

# Linking formative and summative assessment with Explainable Artificial Intelligence

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### Machine Learning for Data Analysis

- Machine Learning [subfield of Artificial Intelligence]
- Best known for application in technical devices (robotics, face recognition, automatic translation, synthetic image generation...)
- Also usable as tool for statistical data analysis (e.g., Kosinski, Stillwell & Graepel, 2013)
- But: not able to explain their autonomous decisions and actions to human users ("Black Box")





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- SHAP values (Lundberg & Lee, 2017)
  - Based on Game theory (Shapley, 1953)



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#### = Marginal Contribution

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	1	Name 🍦	Т1.МК.1 🗦	Т1.МК.2 🗦	т1.МК.3 🗦	Т1.МК.4 🗦	Т1.МК.5 🗦	T1.MV.1 🗘
	1	star0543	1	1	0	1	1	1
	2	star0573	1	1	0	1	0	0
	3	star0592	1	1	1	1	1	0
	4	star0616	0	0	0	0	0	0
	5	star0652	1	0	1	1	1	1
	6	star0664	1	0	0	1	0	0
	7	star0831	0	0	0	0	0	0
	8	star0851	1	0	0	1	1	0
	9	star0875	1	0	0	1	0	0
	10	star0940	0	0	0	0	0	0
Î	11	star1200	1	1	1	1	0	0
	12	star1202	0	0	0	0	0	0



	<ul> <li>SHAP values (Lundberg &amp; Lee, 2017)</li> </ul>					^	Name 🍦	Т1.МК.1 ♀	Т1.МК.2 🗘	т1.МК.3	Т1.МК.4	🕴 🗘 т1.	мк.5 🔅	T1.MV.1	÷
						1	star0543	1	1	0	1	1		1	
	<ul> <li>Based on Game theory (Shapley, 1953)</li> </ul>				2	star0573	1	1	0	1	0		0		
						3	star0592	1	1	1	1	1		0	
						4	star0616	0	0	0	0	0		0	
	Individual regression models for each person!				5	star0652	1	0	1	1	1		1		
						6	star0664	1	0	0	1	0		0	
						7	star0831	0	0	0	0	0		0	
						8	star0851	1		0	1			0	
							star0875	1				1			
					star083		tar0940	0			0				
	star0543		star0616			1	tar1200	<sup>1</sup> St	tar0940		1	star1202		2	
							star1202	0			0				
	IQ: .12		IQ: .19		IQ: .03			IQ:	.16		I	Q:	.14		
	SES: .43		SES: .27		SES: .02			SES	6: .14		S	SES:	.28		
	SRI: 07		SRI: 17		SRI: 34			SRI - 26			SE		00		
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	WOT:14		WUT: .20		WOT: .37			UN	III				.51		

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as a process

Background: Formative and summative assessment

Formative assessments

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Summative assessment

onsiders evaluation at a product

Source of illustration: <u>https://www.bookwidgets.com/blog/2017/0</u> <u>a 016 dfferences-between-formative-and-</u> <u>summative-assessment-infographic</u> 12



### Background: Formative and summative assessment

Formative assessments e.g., weekly digital assignments (not graded)

- $\rightarrow$  Feedback on strengths and weaknesses (Hattie & Timperley 2007)
- $\rightarrow$  Regulation of goal setting and learning strategies (Black & Wiliam 2009)



Summative assessment e.g., final exam (graded)

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### Background: Formative and summative assessment

Formative assessments e.g., weekly digital assignments (not graded)



Summative assessment e.g., final exam (graded)

- Participating in formative assessments increases success in summative assessments (Angus and Watson 2009; Förster, Weiser & Maur 2018)
- But: "...it remains uncertain "[...] whether success in completing the homework influences the success in the examination" (Leong & Alexander 2014, p.614)

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#### Our data: Formative and summative assessment

## Formative assessments weekly digital homework



Summative assessment final exam (graded)



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### Our data: Formative and summative assessment

Formative assessments weekly digital homework Summative assessment final exam

- Introductory lecture for Mathematics (Bachelor of Economics; Linear Algebra & Analysis)
- N=408 students (female: 47.8%; M<sub>age</sub>=20.6; SD<sub>age</sub>=1.97)
- DV: Exam grade (in %)
- IVs:
- Performance in weekly assessments (in %)
- Prior knowledge (school GPA; school math grade; advanced math course at school)
- Affect (math affinity; math anxiety)
- Goal orientation (goal setting for final exam)
- Demographics (gender; age; repetition of lecture)

### Our data: Formative and summative assessment



Our 1. research question (not our focus today): What makes **individual** students successful in the formative assessments?

Our 2. research question: To what extend does the success in formative assessments affect the summative assessment in individual students?

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### Summary plot



#### • Overview of sample:

eature value

- SHAP values for each participant depending on his/her feature values
- Different distributions of SHAP values for each feature
  - Weekly assignments with strong negative impact for many, but not all participants

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#### Clustering participants

Based on similarities of Shap values Four cluster solution

 $\rightarrow$  Possibility to provide early feedback for students at risk

### Summary: Explainable Artificial Intelligence



#### Thank you!

#### Example paper with Explainable Artificial Intelligence:

Pereira, F. D., Fonseca, S. C., Oliveira, E. H., Cristea, A. I., Bellhäuser, H., Rodrigues, L., ... & Carvalho, L. S. (2021). Explaining Individual and Collective Programming Students' Behavior by Interpreting a Black-Box Predictive Model. *IEEE Access*, *9*, 117097-117119.



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