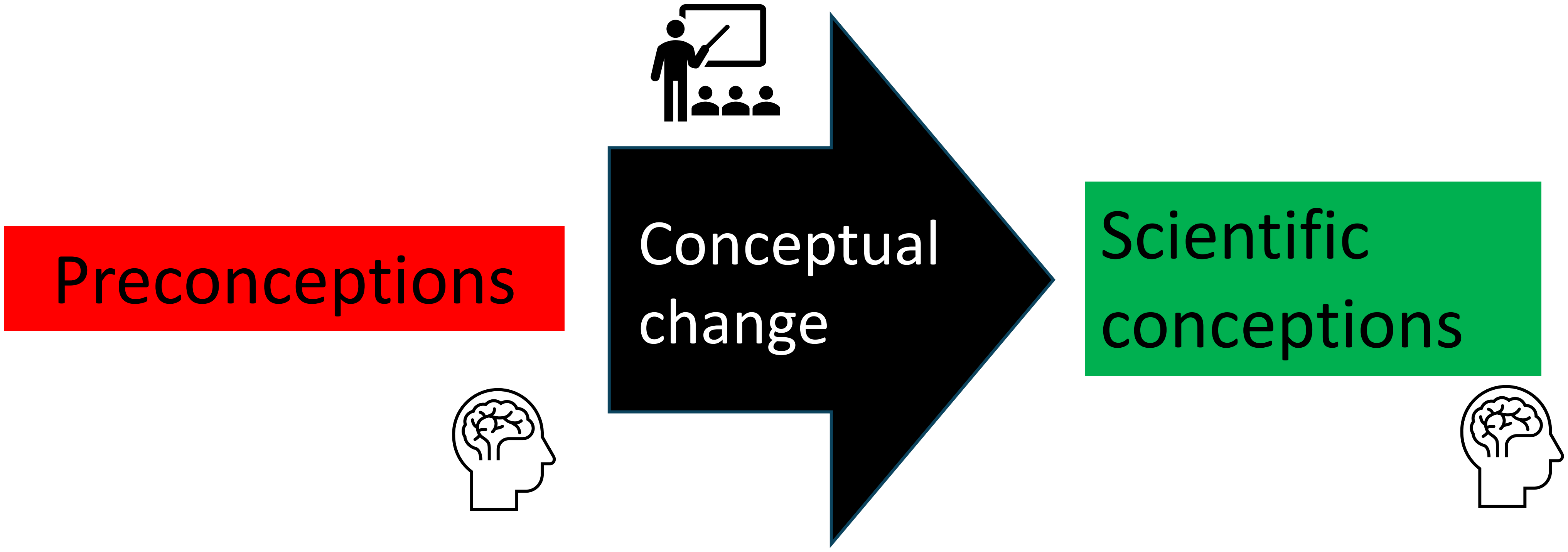
How should we teach scientific conceptions accordingly?

Conceptual change: classical models



***Monist* (>< pluralist) models**

- Scientific conceptions always a higher value
- Preconceptions must be discarded, forgotten

(Posner et al., 1982; Vosniadou, 1994)

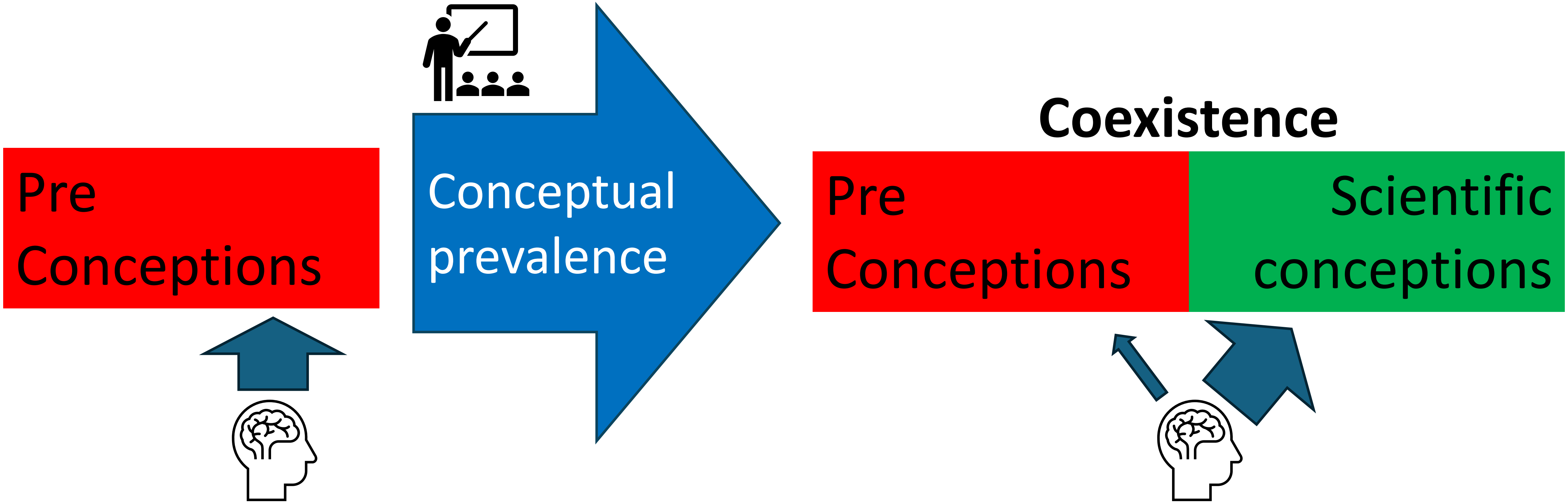
We now know preconceptions never disappear from our minds…

How should we teach scientific conceptions accordingly?

Coexistence hypothesis

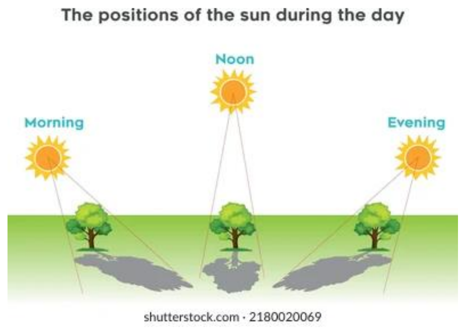
- Experts still hold preconceptions about science (Potvin et al., 2015; Shtulman & Harrington, 2016)
- Preconceptions coexist with scientific conceptions (Bélanger et al., 2023)
- Good management of conceptions necessitates **inhibition** (Masson et al., 2014; Houdé, 2000)

Theoretical framework: conceptual prevalence



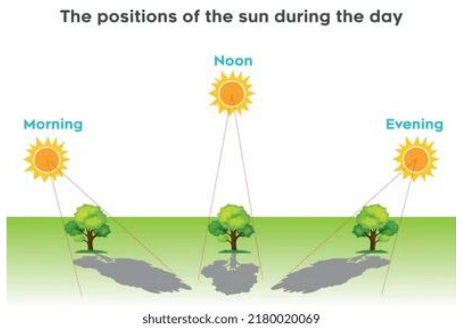
(Potvin et al., 2015; Potvin et al., 2017)

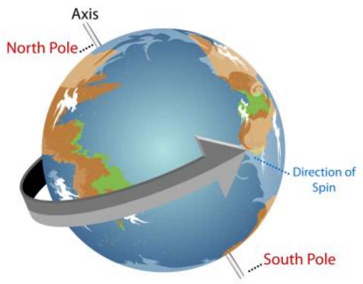
Theoretical framework: pluralism



Conception 1

Pluralist teaching





Conception 1 Conception 2

- Knows **when** to use each one
- Conceptions = tools in a shed

(Bélanger et al., 2023; Bélanger, 2024)

Research question

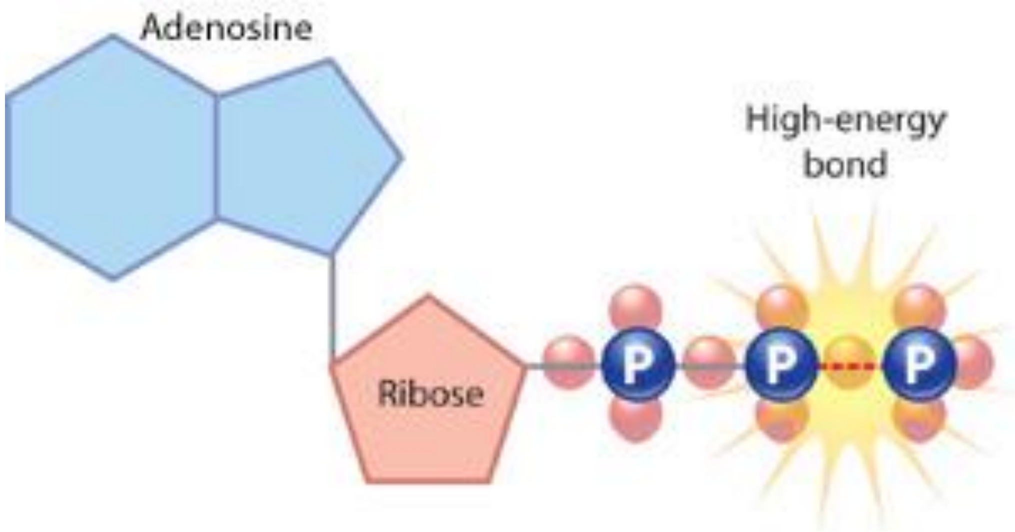
Does a *pluralist* teaching help students manage their conceptions about thermodynamics better than a *monist* teaching?

4 targeted preconceptions

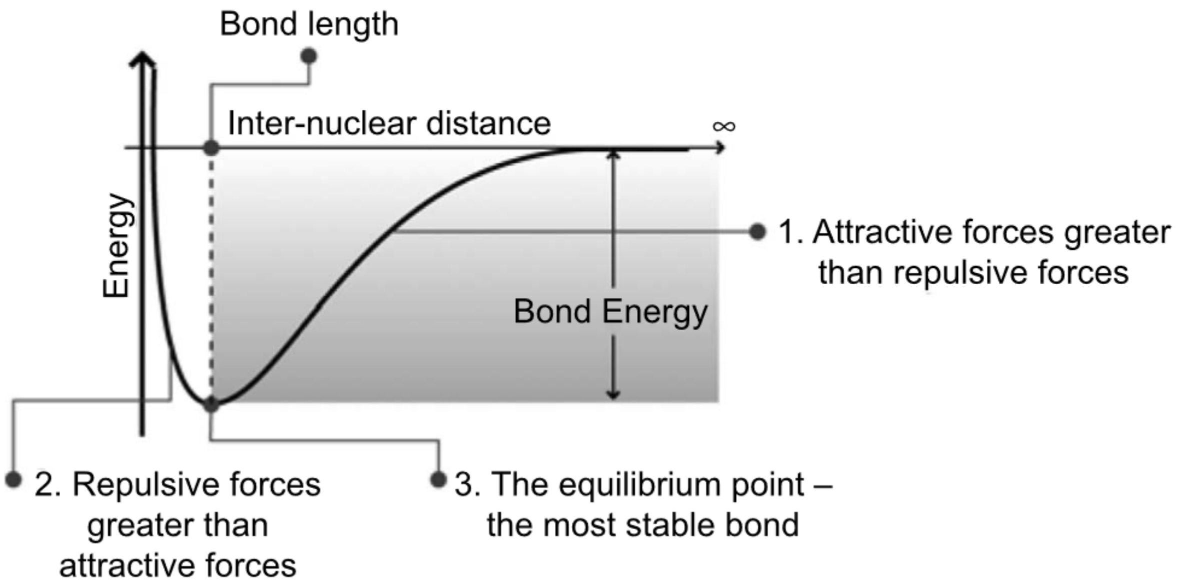
Conception 1 (preconception)	Conception 2
Breaking a chemical bond releases energy	Breaking a chemical bond absorbs energy
Variable X is intensive	Variable X is extensive
X et ΔX are the same thing	X et ΔX are different things
Entropy increases when substances are mixed up	Entropy increases when accessible volume increases

4 targeted preconceptions

Conception 1 (preconception)	Conception 2
Breaking a chemical bond releases energy	**Breaking a chemical bond absorbs energy**

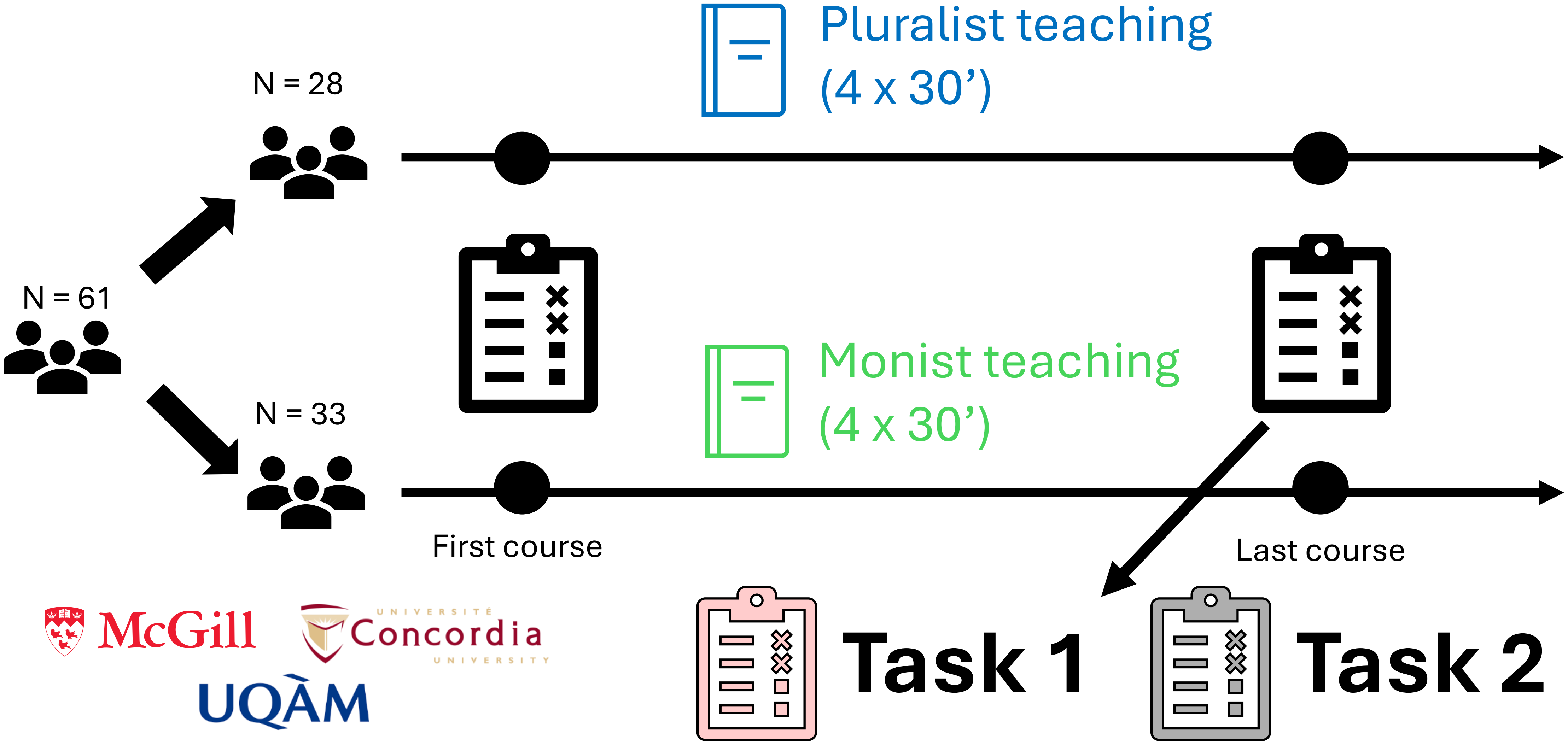


(Atkins, 2024)



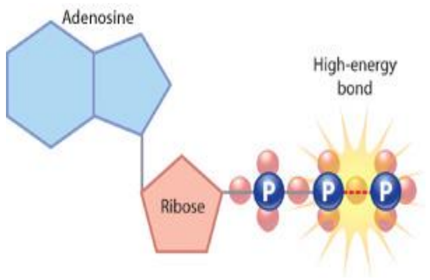
(Levy Nahum et al., 2010)

Study design

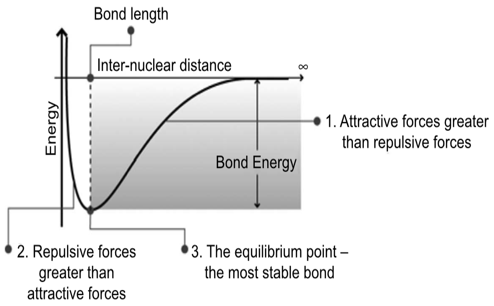


Measurement tool: two-tasks questionnaire

Task 1



Vs.



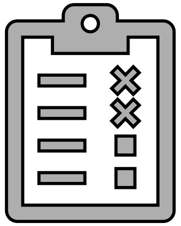
The formation of a chemical bond transforms energy
The formation of a chemical bond releases energy
The formation of a chemical bond creates energy
The formation of a chemical bond absorbs energy

TRUE OF FALSE ?

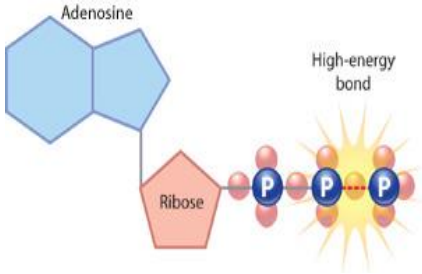
Variables

- Accuracy
- Confidence*
- Response times*

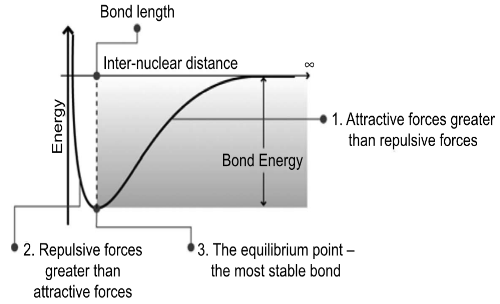
Measurement tool: two-tasks questionnaire



Task 2



Vs.



<u>Variables</u>

- Accuracy
- Confidence*
- Justification
- Hesitation with another answer

Consider the following reaction, in which chlorine gas breaks up into two chlorine atoms.

$$Cl_{2\,(g)} \rightarrow 2\,Cl\cdot_{\,(g)}$$

Choose the correct proposition.

a. The reaction releases energy
b. The reaction absorbs energy
c. The reaction does not absorb or release energy
d. There is not enough information to answer

Pluralist and monist files

monist

pluralist

1) Reactivation

Consider the following reaction, in which chlorine gas breaks up into two chlorine atoms.

$$Cl_{2\,(g)} \rightarrow 2\,Cl\cdot_{\,(g)}$$

Choose the correct proposition.

a. The reaction releases energy
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d. There is not enough information to answer

+ confidence
+ justification

Pluralist and monist files

monist

pluralist

1) Reactivation

Consider the following reaction, in which chlorine gas breaks up into two chlorine atoms.

$$Cl_{2\,(g)} \rightarrow 2\,Cl\cdot_{\,(g)}$$

Choose the correct proposition.

a. The reaction releases energy
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d. There is not enough information to answer

+ justification
+ confidence
for all answers

Pluralist and monist files

monist

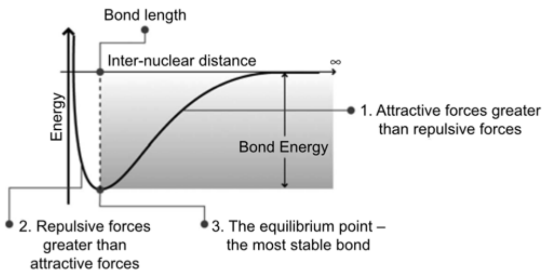
pluralist

1) Reactivation

2) Explanation

Part 2 - Please read the following text carefully

In general, a chemical bond is formed because it stabilizes two atoms. Atoms are composed of protons and electrons. Coulomb's law states that two opposite charges attract each other, and that two identical charges (negative or positive) repel each other. Thus, if we imagine two atoms infinitely far from each other, and we gradually bring them closer together, the protons of the first atom will attract the electrons of the other atom and vice versa. If we bring the two atoms too close, particles with the same charges will repel each other: the protons will repel the protons, and the electrons will repel the electrons. This is illustrated in the following diagram.



On the y-axis, we see the energy, and on the x-axis (x-axis), the distance between the two atoms. If the two atoms are far from each other (on the right), the forces of attraction between electrons and

Informative text
No negations, no comparisons

Pluralist and monist files

monist

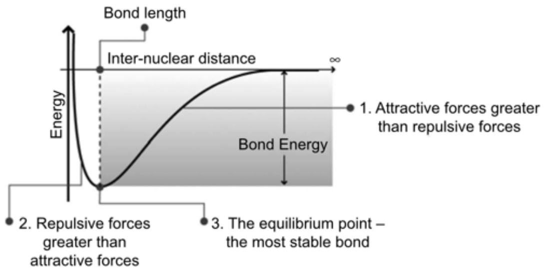
pluralist

1) Reactivation

2) Explanation

Part 2 - Please read the following text carefully

In general, a chemical bond is formed because it stabilizes two atoms. Atoms are composed of protons and electrons. Coulomb's law states that two opposite charges attract each other, and that two identical charges (negative or positive) repel each other. Thus, if we imagine two atoms infinitely far from each other, and we gradually bring them closer together, the protons of the first atom will attract the electrons of the other atom and vice versa. If we bring the two atoms too close, particles with the same charges will repel each other: the protons will repel the protons, and the electrons will repel the electrons. This is illustrated in the following diagram.



On the y-axis, we see the energy, and on the x-axis (x-axis), the distance between the two atoms. If the two atoms are far from each other (on the right), the forces of attraction between electrons and

Pluralist text

Refutes, compares, defines DoV

Pluralist and monist files

monist

pluralist

1) Reactivation

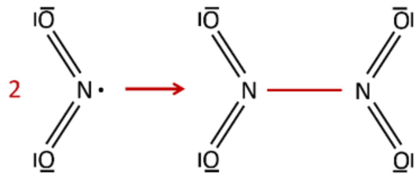
2) Explanation

3) Training

2. The chemical reaction between two molecules of nitrogen dioxide is written as follows:

$$2\ NO_{2\ (g)} \rightarrow N_2O_{4\ (g)}$$

The nitrogen atoms in each molecule covalently bond to form an N-N bond in N_2O_4, as shown in the following diagram:



What is the correct proposal?

a. This reaction releases energy
b. This reaction absorbs energy
c. This reaction does not release or absorb energy

1 congruent exercise
1 incongruent exercise
1 congruent exercise

Pluralist and monist files

monist

pluralist

1) Reactivation

2) Explanation

3) Training

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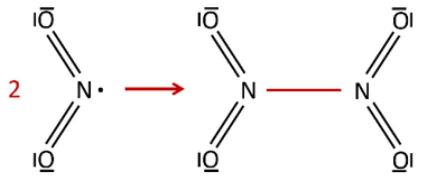


What is the correct proposal?

a. This reaction releases energy
b. This reaction absorbs energy
c. This reaction does not release or absorb energy

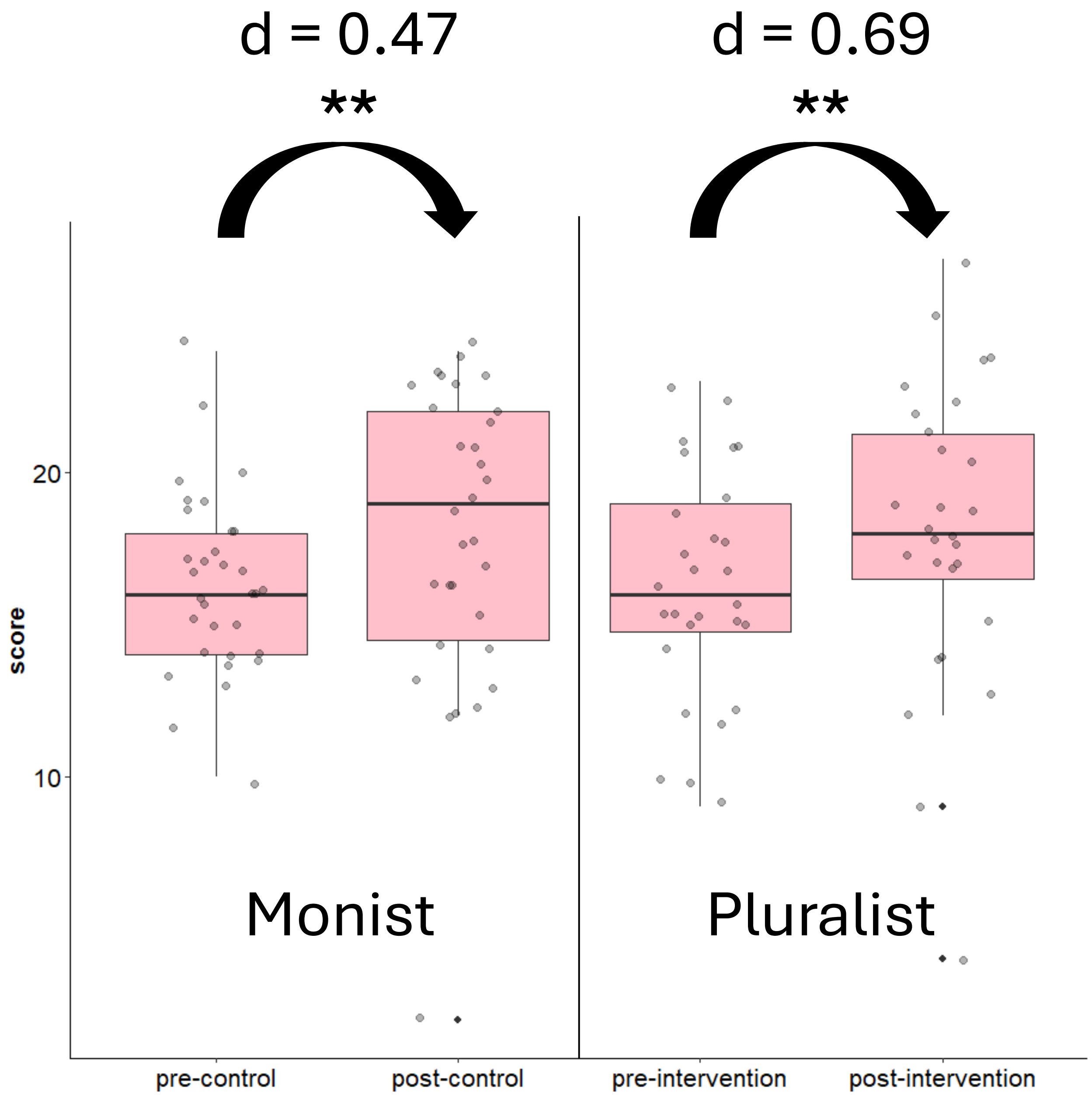
1 congruent exercise
1 incongruent exercise
1 « mistake » exercise

Results: accuracy

Task 1

28 true-false statements

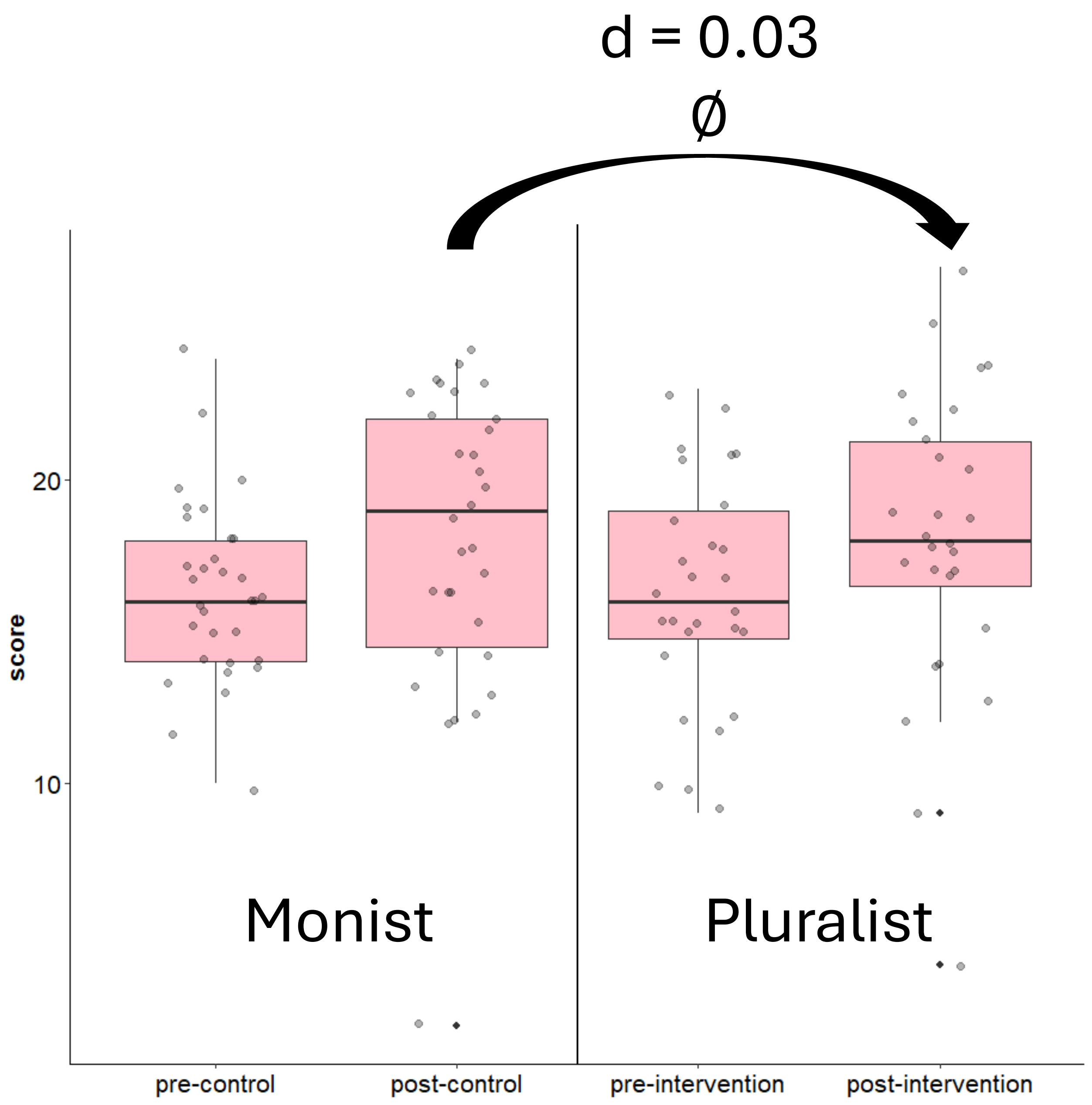
Example : *A chemical bond that breaks absorbs energy*



Results: accuracy
Task 1

28 true-false statements

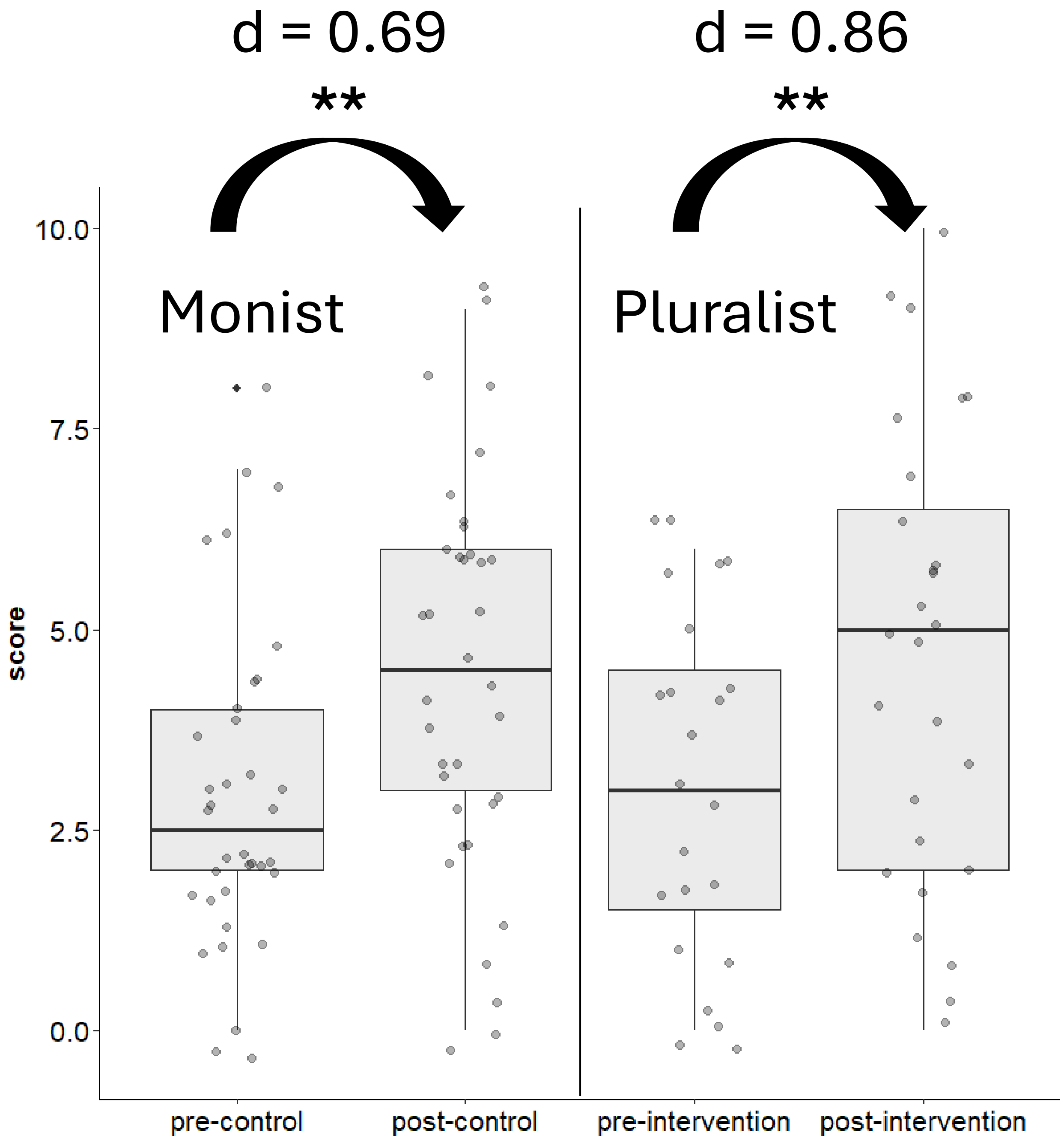
Example : *A chemical bond that breaks absorbs energy*



Results: accuracy

Task 2

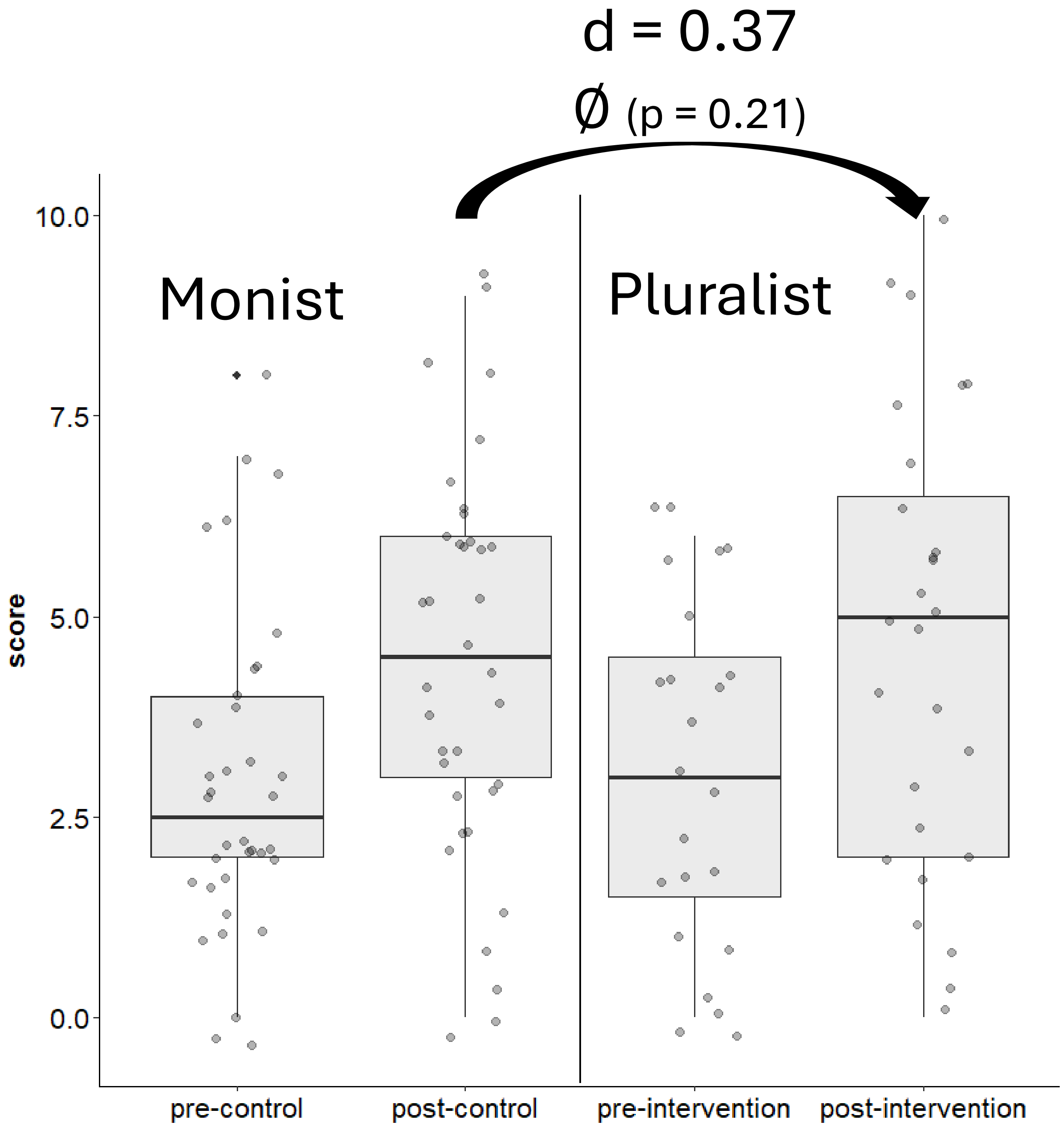
Conceptual MCQ (+jus)



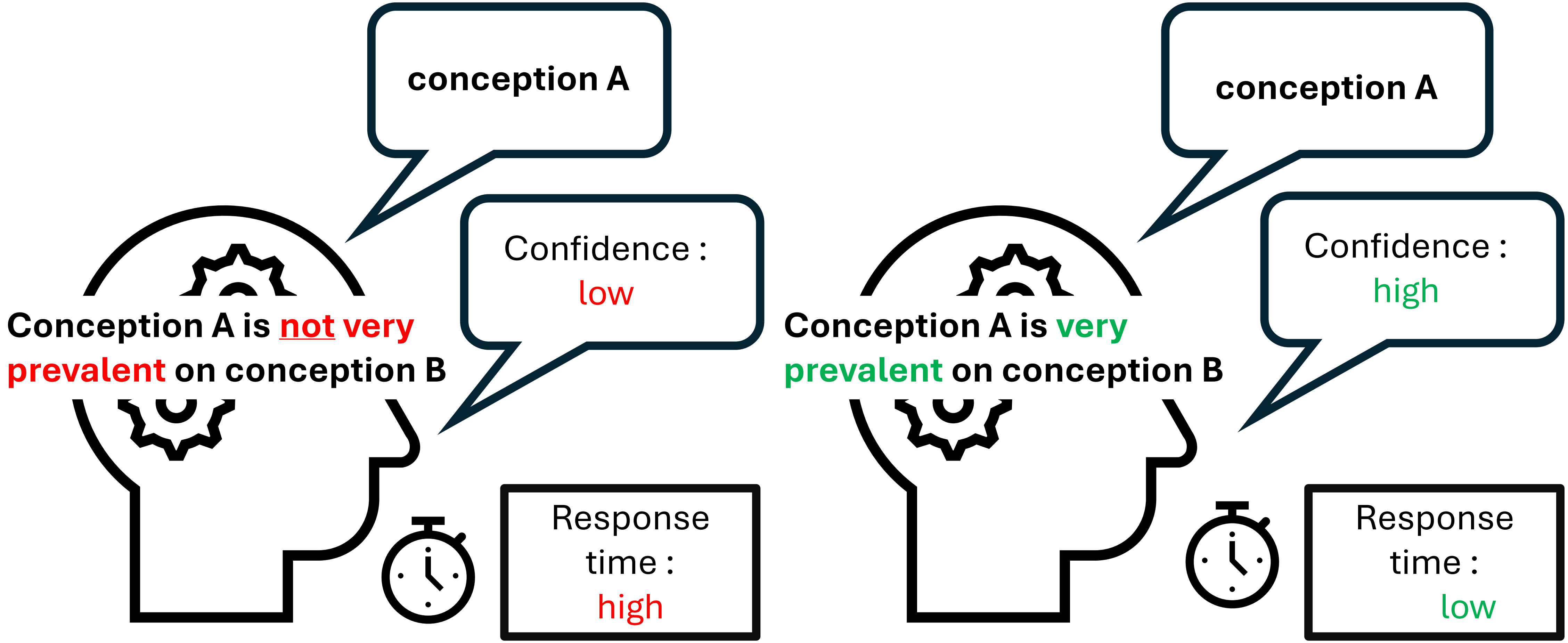
Results: accuracy

Task 2

Conceptual MCQ (+jus)

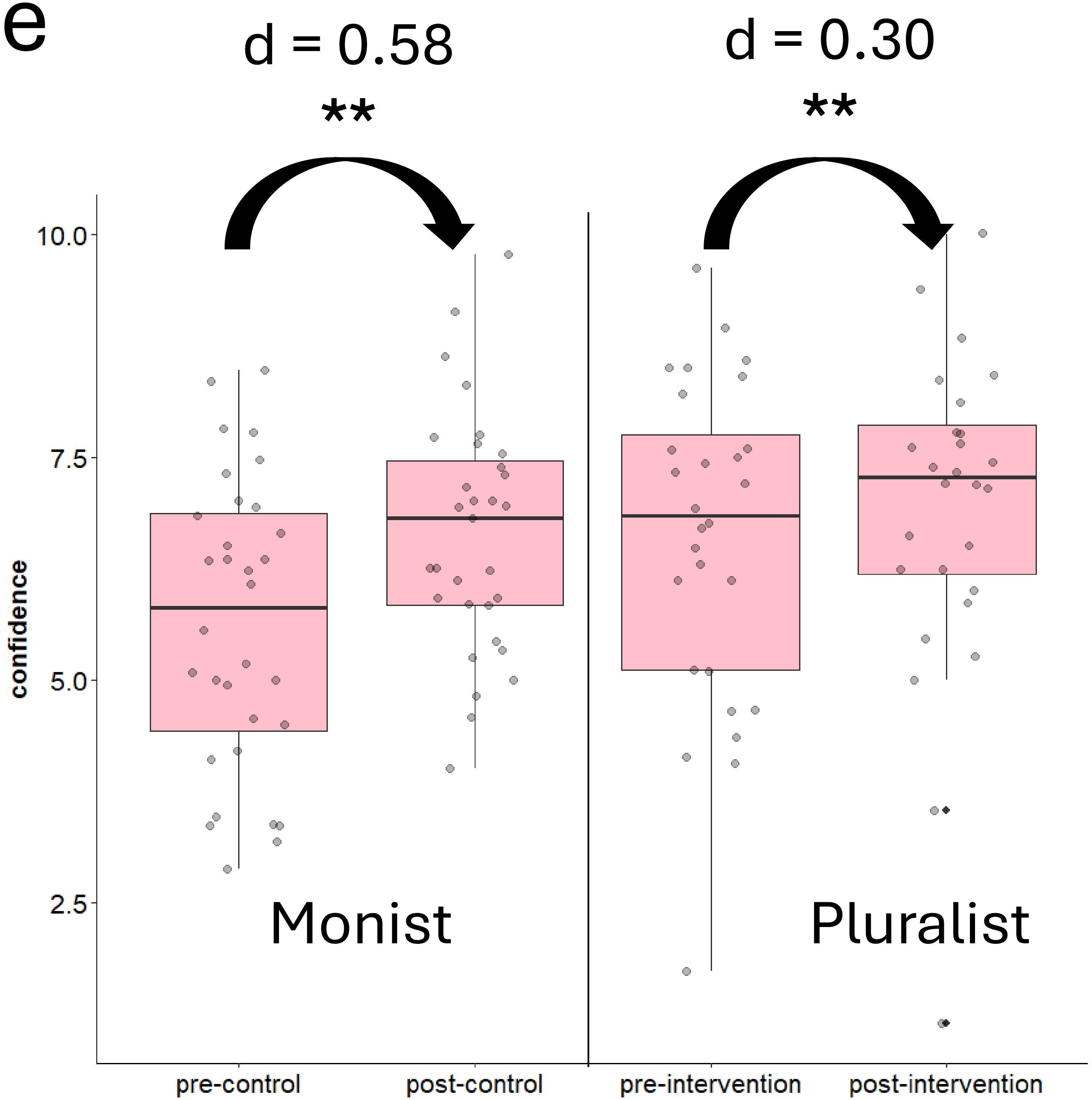


Confidence and RT hypotheses



Results: confidence

Task 1



28 true-false statements

Example : *A chemical bond that breaks absorbs energy*

Confidences from correct answers only

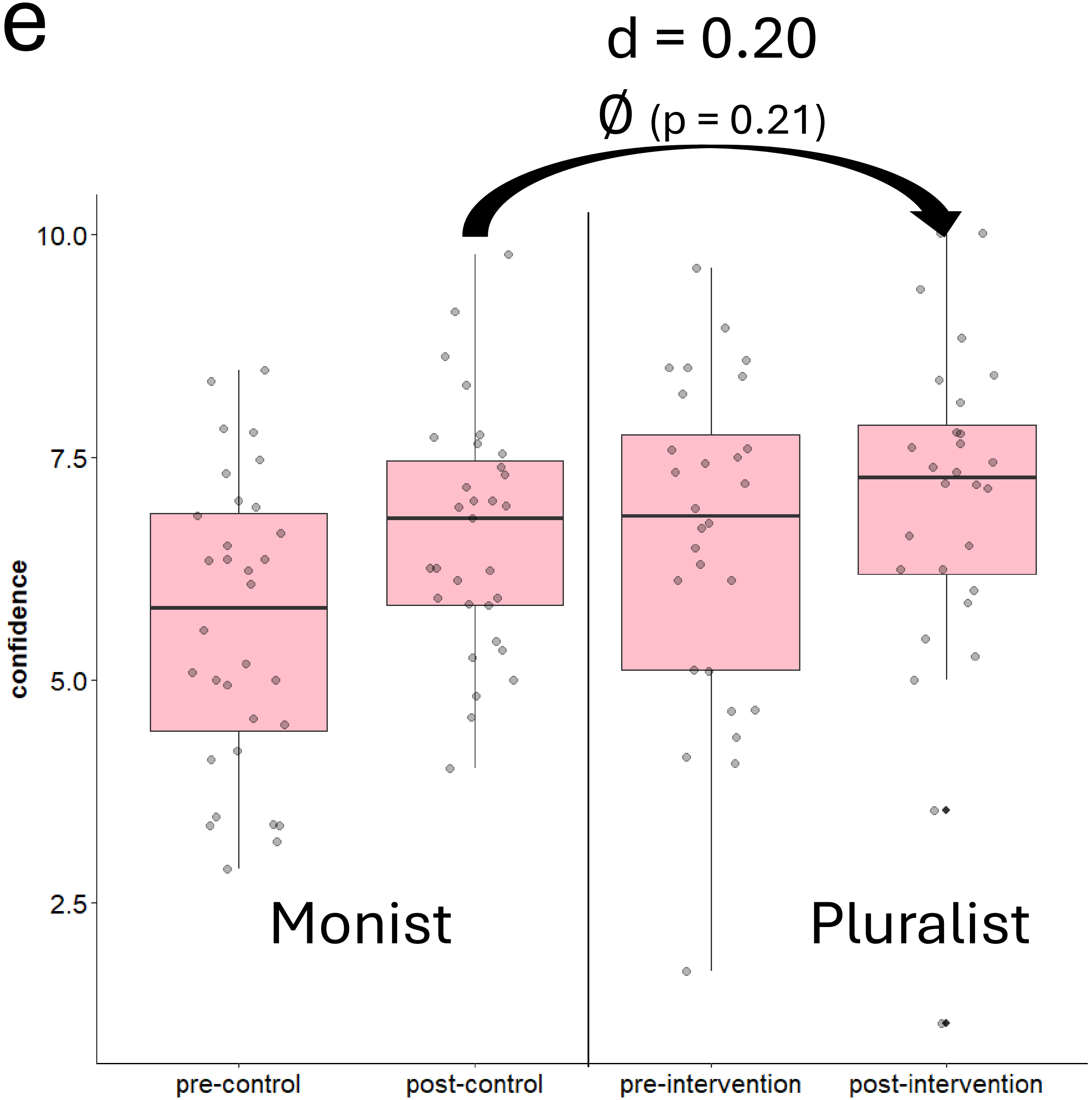
Results: confidence

Task 1

28 true-false statements

Example : *A chemical bond that breaks absorbs energy*

Confidences from correct answers only

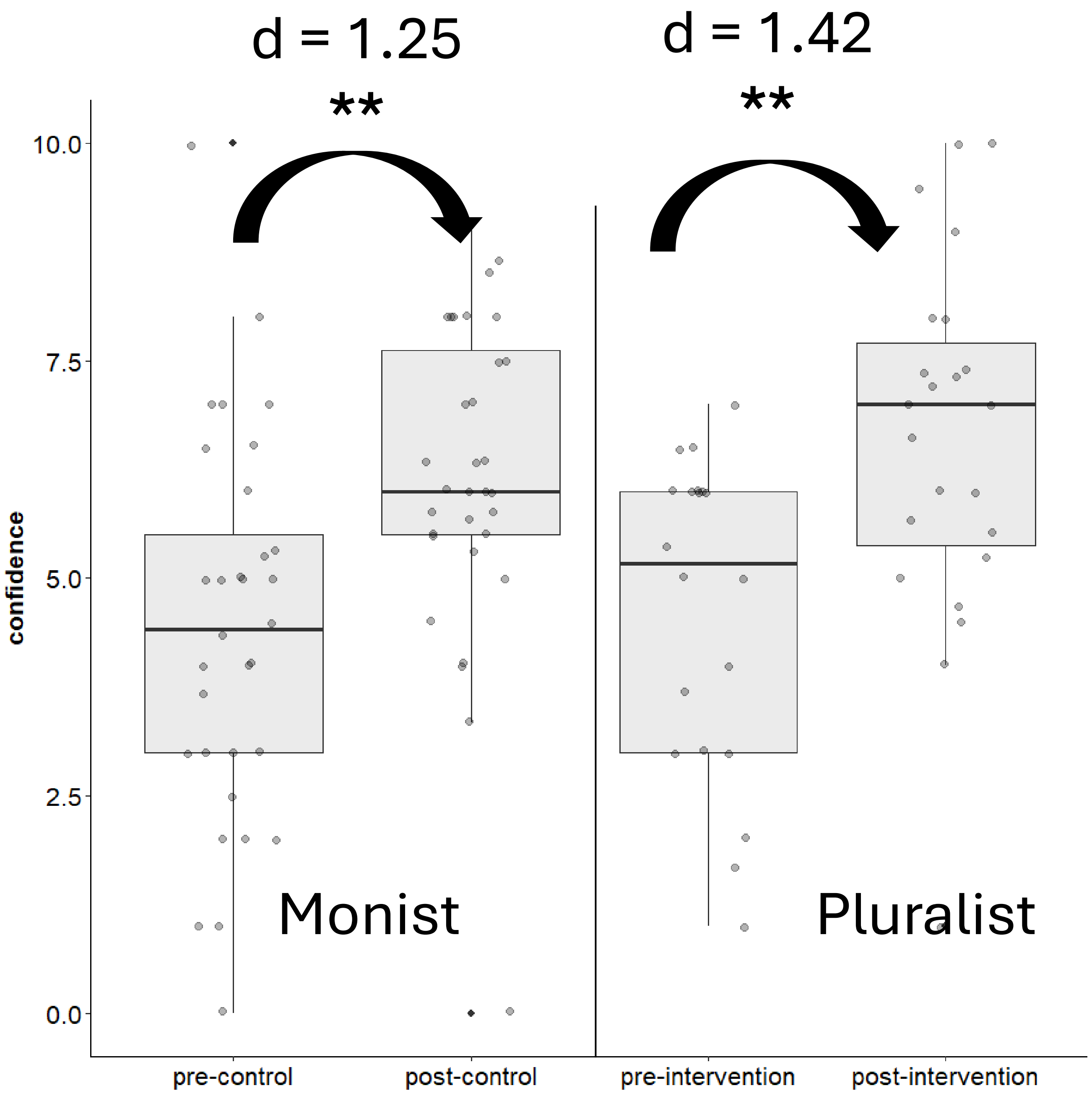


Results: confidence

Task 2

Conceptual MCQ (+jus)

Confidences from correct answers only

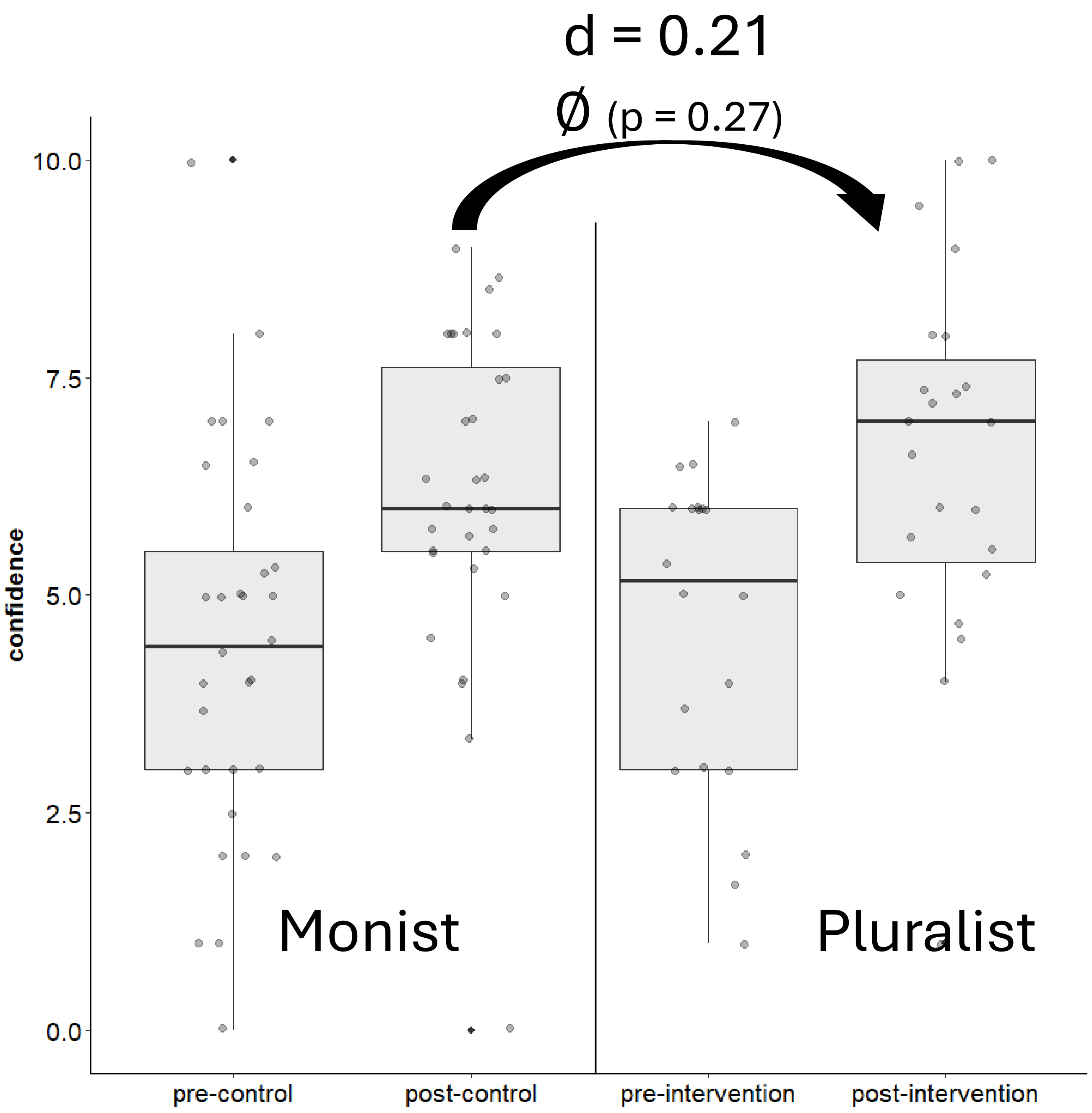


Results: confidence

Task 2

Conceptual MCQ (+jus)

Confidences from correct answers only



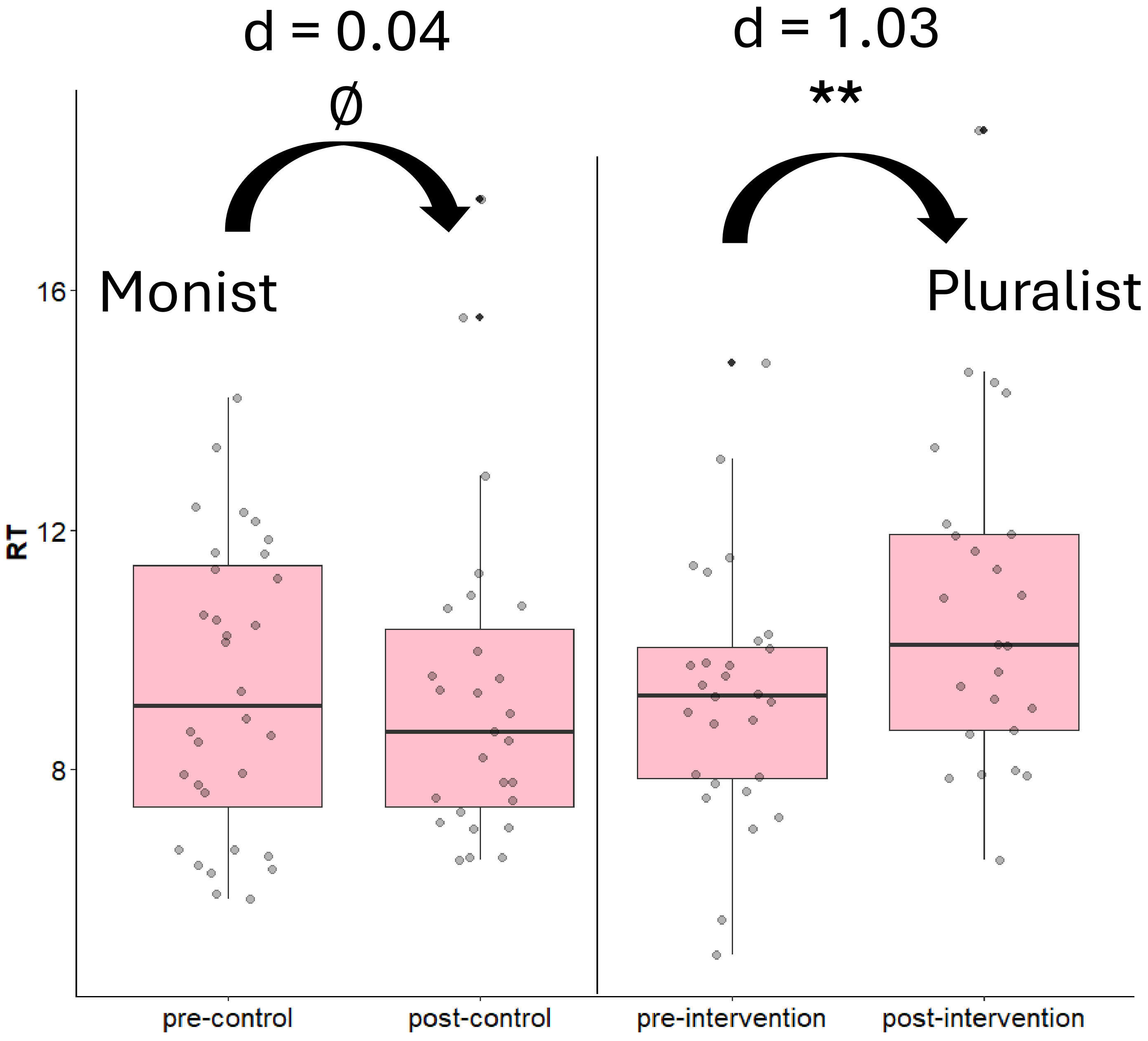
Results: RT

Task 1

28 true-false statements

Example : *A chemical bond that breaks absorbs energy*

RTs from correct answers only, excluding Values above +1SD



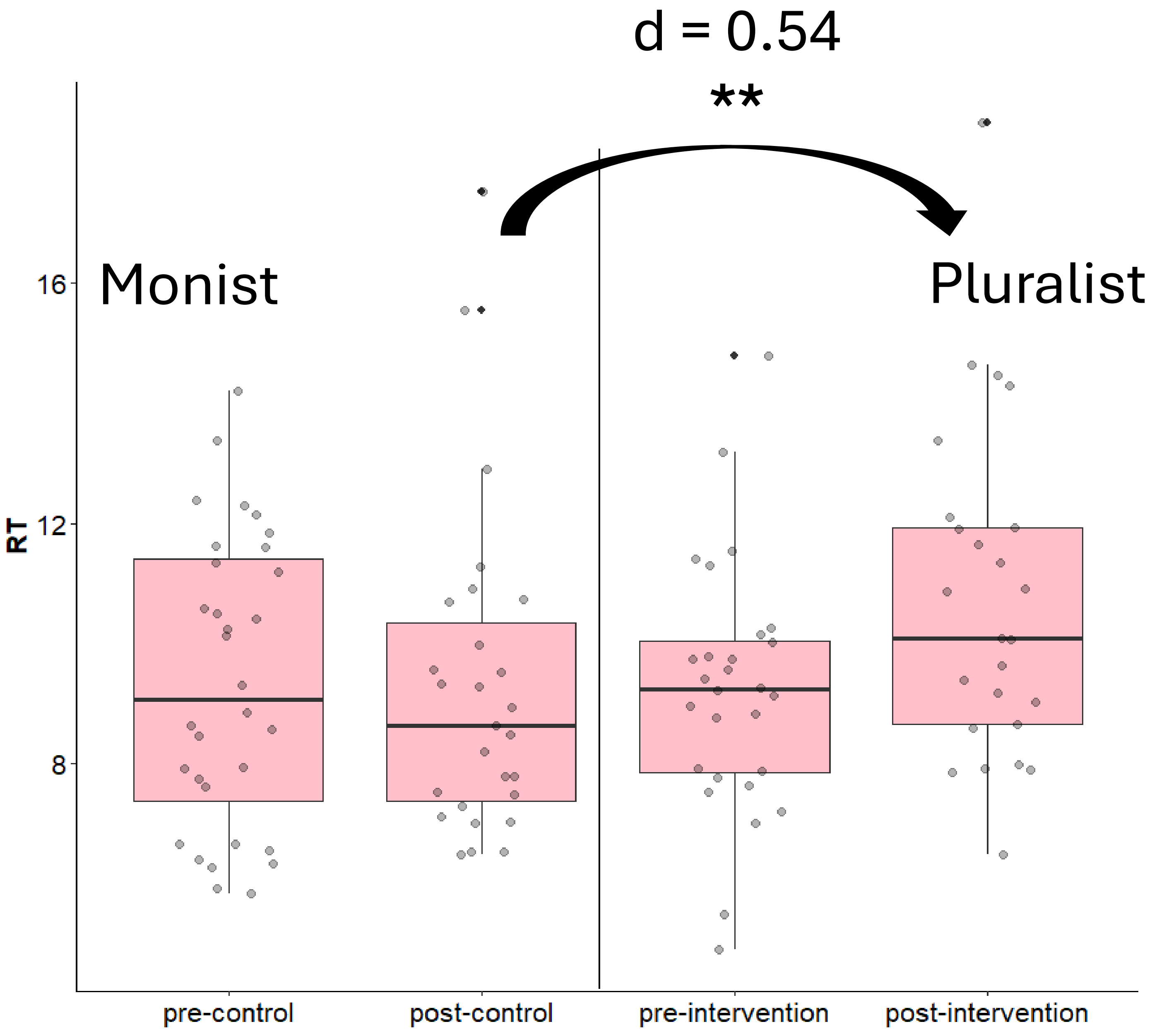
Results: RT

Task 1

28 true-false statements

Example : *A chemical bond that breaks absorbs energy*

RTs from correct answers only, excluding Values above +1SD



Results: synthesis

	Task 1	Task 2
Accuracy	Pluralist ↗	Pluralist ↗
Confidence	Pluralist ↘	Pluralist ↗
Response times	Pluralist = longer RTs	

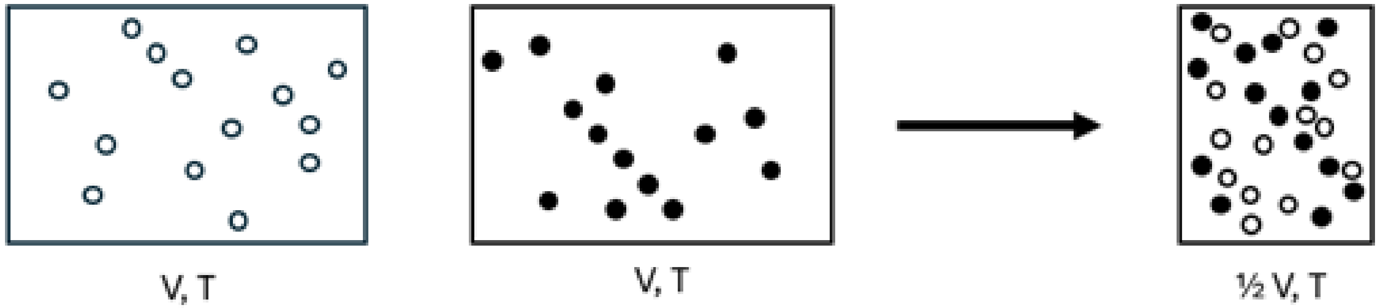
Results: synthesis

	Task 1	**Task 2**
Accuracy	**Pluralist ↗**	**Pluralist ↗**
Confidence	Pluralist ↘	**Pluralist ↗**
Response times	Pluralist = longer RTs	

Results: synthesis

	Task 1	Task 2
Accuracy	Pluralist ↗	Pluralist ↗
Confidence	**Pluralist ↘**	Pluralist ↗
Response times	**Pluralist = longer RTs**	

Discussion: observed improvements



Conception A
Entropy ∝ Mixing

Conception A
Entropy ∝ Volume

- Might have well-defined domains of validity
- Might be the most visual
- Students agree there is a problem (important cognitive conflict)
- Might be students' familiarity (4th intervention)

(Ben-Naim, 2011)

Discussion: limitations and perspectives

- Reproduction to obtain significance (n = 61)
- Investigate « susceptible » conceptions
- Two promising pluralist frameworks
  - Metaconceptual knowledge (Hartelt & Martens, 2024)
  - Domain-of-validity framework (Sommeillier et al., 2021)

Conclusion

We now know preconceptions never disappear from our minds…

Pluralist teaching might help manage conceptions but make students more doubtful

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