Título Understanding the underpinnings of complex problem solving in a higher-education setting

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Factors Underlying Performance in Complex Problem Solving in a Higher-Education Setting

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INTRODUCTION (1)

- Educational and cognitive research has emphasized the importance of cross-curricular skills such as complex problem solving (CPS) (Greiff & Kyllonen, 2016; OECD, 2010).
- CPS involves the skills to achieve a goal state by transforming a given initial state, where the solution method is not obvious (Mayer, 2003).
- These skills allow to deal with novel, highly inter-related and nontransparent problems.

INTRODUCTION (2)

- Previous studies have shown a high correlation between CPS, intelligence, and WMC (Wustenberg, Greiif & Funke, 2012; Meißner, Greiff, Frischkorn, & Steinmayr, 2016).

- However, more research is needed involving a larger set of cognitive, motivational and background variables.

OBJECTIVE

- To understand the cognitive and motivational underpinnings of CPS, using machine-learning modelling of high-performing and low-performing groups, to then analyze the differences between these groups considering all the participating variables and their interactions.

THEORETICAL FRAMEWORK (1)

Working Memory Capacity (WMC)

It is limited capacity system, responsible for the active maintenance and executive processing of information available to the cognitive system (Shipstead, Lindsey, Marshall & Engle, 2014).

THEORETICAL FRAMEWORK (2)

Attentional Networks (Posner & Petersen,1990)

Three different attentional networks:

Orienting

is responsible for the selection of information from stimulus entering the system.

Alerting

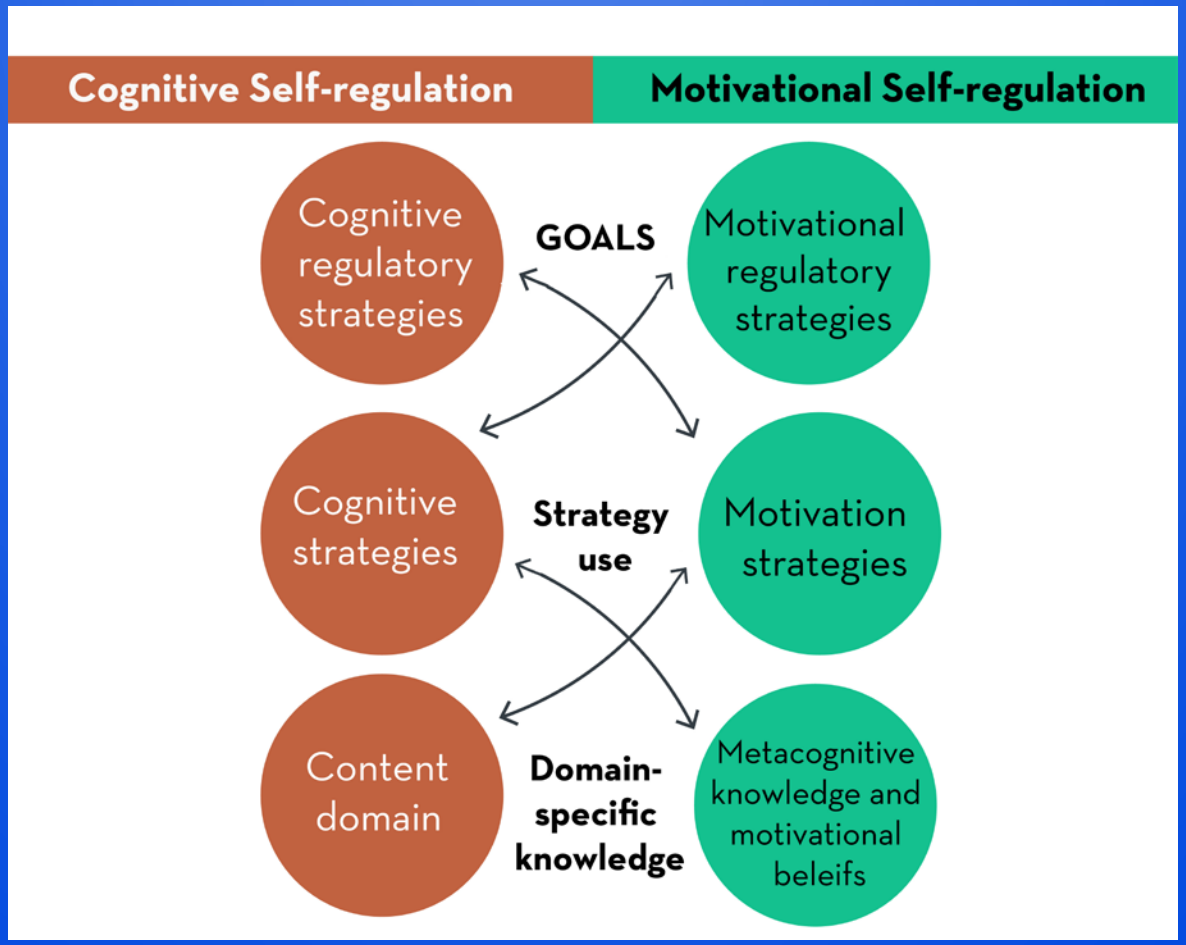
facilitates achieving and sustaining an alert state

Executive Attention

refers to a system that controls interference and solves conflicts between possible responses.

SELF-REGULATED LEARNING

"…refers to a **multi-component**, **multi-level**, **iterative self-steering process** that targets one's own cognitions, feelings and actions as well as features of the environment for modulation in the service of one's own goals" (Boekaerts, 2012)



THEORETICAL FRAMEWORK (3)

- **Complex Problem Solving**: it is a process of **knowledge acquisition** and **knowledge application**, oriented to control a system with a specific goal, which has several interconnected elements.

- **Dimensions**:
  - Knowledge acquisition (KAQ): describes how a mental representation of a problem's structure is established (Wustenberg, Greiff, & Funke, 2012)
  - Knowledge application (KAP): describes the process of actually using the knowledge acquired in order to solve a problem (Fischer, Greiff, & Funke, 2012)
  - Strategy (S) (Apedoe & Schunn, 2013): one multistep exploration strategy used in CPS research named the vary-one-thing-at-a-time (VOTAT)

METHOD (1)

- Sample:

  * 235 university students

  * from several disciplines at the end of their first-year

  * both genders (female: 70%),

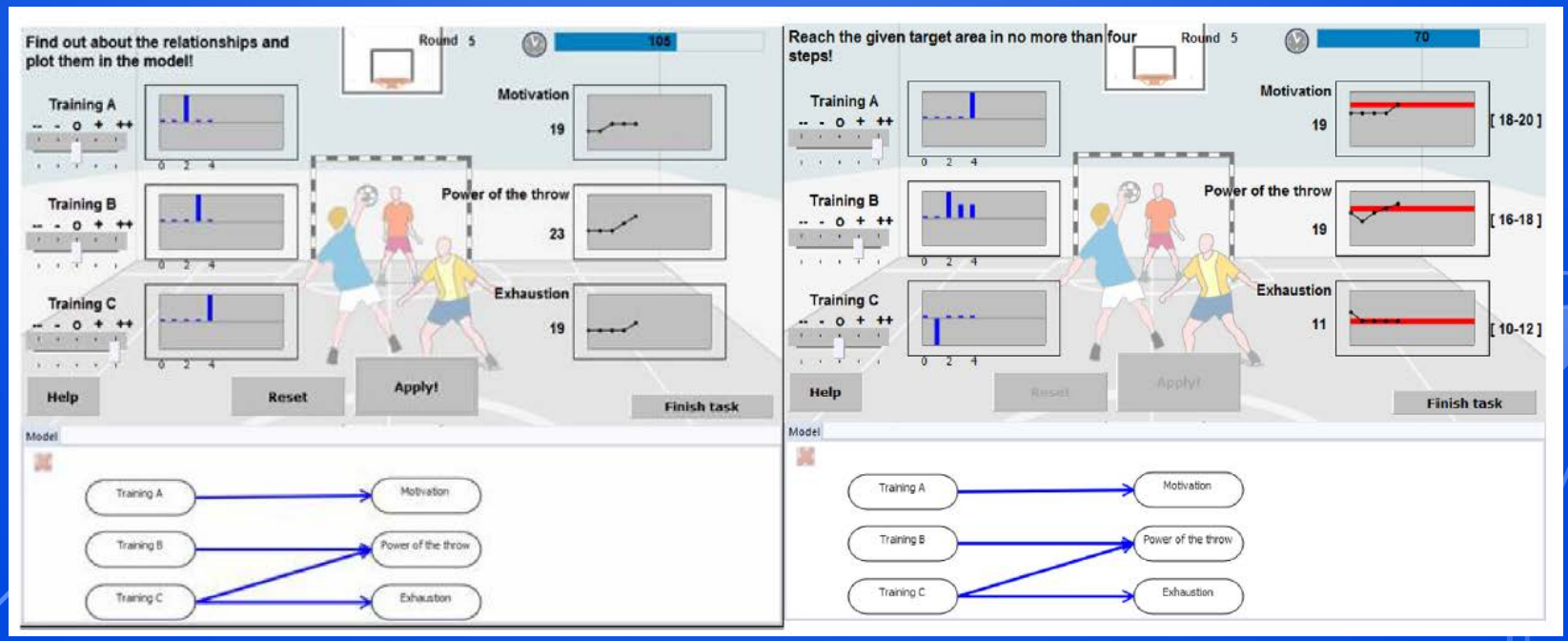
  * ages between 18 and 37 years-old (M= 22.51; SD= 5.265).

METHOD (2)

Instruments:

1- A socio-demographic questionnaire

2- A computerized micro-world environment (MicroDYN): three CPS dependent measures: knowledge acquisition, knowledge application, and strategy (Greiff, Holt, & Funke, 2013; Scherer & Gustafsson, 2015).



METHOD (3)

3) AOSPAN test to measure WMC: accuracy and RT (Unsworth, Heitz, Schrock, & Engle, 2005)

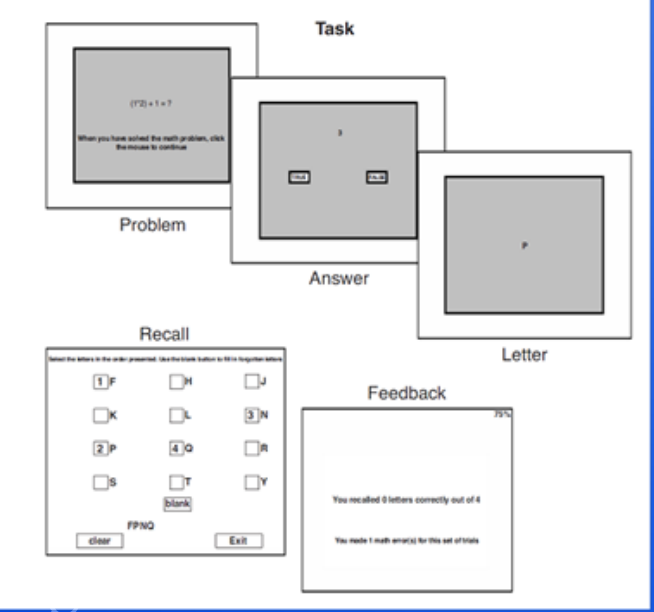


Figura extraida de Unsworth, N., Heitz, R.P., Schrock, J.C., & Engle, R.W. (2005). An automated version of the operation span task. *Behavior Research Methods, 37*(3), 498-505.

4) ANT test to evaluate attentional networks: alerting, orienting and executive attention (all derived RT measures, plus an overall RT) (Fan, McCandliss, Summer, Raz, & Posner, 2002)

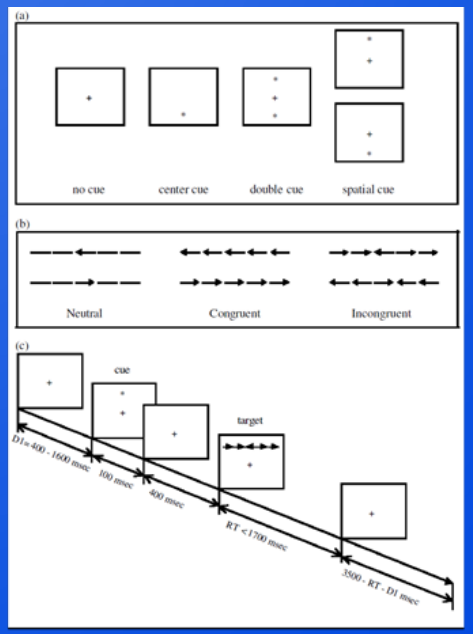


Figura extraida de Fan, J., McCandliss, B. D., Sommer, T., Raz, A. & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience, 14*, 340-347.

METHOD (4)

5) Two brief Likert-scales from PISA 2012 (OECD, 2012; $\alpha = .77$) to measure:

- openness to problem solving
- perseverance

METHOD (5)

Analyses:

1- A machine-learning method was used: multilayer perceptron artificial neural networks, with a backpropagation algorithm to develop 6 models classifying Low 33% and High 33% performance groups for each CPS phase (KAQ, KAP, STR).

2- A generalized linear model was used to analyze the differences and the interactions of cognitive and motivational variables in the two performance level groups.

RESULTS (1)

Table: Summary of ANN results

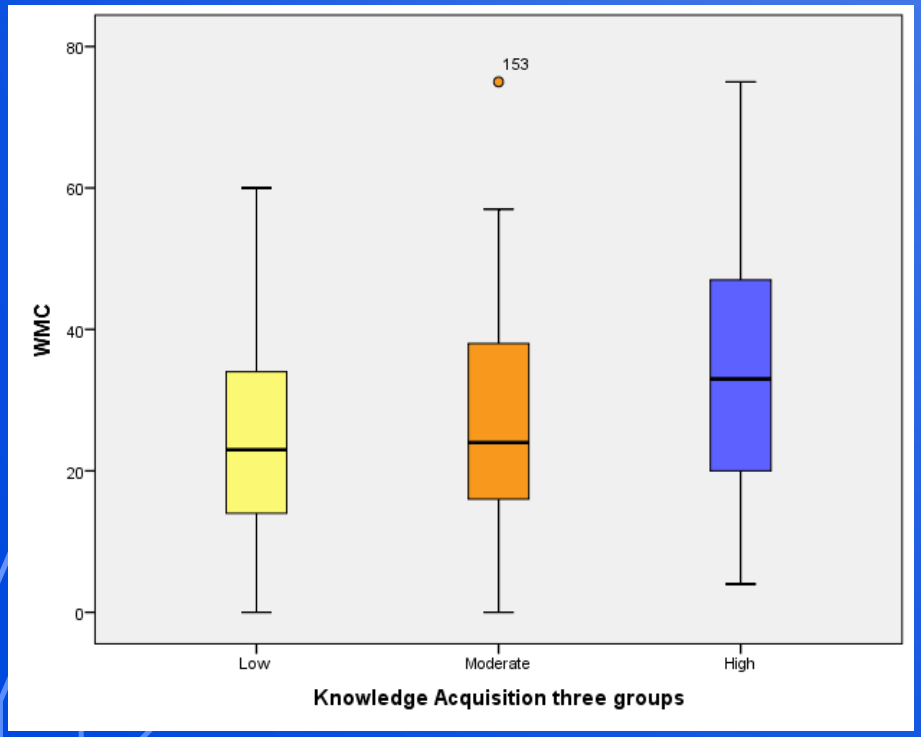
Measures	ANN1 Low 33% Knowledge Acquisition	ANN2 High 33% Knowledge Acquisition	ANN3 Low 33% Knowledge Application	ANN4 High 33% Knowledge Application	ANN5 Low 33% Strategy	ANN6 High 33% Strategy
Overall accuracy	**100%**	**100%**	**100%**	**100%**	**94.7%**	**91.7%**
Accuracy for the target group	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Accuracy for non-target group	**100%**	**100%**	**100%**	**100%**	**93.80%**	**88.90%**

RESULTS (2)

KNOWLEDGE ACQUISITION

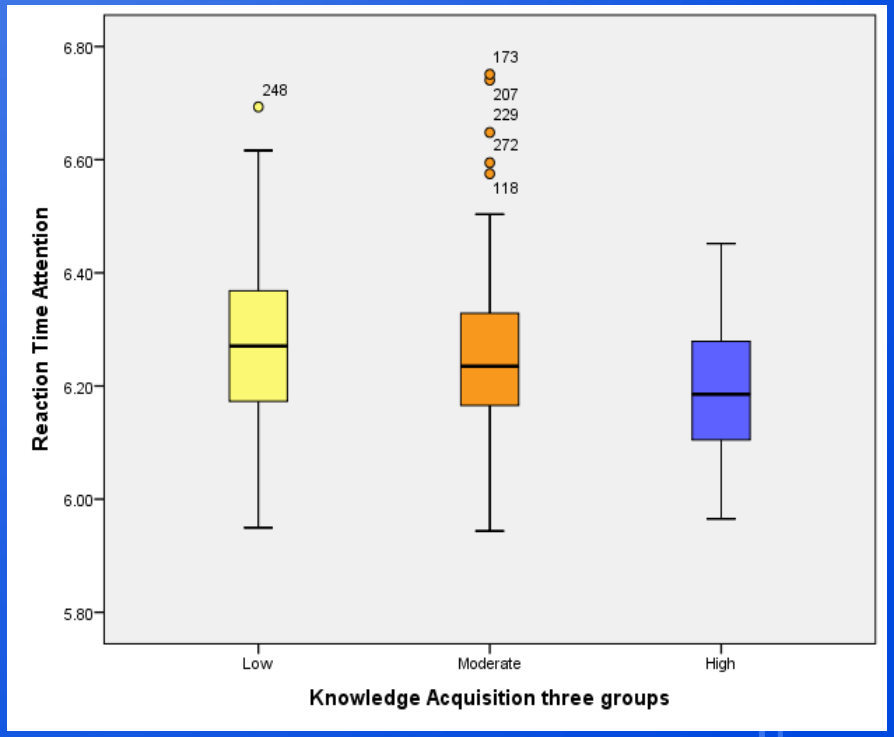
Students with Low & Moderate performance have:

Lower WMC



(F(2,238)= 6.698; p<.001; η²=.053)

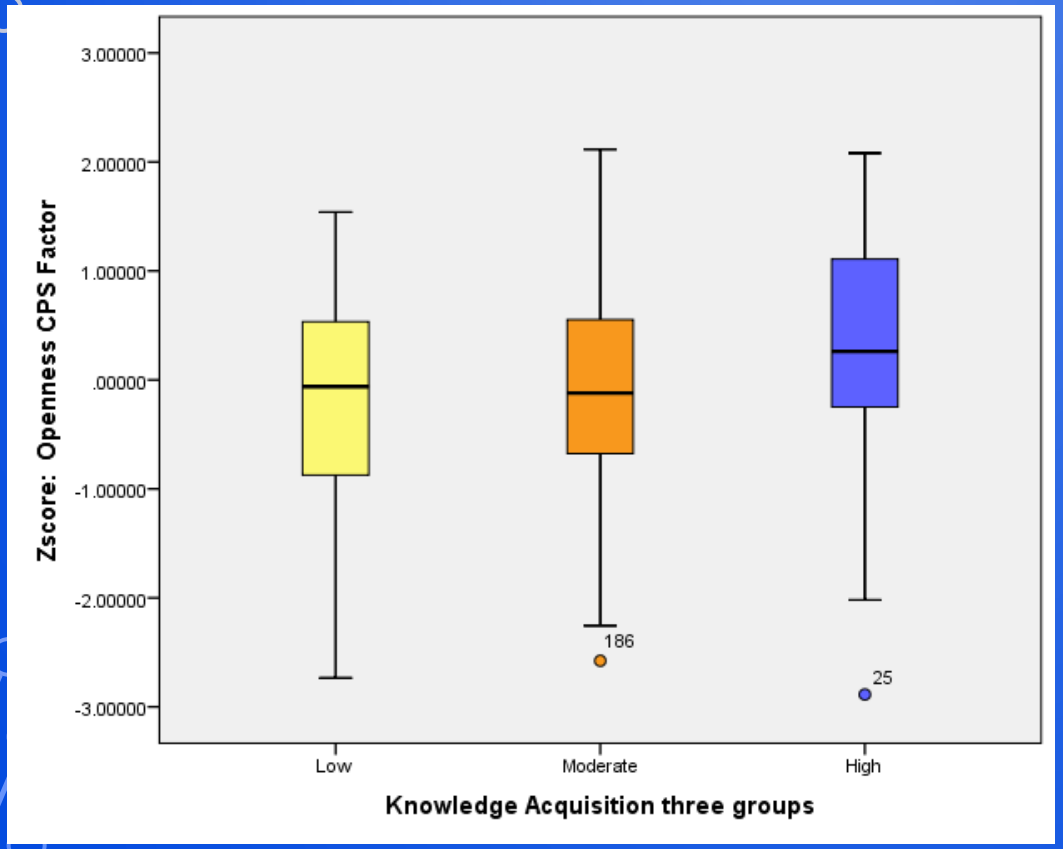
Slower RT in attentional networks



(F(2,230)= 7.691; p<.001; η²=.063)

RESULTS (3)

KNOWLEDGE ACQUISITION



Students with Low & Moderate performance have:

Lower Openness to CPS

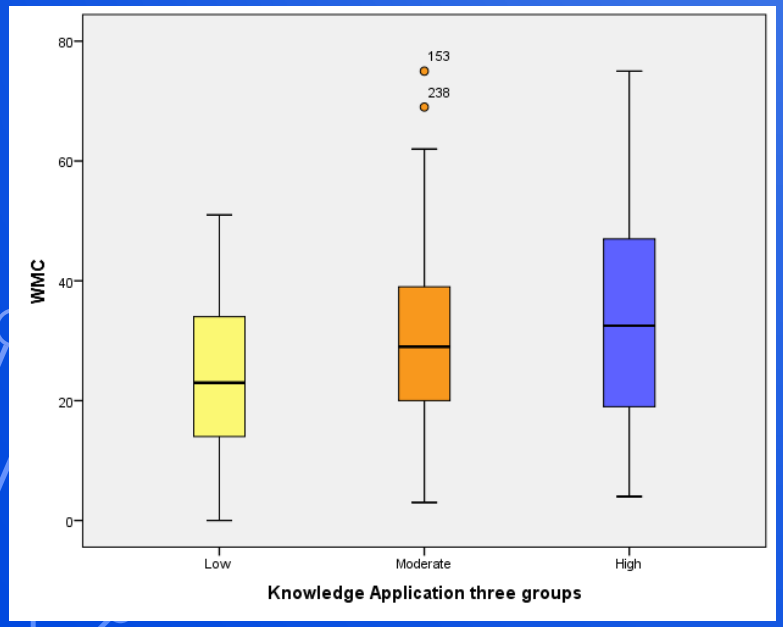
($F(2,238)= 4.852$; $p<.01$; $\eta^2=.039$)

RESULTS (4)

KNOWLEDGE APPLICATION

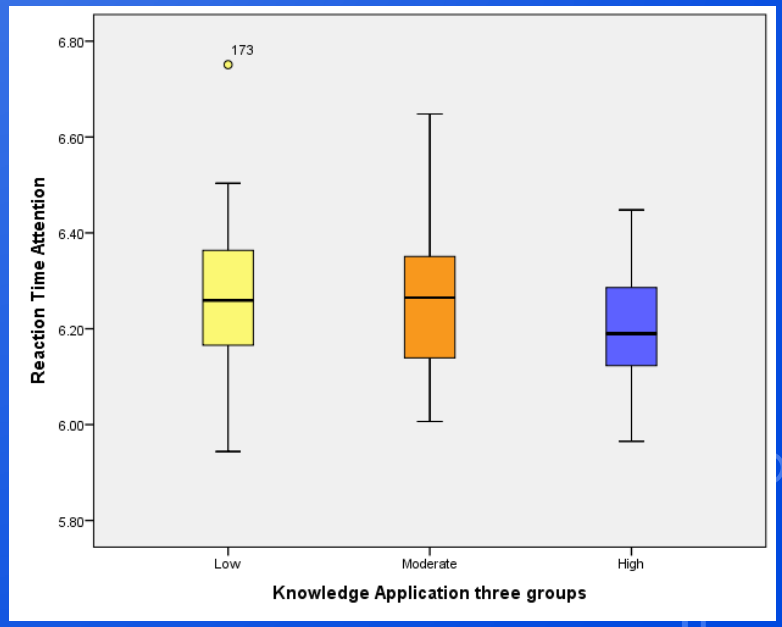
Students with Low performance have:

Lower WMC compared to Moderate & High 33%



(F(1,192)= 10.094; p<.005; η^2=.050)

Slower RT in attentional networks compared to High 33%



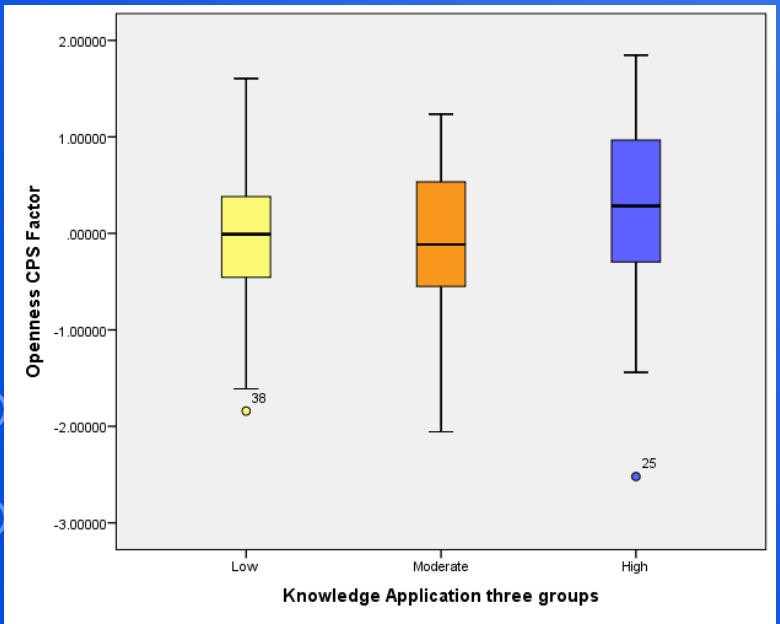
(F(2,183)= 4.068; p<.05; η^2=.043)

RESULTS (5)

KNOWLEDGE APPLICATION

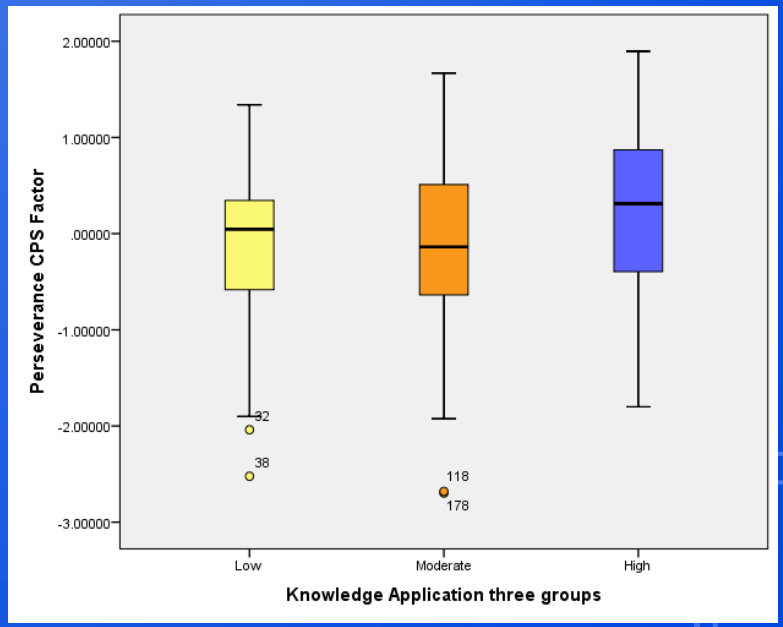
Students with High performance have:

Higher Openness CPS compared to Moderate 33%



(F(1,191)= 4.210; p<.05; η²=.042)

Higher Perseverance compared to Moderate 33%



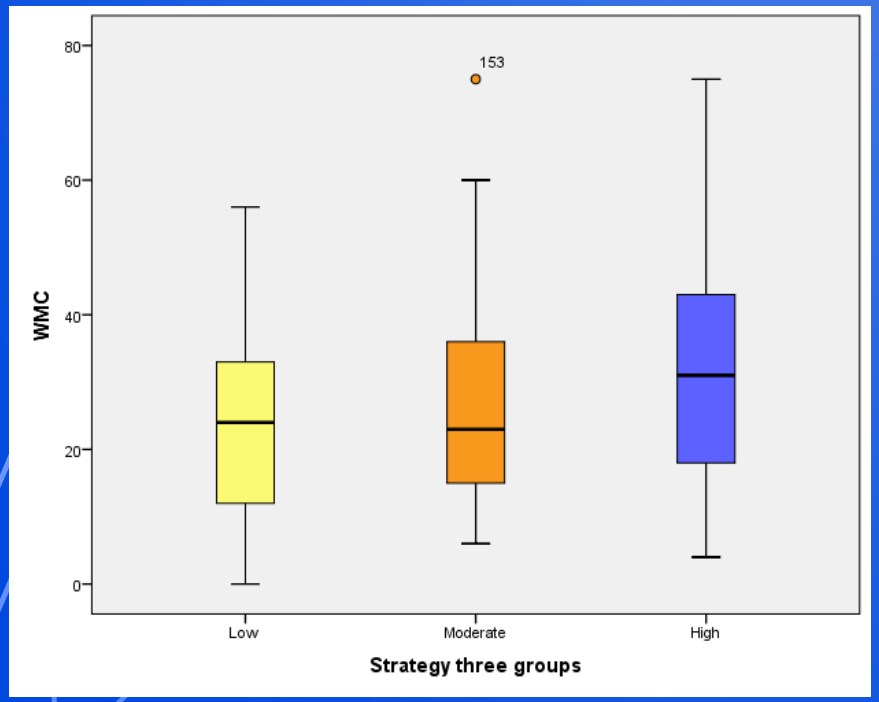
(F(2,191)= 4.143; p<.05; η²=.042)

RESULTS (6)

STRATEGY

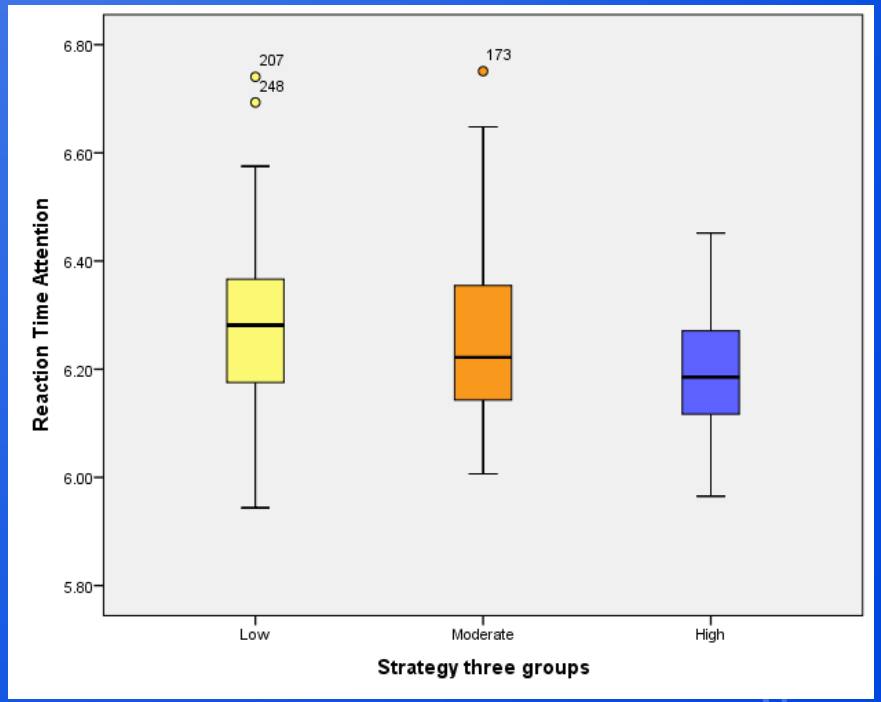
Students with Low performance have:

Lower WMC compared to High 33%



(F(2,265)= 5.315; p<.01; η^2=.039)

Slower RT in attentional networks compared to High 33%



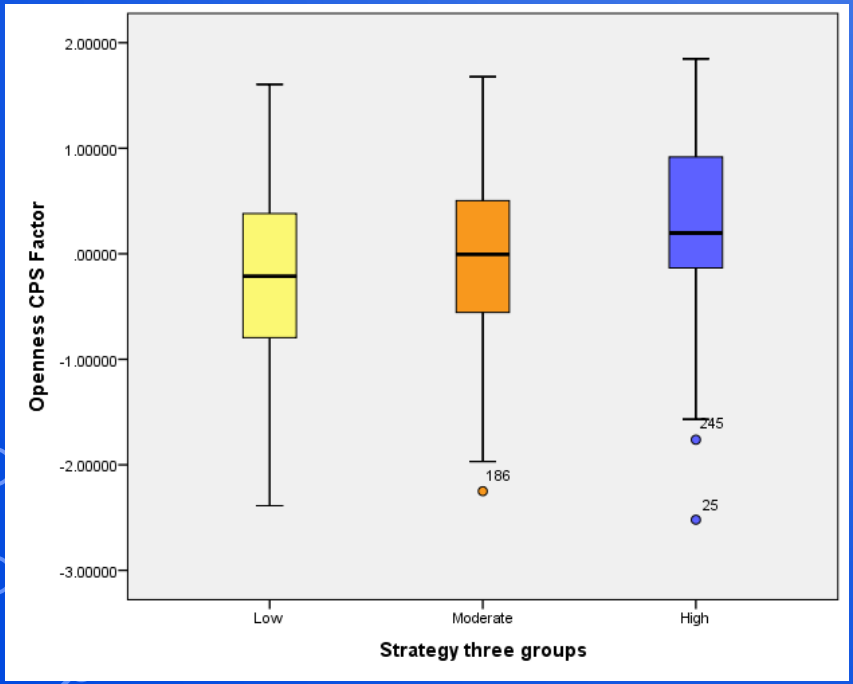
(F(2,257)= 10.168; p<.001; η^2=.073)

RESULTS (7)

STRATEGY

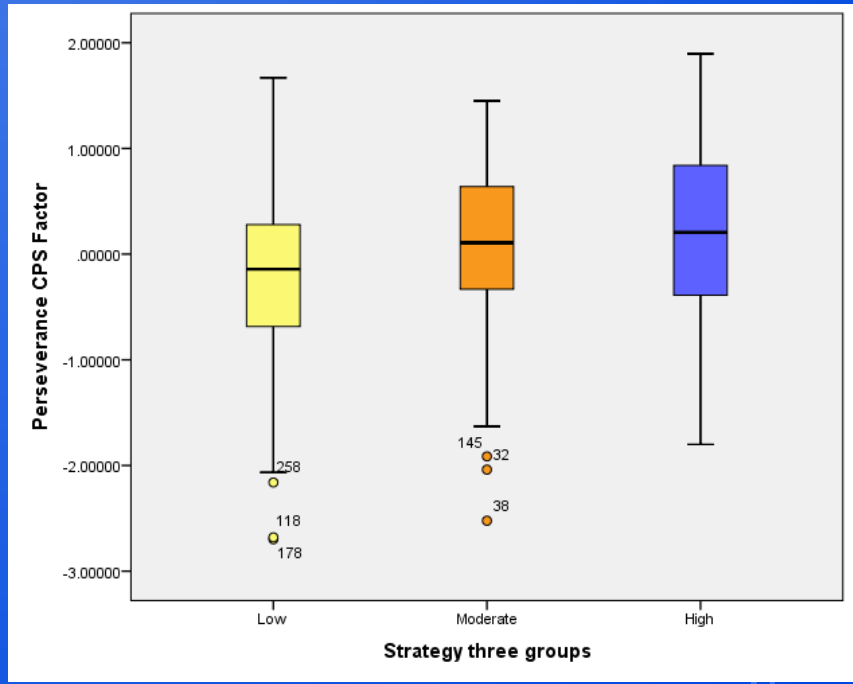
Students with High performance have:

Higher Openness CPS compared to Low & Moderate 33%



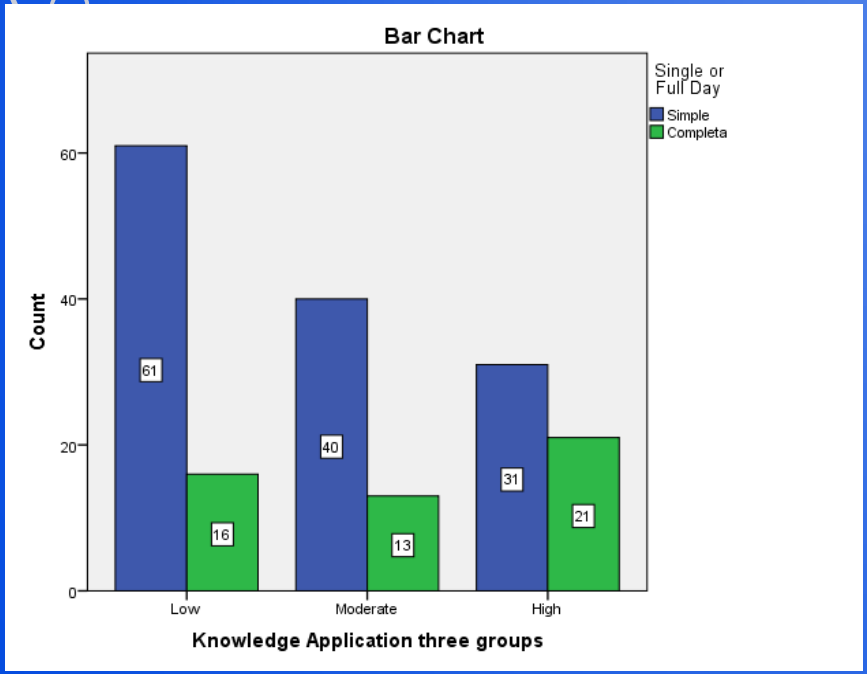
(F(2,266)= 7.263; p<.001; η^2=.052)

Higher Perseverance compared to Low 33%

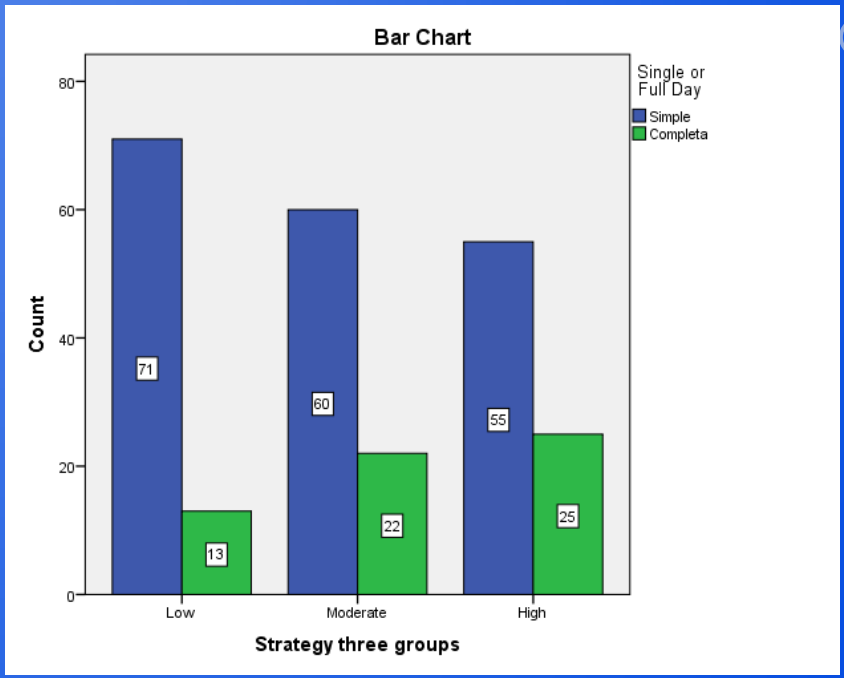


(F(2,266)= 6.760; p<.001; η^2=.048)

RESULTS (8)



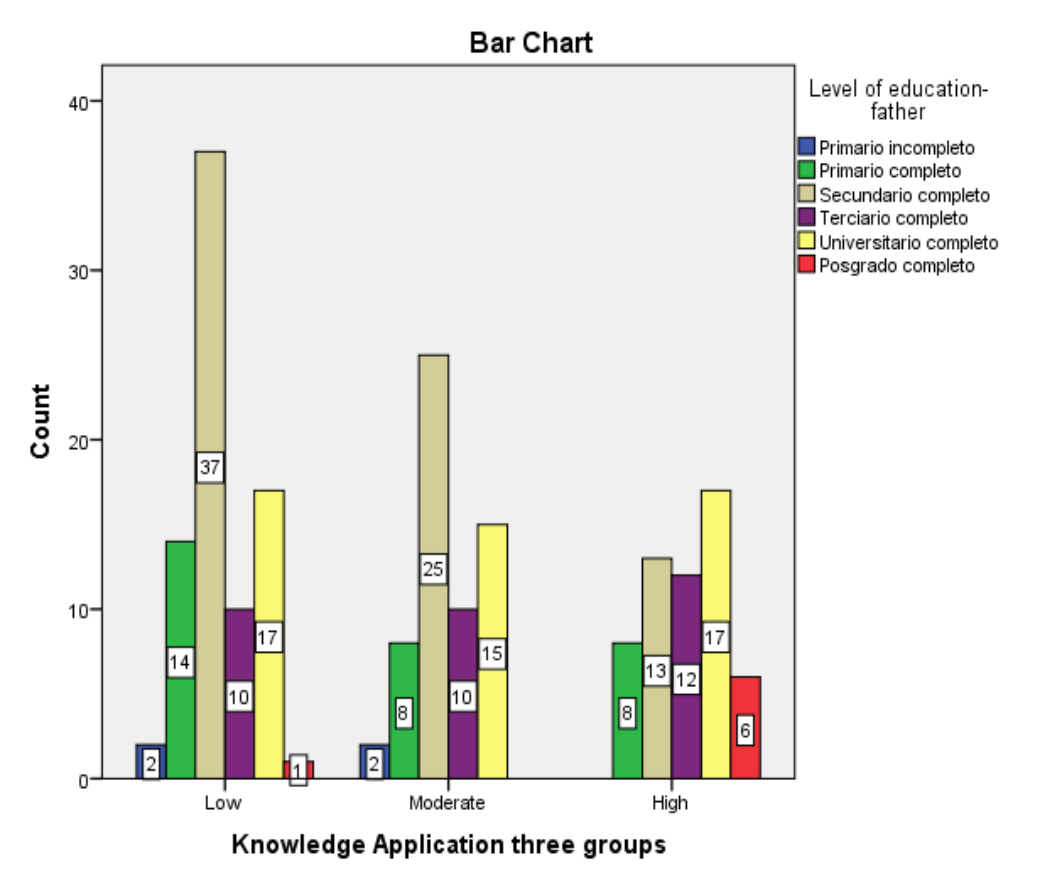
(Chi^2 = 6.313; p< .05)



(Chi^2 = 5.925; p< .05)

Students with low performance in K App & Strategy come from half-day secondary schools

RESULTS (9)



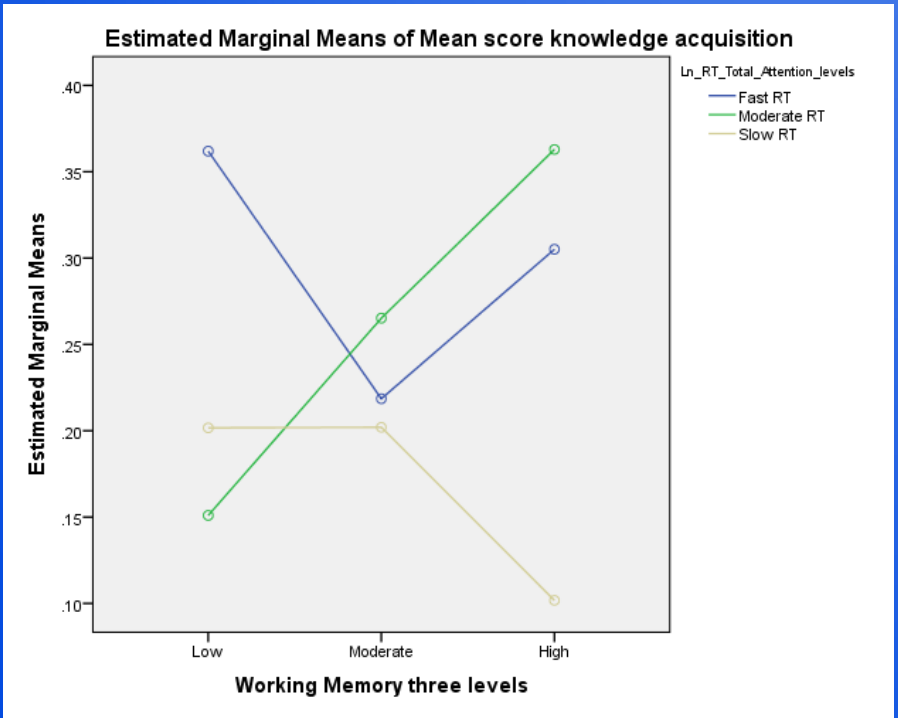
Students with Low Knowledge Application performance
have parents with lower levels of formal education

(Chi^2= 21.096; p< .05)

RESULTS (11)

- There was an interaction effect WMC * RT Attention in the KAQ dimension:

Knowledge Acquisition



($F(4,224)= 3.107$; $p<.01$; $\eta^2=.053$

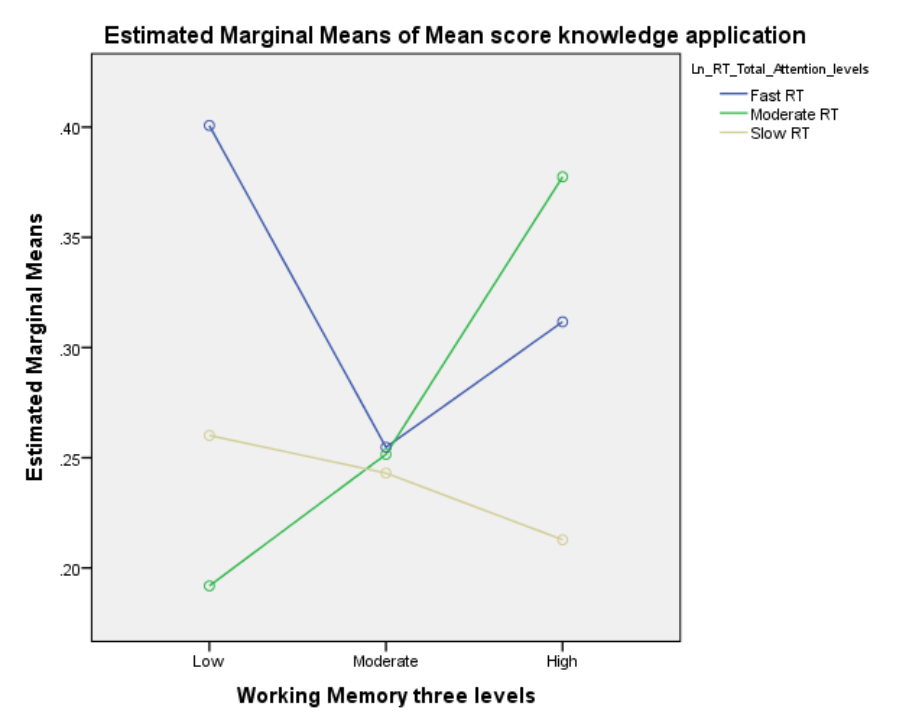
Students with low and moderate RT have lower KAQ performance in low WMC students

Students with high and moderate RT have higher KAQ performance in high WMC students

RESULTS (12)

- There was an interaction effect WMC * RT Attention in the KAP dimension:

Knowledge Application



Students with low and moderate RT have lower KAP performance in low WMC students

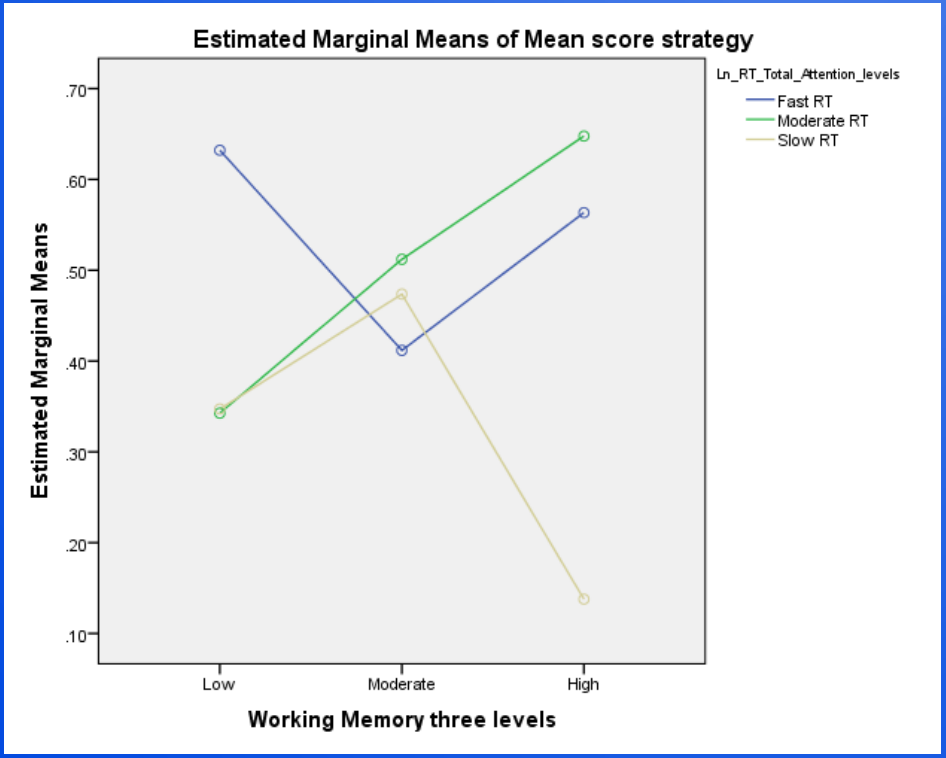
Students with high and moderate RT have higher KAP performance in high WMC students

($F(4,224)= 3.487$; $p<.01$; $\eta^2=.059$

RESULTS (10)

- There was an interaction effect WMC * RT Attention in the Strategy dimension:

Strategy



(F(4,224)= 3.476; p<.01; η^2=.058

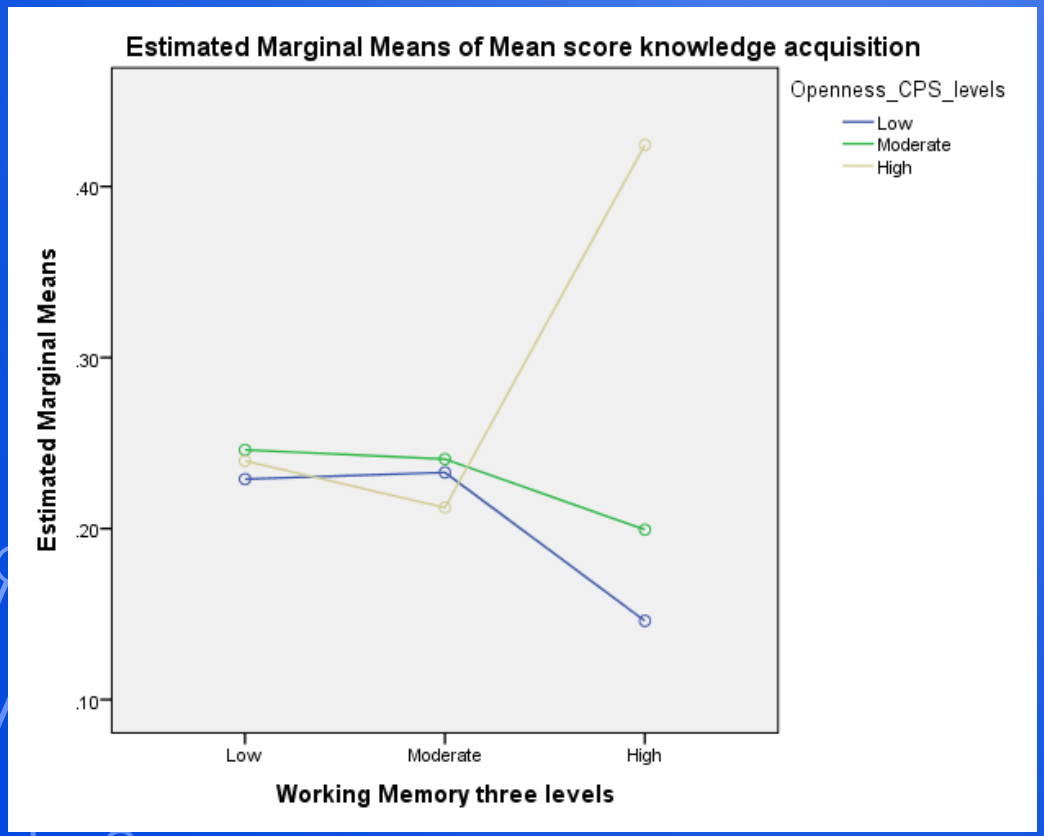
Students with low and moderate RT have lower STR performance in low WMC students

Students with high and moderate RT have higher STR performance in high WMC students

RESULTS (13)

- There was an interaction effect WMC * Openness CPS in the KAQ dimension

Knowledge Acquisition



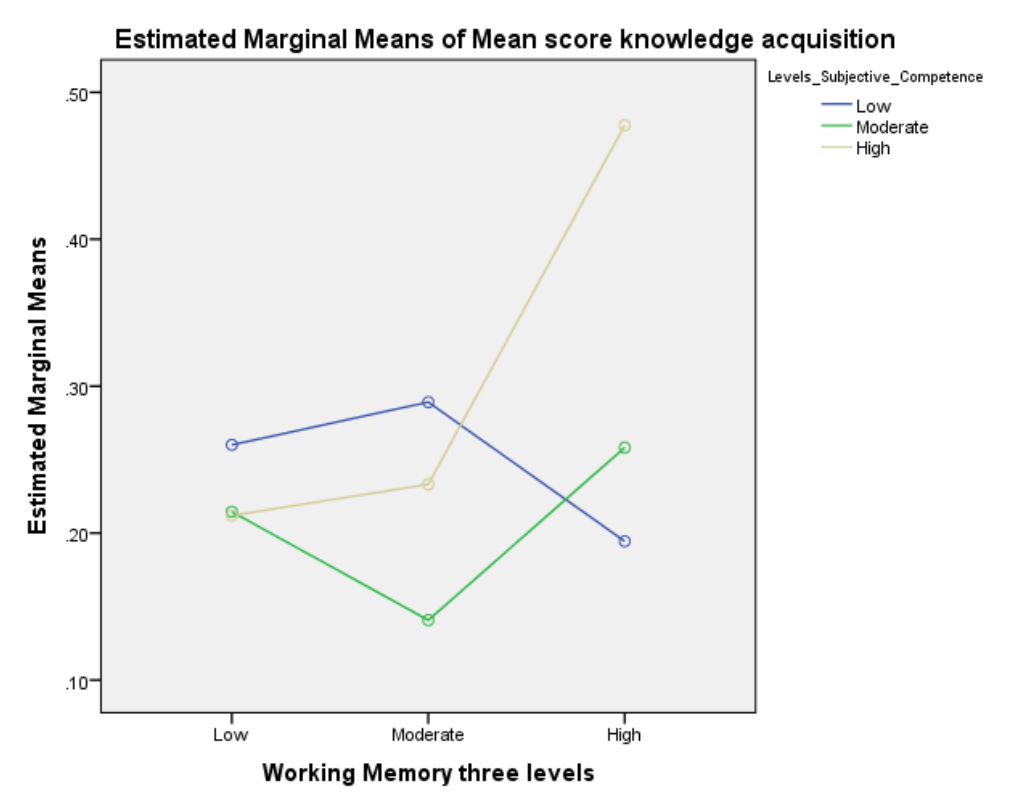
Students with High Openness CPS score have higher KAQ performance in high WMC students

$(F(4,224)= 2.494;\ p<.05;\ \eta^2=.043$

RESULTS (15)

- There was an interaction effect WMC * Subjective Competence in the KAQ dimension:

Knowledge Acquisition



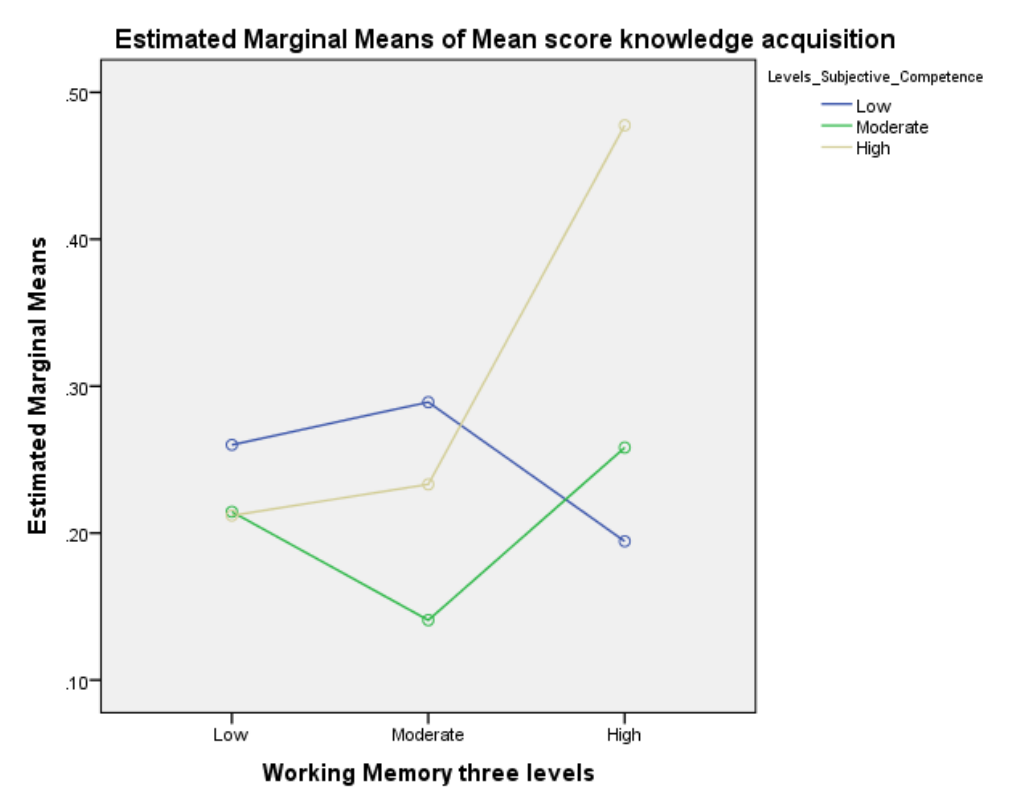
(F(4,191)= 3.052; p<.01; η^2=.06

Students with High Subjective Competence for CPS have higher KAQ performance in high WMC students

RESULTS (16)

- There was an interaction effect WMC * Subjective Competence in the KAP dimension:

Knowledge Application



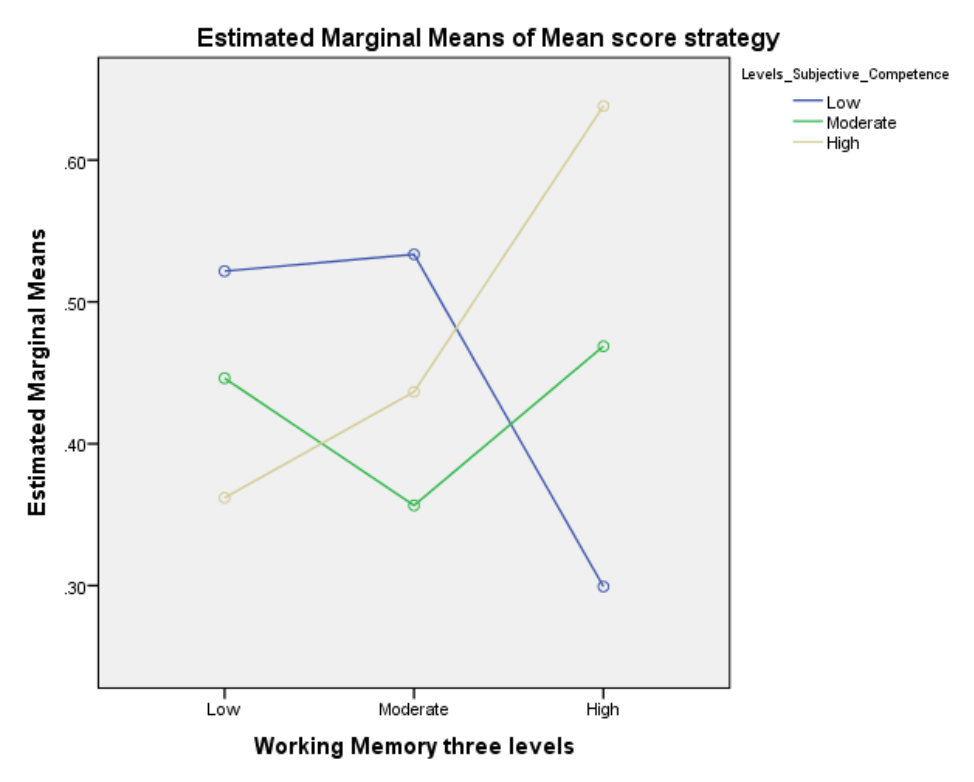
Students with High Subjective Competence for CPS have higher KAP performance in high WMC students

($F(4,191)= 3.289$; $p<.01$; $\eta^2=.064$

RESULTS (14)

- There was an interaction effect WMC * Subjective Competence in the Strategy dimension:

Strategy



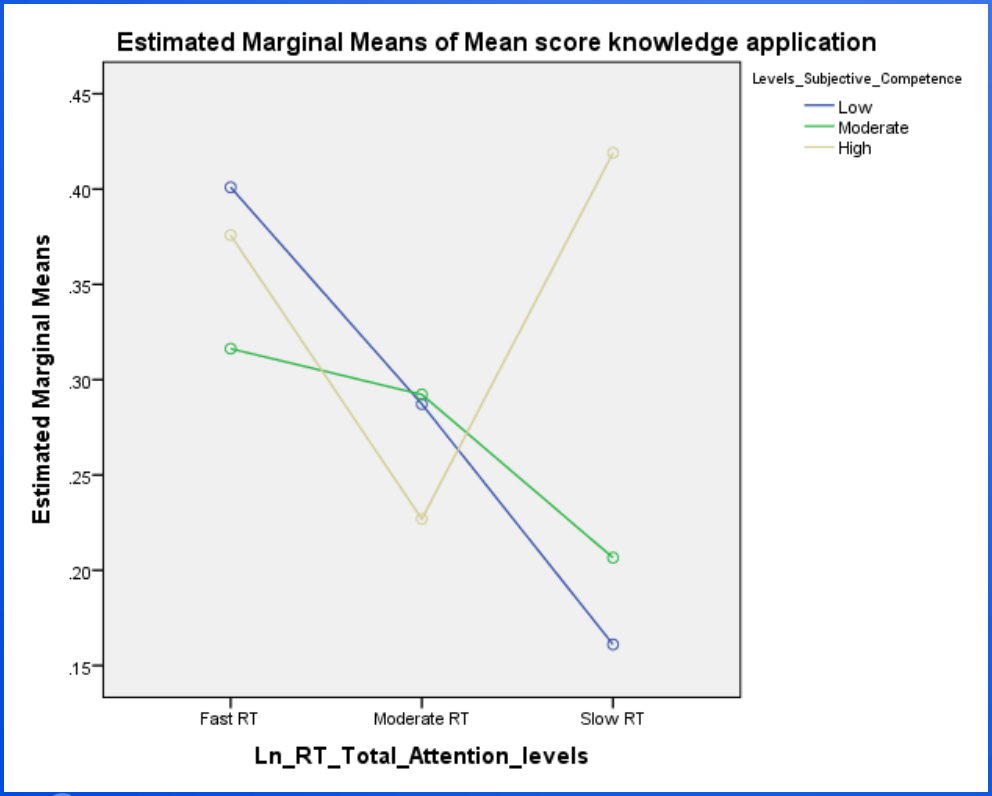
Students with High Subjective Competence for CPS have higher STR performance in high WMC students

($F(4,191)= 2.407$; $p<.05$; $\eta^2=.048$

RESULTS (16)

- There was an interaction effect RT Attention * Subjective Competence in the KAP dimension:

Knowledge Application



(F(4,191)= 4.156; p<.01; η^2=.080

Students with High Subjective Competence for CPS have higher KAP performance in slow RT students

As long as RTs are fast, Subjective Competence does not show an effect on KAP performance

DISCUSSION

- These results confirmed the crucial role of WMC and speed of processing as basic cognitive processes for all three dimensions of CPS.
- We also find that a minimum threshold of processing speed is necessary to achieve a high level of performance in the three CPS dimensions if WMC is high.
- Similarly, in all CPS dimensions, if WMC is low, CPS performance is low unless students have high processing speed.

DISCUSSION

- Therefore, according to a dual conceptualization of WM as having capacity and information-flow dimensions, speed of processing facilitates better cognitive performance when sufficient capacity is present, and when rapid flow of information helps a limited capacity WM.

- Further research should explore the interaction of varying the complexity of the problem and differentiate between the above mentioned conditions (i.e., see if for low WMC students, fast RT still facilitate performance even in very high complexity problems).

DISCUSSION

- Complex interactions between WMC and motivational variables, such as openness and subjective competence, have been found to be significant for all dimensions of CPS.

- Openness to CPS and Subjective Competence moderate the effect of WMC. This result is consistent with PISA 2012 results where motivational factors have only had an effect for high performance students in the CPS assessment (OECD, 2013).

- In addition, this result is consistent with previous research regarding the importance of WM and attention mediating motivational SRL and background environment factors (Musso, 2016; Musso, Kyndt, Cascallar & Dochy, 2012, 2013).

DISCUSSION

- The study also shows the usefulness of a machine-learning approach to develop accurate models of cognitive performance and thus provide an appropriate basis for further analysis of the phenomenon being researched.

- Once we have a valid model to study, classical statistical analyses can be used to reach a more comprehensive understanding of the processes involved in CPS or other cognitive performance.

Thank you for your attention!

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