



## **COMBINED MEASURES OF STUDENTS' SUCCESS: recent trends and developments in science education research**

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# Measures of students' success

trends and developments



## Students' performance

- developing instructions
- developing tools



## Mental effort

- construct of cognitive load
- real measure of cognitive load



## Combined measures

- performance
- mental effort

# Mental effort measures

classification

## Subjective measures

**Likert Scales**  
Please fill in the number that represents how you feel about the computer software you have been using

I am satisfied with it				
①	②	③	④	⑤
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree
It is simple to use				
①	②	③	④	⑤
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree
It is fun to use				
①	②	③	④	⑤
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree
It does everything I would expect it to do				
①	②	③	④	⑤
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree
I don't notice any inconsistencies as I use it				
①	②	③	④	⑤
Strongly Agree	Agree	Neither	Disagree	Strongly Disagree

## Objective measures



based on the assumption that people are able to introspect on their own cognitive processes

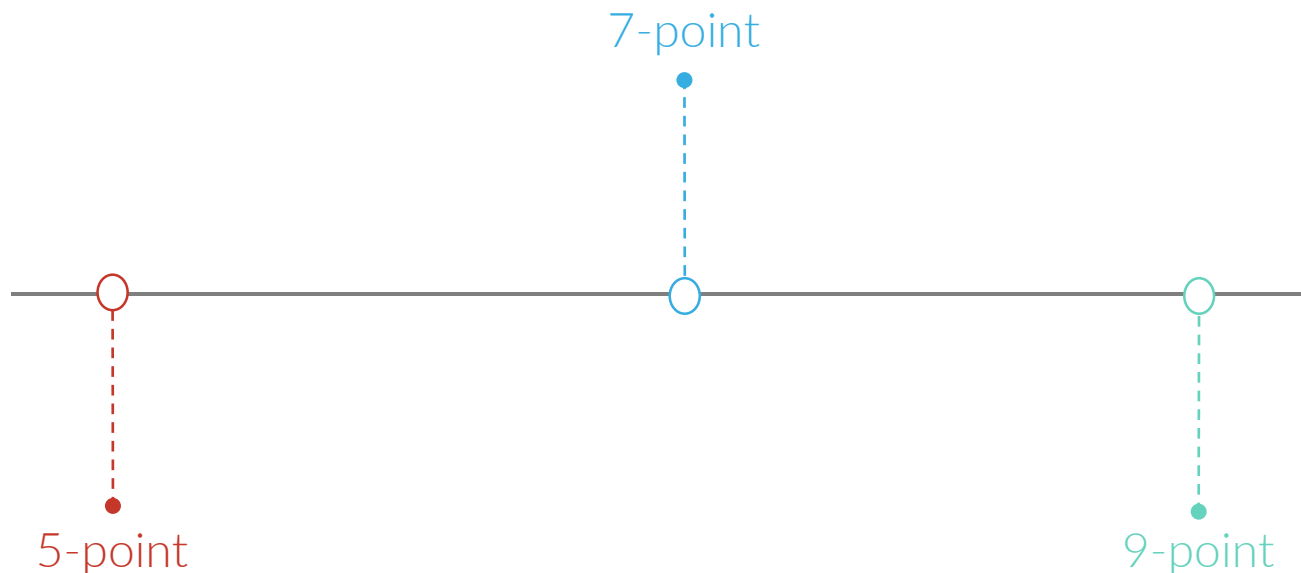
based on physiological and behavioral measures

# Mental effort measures

subjective measures

Likert-type scales are sufficiently reliable and above all simple and practical for application in a teaching environment.

How effective are the scales, and how the efficiency is influenced by the number of points?



# Mental effort measures

study I

**Aim:** to compare efficiency of 5, 7 and 9-point scales

**Instruments:** 3 tests (analogous items, the only difference could be found in numerical values and types of substances used)

## 5-point

very easy - very difficult

How many grams of glycerol would you need to prepare 120 g of 20% solution?

## 7-point

exc. easy – exc. difficult

How many grams of sodium-hydroxide is necessary to prepare 80 g of 15% solution?

## 9-point

ext. easy – ext. difficult

How many grams of sugar are required to prepare 124 g of 24% solution?

# Mental effort measures

study I

**Test validation:** item difficulty, discrimination indices, descriptive statistics

5-point  
scale

Source	SS	F	P
Model	0.581449	40.31	< 0.0001
Residual	0.865443		
Total	1.44689		

Corr. Coeff. = **-0.63**

7-point  
scale

Source	SS	F	P
Model	1.66001	45.19	< 0.0001
Residual	2.20398		
Total	3.86399		

Corr. Coeff. = **-0.66**

9-point  
scale

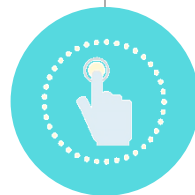
Source	SS	F	P
Model	5060.65	18.40	0.0001
Residual	16502.3		
Total	21563.0		

Corr. Coeff. = **-0.48**

# Mental effort measures

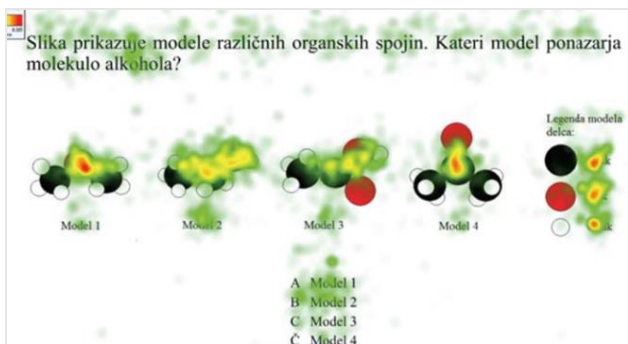
study I conclusion

- Subjective scales are reliable and valid tools for evaluation of invested mental effort.
- There is satisfactory correlation with students' performances.
- 5-point and 7-point scales correlate better with students' performances than 9-point scales.
- **Possible reasons:** more nuances in estimations, more difficult for students to distinguish between them (Miller's magical number seven)
- Can we combine them with objective measures?



User friendly technology

Data include the location, duration, and sequence of subjects' fixations



Widely used in SER



# Mental effort measures

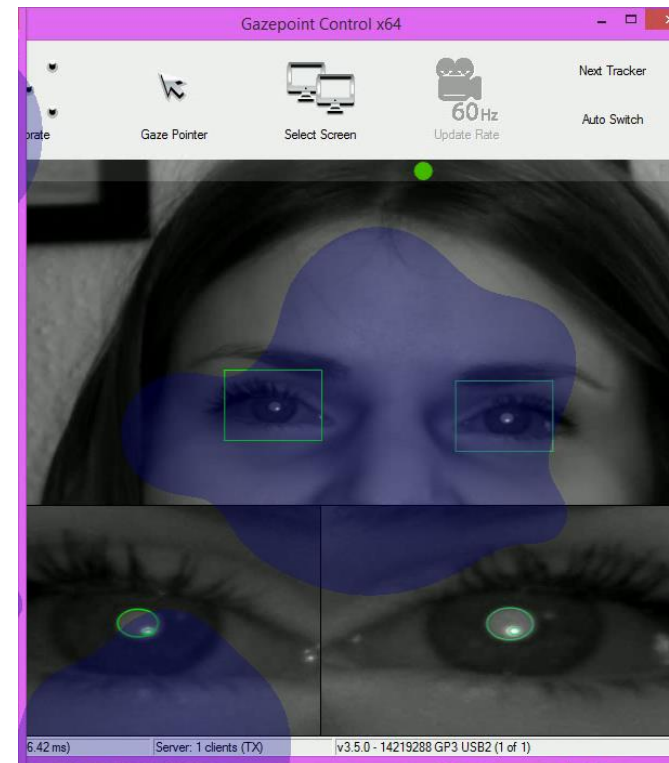
## study II

**Aim:** to provide information on the invested mental effort using eye tracking methodology

**Participants:** 17 students majoring in chemistry teaching from the Faculty of Sciences, University of Novi Sad

**Device:** Gazepoint<sup>®</sup> eye-tracker  
( $v = 60$  Hz;  $d = 30$ -40 cm)

**Instrument:** students were solving an online test on stereochemistry (6 items)



# Mental effort measures

study II

Instrument: Stereochemistry

http://localhost:1337/ http://localhost:1337/pitanje2.html

localhost:1337/pitanje2.html

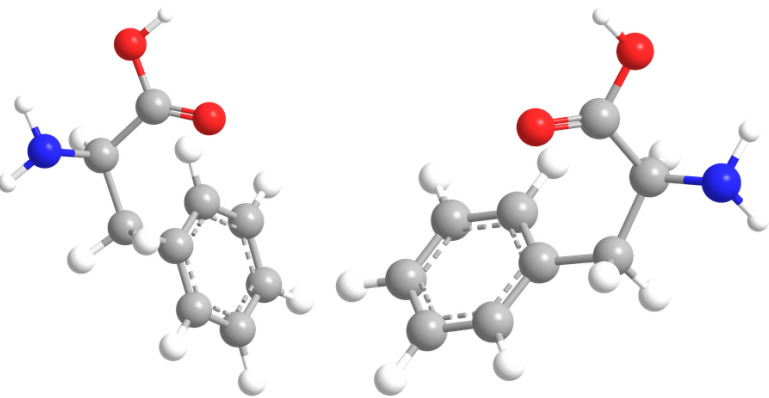
Most Visited Getting Started http://localhost:1337/L...

Redni broj studenta

Početna stranica

## 2. pitanje

Da li su prikazani molekuli hiralni? Obrazložite svoj odgovor.



Ocenite težinu pitanja

Izuzetno lako	Veoma lako	Lako	Ni teško ni lako	Teško	Veoma teško	Izuzetno teško
<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Sljedeće pitanje

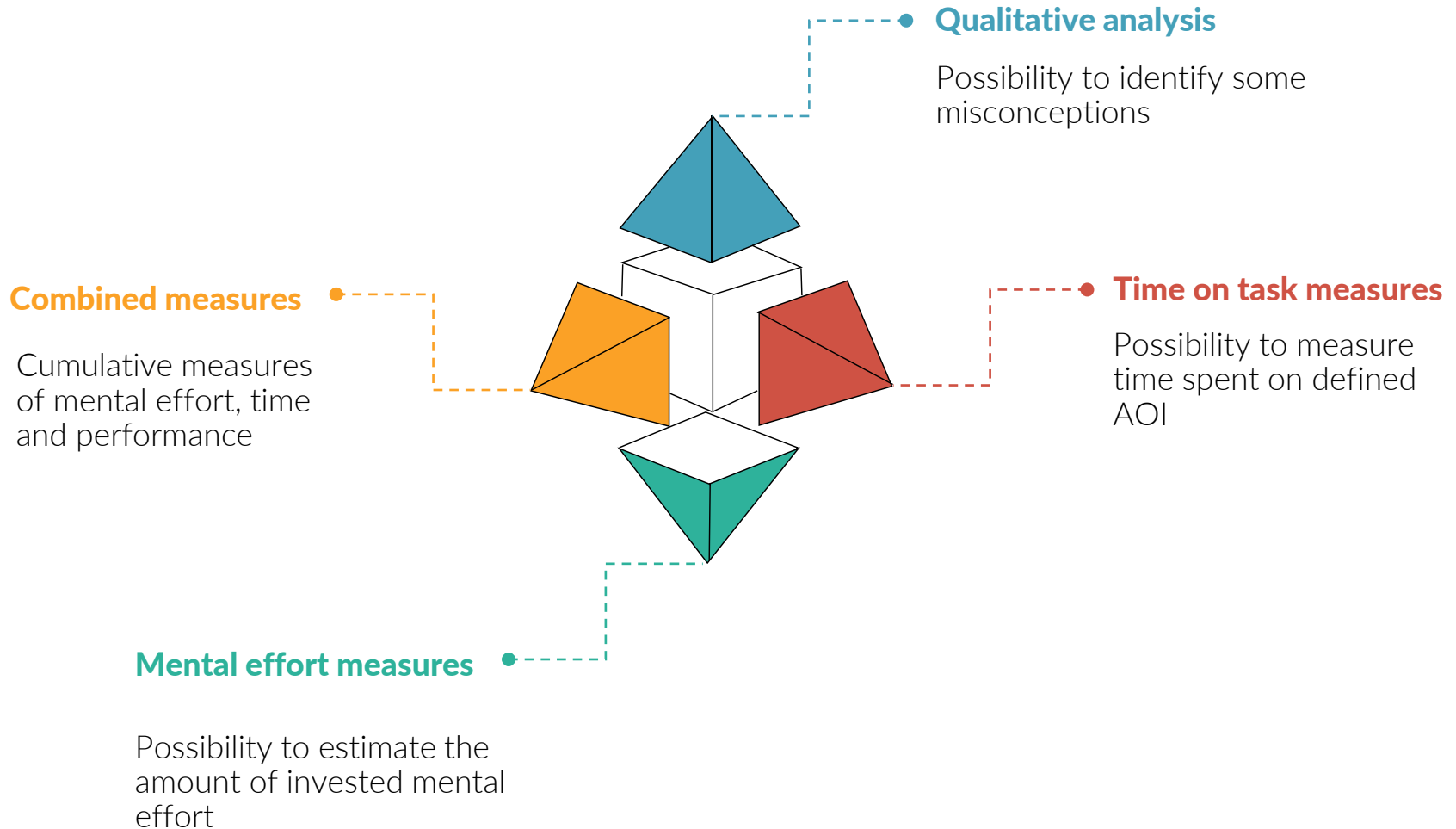
Item example

Space for answer

7-point Likert scale

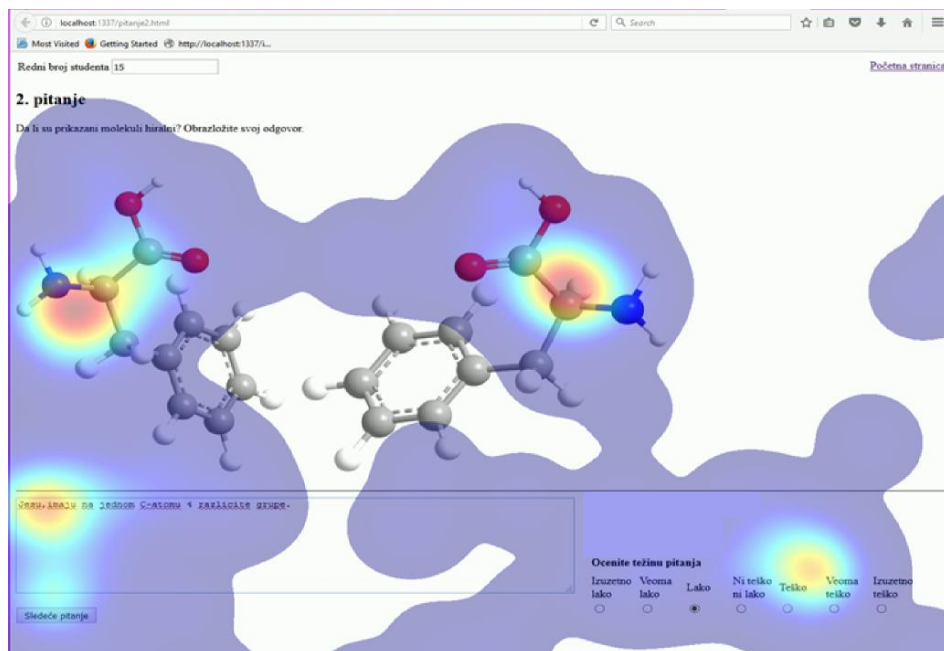
# Mental effort measures

study II

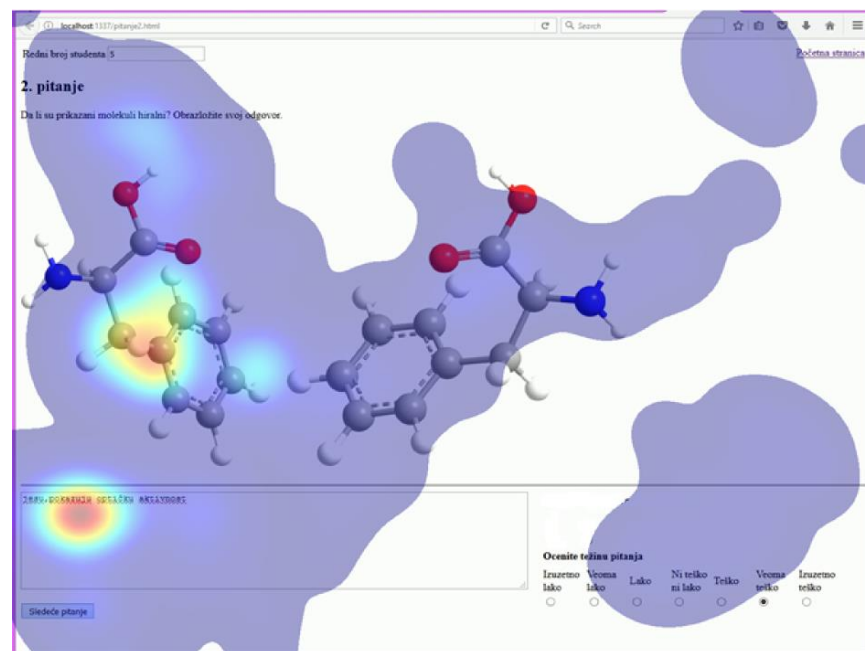


# Mental effort measures

## study II



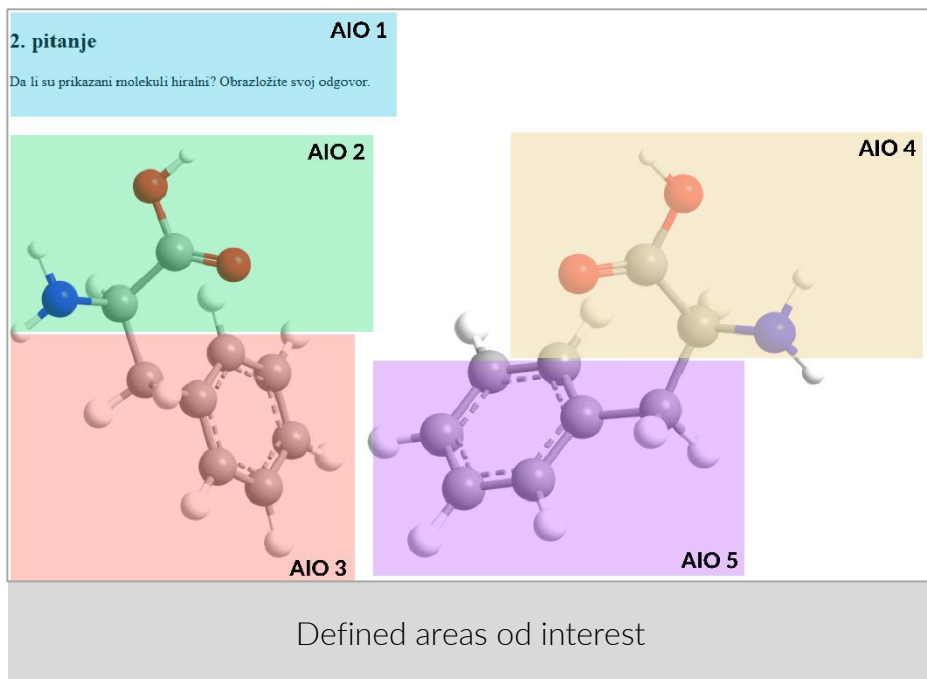
The correct answer with eye-tracking confirmation



The correct answer without eye-tracking confirmation

# Mental effort measures

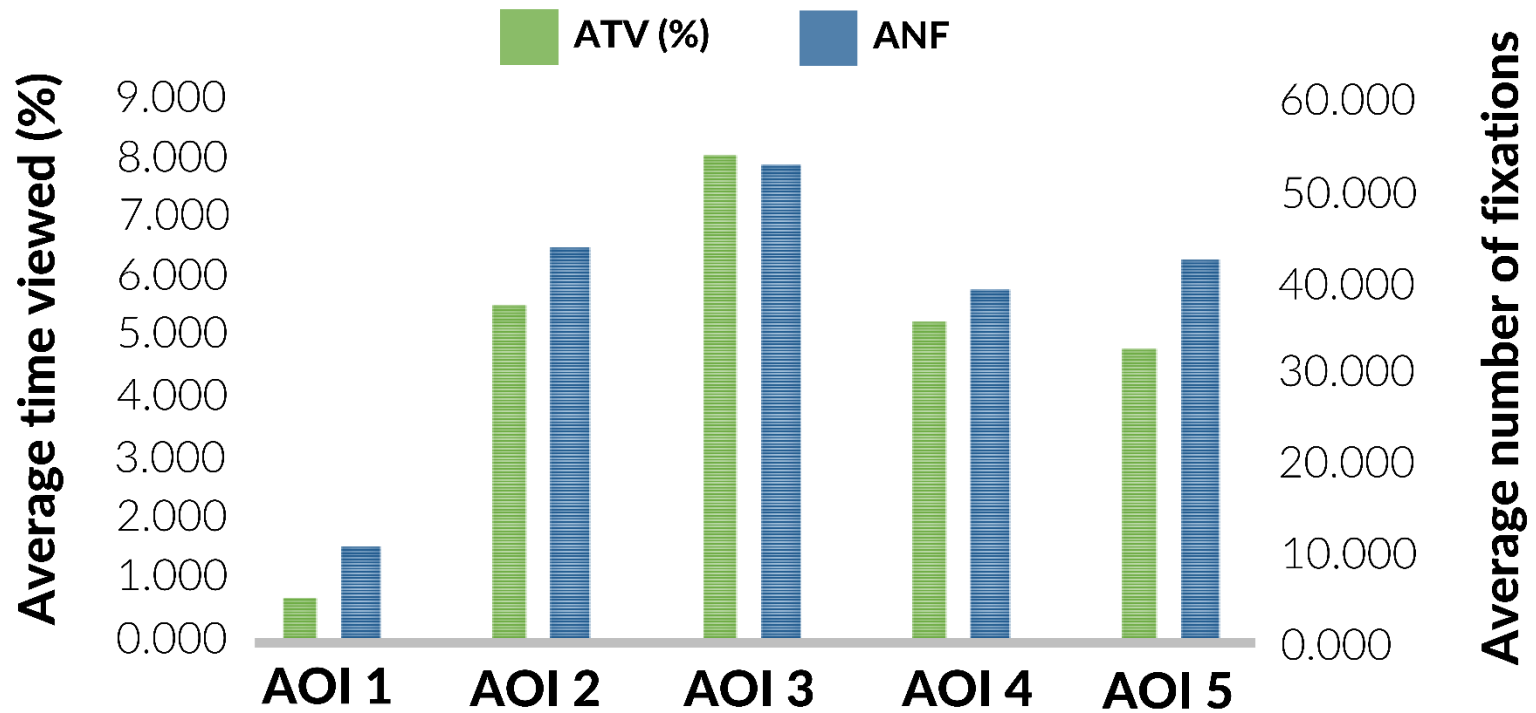
## study III



Parameters	AOI 1	AOI 2	AOI 3	AOI 4	AOI 5
Number of students	15	17	17	17	17
Average time viewed (s)	1.650	12.302	17.685	11.651	10.692
Average time viewed (%)	0.755	5.630	8.094	5.332	4.893
Average number of fixations	10.600	43.882	53.000	39.118	42.412
Revisitors	13	17	17	17	17
Average revisits	10.462	31.824	32.118	20.471	25.941

# Mental effort measures

study III



Average time viewed and average number of fixations for defined areas of interest

# Combined measures of performance and mental effort

study IV

## Data collection

Combining results of students performance and invested mental effort using formula:

$$E = \frac{P - R}{\sqrt{2}}$$

## Instrument

15 two-tier items covering the topics: Group 14, 15, 16 and 17 Elements.

7-point Likert scale within each item.

## Aim

To determine instructional efficiency by combining performance and mental effort measures.

## Sample

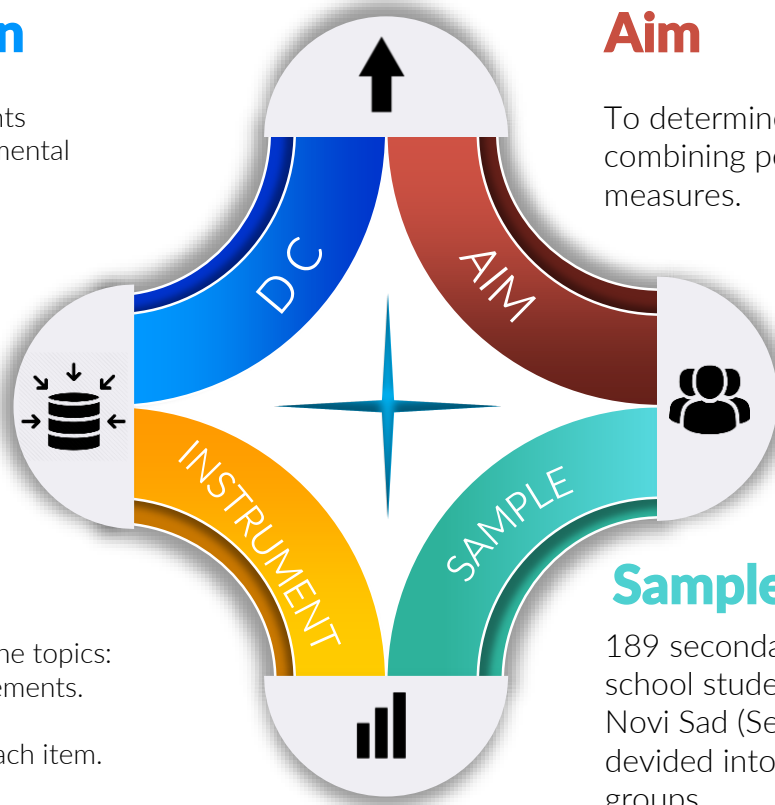
189 secondary school students from Novi Sad (Serbia), divided into E and K groups.



47%

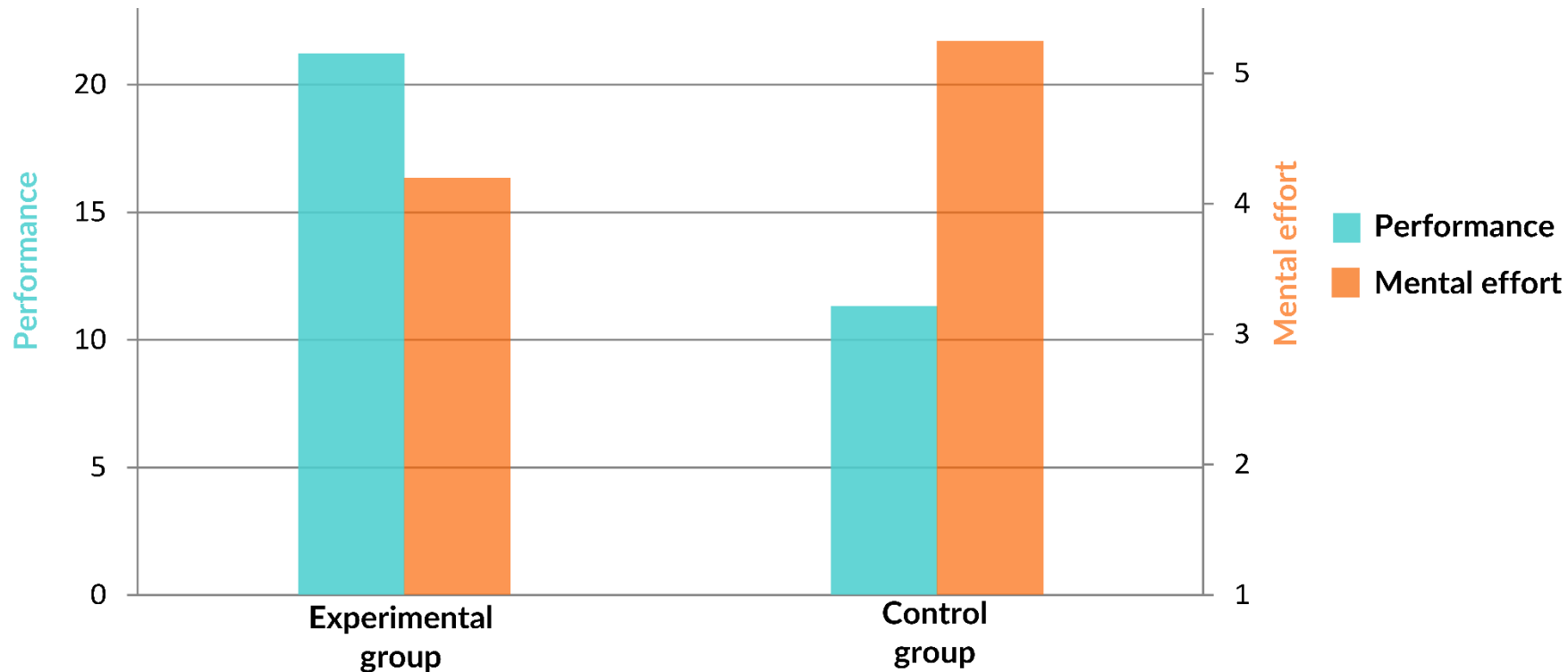


53%



# Combined measures of performance and mental effort

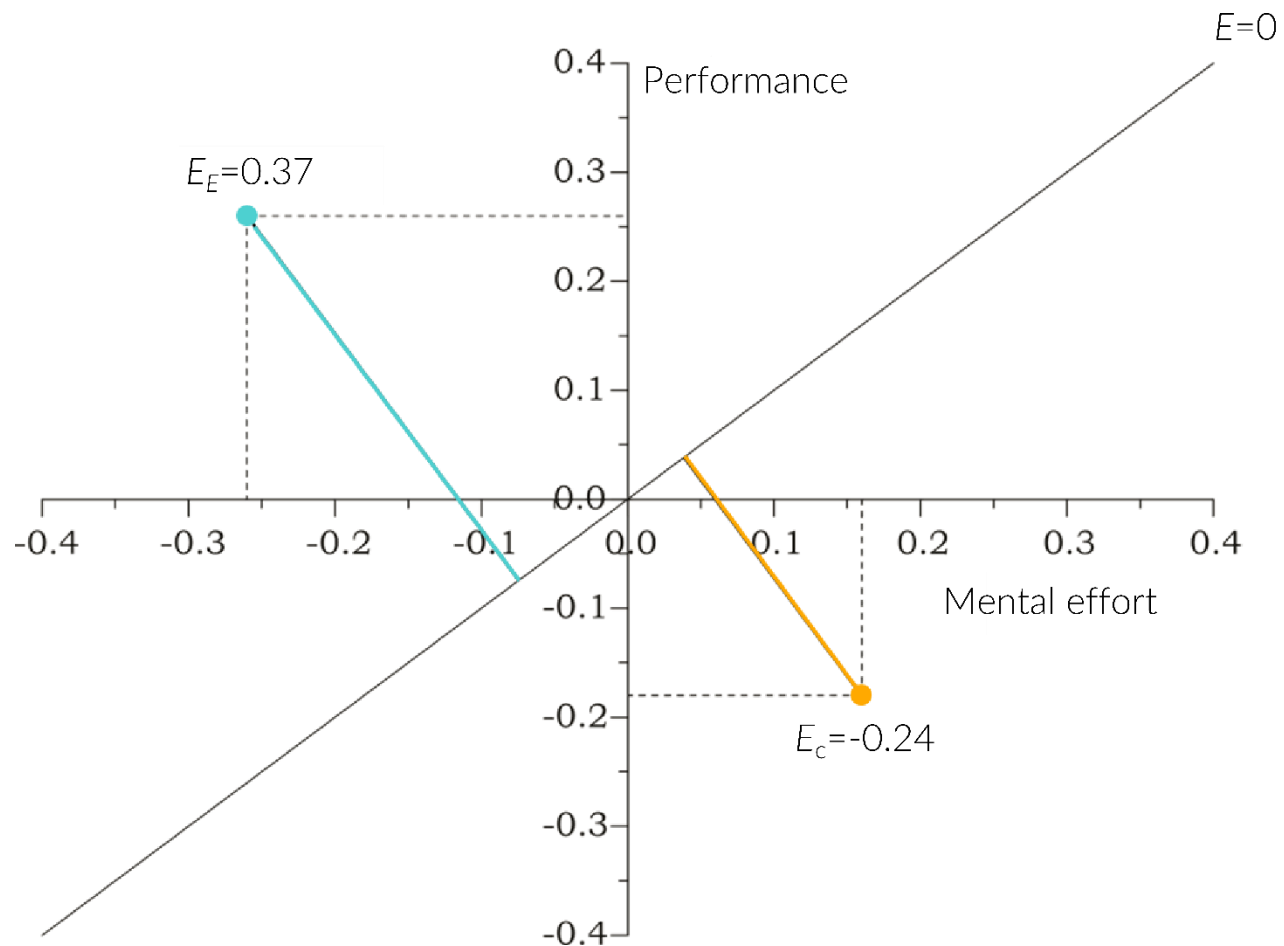
study IV





# Combined measures of performance and mental effort

study IV



# Instead of conclusion

„Different sources mean different perspectives”



**Thank You**



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