Interactive Visualisations for Explainable AI Research and Research Practices

Jeroen Ooge

jeroenooge.be

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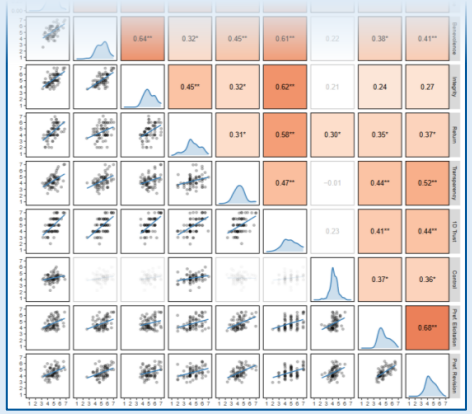
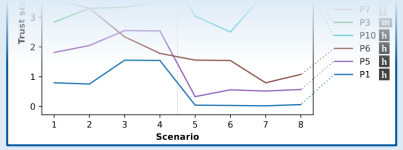
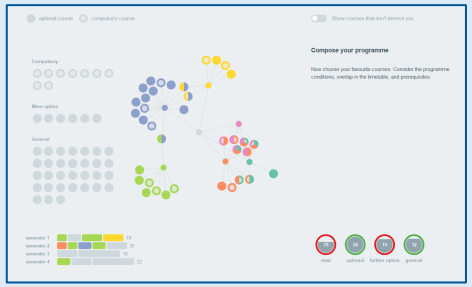
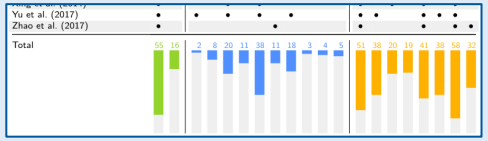
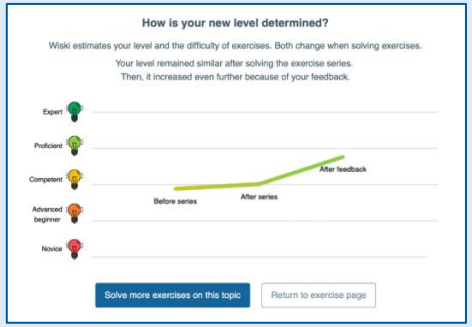
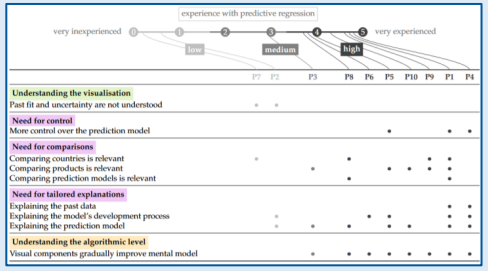


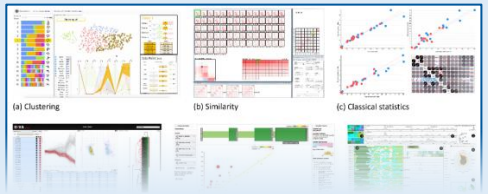


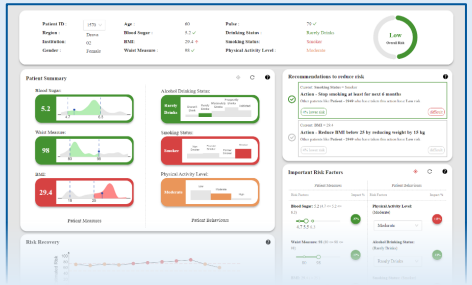


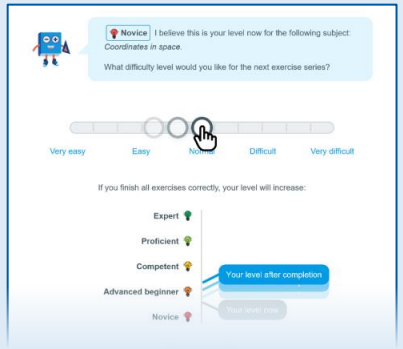












About Me

Jeroen Ooge

jeroenooge.be

“yeh-roon ow-geh” 😂

About Me

I am **VIS**

Jeroen Ooge
jeroenooge.be

About Me

Human-centred explainable AI
*with **visualisations***

My short life

MSc fundamental mathematics
MSc applied informatics
2012-2019

PhD researcher
at KU Leuven
2019-2023

Assistant professor
at Utrecht University
2023-now

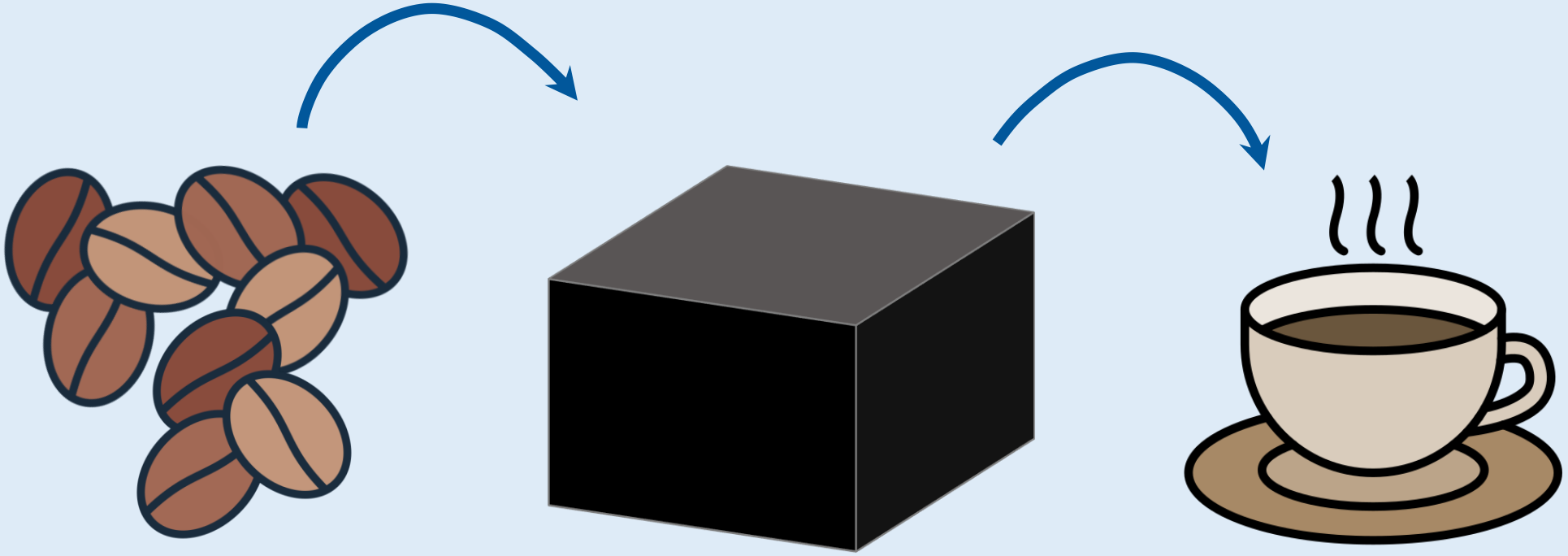
Universiteit Utrecht

Jeroen Ooge
jeroenooge.be

Input

AI model

Output

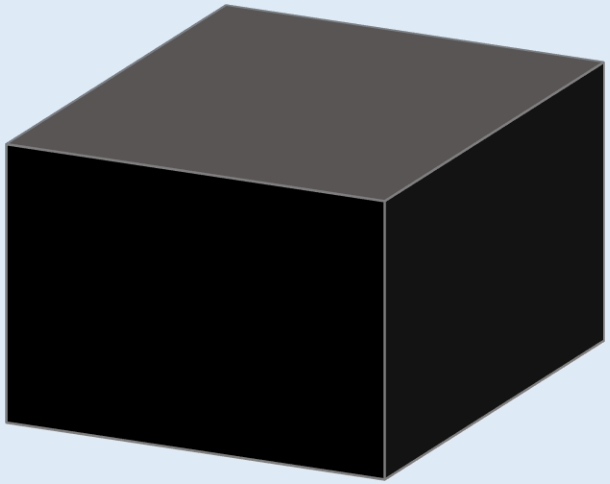


Input

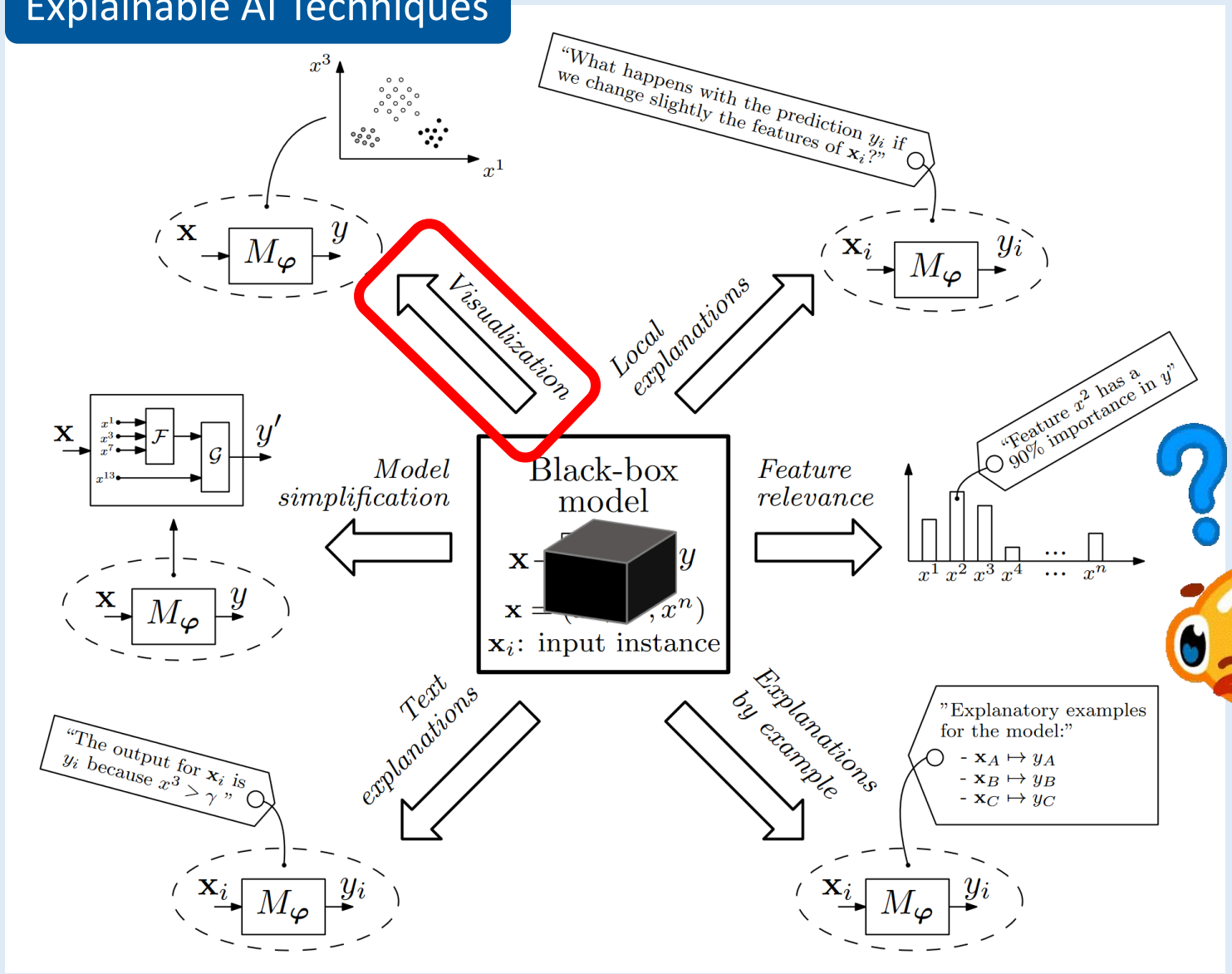
AI model

Output

Can we “open” this black box?



Explainable AI Techniques



Which explanation type do we use?

Who is the audience?

What is the context?

Alejandro Barredo Arrieta et al. 2020. Explainable Artificial Intelligence (XAI): Concepts, taxonomies, opportunities and challenges toward responsible AI. Information Fusion 58: 82–115. https://doi.org/10.1016/j.inffus.2019.12.012

Human-Centred Explainable AI

Different people and contexts
need different explainability solutions

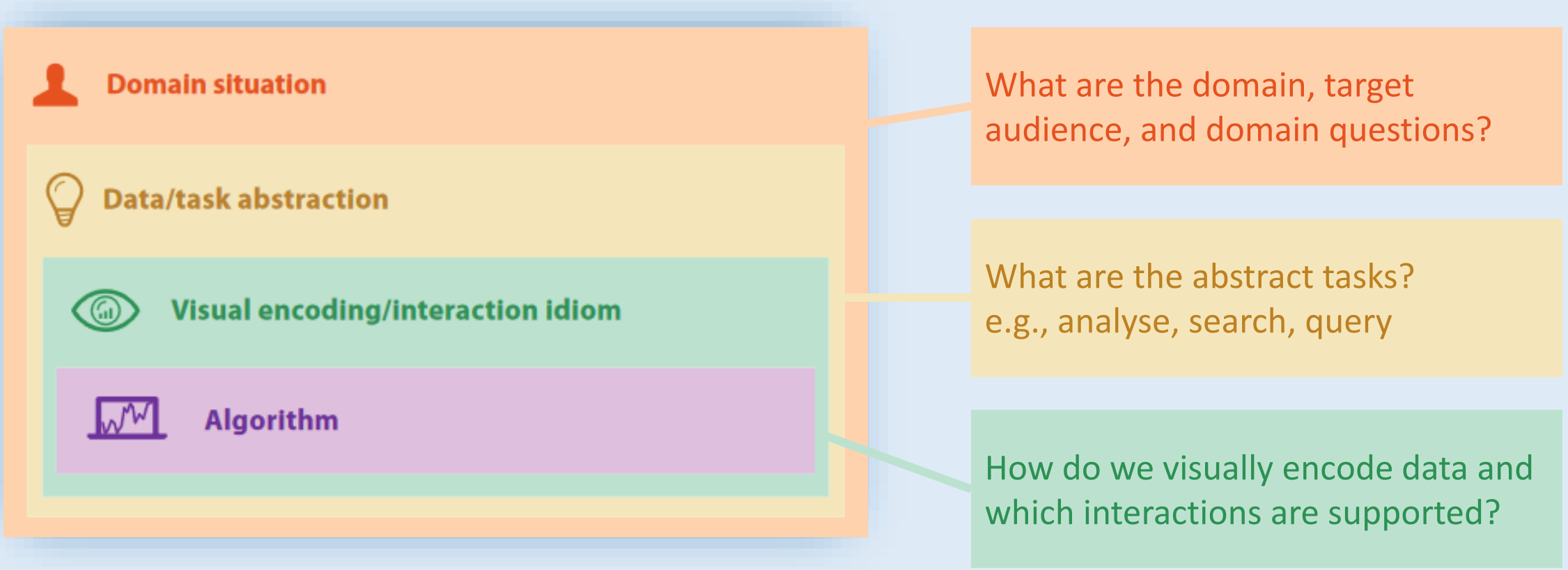
My goal: design visual explanations and evaluate how they affect people's behaviour (e.g., trust, understanding, motivation)

I Complex Visual Dashboards

II Simple Visualisations

III Visualisations in Reports

Quick Recap of the Nested Model

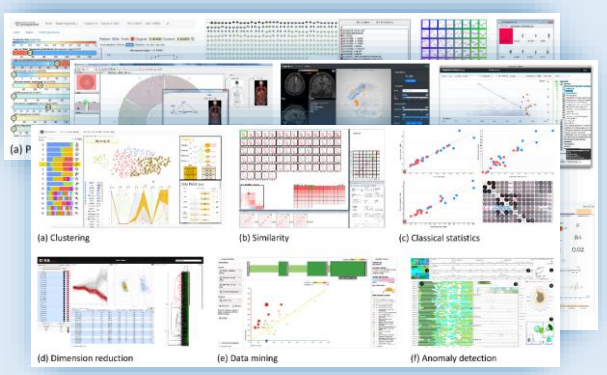


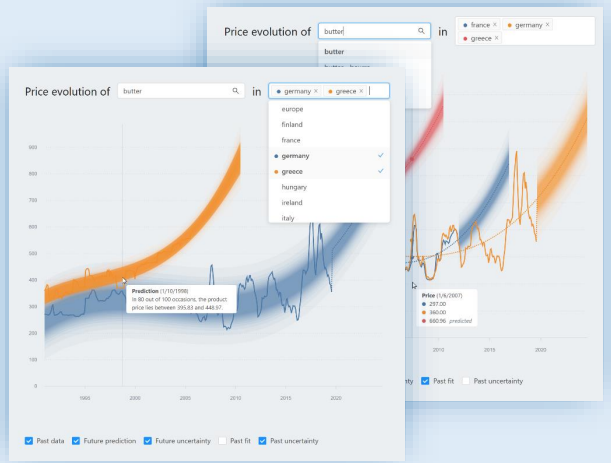
Tamara Munzner. 2014. *Visualization Analysis and Design*. A K Peters/CRC Press. https://doi.org/10.1201/b17511

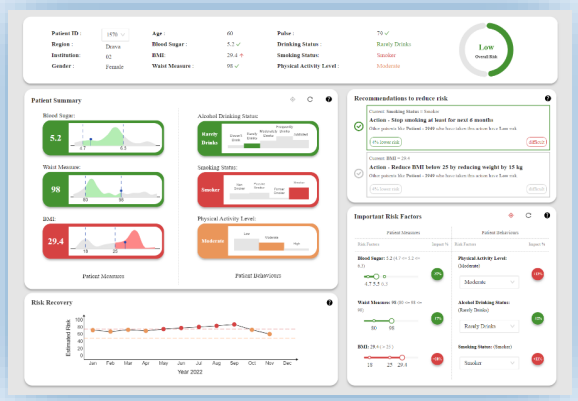
I Complex Visual Dashboards

II Simple Visualisations

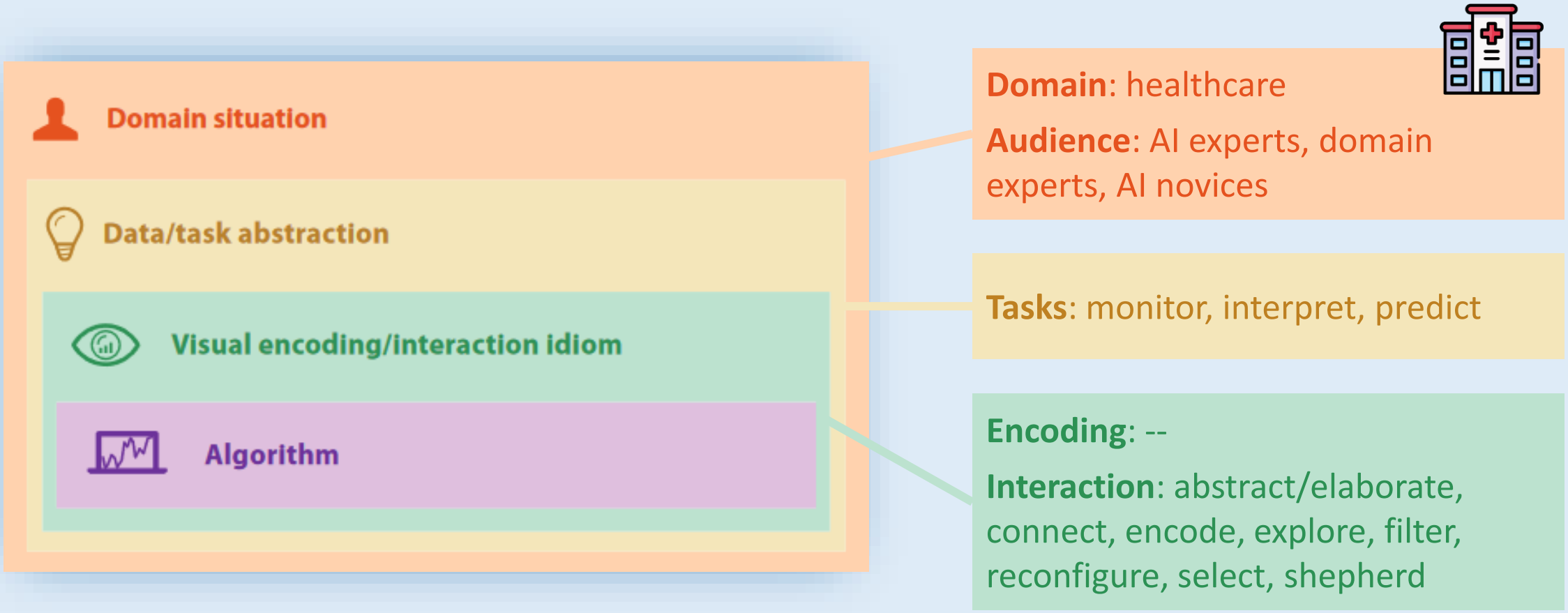
III Visualisations in Reports



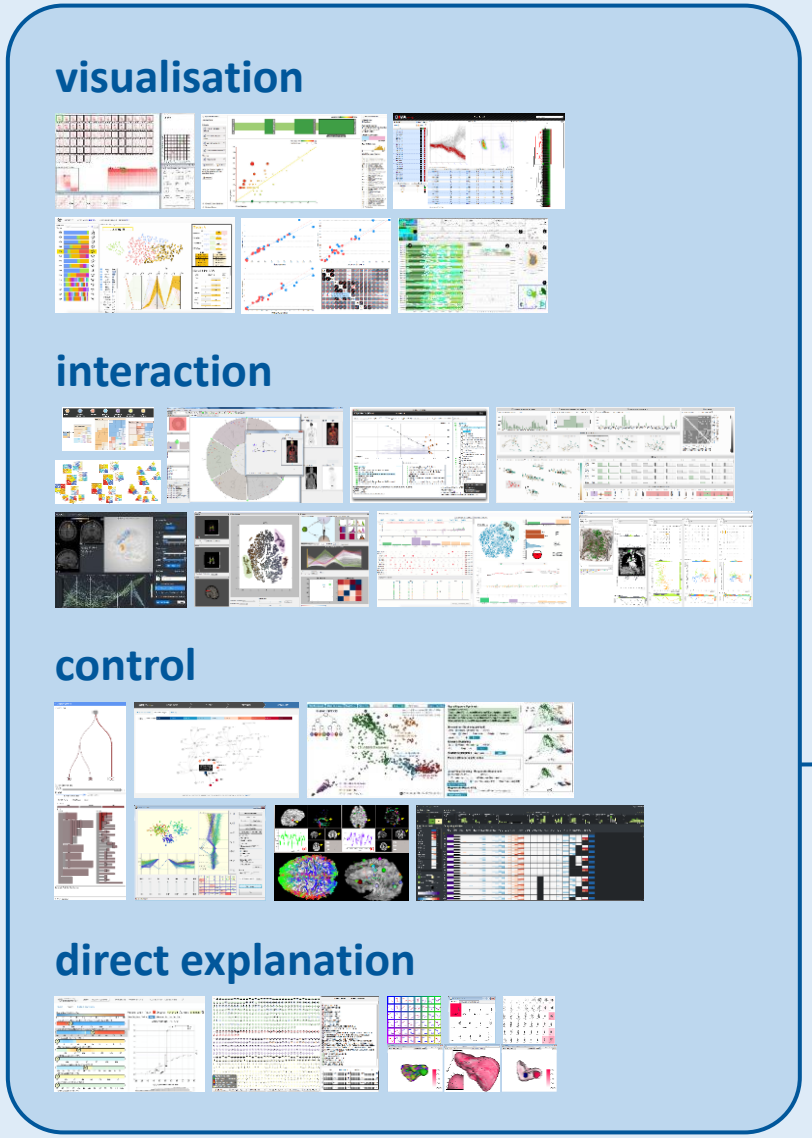


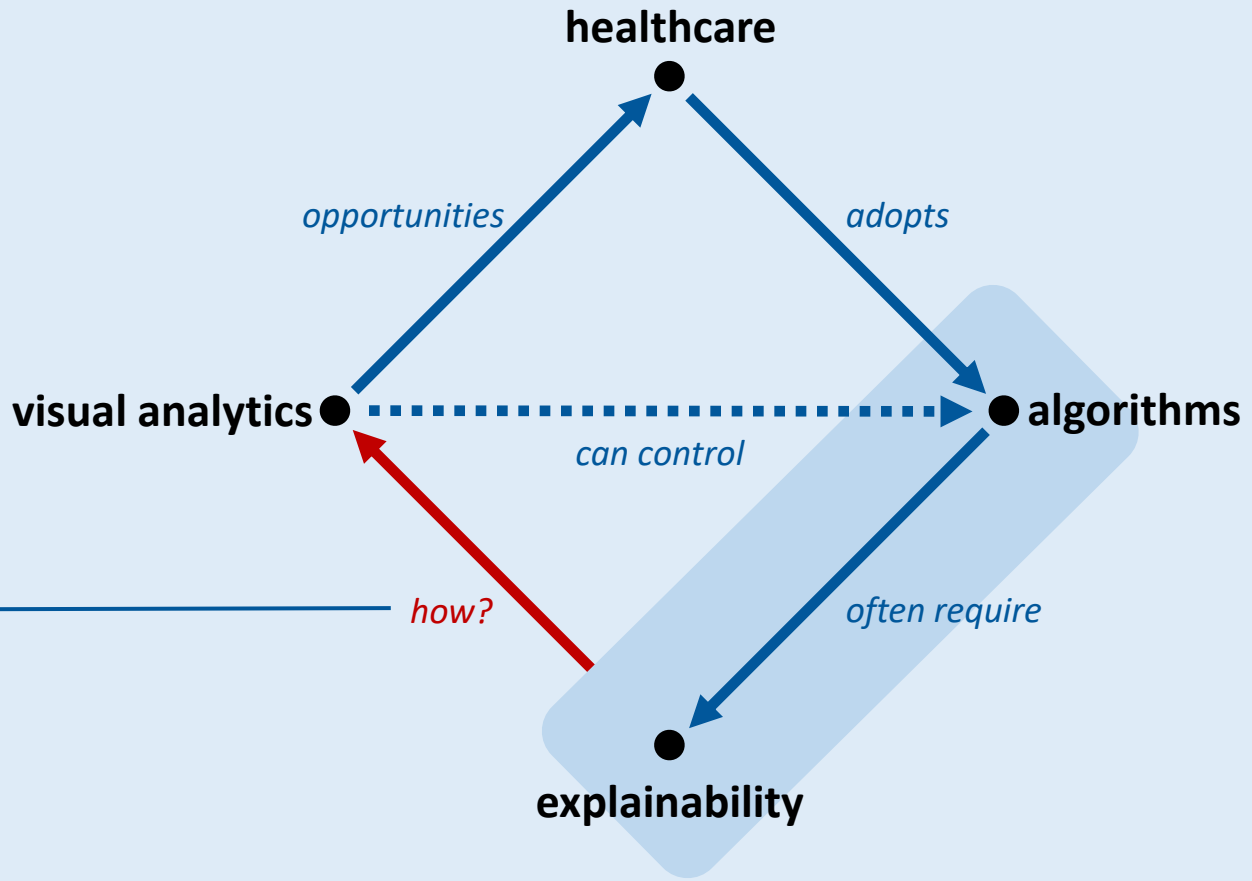


#1: Visual Analytics in Healthcare



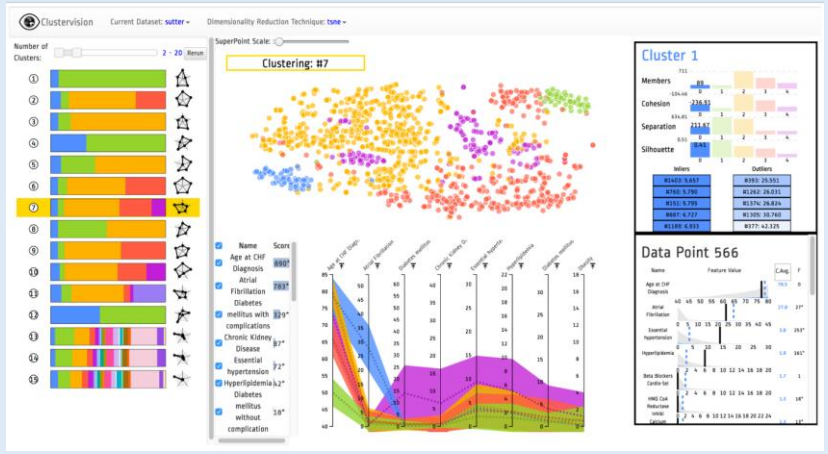
Jeroen Ooge, Gregor Stiglic, and Katrien Verbert. 2022. Explaining artificial intelligence with visual analytics in healthcare. *WIREs Data Mining and Knowledge Discovery* 12, 1: e1427. https://doi.org/10.1002/widm.1427



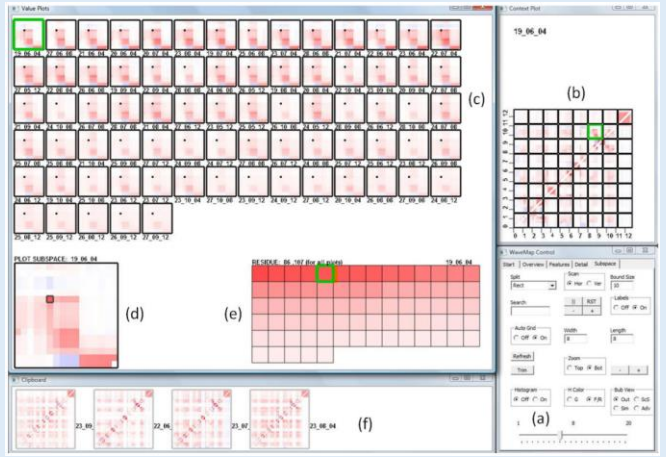


Jeroen Ooge, Gregor Stiglic, and Katrien Verbert. 2022. Explaining artificial intelligence with visual analytics in healthcare.
WIREs Data Mining and Knowledge Discovery 12, 1: e1427. https://doi.org/10.1002/widm.1427

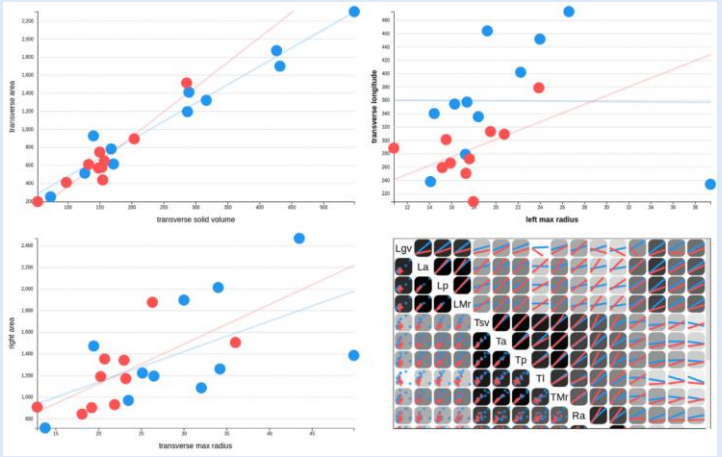
Visualisation



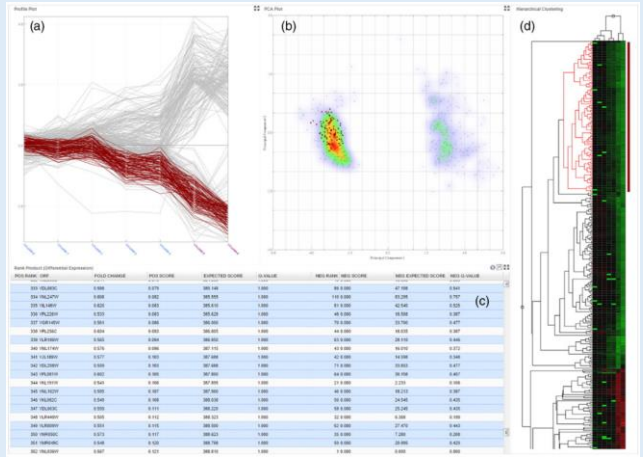
Clustering



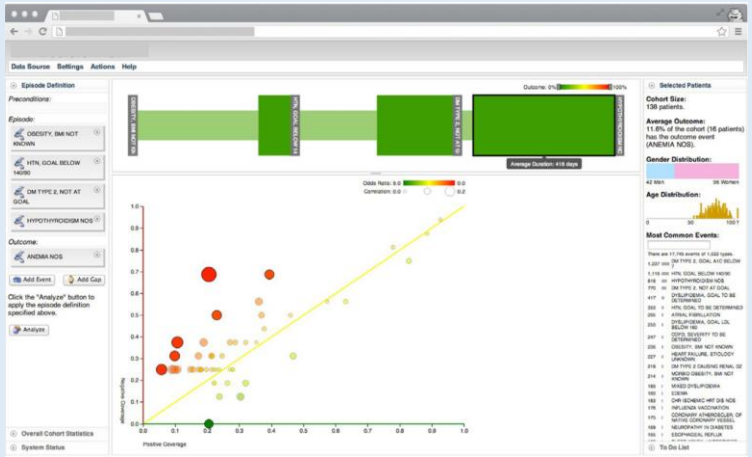
Similarity



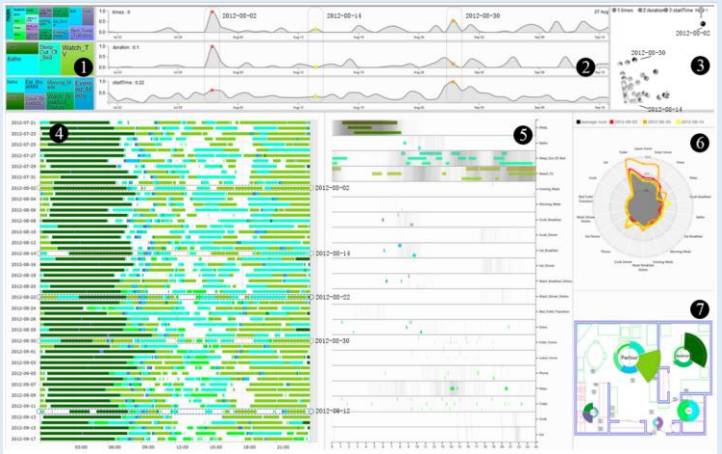
Classical statistics



Dimension reduction



Data mining



Anomaly detection

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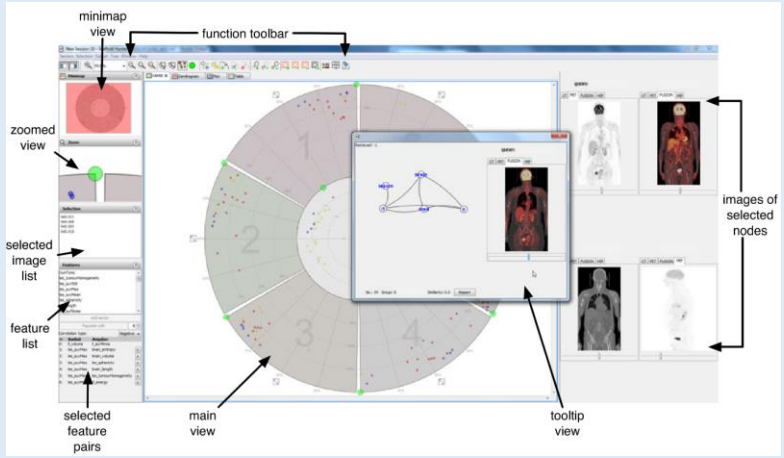
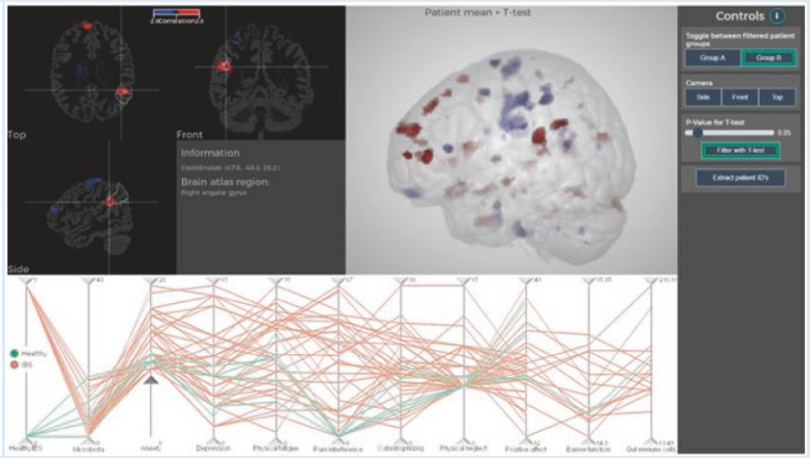
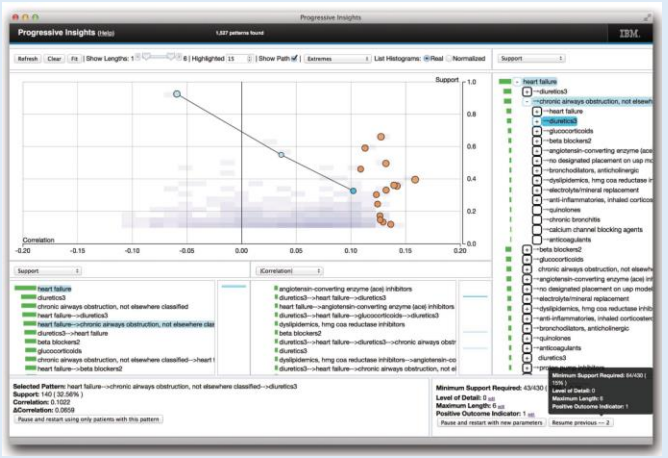
Interaction



Abstract/elaborate

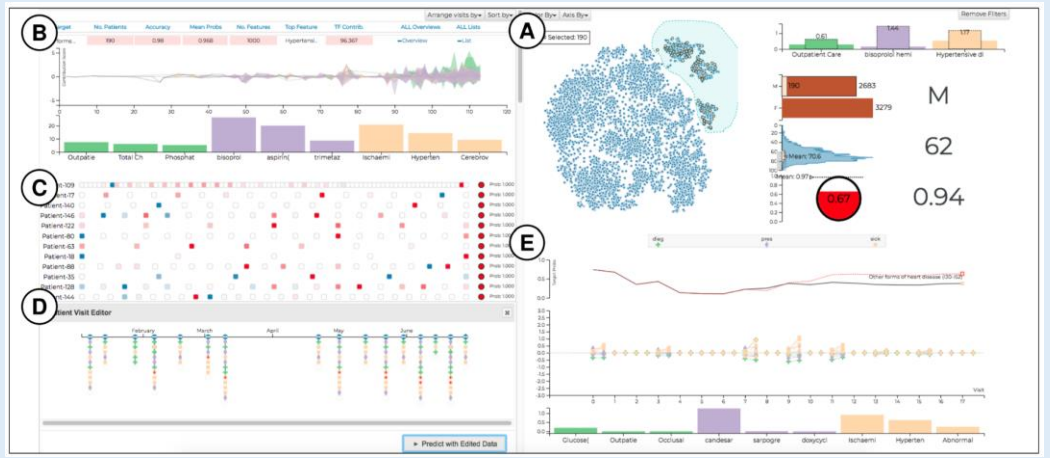


Filter



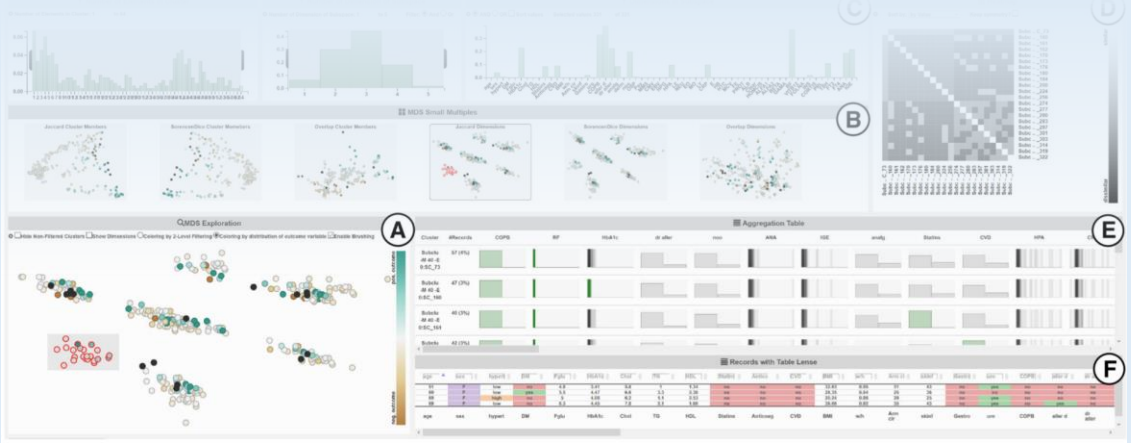
Reconfigure

Encode



Select

Interaction



Encode

Select

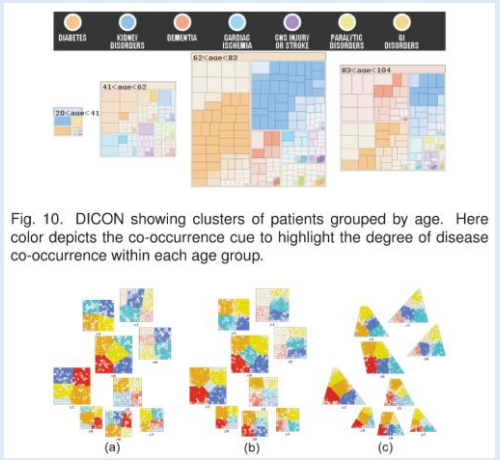
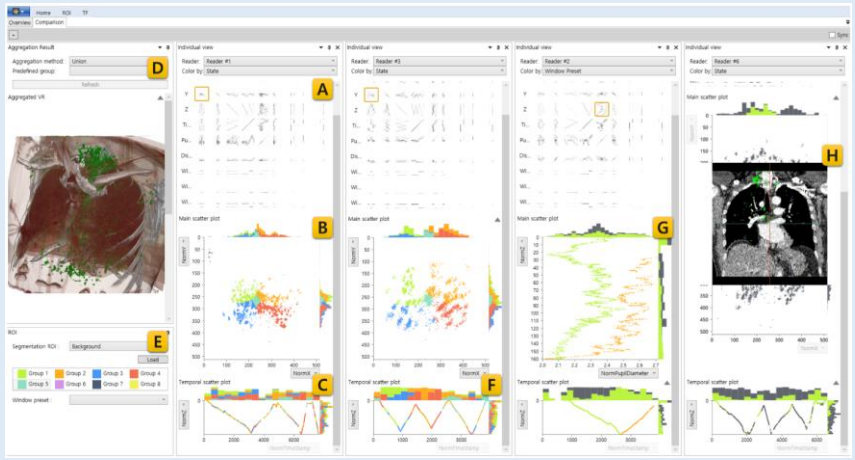
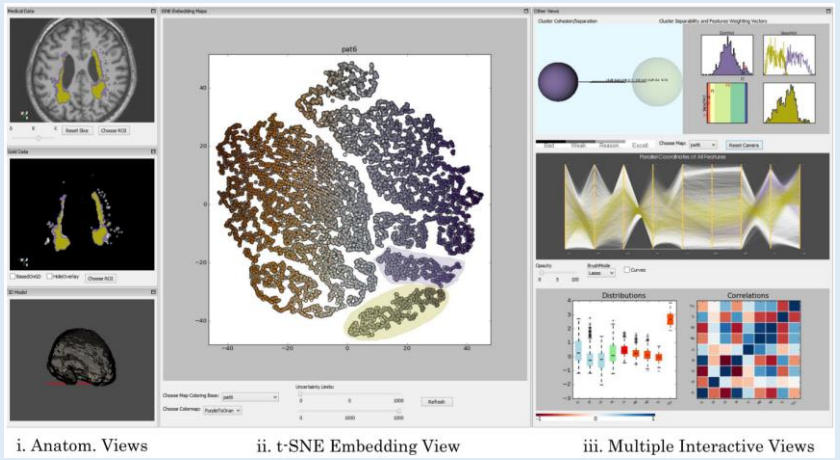


Fig. 10. DICON showing clusters of patients grouped by age. Here color depicts the co-occurrence cue to highlight the degree of disease co-occurrence within each age group.

Connect



Explore



i. Anatom. Views ii. t-SNE Embedding View iii. Multiple Interactive Views

Select + connect

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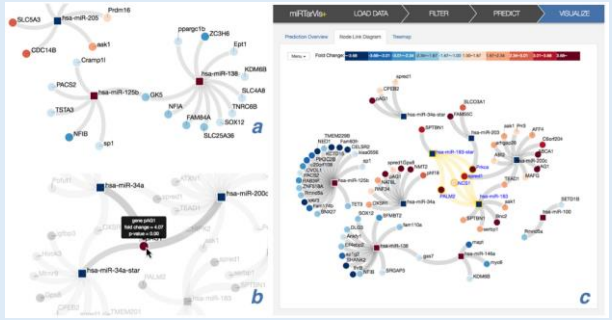
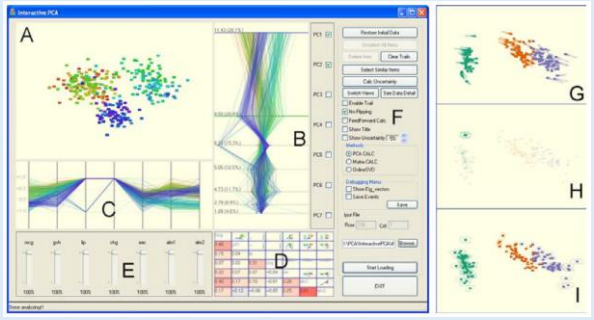
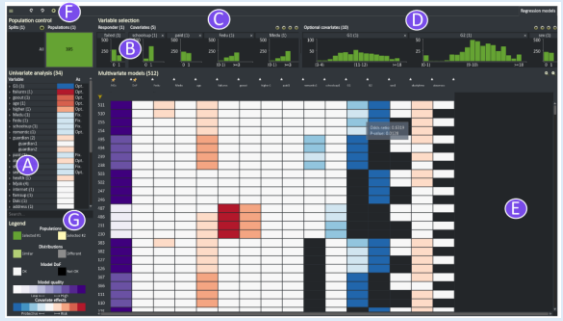
Control



Configuration window separate from visualisation



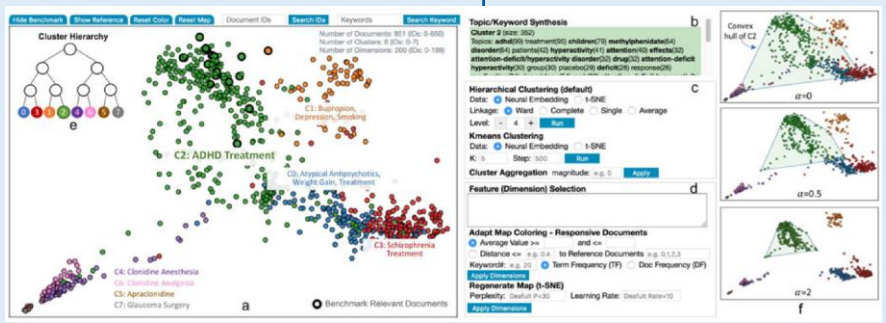
Fixed settings panel, automatically rerun algorithm



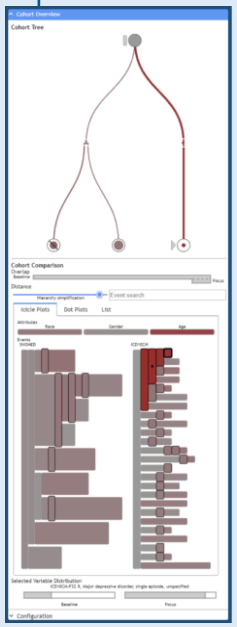
Automatically rerun algorithm when input features change

Semi-interactive

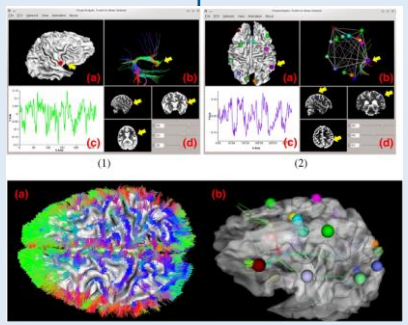
Tight integration



Fixed settings panel, manually rerun algorithm



Configuration in visualisation interface, automatically rerun algorithm



Interact with visualisation

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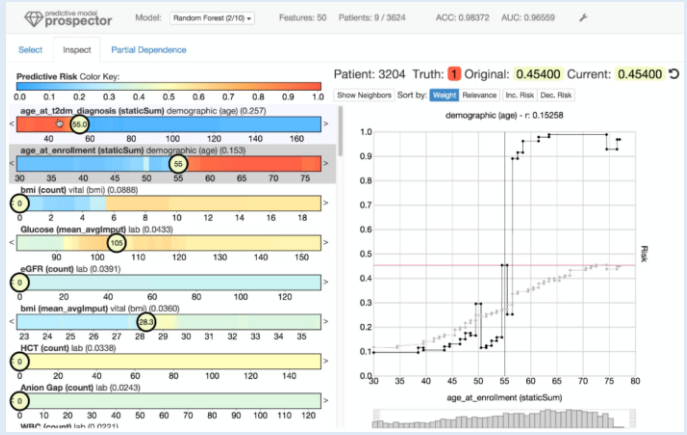
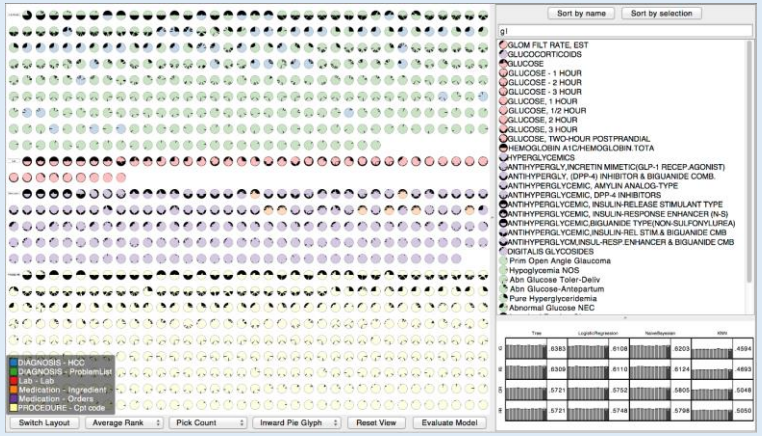
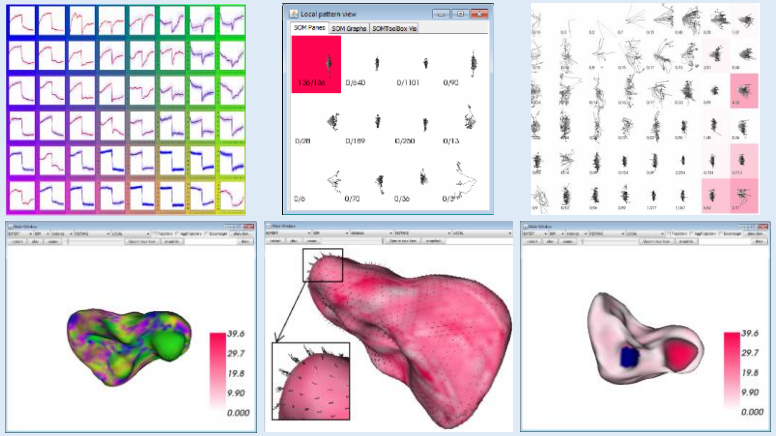
Direct explanation



Partial dependence plot



Feature importance



Visualisation

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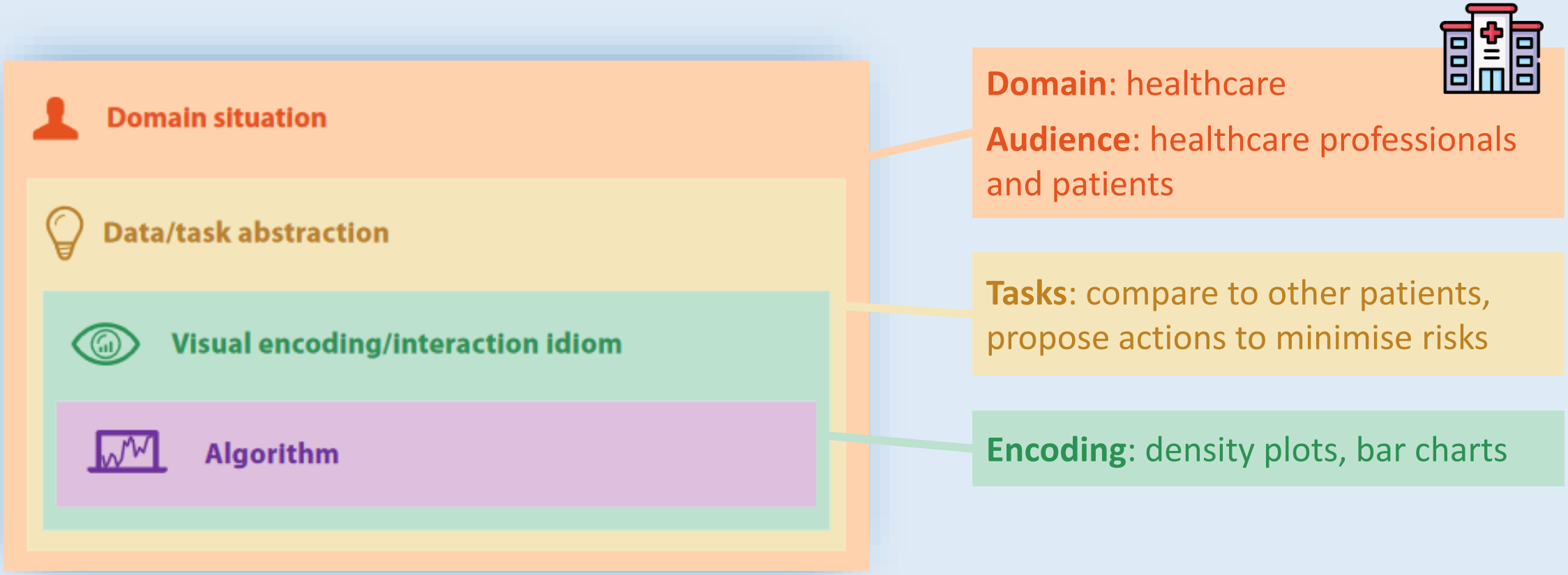
#2: Predicting Diabetes Onset

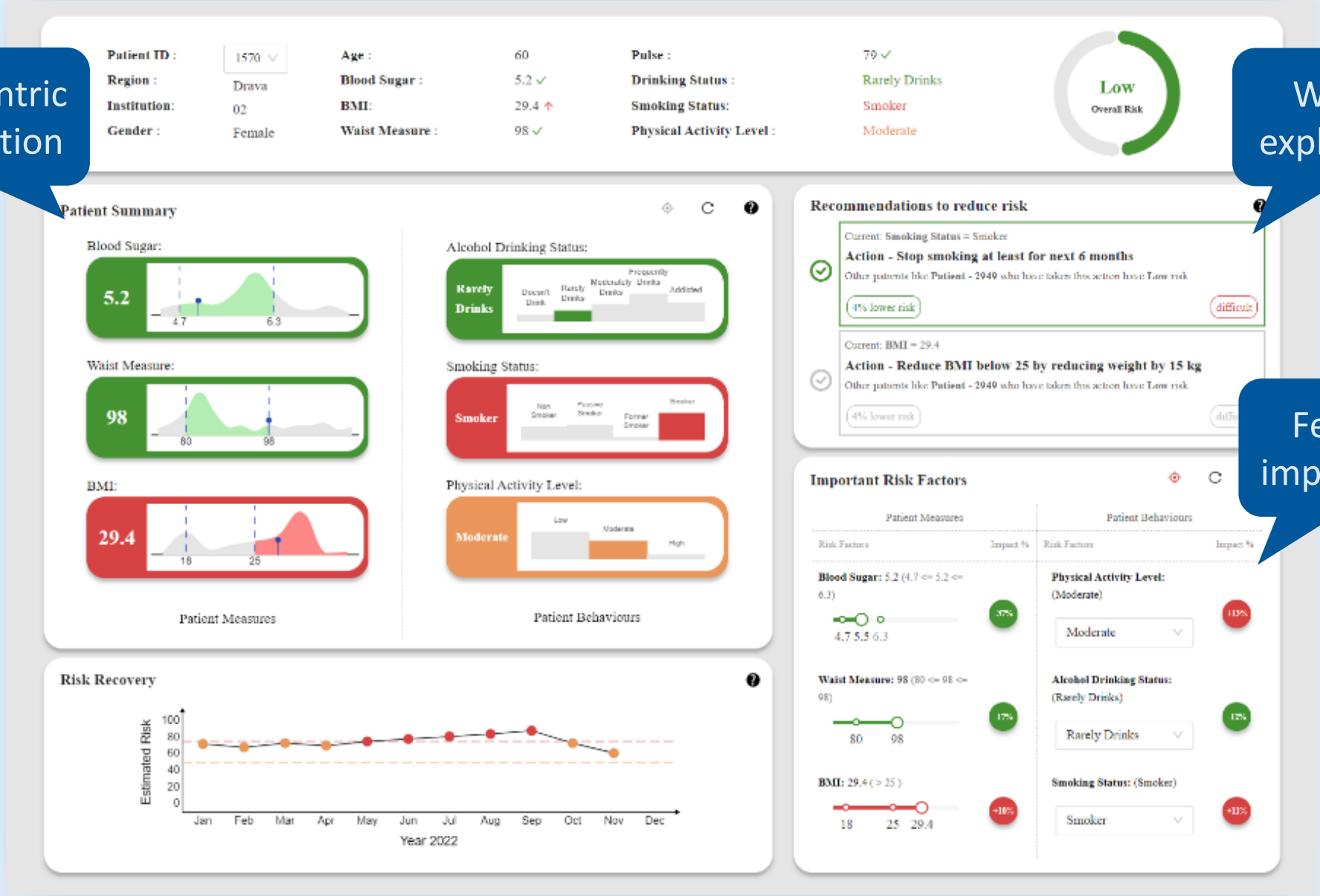


Aditya Bhattacharya, Jeroen Ooge, Gregor Stiglic, and Katrien Verbert. 2023. Directive Explanations for Monitoring the Risk of Diabetes Onset: Introducing Directive Data-Centric Explanations and Combinations to Support What-If Explorations. In *Proceedings of* IUI '23, 204–219. https://doi.org/10.1145/3581641.3584075

Data-centric explanation

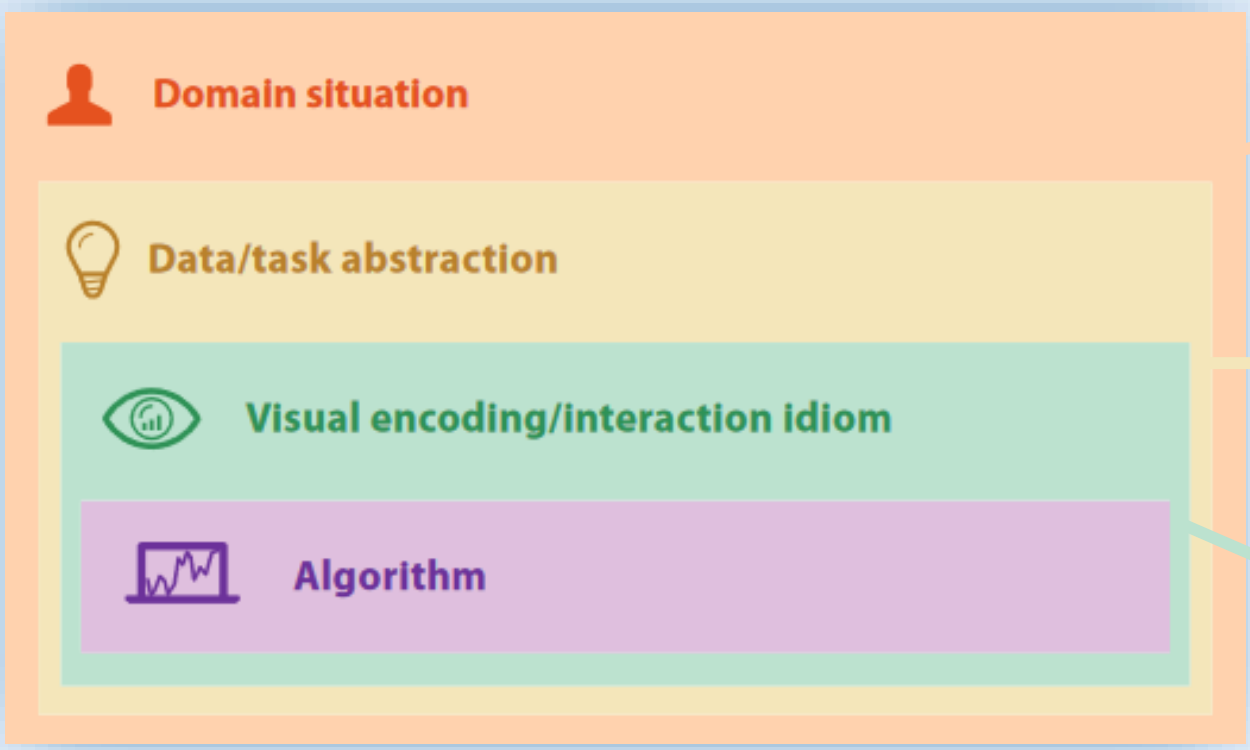
What-if explanation

Feature importance



Aditya Bhattacharya, Jeroen Ooge, Gregor Stiglic, and Katrien Verbert. 2023. Directive Explanations for Monitoring the Risk of Diabetes Onset: Introducing Directive Data-Centric Explanations and Combinations to Support What-If Explorations. In *Proceedings of* IUI '23, 204–219. https://doi.org/10.1145/3581641.3584075

#3: Uncertain Predictions in Agrifood



Domain: agrifood

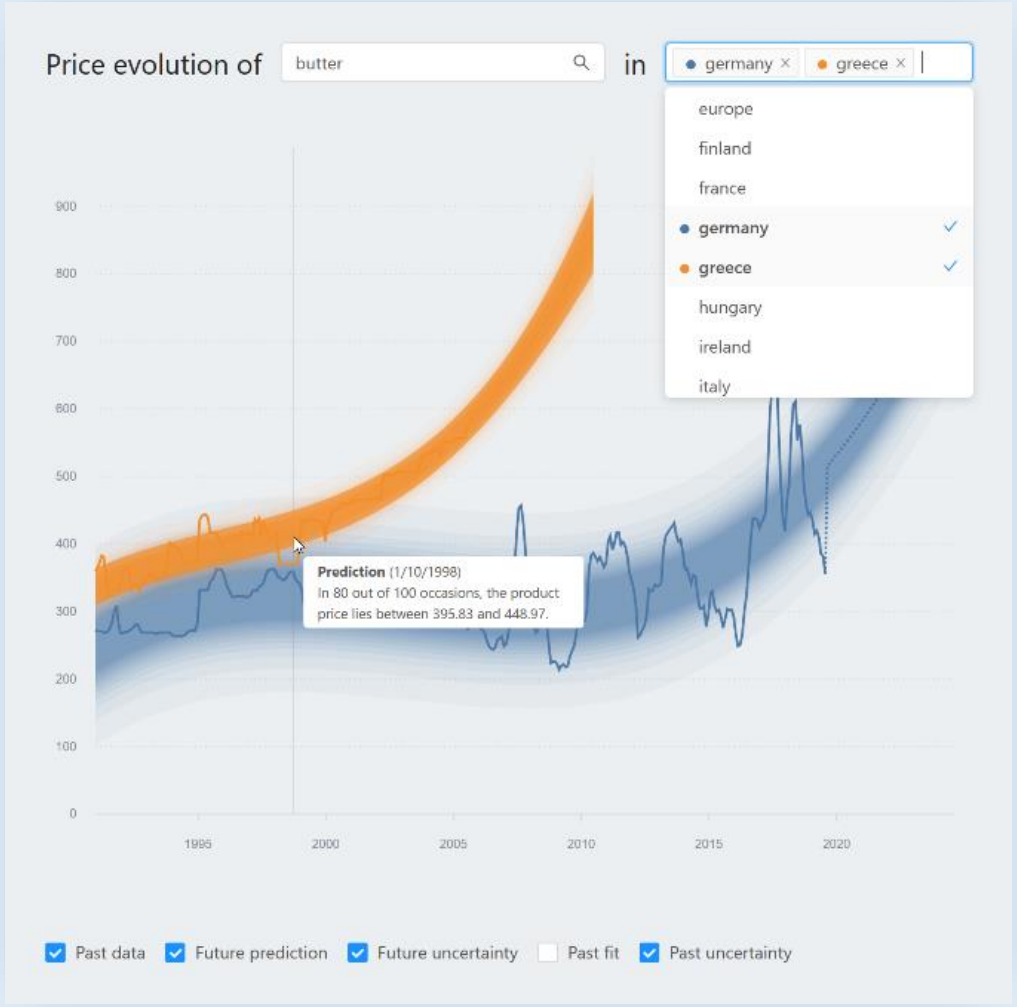
Audience: domain experts

Tasks: compare countries

Encoding: fan charts

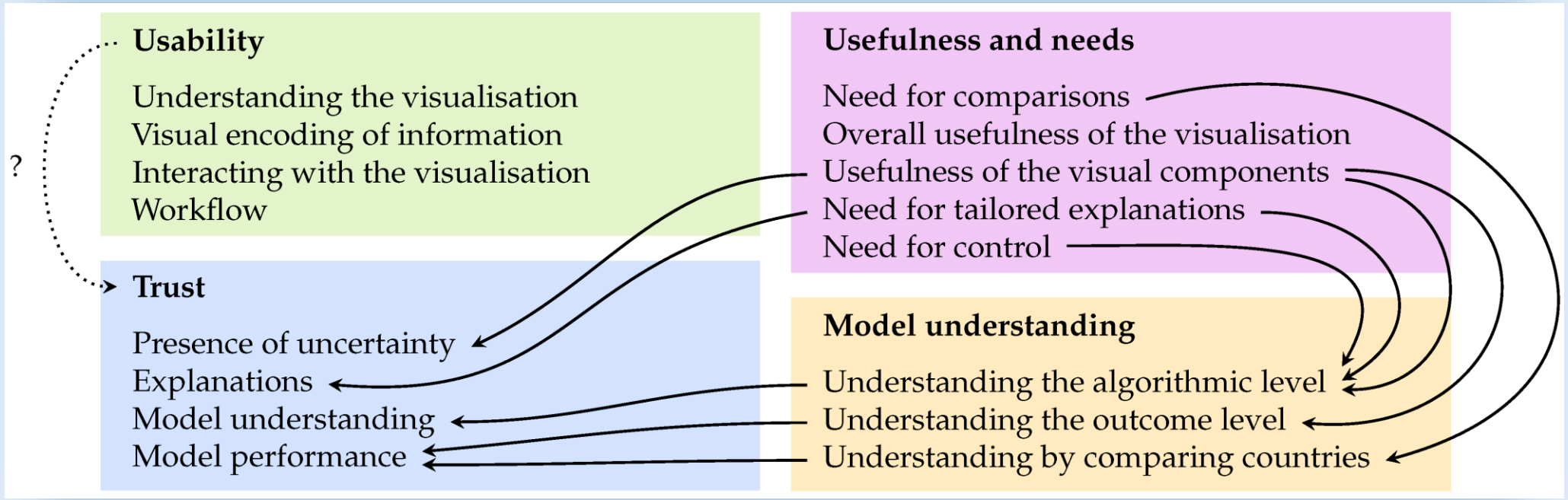
Interaction: details on demand, filter, enable visual components

Jeroen Ooge and Katrien Verbert. 2022. Visually Explaining Uncertain Price Predictions in Agrifood: A User-Centred Case-Study. *Agriculture* 12, 7: 1024. https://doi.org/10.3390/agriculture12071024



Jeroen Ooge and Katrien Verbert. 2022. Visually Explaining Uncertain Price Predictions in Agrifood: A User-Centred Case-Study. *Agriculture* 12, 7: 1024. https://doi.org/10.3390/agriculture12071024

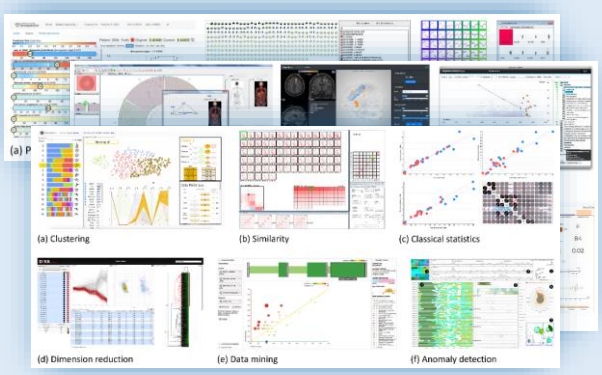
Jeroen Ooge and Katrien Verbert. 2022. Visually Explaining Uncertain Price Predictions in Agrifood: A User-Centred Case-Study. *Agriculture* 12, 7: 1024. https://doi.org/10.3390/agriculture12071024

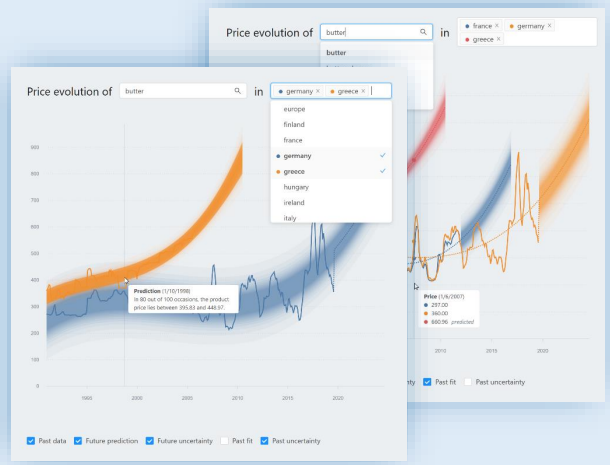


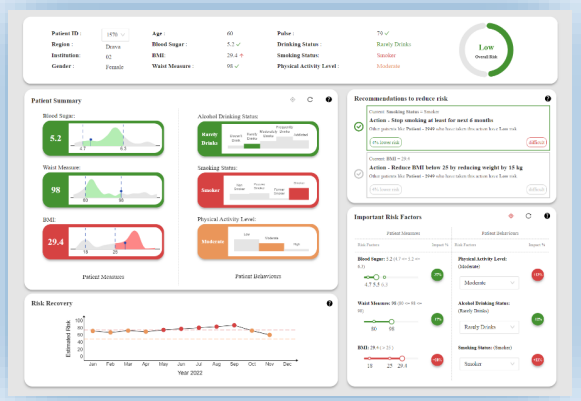
Usability, usefulness and needs, and model understanding
can directly and indirectly affect trust

Jeroen Ooge and Katrien Verbert. 2022. Visually Explaining Uncertain Price Predictions in Agrifood:
A User-Centred Case-Study. *Agriculture* 12, 7: 1024. https://doi.org/10.3390/agriculture12071024

Break for Questions







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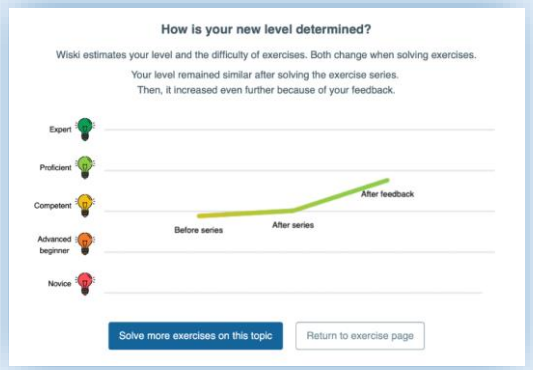
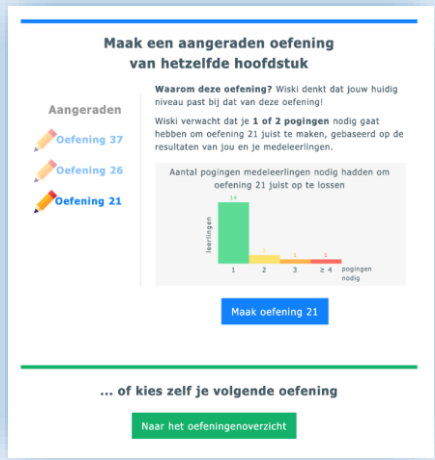
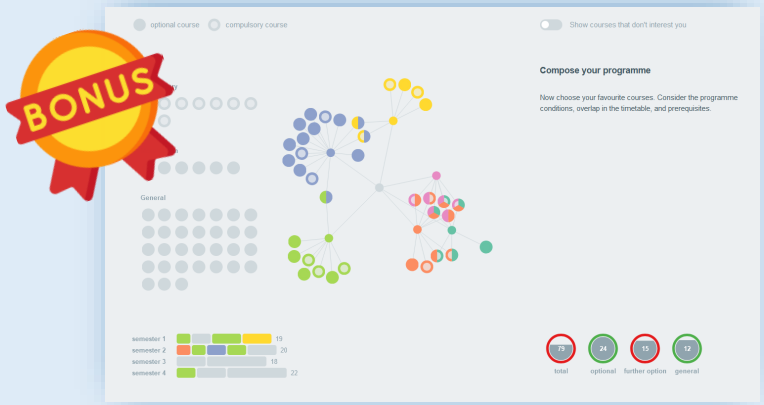
II Simple Visualisations

III Visualisations in Reports





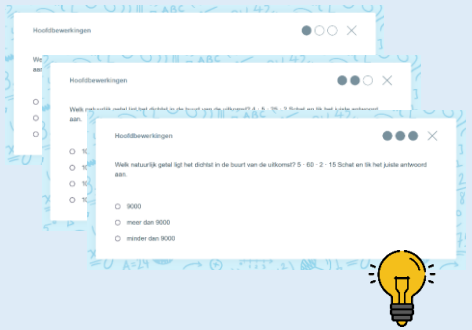


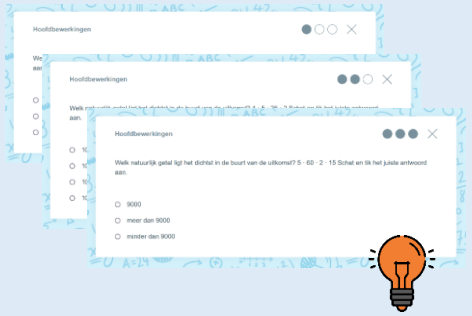
expert

competent

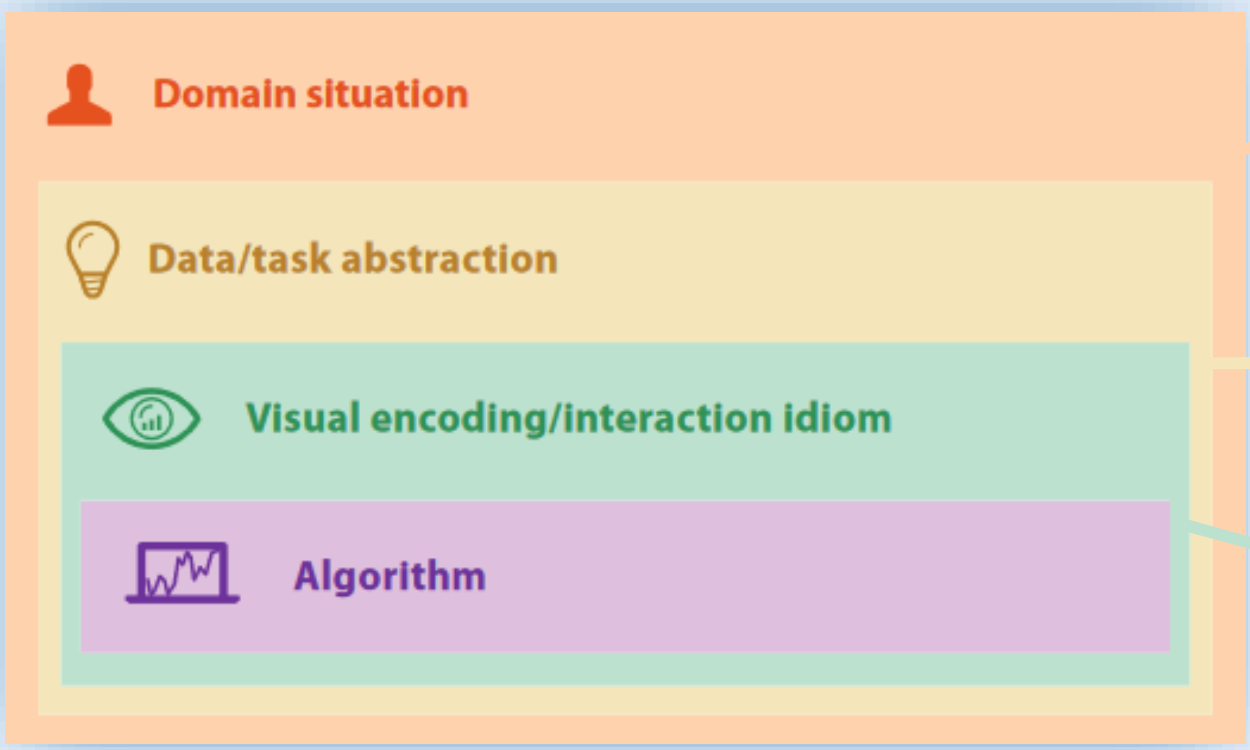
beginner

Recommender system





#4: Justifying Recommendations



Domain: education

Audience: teenagers

Tasks: see performance of others

Encoding: bar chart

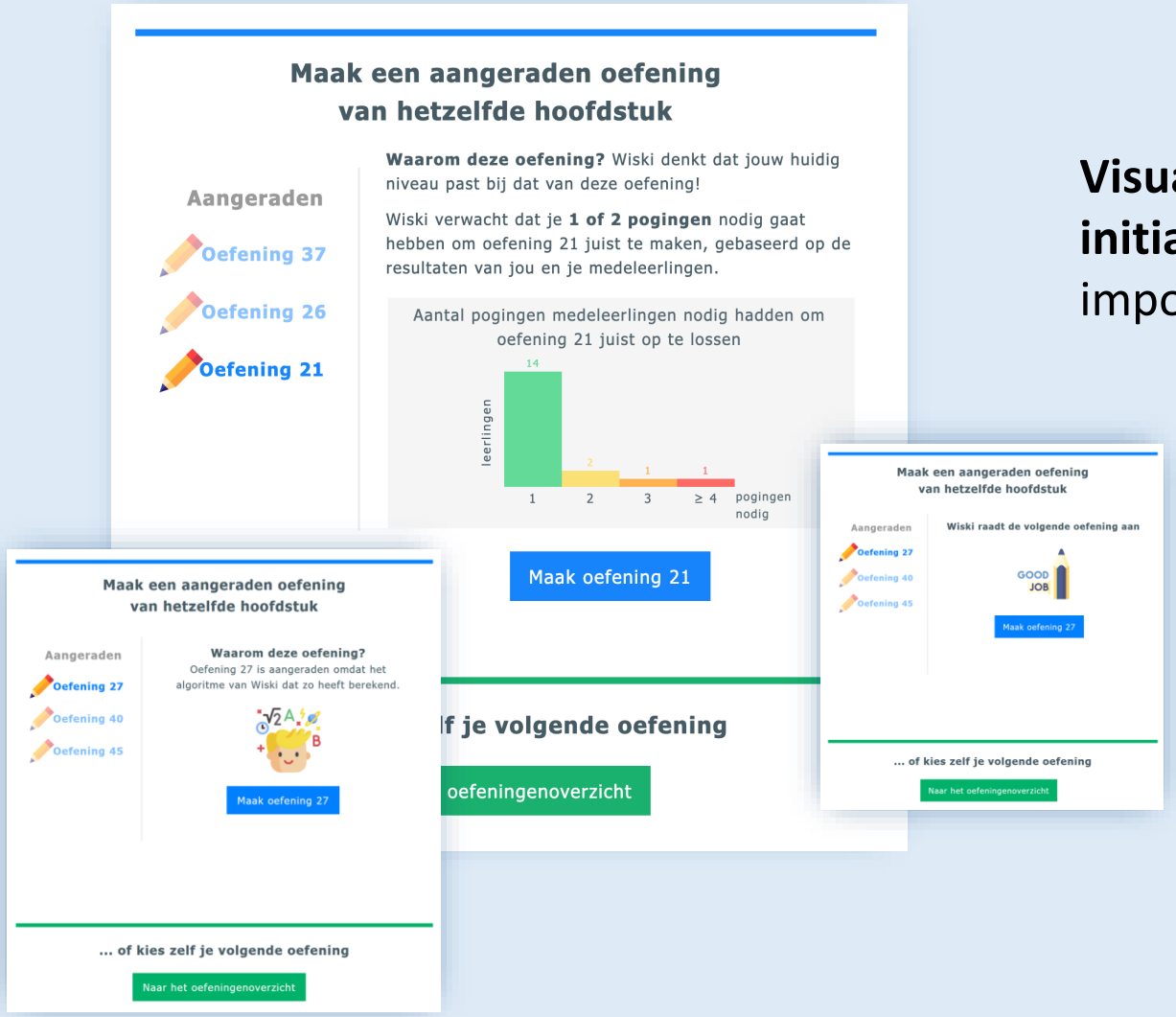
Interaction: --

Jeroen Ooge, Shotallo Kato, and Katrien Verbert. 2022. Explaining Recommendations in E-Learning: Effects on Adolescents' Trust. In *27th International Conference on Intelligent User Interfaces* (IUI '22), 93–105. https://doi.org/10.1145/3490099.3511140

Textual explanation

Visual explanation

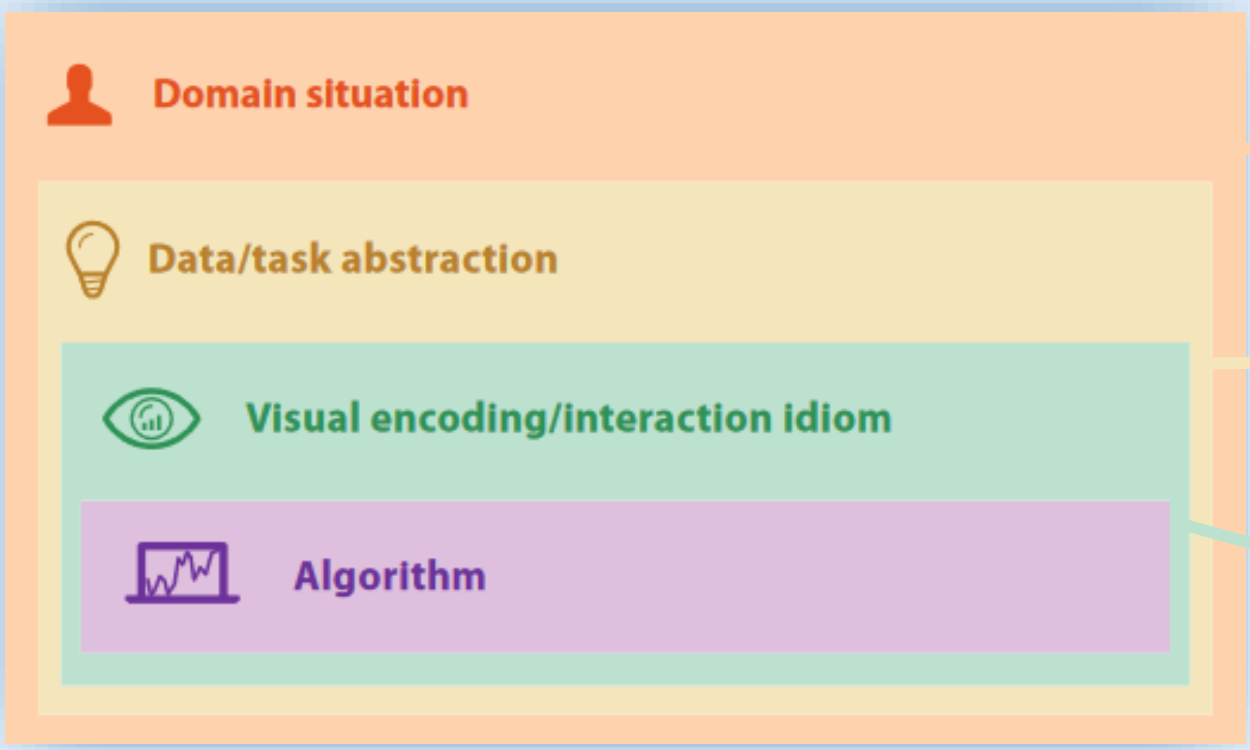
Jeroen Ooge, Shotallo Kato, and Katrien Verbert. 2022. Explaining Recommendations in E-Learning: Effects on Adolescents' Trust. In *27th International Conference on Intelligent User Interfaces* (IUI '22), 93–105. https://doi.org/10.1145/3490099.3511140



Visual explanations can increase initial trust but may not be the most important factor for building it

Jeroen Ooge, Shotallo Kato, and Katrien Verbert. 2022. Explaining Recommendations in E-Learning: Effects on Adolescents' Trust. In *27th International Conference on Intelligent User Interfaces* (IUI '22), 93–105. https://doi.org/10.1145/3490099.3511140

#5: Visualise the Effect of Control



Domain: education

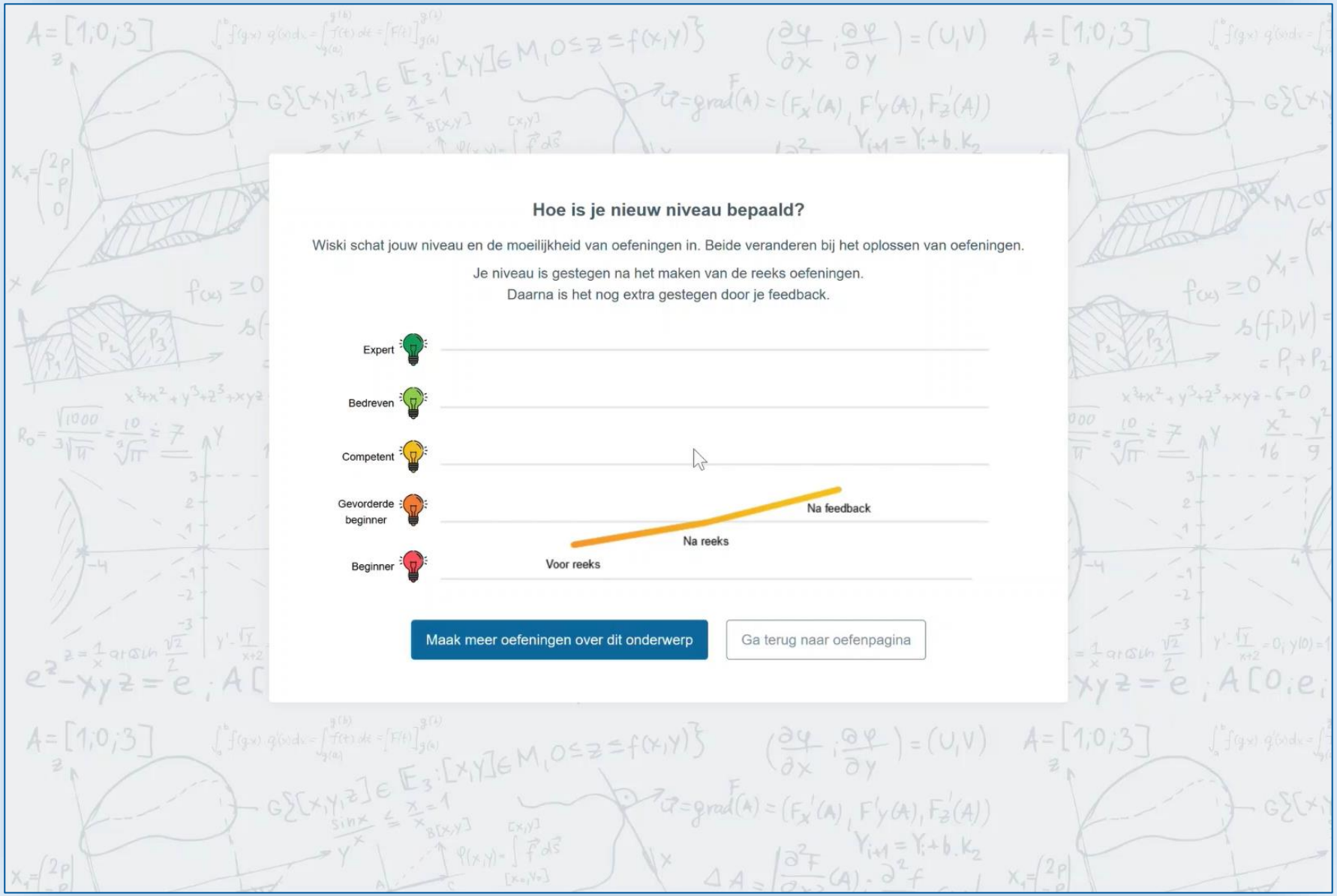
Audience: teenagers

Tasks: see mastery changes

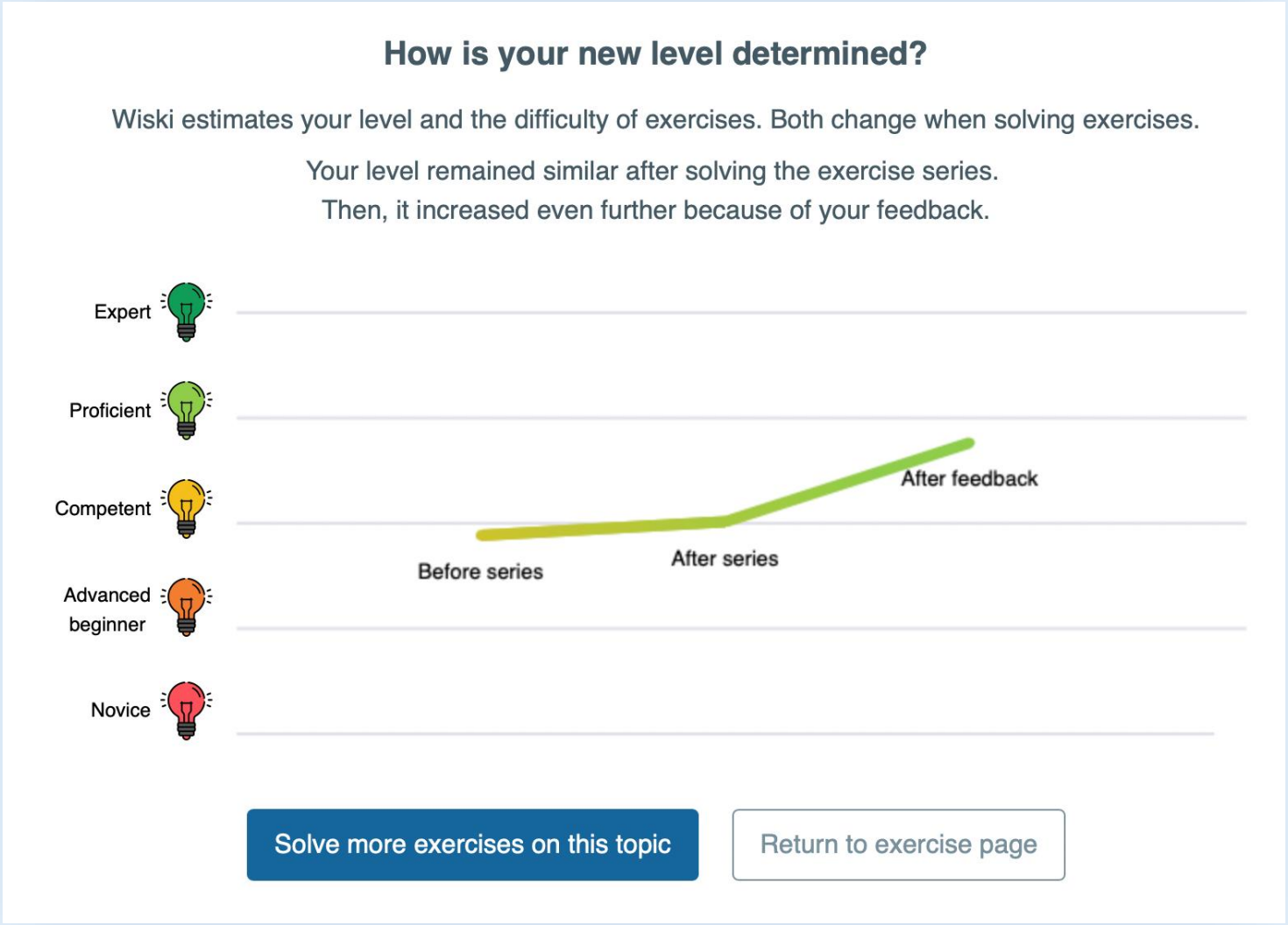
Encoding: line chart

Interaction: --

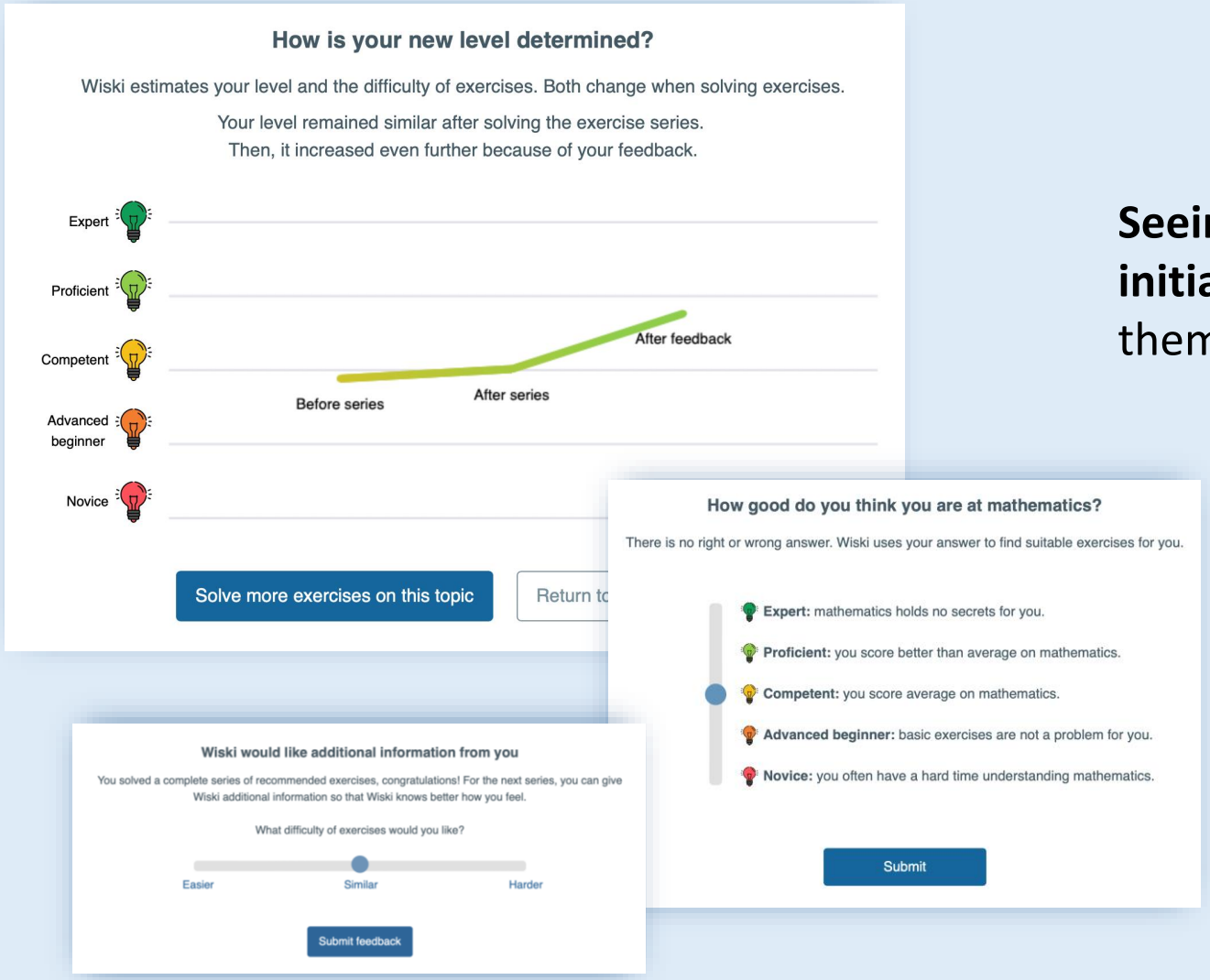
Jeroen Ooge, Leen Dereu, and Katrien Verbert. 2023. Steering Recommendations and Visualising Its Impact: Effects on Adolescents' Trust in E-Learning Platforms. In *Proceedings of the 28th International Conference on Intelligent User Interfaces* (IUI '23), 156–170. https://doi.org/10.1145/3581641.3584046



Jeroen Ooge, Leen Dereu, and Katrien Verbert. 2023. Steering Recommendations and Visualising Its Impact: Effects on Adolescents' Trust in E-Learning Platforms. In *Proceedings of the 28th International Conference on Intelligent User Interfaces* (IUI '23), 156–170. https://doi.org/10.1145/3581641.3584046



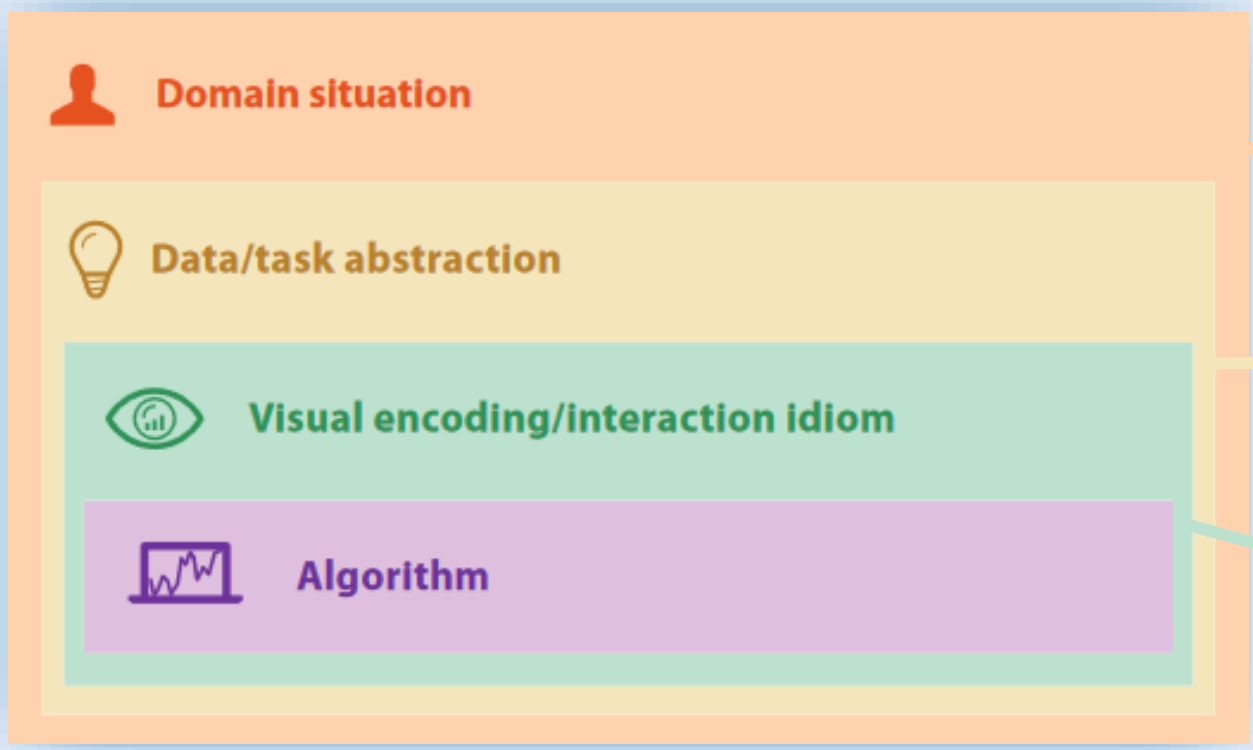
Jeroen Ooge, Leen Dereu, and Katrien Verbert. 2023. Steering Recommendations and Visualising Its Impact: Effects on Adolescents' Trust in E-Learning Platforms. In *Proceedings of the 28th International Conference on Intelligent User Interfaces* (IUI '23), 156–170. https://doi.org/10.1145/3581641.3584046



Seeing the impact of control can increase initial trust, but control mechanisms by themselves do not necessarily

Jeroen Ooge, Leen Dereu, and Katrien Verbert. 2023. Steering Recommendations and Visualising Its Impact: Effects on Adolescents' Trust in E-Learning Platforms. In *Proceedings of the 28th International Conference on Intelligent User Interfaces* (IUI '23), 156–170. https://doi.org/10.1145/3581641.3584046

#6: Visual What-If Analysis



Domain: education

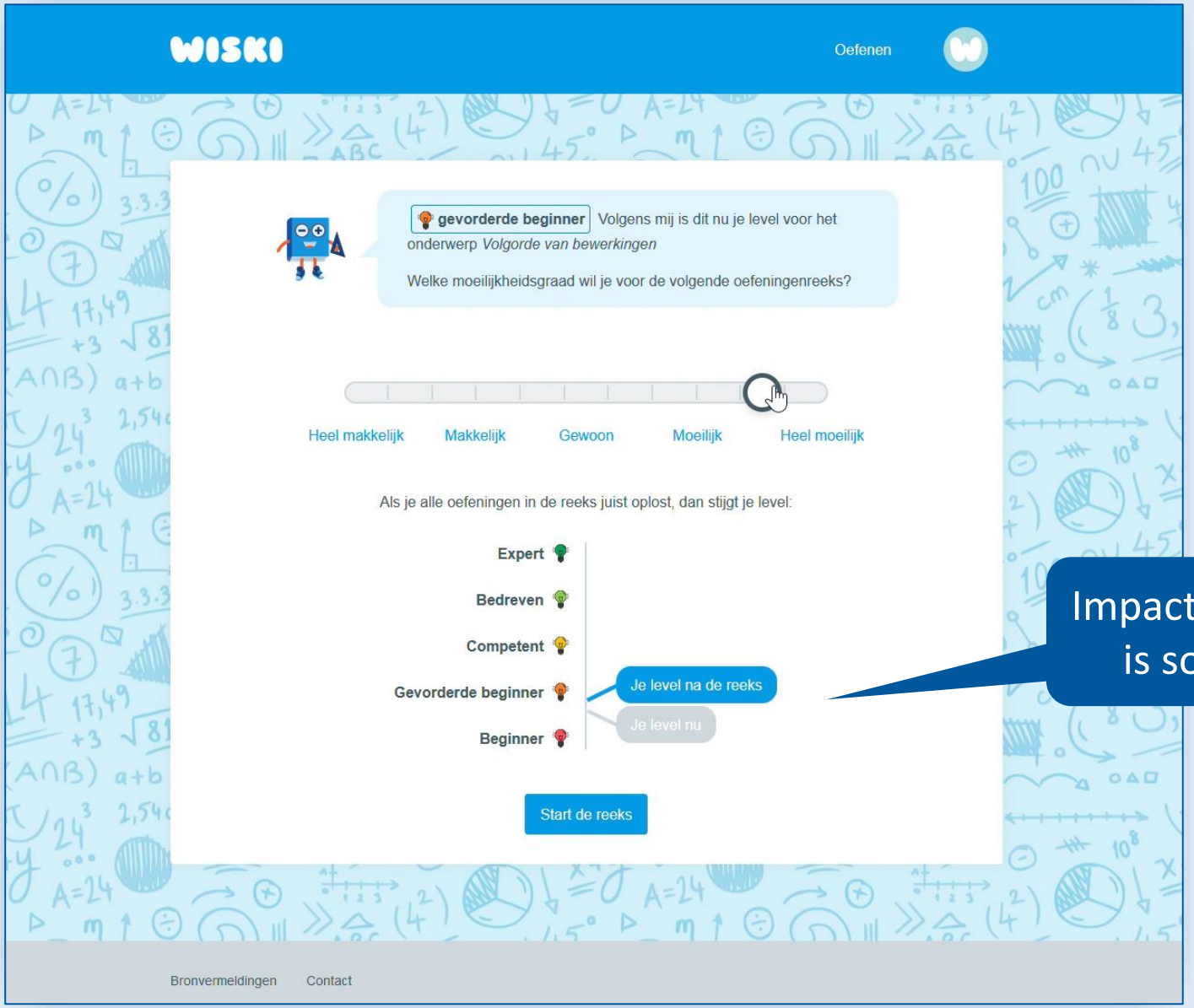
Audience: teenagers

Tasks: see predicted mastery change

Encoding: axis

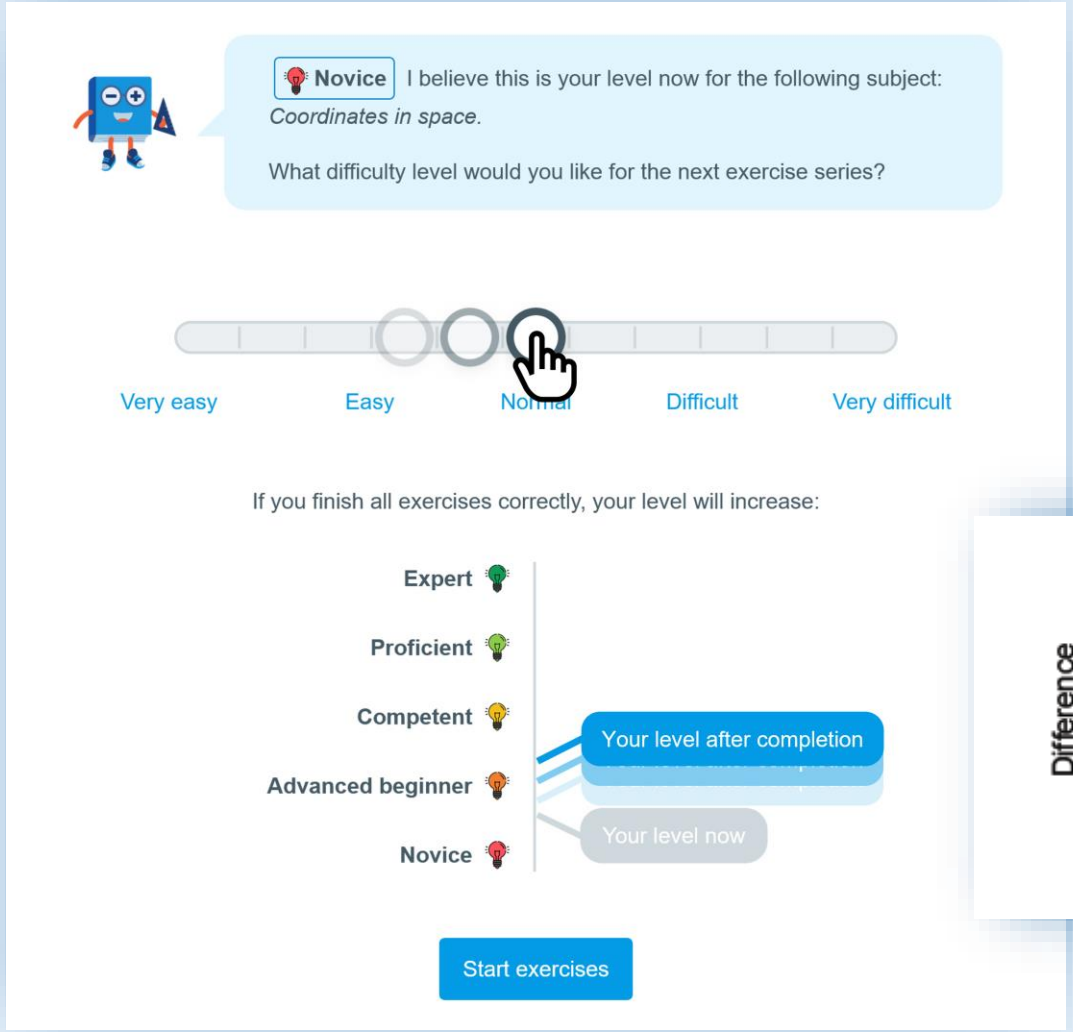
Interaction: change prediction input

Jeroen Ooge, Arno Vanneste, Maxwell Szymanski, and Katrien Verbert. Under review.

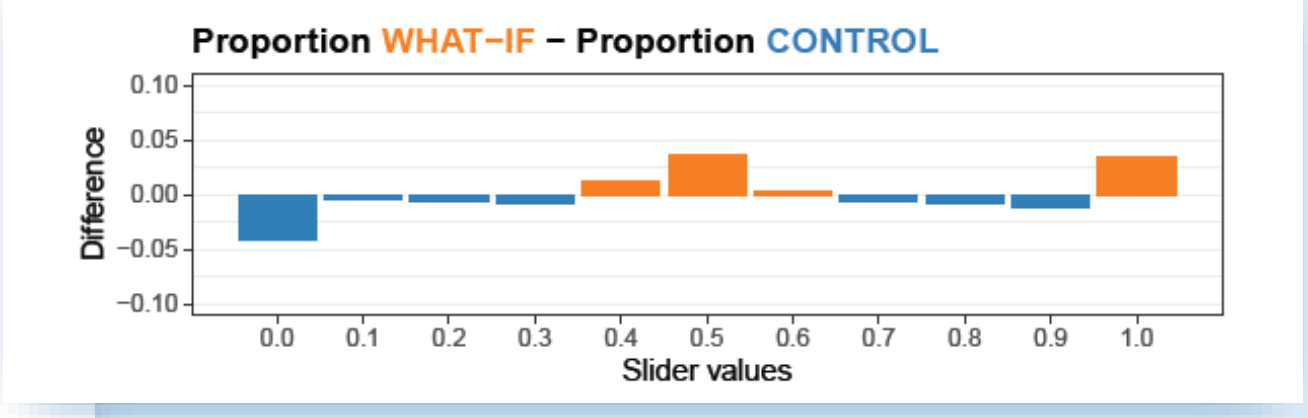


Impact on level if series is solved correctly

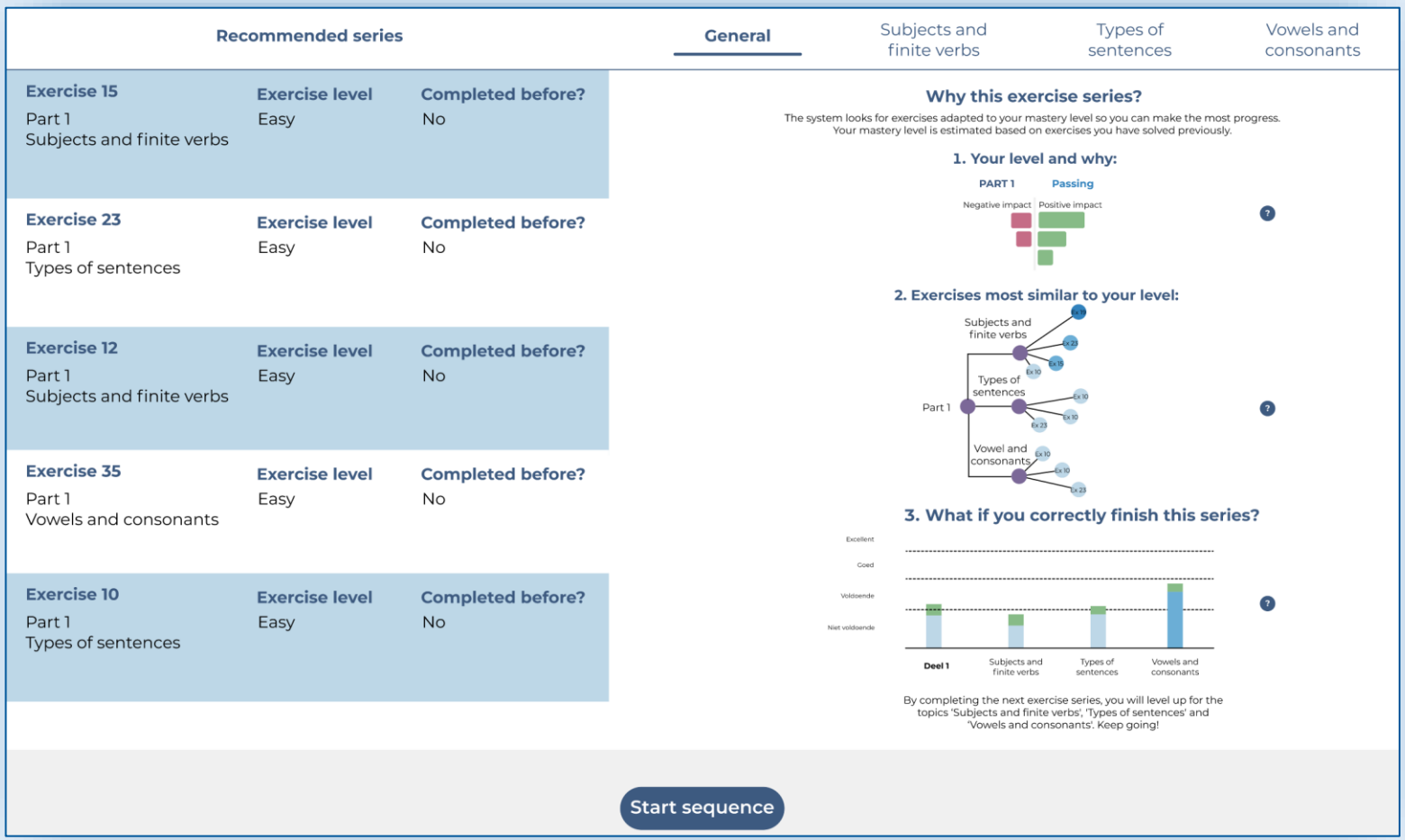
Jeroen Ooge, Arno Vanneste, Maxwell Szymanski, and Katrien Verbert. Under review.



***What-if* explanations can encourage teenagers to try harder exercises**, but do not necessarily affect initial trust, metacognition, motivation, or performance

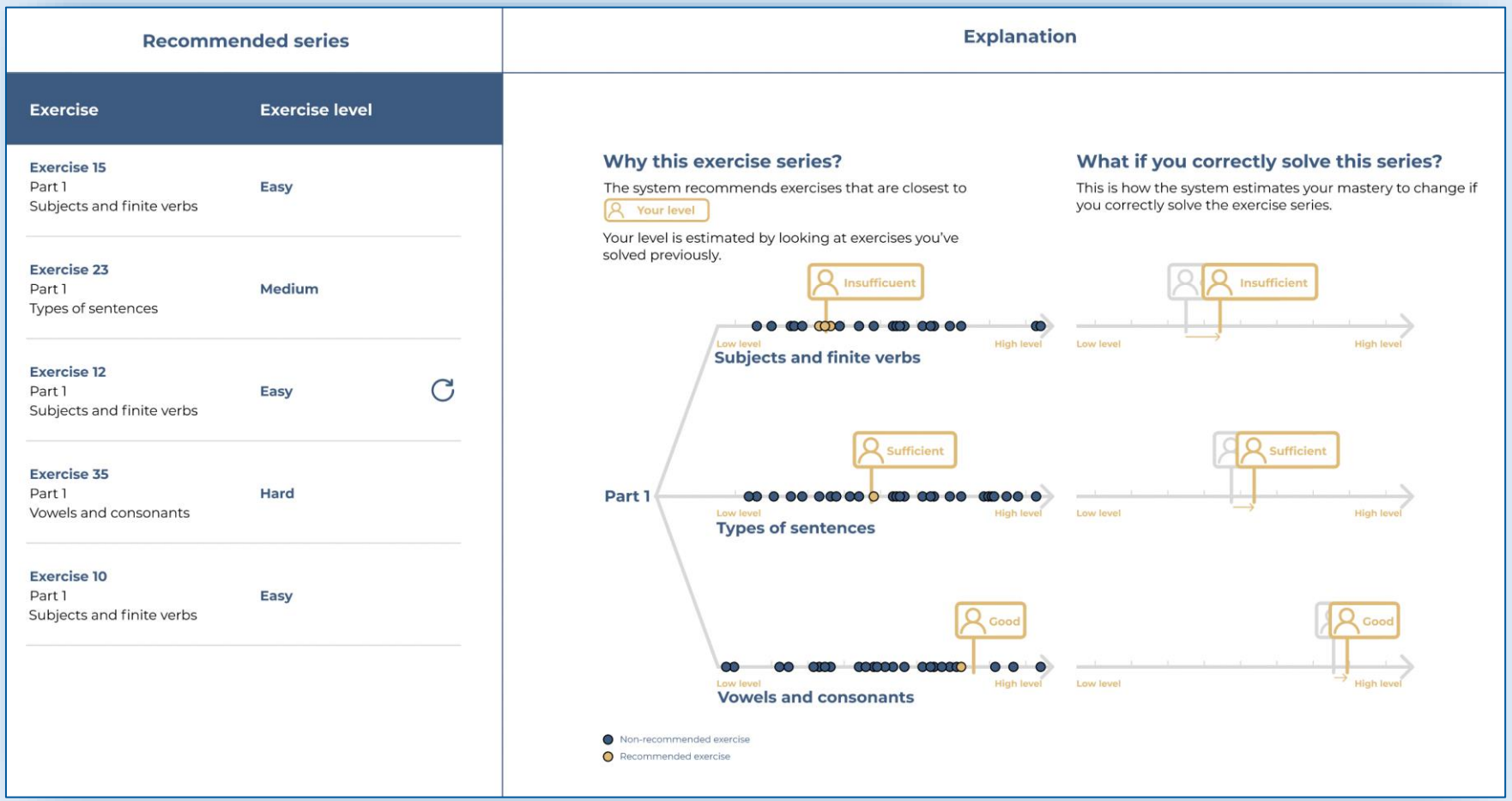


Jeroen Ooge, Arno Vanneste, Maxwell Szymanski, and Katrien Verbert. Under review.



Group discussions with teachers and people developing educational technologies

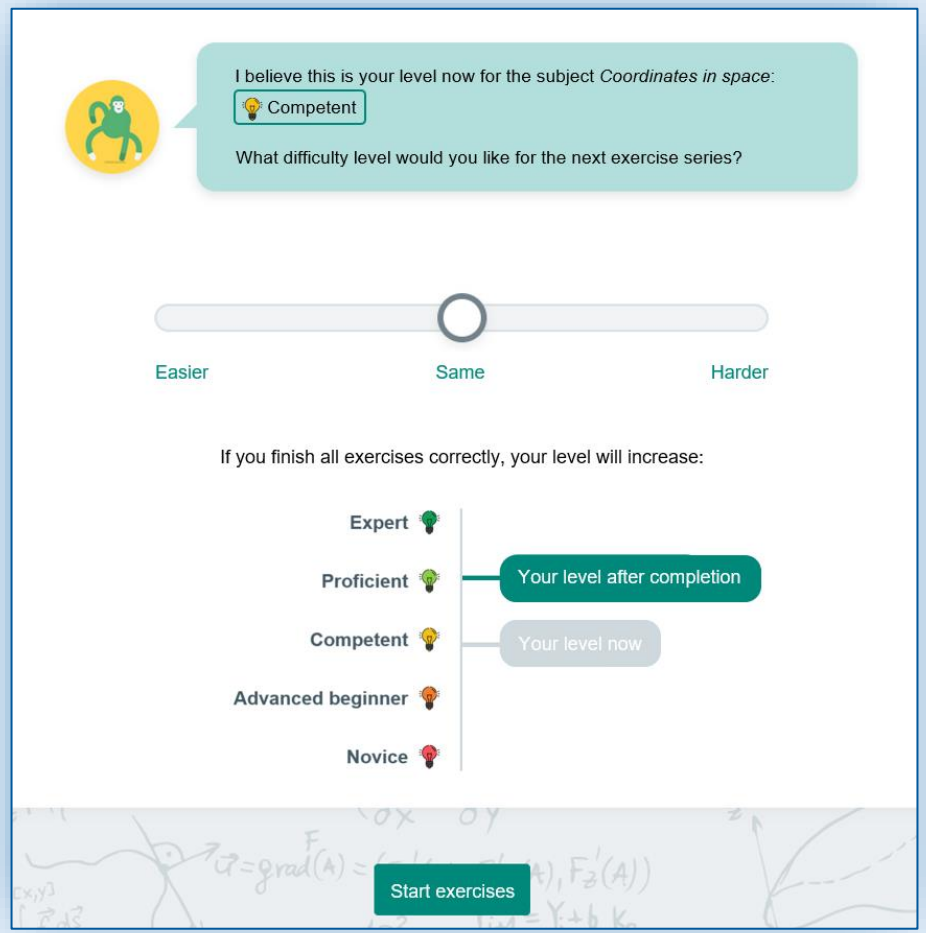
Jeroen Ooge, Arno Vanneste, Maxwell Szymanski, and Katrien Verbert. Under review.

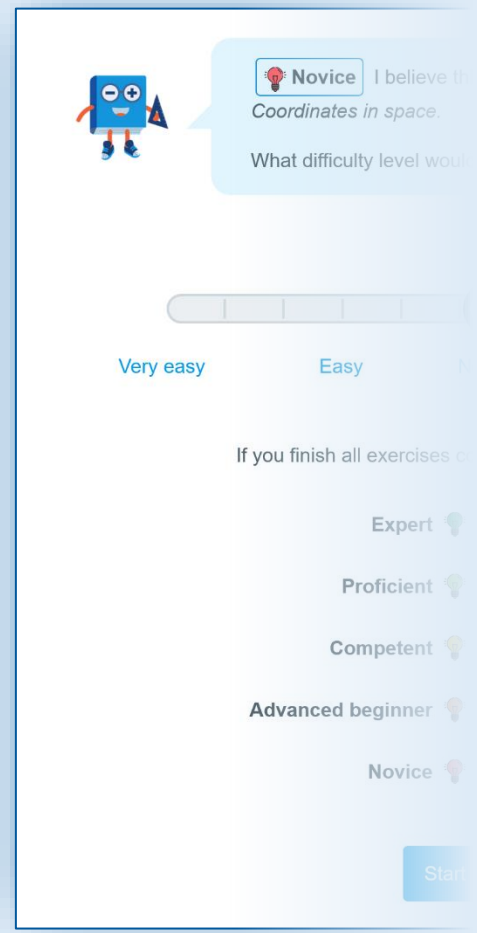


Focus groups with teachers and educational experts

Think-aloud sessions with adolescents

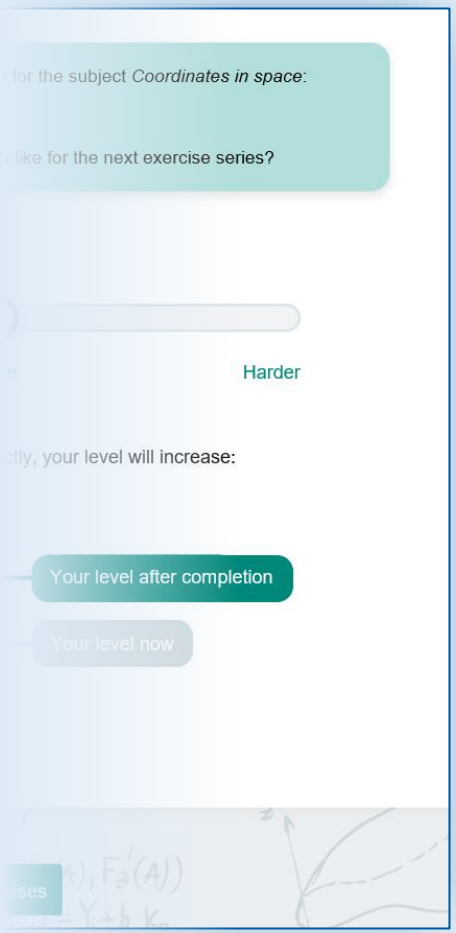
Jeroen Ooge, Arno Vanneste, Maxwell Szymanski, and Katrien Verbert. Under review.

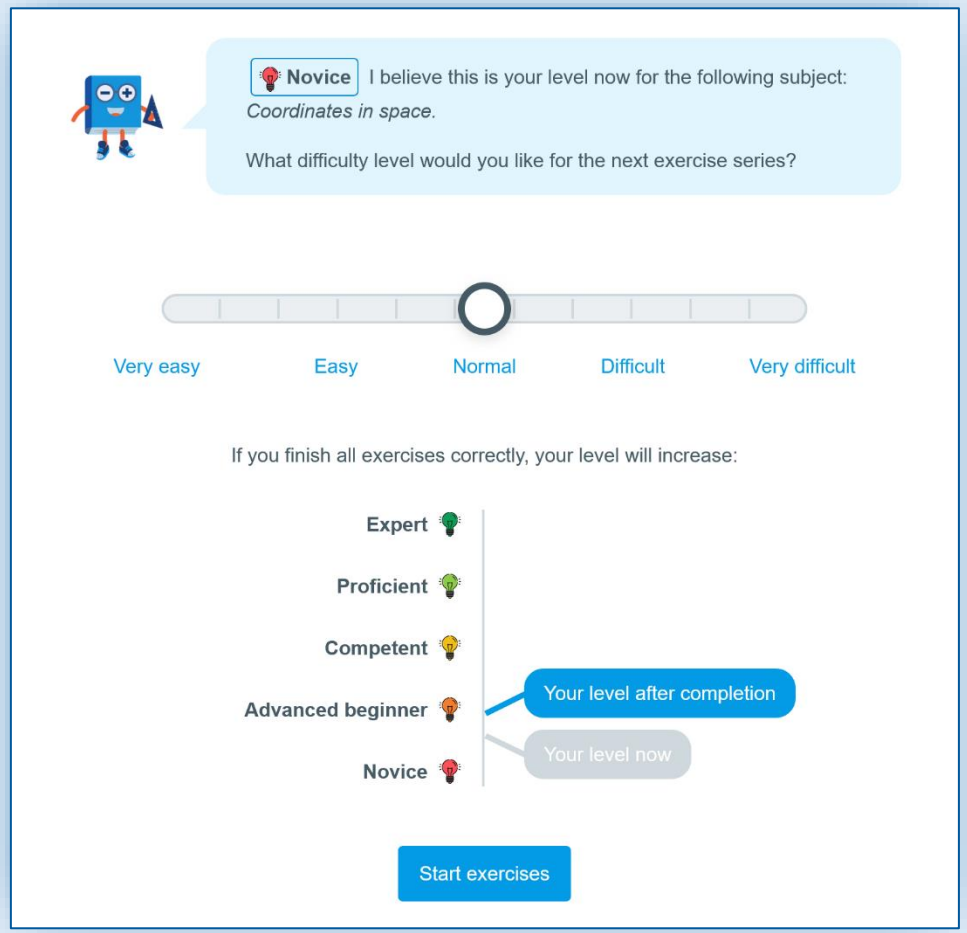




More think-aloud sessions with adolescents

Jeroen Ooge, Arno Vanneste, Maxwell Szymanski, and Katrien Verbert. Under review.

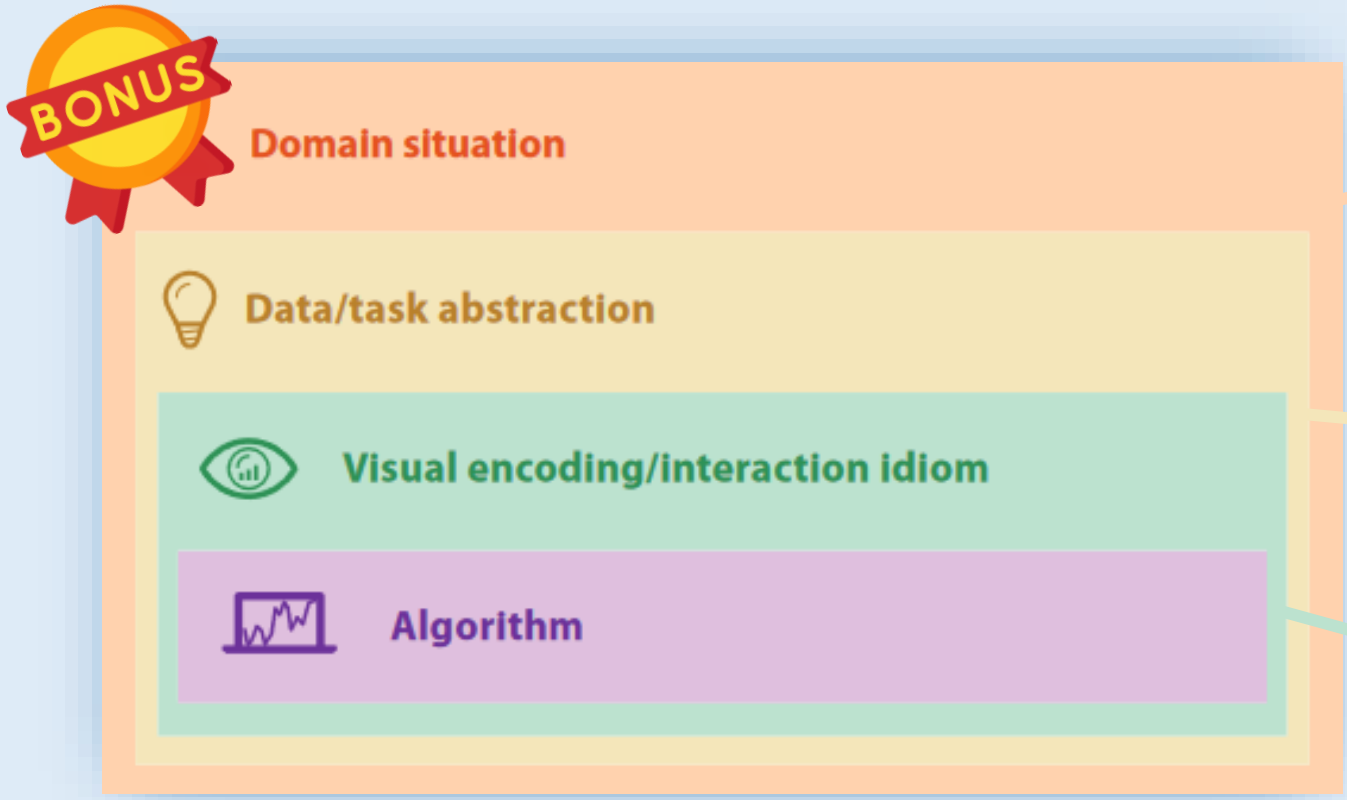




Final prototype for evaluation!

Jeroen Ooge, Arno Vanneste, Maxwell Szymanski, and Katrien Verbert. Under review.

#6: Visually Compose a University Programme



Domain: education

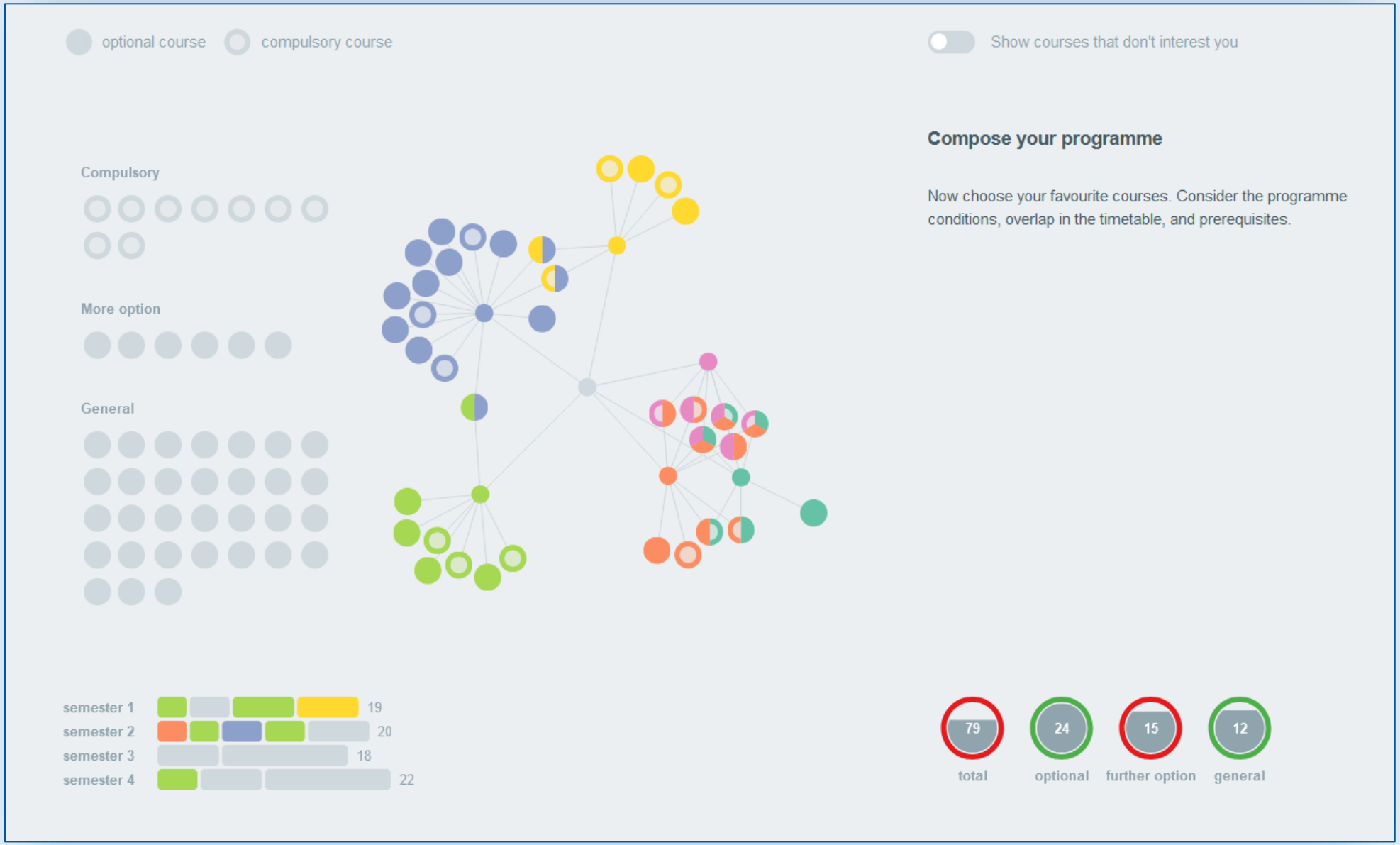
Audience: adult students

Tasks: see connections between courses, compose programme

Encoding: network, bar chart, gauges

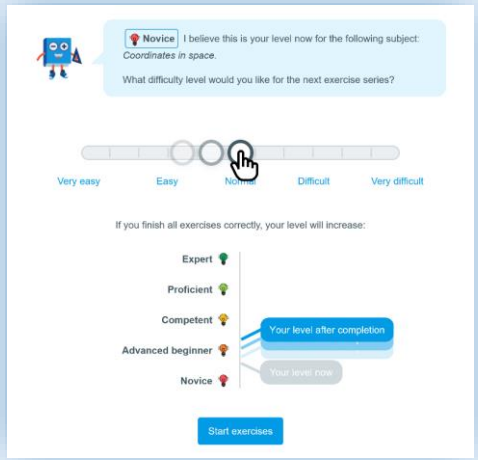
Interaction: filter, connect, select

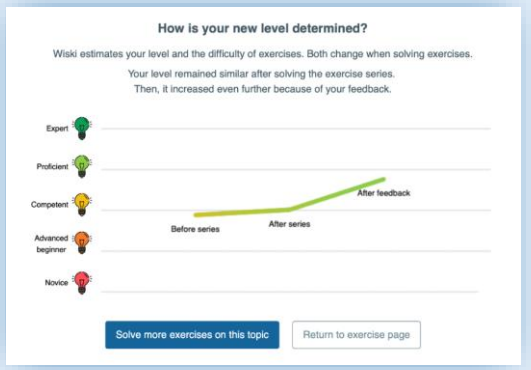
Jeroen Ooge, Niels Van Belle, Robbe Cools. Visually composing a Master's programme (2018). github.com/Robbec/Infovis1718/tree/English



Jeroen Ooge, Niels Van Belle, Robbe Cools. Visually composing a Master's programme (2018). github.com/Robbec/Infovis1718/tree/English

Break for Questions

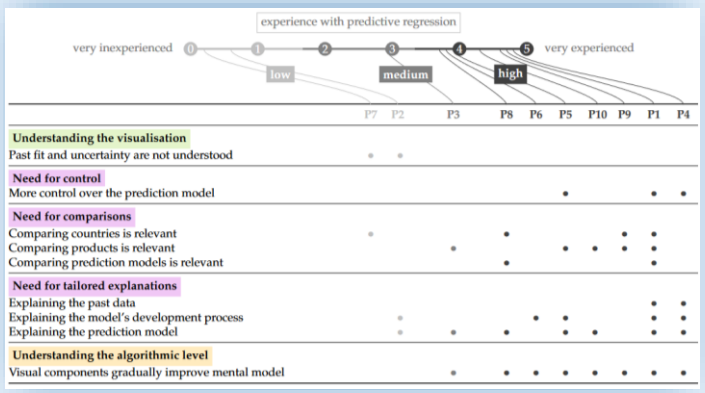


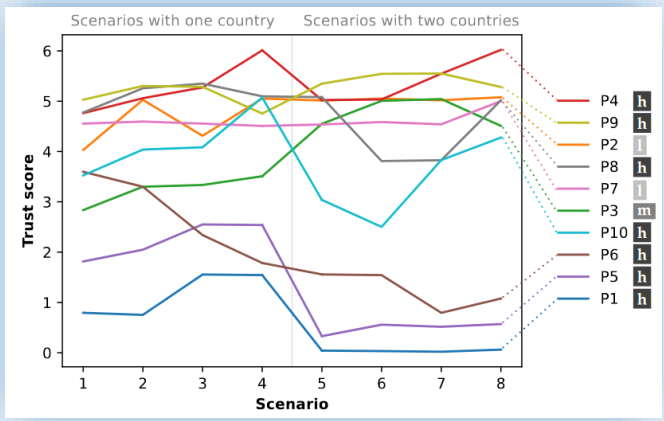


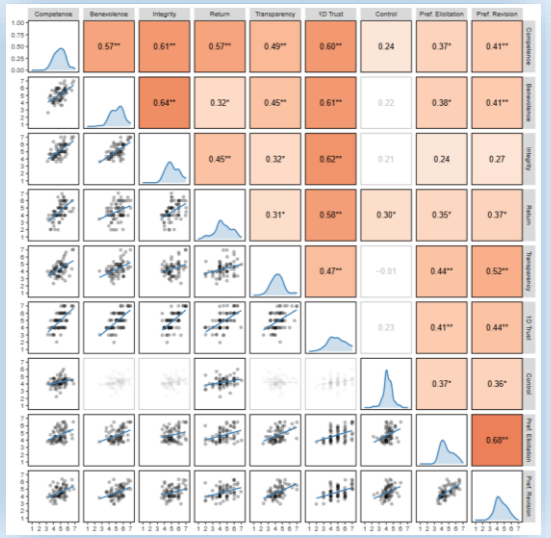
I Complex Visual Dashboards

II Simple Visualisations

III Visualisations in Reports

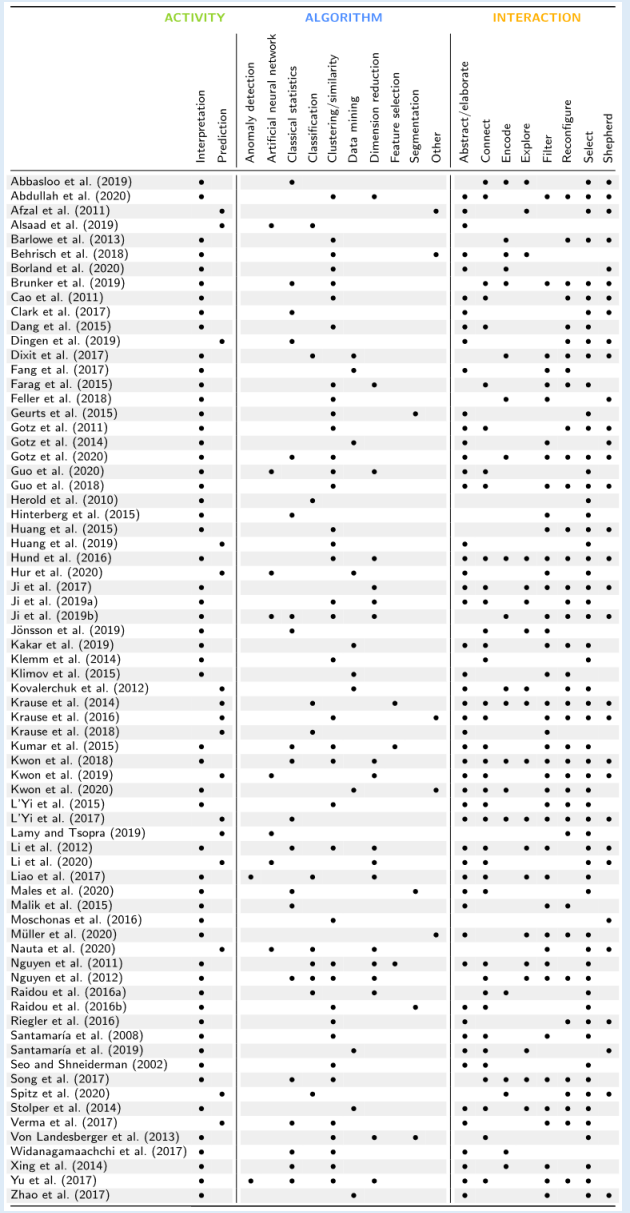






#1: Make Tables Insightful

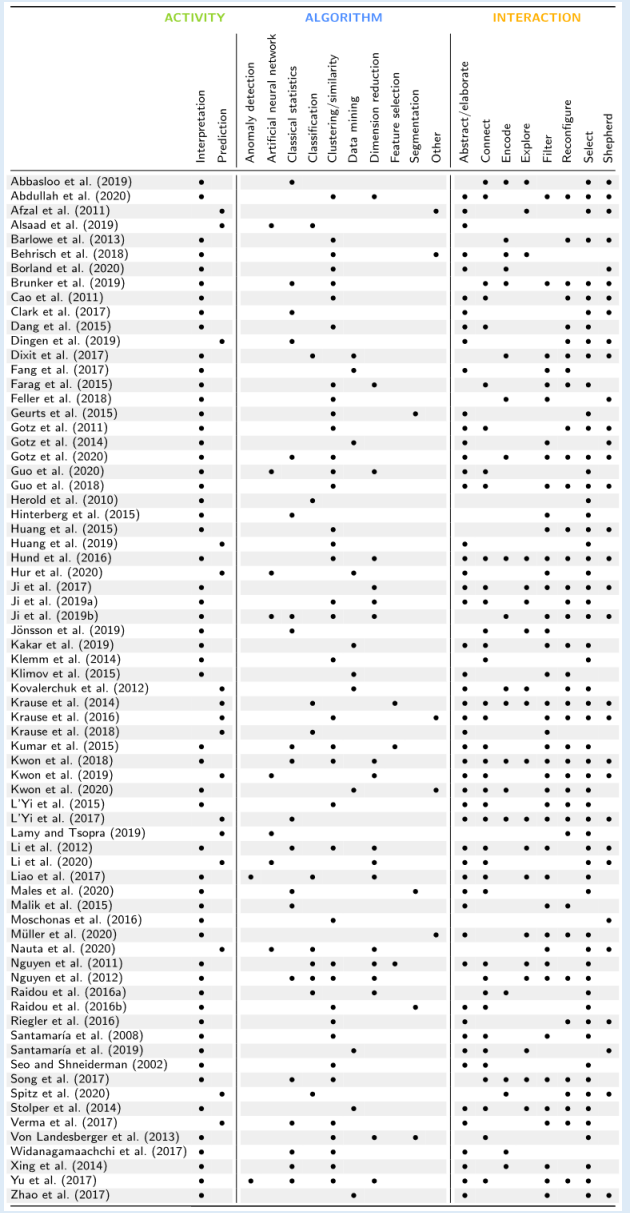
	ACTIVITY		ALGORITHM									INTERACTION							
	Interpretation	Prediction	Anomaly detection	Artificial neural network	Classical statistics	Classification	Clustering/similarity	Data mining	Dimension reduction	Feature selection	Segmentation	Other	Abstract/elaborate	Connect	Encode	Explore	Filter	Reconfigure	Select	Shepherd
Abbasloo et al. (2019)	●				●									●	●	●			●	●
Abdullah et al. (2020)	●						●		●				●	●			●	●	●	●
Afzal et al. (2011)		●										●	●			●			●	●
Yu et al. (2017)	●		●		●		●		●				●	●			●	●	●	
Zhao et al. (2017)	●							●					●				●		●	●



Jeroen Ooge, Gregor Stiglic, and Katrien Verbert. 2022. Explaining artificial intelligence with visual analytics in healthcare. *WIREs Data Mining and Knowledge Discovery* 12, 1: e1427. https://doi.org/10.1002/widm.1427

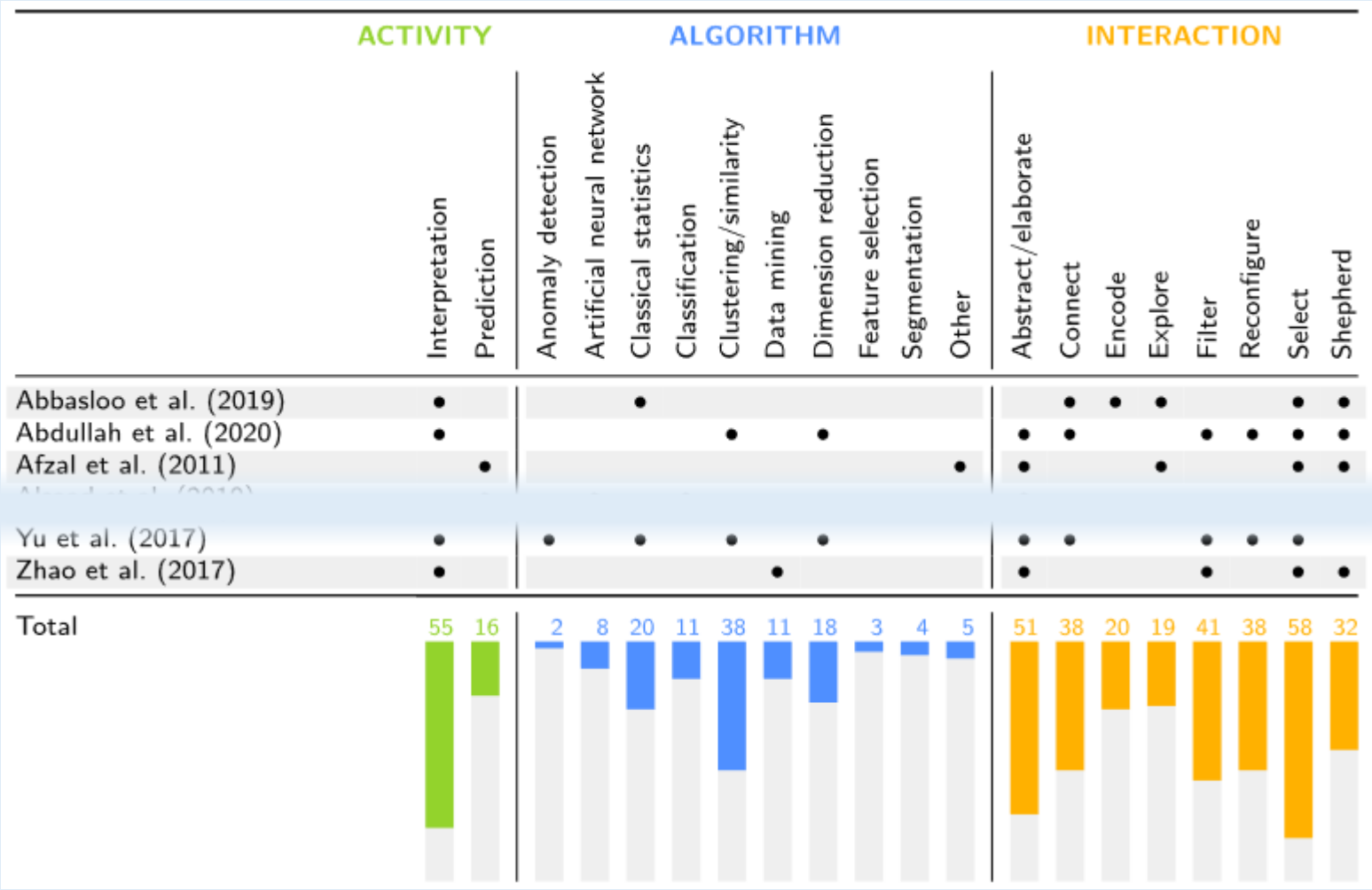
#1: Make Tables Insightful

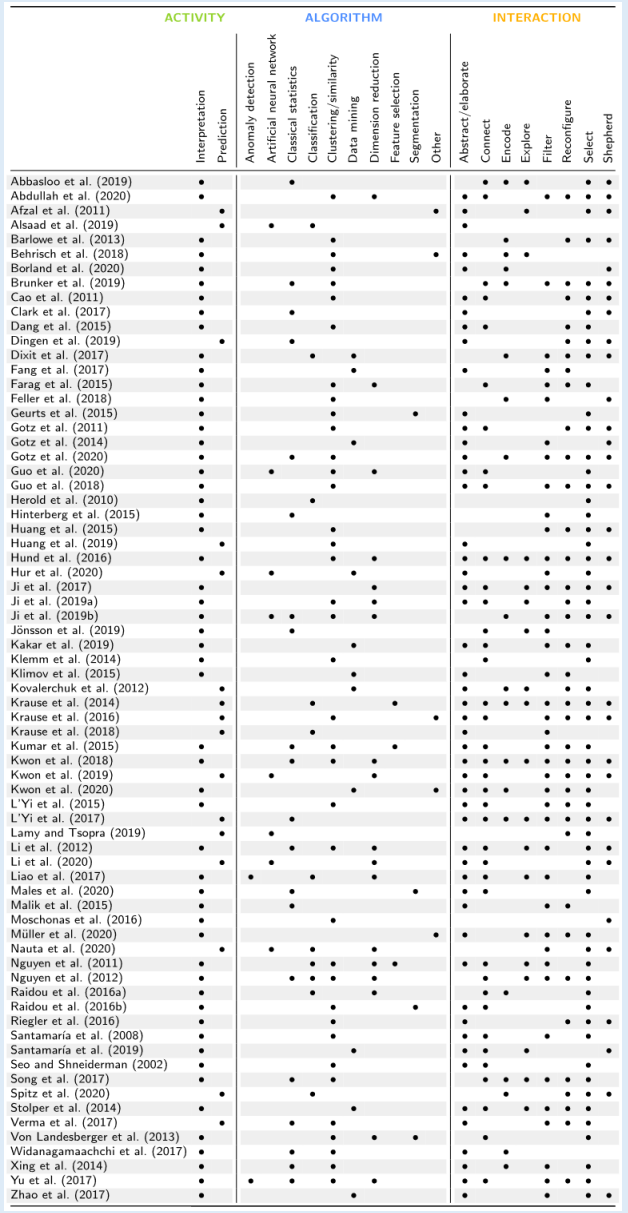
	ACTIVITY		ALGORITHM										INTERACTION							
	Interpretation	Prediction	Anomaly detection	Artificial neural network	Classical statistics	Classification	Clustering/similarity	Data mining	Dimension reduction	Feature selection	Segmentation	Other	Abstract/elaborate	Connect	Encode	Explore	Filter	Reconfigure	Select	Shepherd
Abbasloo et al. (2019)	•				•									•	•	•			•	•
Abdullah et al. (2020)	•						•		•				•	•			•	•	•	•
Afzal et al. (2011)		•										•	•			•			•	•
Yu et al. (2017)	•		•		•		•		•				•	•			•	•	•	
Zhao et al. (2017)	•							•					•				•		•	•
Total	55	16	2	8	20	11	38	11	18	3	4	5	51	38	20	19	41	38	58	32



Jeroen Ooge, Gregor Stiglic, and Katrien Verbert. 2022. Explaining artificial intelligence with visual analytics in healthcare. *WIREs Data Mining and Knowledge Discovery* 12, 1: e1427. https://doi.org/10.1002/widm.1427

#1: Make Tables Insightful



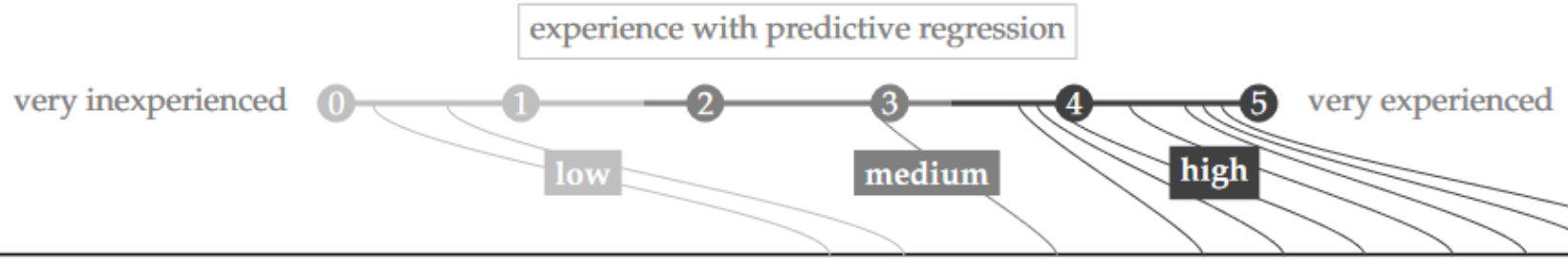


Jeroen Ooge, Gregor Stiglic, and Katrien Verbert. 2022. Explaining artificial intelligence with visual analytics in healthcare. *WIREs Data Mining and Knowledge Discovery* 12, 1: e1427. https://doi.org/10.1002/widm.1427

	P7	P2	P3	P8	P6	P5	P10	P9	P1	P4
Understanding the visualisation										
Past fit and uncertainty are not understood	•	•								
Need for control										
More control over the prediction model						•			•	•
Need for comparisons										
Comparing countries is relevant	•			•				•	•	
Comparing products is relevant			•			•	•	•	•	
Comparing prediction models is relevant				•					•	
Need for tailored explanations										
Explaining the past data									•	•
Explaining the model's development process		•			•	•			•	•
Explaining the prediction model		•	•	•		•	•		•	•
Understanding the algorithmic level										
Visual components gradually improve mental model			•	•	•	•	•	•	•	•

Jeroen Ooge and Katrien Verbert. 2022. Visually Explaining Uncertain Price Predictions in Agrifood: A User-Centred Case-Study. *Agriculture* 12, 7: 1024. https://doi.org/10.3390/agriculture12071024

Table 2. Some topics raised by the participants, ordered by their experience with predictive regression (P2 and P7 have low experience; P3 has medium experience; others have high experience).



	P7	P2	P3	P8	P6	P5	P10	P9	P1	P4
Understanding the visualisation										
Past fit and uncertainty are not understood	•	•								
Need for control										
More control over the prediction model						•			•	•
Need for comparisons										
Comparing countries is relevant	•			•				•	•	
Comparing products is relevant			•			•	•	•	•	
Comparing prediction models is relevant				•					•	
Need for tailored explanations										
Explaining the past data									•	•
Explaining the model's development process		•			•	•			•	•
Explaining the prediction model		•	•	•		•	•		•	•
Understanding the algorithmic level										
Visual components gradually improve mental model			•	•	•	•	•	•	•	•

Jeroen Ooge and Katrien Verbert. 2022. Visually Explaining Uncertain Price Predictions in Agrifood: A User-Centred Case-Study. *Agriculture* 12, 7: 1024. https://doi.org/10.3390/agriculture12071024

#2: Use Consistent Colours

prices and uncertainty in the predictions. We evaluated
who are active in different parts of agrifood; collecting
quantitative data. In particular, we focused on the follo

RQ1 **Usability** : How user-friendly are the interaction
in our visual DSS?

RQ2 **Usefulness and needs** : How useful is our visual
the needs of people active in agrifood?

RQ3 **Model understanding** : How does visualising u
understanding of the prediction model underlyin

RQ4 **Trust** : How does visualising uncertain predicti
diction model underlying our visual DSS?

Our research contribution consists of extensively e
perspectives. First, considering our prototype as a pro

agriculture MDPI

Article

Visually Explaining Uncertain Price Predictions in Agrifood: A User-Centred Case-Study

Jeroen Ooge * and Katrien Verbert

Department of Computer Science, KU Leuven, 3001 Leuven, Belgium; katrien.verbert@kuleuven.be
* Correspondence: jeroen.ooge@kuleuven.be; Tel.: +32-16-32-42-86

Abstract: The rise of 'big data' in agrifood has increased the need for decision support systems that harvest the power of artificial intelligence. While many such systems have been proposed, their uptake is limited, for example because they often lack uncertainty representations and are rarely designed in a user-centred way. We present a prototypical visual decision support system that incorporates price prediction, uncertainty, and visual analytics techniques. We evaluated our prototype with 10 participants who are active in different parts of agrifood. Through semi-structured interviews and questionnaires, we collected quantitative and qualitative data about four metrics: usability, usefulness and needs, model understanding, and trust. Our results reveal that the first three metrics can directly and indirectly affect appropriate trust, and that perception differences exist between people with diverging experience levels in predictive modelling. Overall, this suggests that user-centred approaches are key for increasing uptake of visual decision support systems in agrifood.

Keywords: visual analytics; visualisation; uncertainty; explainable artificial intelligence; decision support systems; mixed-methods; thematic analysis

check for updates

Citation: Ooge, J.; Verbert, K. Visually Explaining Uncertain Price Predictions in Agrifood: A User-Centred Case-Study. *Agriculture* **2022**, *12*, 1024. https://doi.org/10.3390/agriculture12071024

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1. Introduction

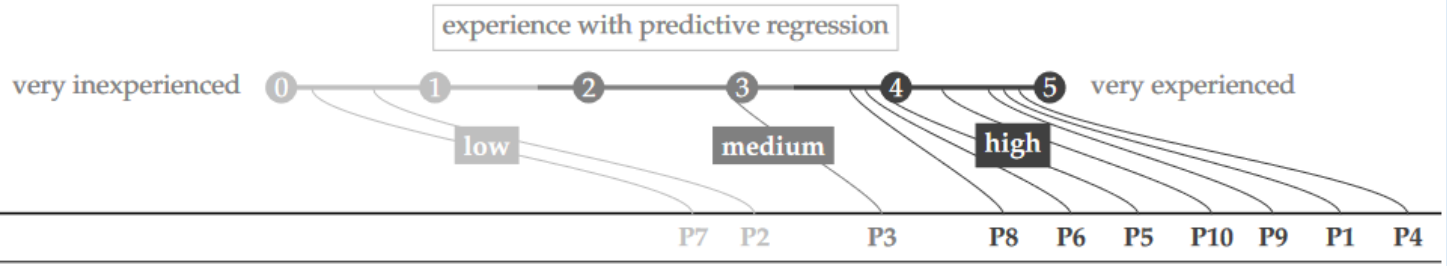
Under the impulse of success stories in other domains, artificial intelligence and 'big data' are on the rise in agrifood [1], leading to promising research directions such as *Agriculture 4.0* [2] and the broader *Agrifood 4.0* [3], *precision agriculture* [4–6], and *smart farming* [7–9]. While the adoption of such technologies is still modest in real-life agrifood applications [10], it is expected that the wide availability of cloud computing and remote sensing [11] will further boost their spread [12]. To process the explosive amount of information in this era of growing digitisation and to make data-grounded decisions, agrifood stakeholders increasingly need the assistance of *decision support systems* (DSSs) [2] that facilitate learning and allow to modify decision processes by integrating domain knowledge, rather than systems that merely prescribe actions [13,14].

Yet, even though the need for DSSs in agrifood has been acknowledged for over two decades [13] and many prototypes have been proposed [2,15], the uptake of these systems has been limited so far. Parker et al. [16,17], Zhai et al. [2], and Rose et al. [18] discussed several reasons for this low uptake: user interfaces of DSSs are not always user-friendly and lack visualisations, DSSs are not necessarily relevant when they do not meet end users' needs or decision-making styles, outputs often miss uncertainty representations, and end users often distrust DSSs with opaque underlying algorithms. In other words, developers of DSSs for agrifood face important design challenges such as increasing usability, guarding usefulness for end users, and raising appropriate trust in underlying decision models.

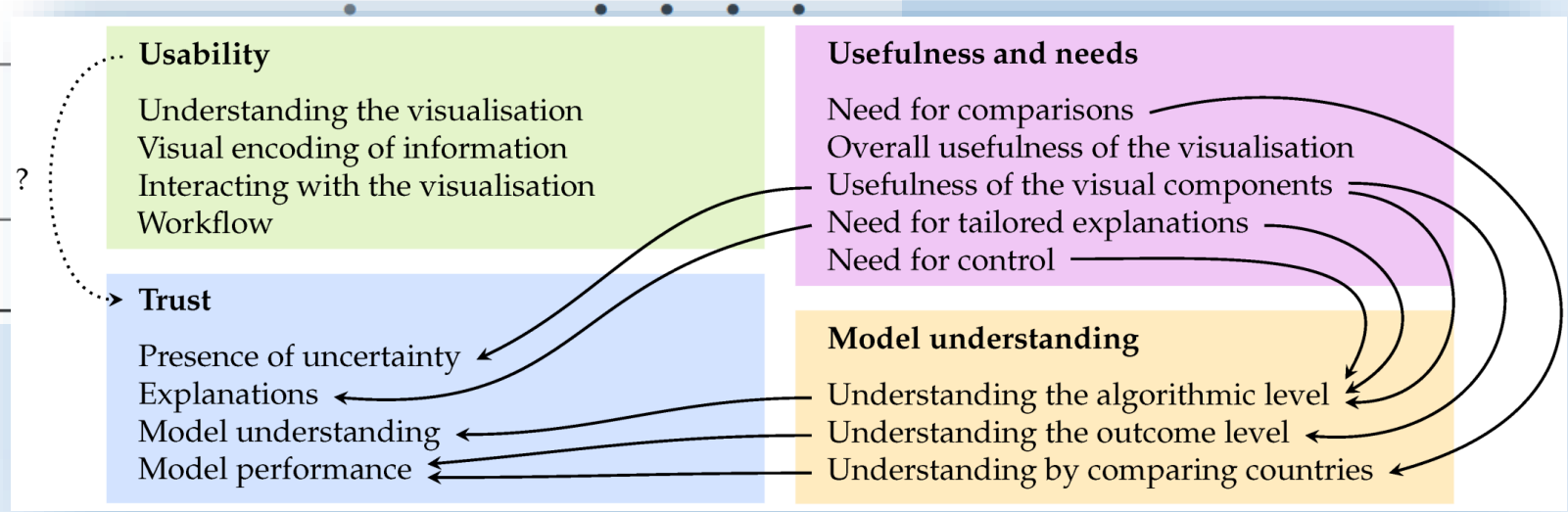
Tackling these challenges requires human-centred approaches, which lie at the core of *human–computer interaction* (HCI), an interdisciplinary field that connects computer science, social sciences, and technology-applying domains such as agrifood. Specifically, HCI studies how interfaces can be designed and tailored to specific end users or application contexts to improve user experience, for example [19–21]. Two subdomains of HCI specialise in visualising complex information and explaining artificial intelligence, respectively.

Jeroen Ooge and Katrien Verbert. 2022. Visually Explaining Uncertain Price Predictions in Agrifood: A User-Centred Case-Study. *Agriculture* 12, 7: 1024. https://doi.org/10.3390/agriculture12071024

Table 2. Some topics raised by the participants, ordered by their experience with predictive regression (P2 and P7 have low experience; P3 has medium experience; others have high experience).



Understanding the visualisation	
Past fit and uncertainty are not understood	● ●
Need for control	
More control over the prediction model	● ● ●
Need for comparisons	
Comparing countries is relevant	● ● ● ●
Comparing products is relevant	● ● ● ● ●
Comparing prediction models is relevant	● ● ● ●
Need for tailored explanations	
Explaining the past data	● ● ● ●
Explaining the model's development process	● ● ● ●
Explaining the prediction model	● ● ● ●
Understanding the algorithmic level	
Visual components gradually improve mental model	● ● ● ●



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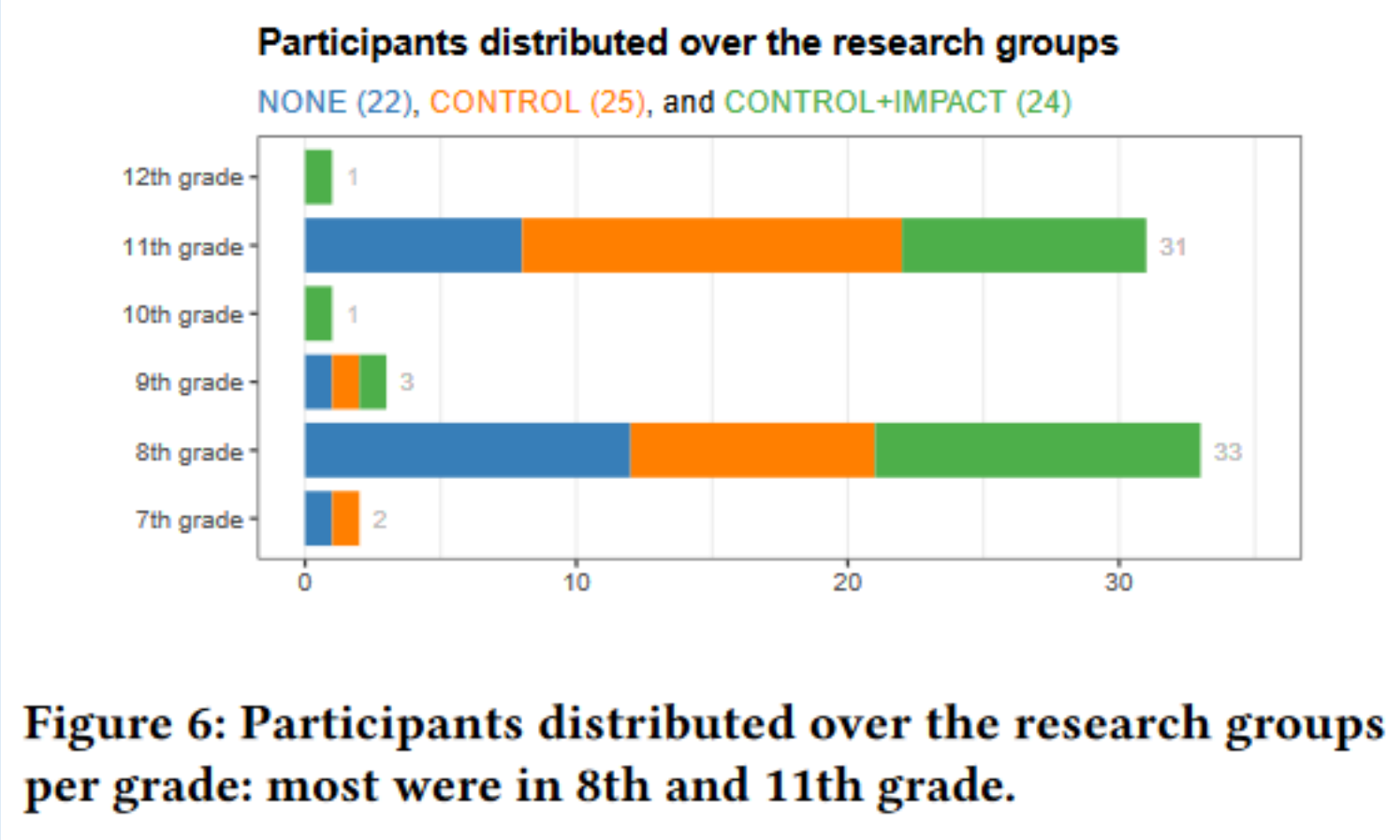

Figure 6: Participants distributed over the research groups per grade: most were in 8th and 11th grade.

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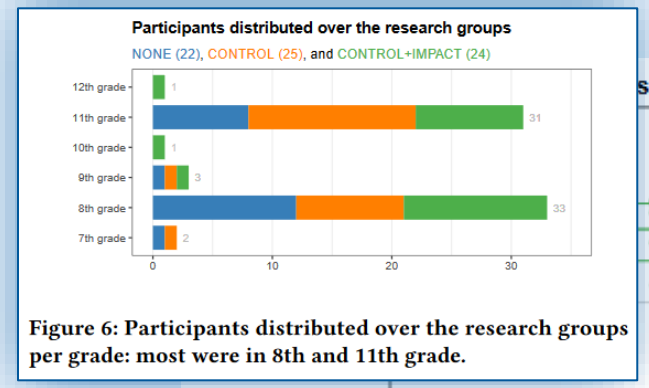

Figure 6: Participants distributed over the research groups per grade: most were in 8th and 11th grade.

Figure 8: Box plots of the responses to the questionnaire in Table 2 for (dot plots are slightly jittered horizontally and vertically.

Figure 10: Evolution of participants' Elo ratings during the experiment and the average evolution per research group.

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#3: Suppress Less Important Information

Table 1: Comparing the research groups with t-tests (Mann-Whitney U test for one-dimensional trust). Cells contain the effect sizes (second group mean minus first group mean).

	NONE VS. CONTROL	NONE VS. CONTROL+IMPACT	CONTROL VS. CONTROL+IMPACT
Benevolence	0.16 ($p = 0.263$)	0.61 ($p = 0.011$)	0.45 ($p = 0.035$)
Trusting beliefs	-0.01 ($p = 0.529$)	0.38 ($p = 0.042$)	0.40 ($p = 0.030$)
Transparency	0.29 ($p = 0.068$)	1.04 ($p = 0.000$)**	0.74 ($p = 0.002$)*
One-dimens. trust	0.00 ($p = 0.504$)	0.78 ($p = 0.017$)	0.78 ($p = 0.020$)
Multidimens. trust	0.15 ($p = 0.207$)	0.55 ($p = 0.009$)*	0.40 ($p = 0.039$)
Preference revision	0.33 ($p = 0.080$)	0.43 ($p = 0.030$)	0.10 ($p = 0.325$)

*$p < 0.01$, **$p < 0.001$, non-significant results ($p \geq 0.5$) are greyed out

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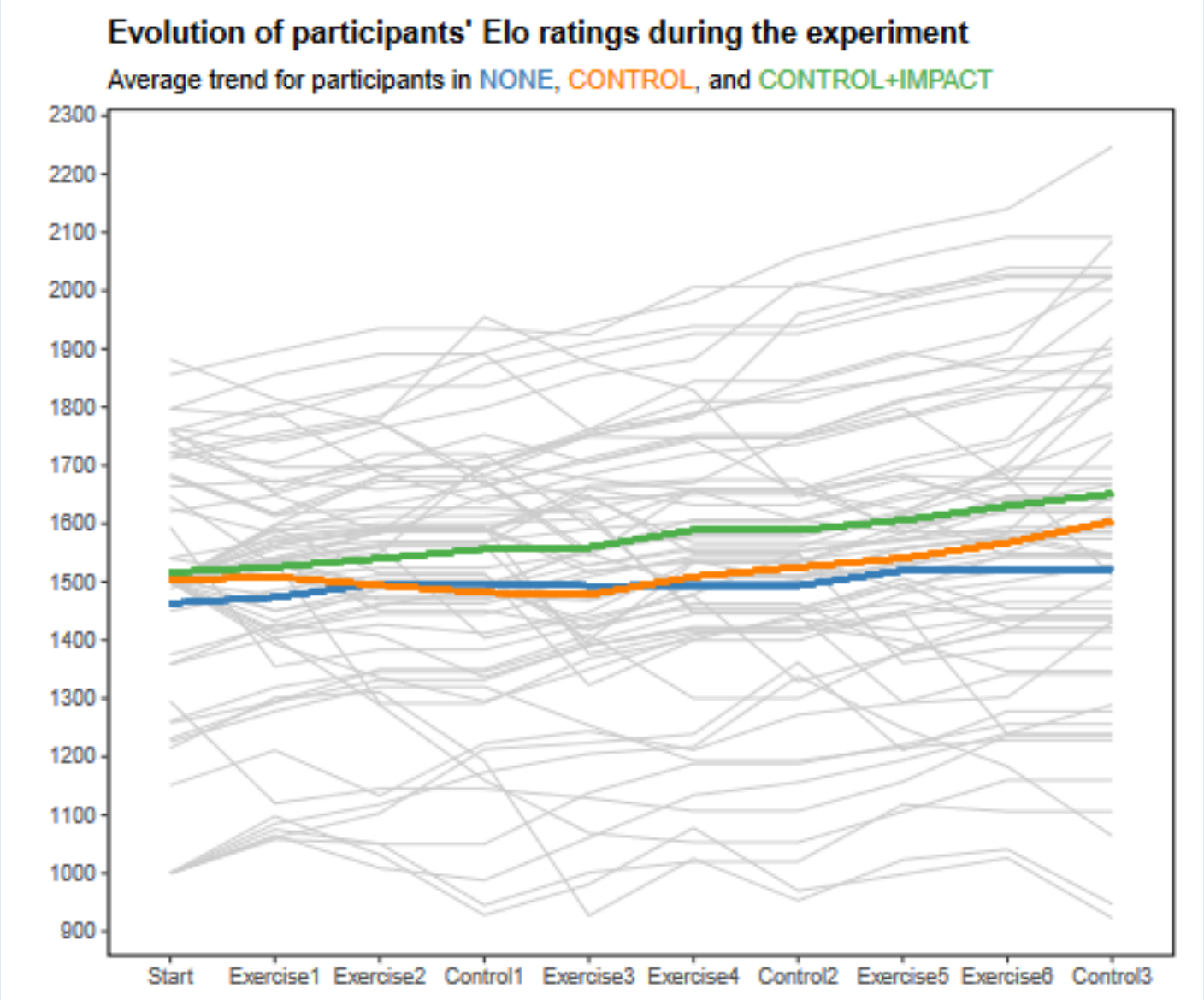

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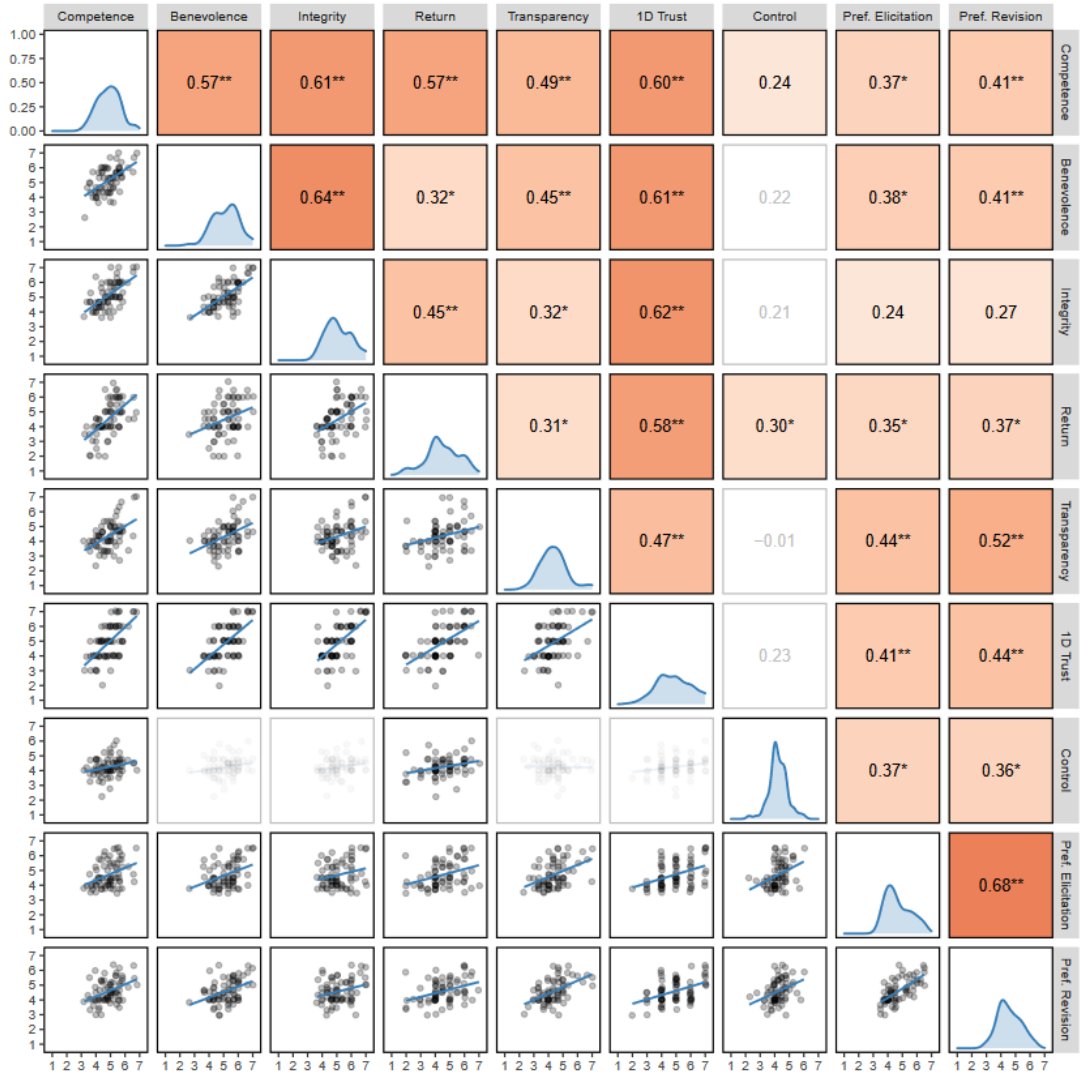

Figure 9: Relations between trust-related and control-related constructs. Lower triangle: dot plots with fitted regression lines. Diagonal: density plot of constructs. Upper triangle: correlations colour-coded by value ($^*p < 0.01$, $^{**}p < 0.001$). Non-significant relations ($p \geq 0.05$) are greyed out.

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#4: Show the Actual Data

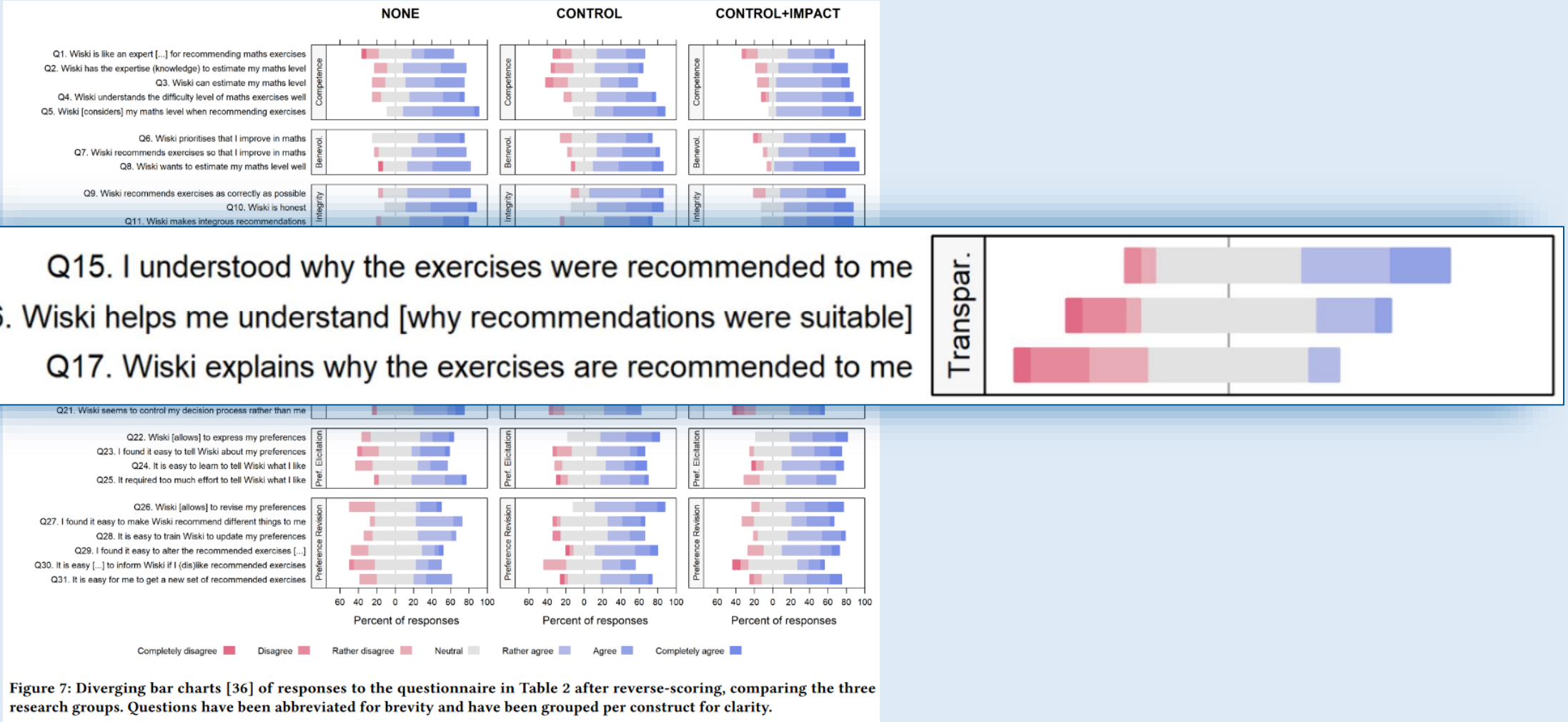

Figure 7: Diverging bar charts [36] of responses to the questionnaire in Table 2 after reverse-scoring, comparing the three research groups. Questions have been abbreviated for brevity and have been grouped per construct for clarity.

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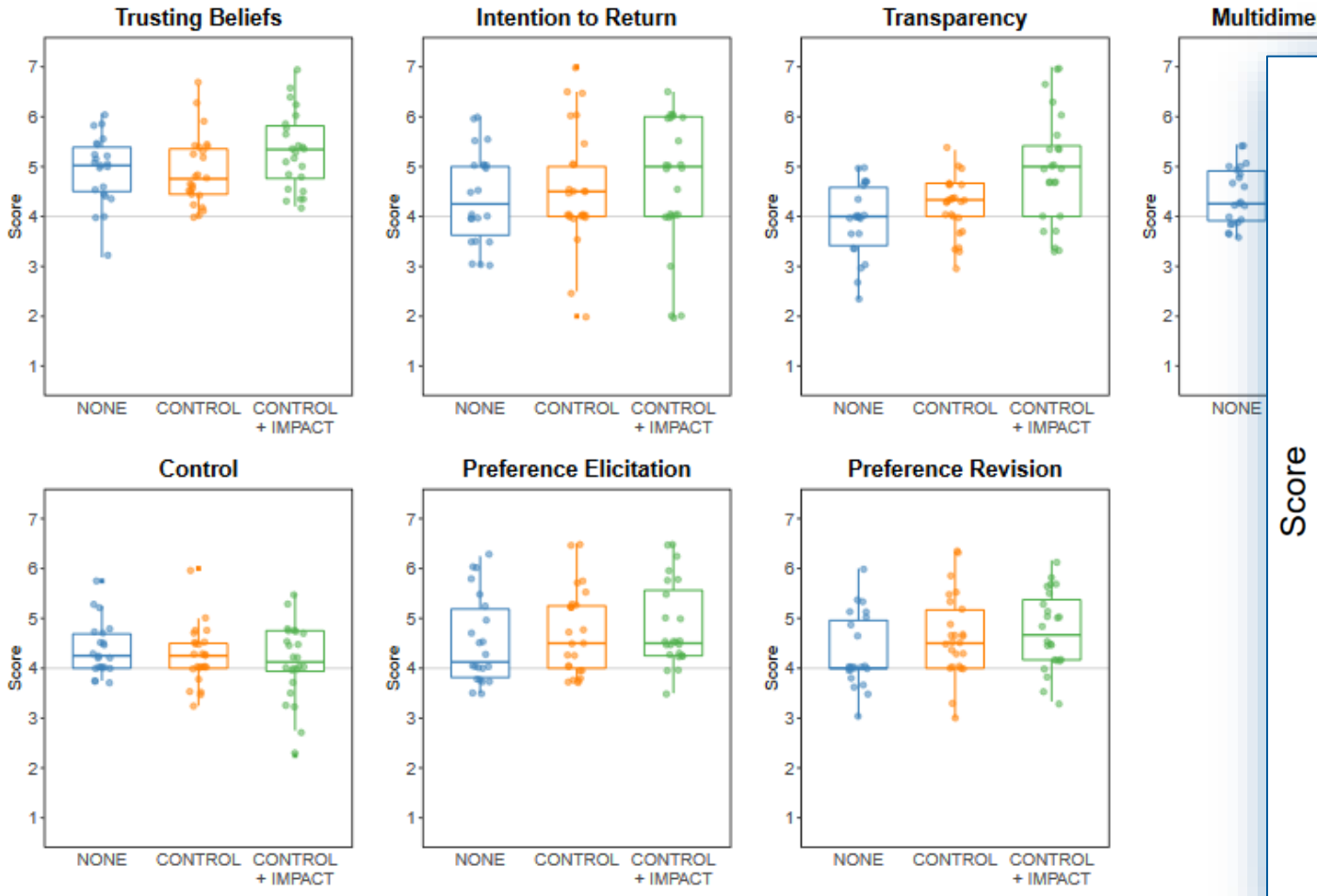

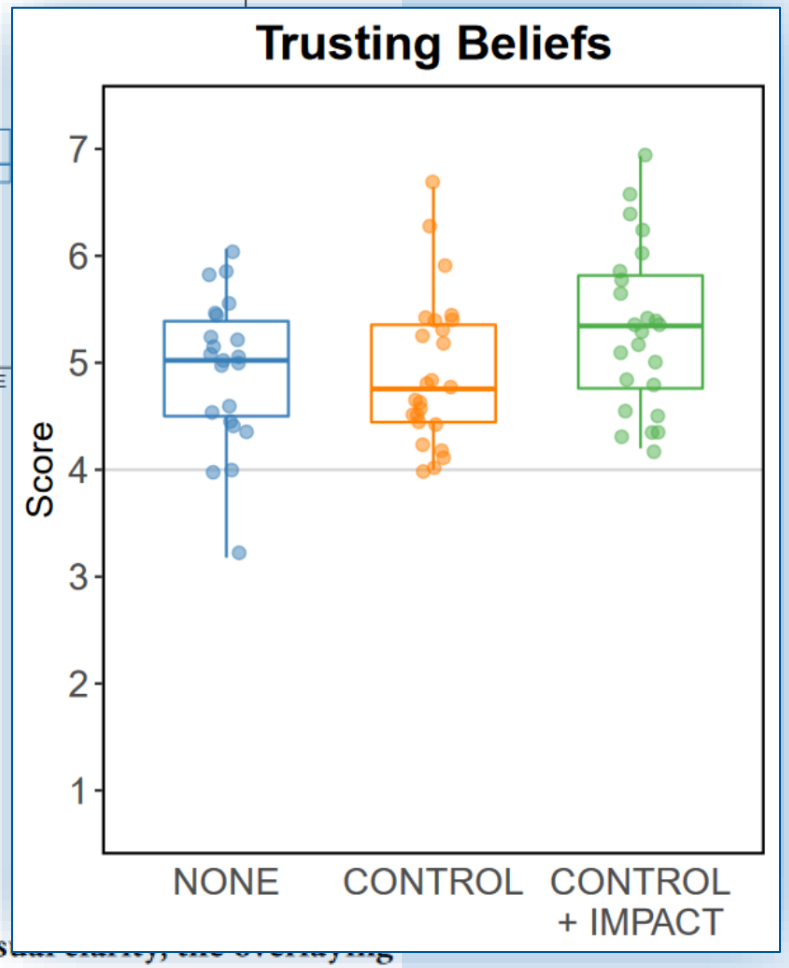

Figure 8: Box plots of the responses to the questionnaire in Table 2 for each research group. For vis… dot plots are slightly jittered horizontally and vertically.

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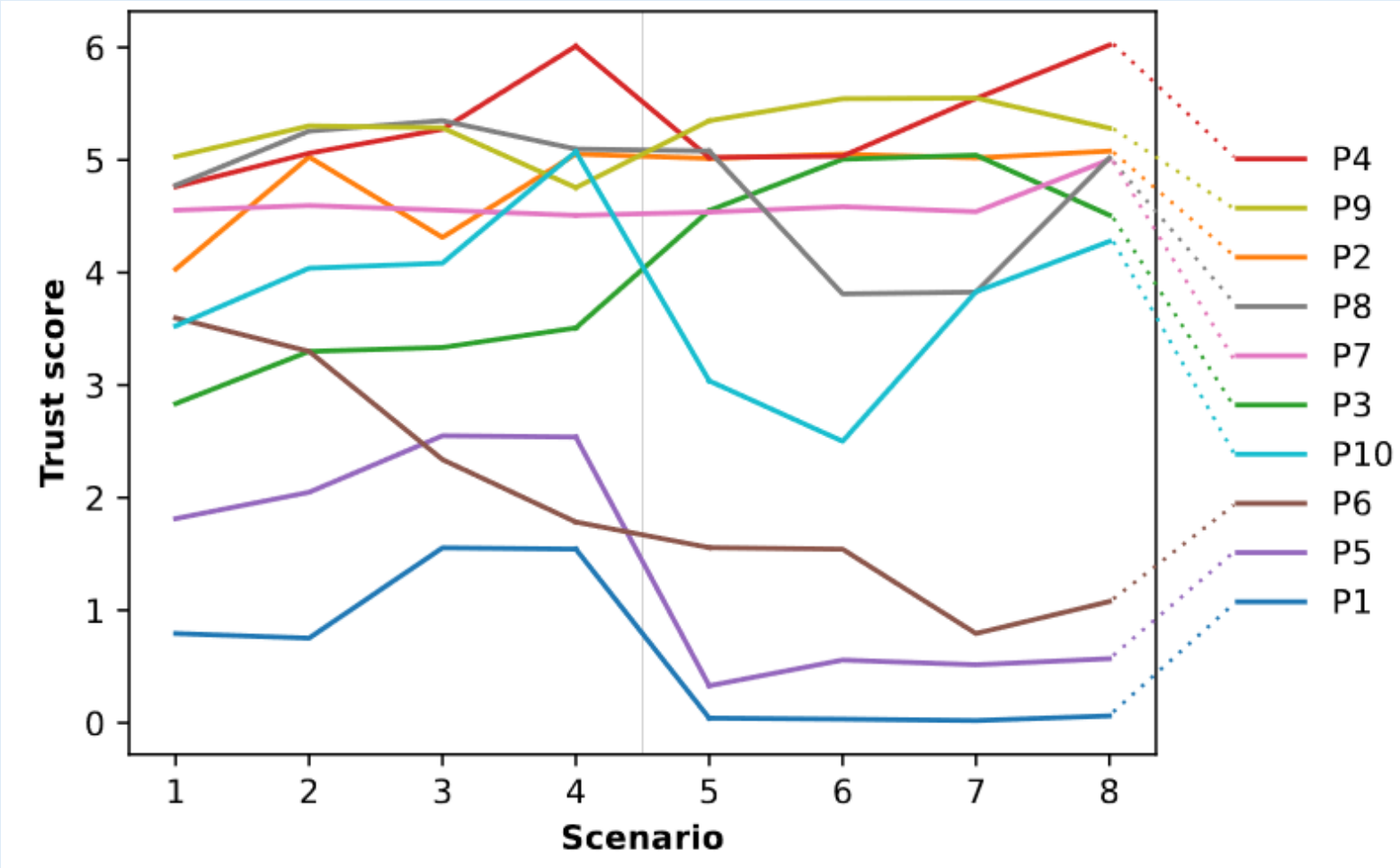
Nick Desbarats. 2021. I've Stopped Using Box Plots. Should You? https://nightingaledvs.com/ive-stopped-using-box-plots-should-you/

#5: Enrich Visualisations Meaningfully



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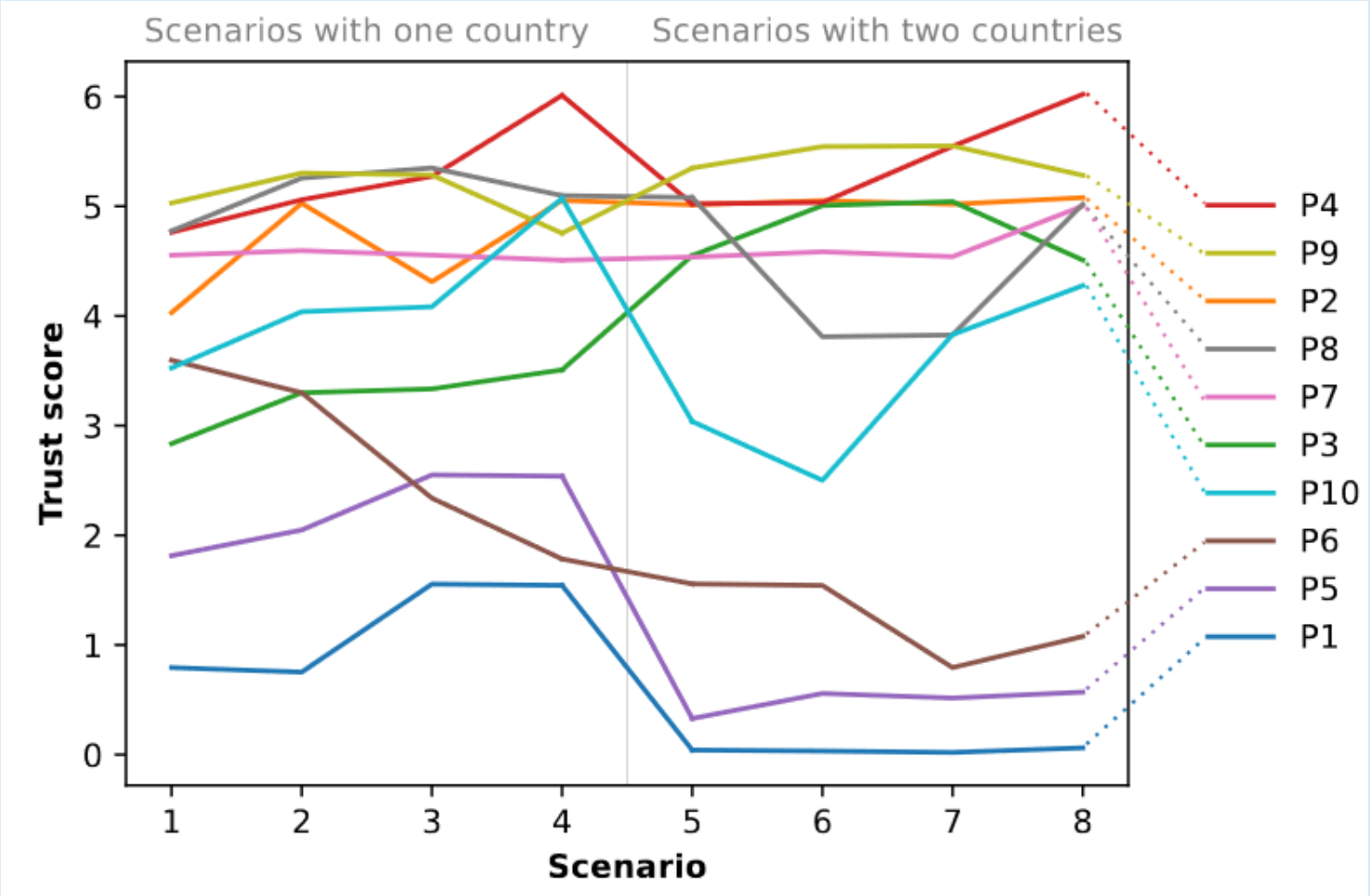

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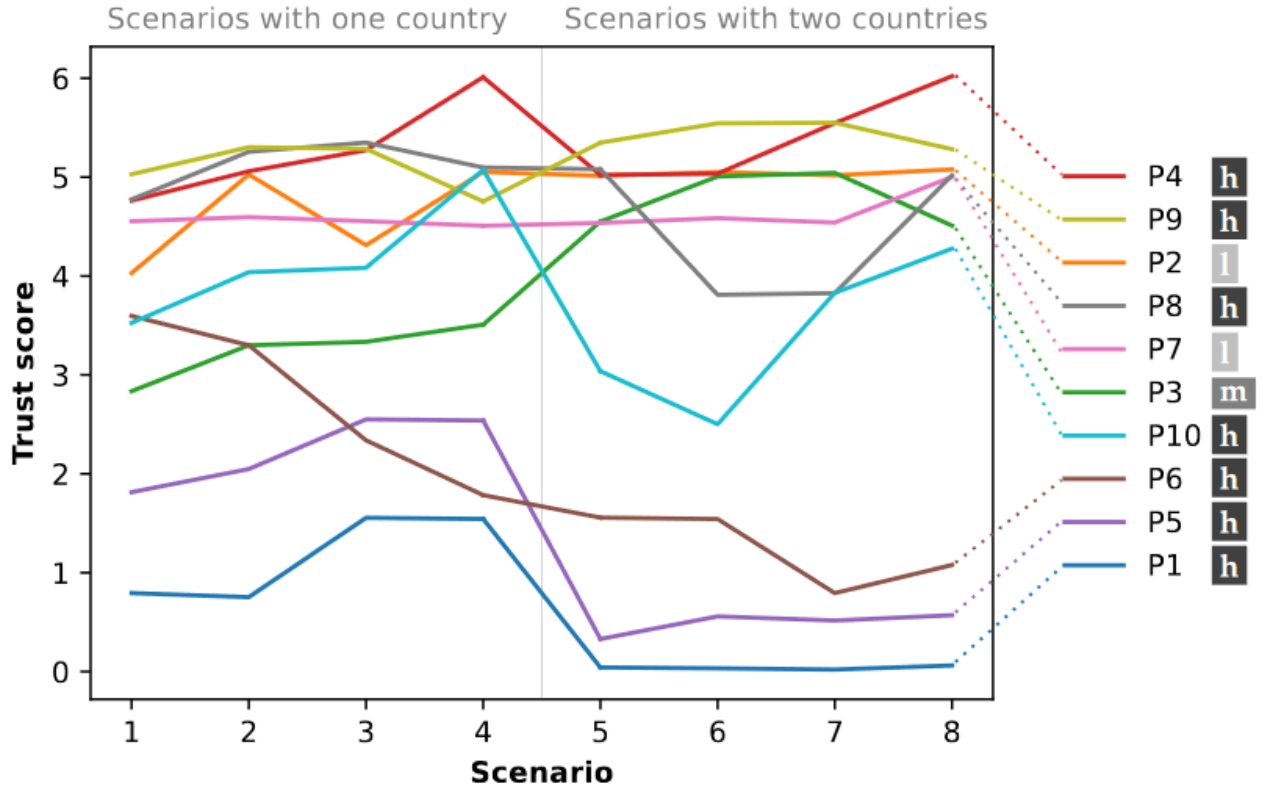

Figure 4. Participants' trust in the prediction model over eight scenarios. Scenarios 1–4 showed data for one country; Scenarios 5–8 showed data for two countries. Lines are slightly jittered for clarity. The legend includes the level of experience with predictive regression (l low, m medium, h high).

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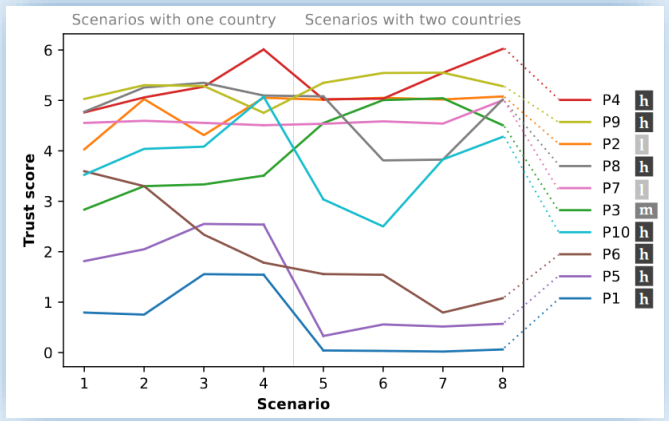
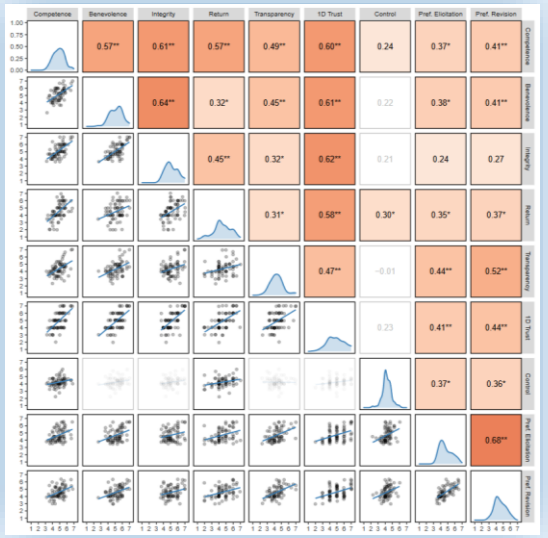
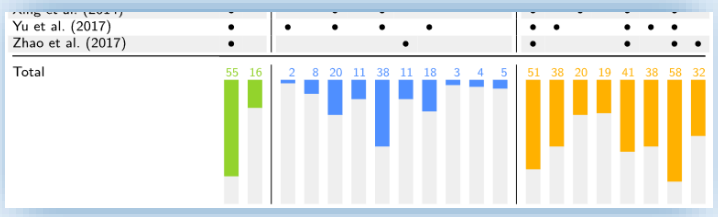
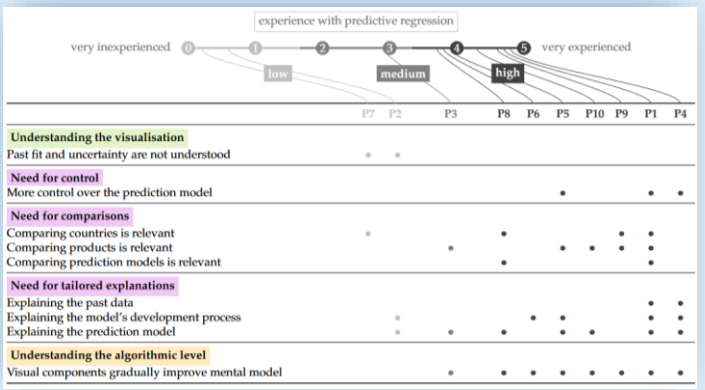
Break for Questions









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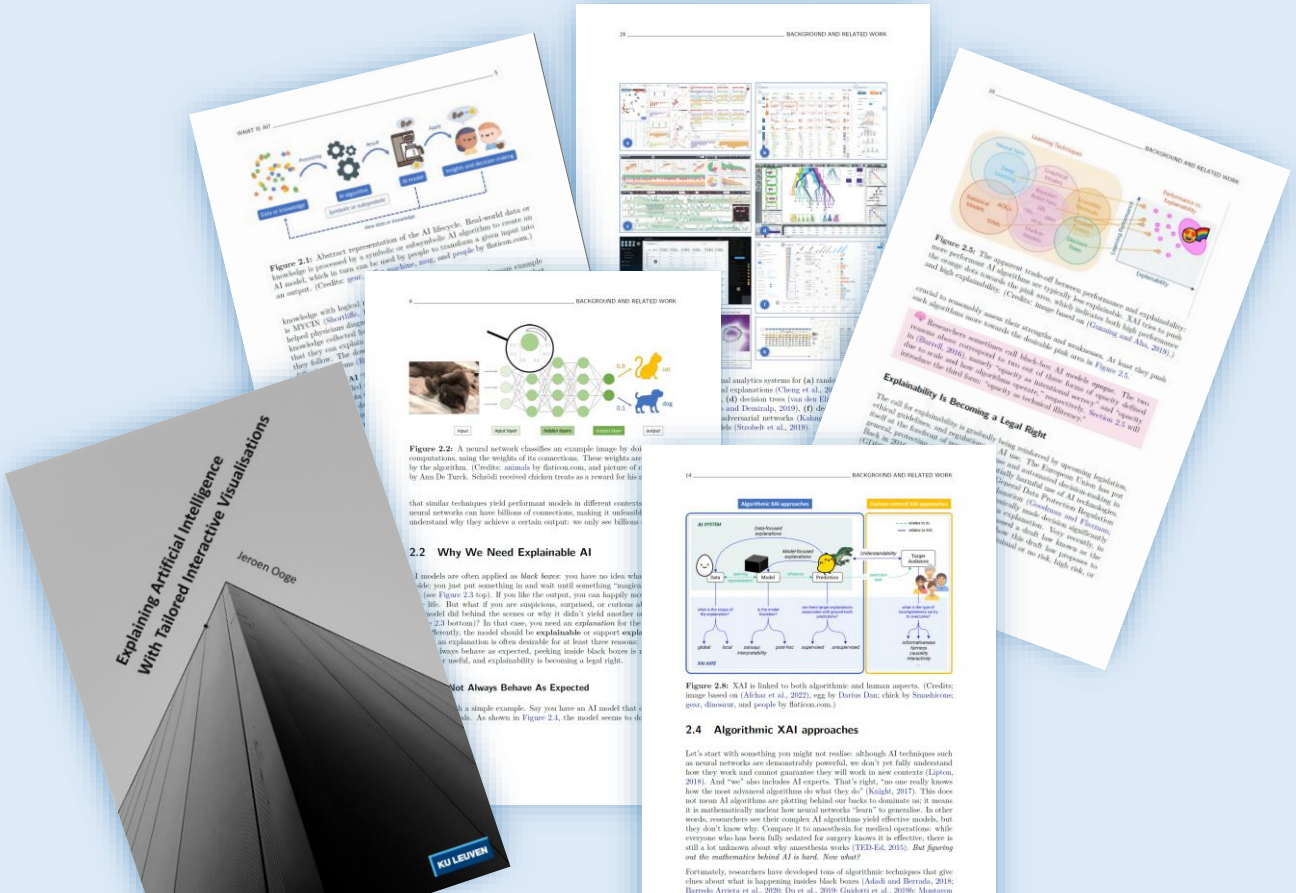

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