Explaining Neural NLP Models for the Joint Analysis of Open- and Closed-Ended Survey Answers

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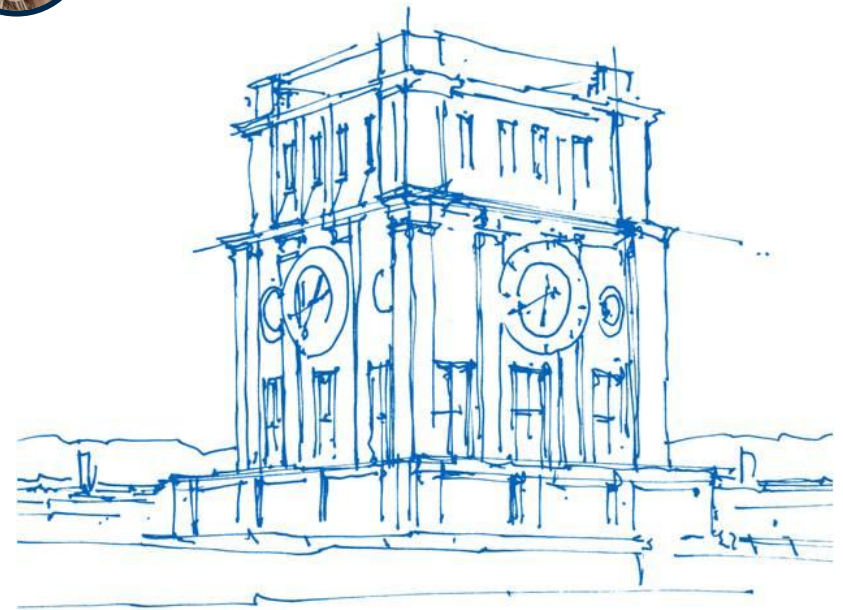
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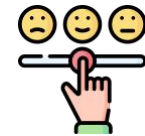
Surveys and Questionnaires

- **Census for a demographic population**
- **Reports for scientific studies**
- **Consumer feedback about a service/product**

An extremely popular tool to inquire an audience for feedback, opinions, and ideas.

Closed-ended answers
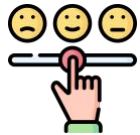(multiple choice, ranges, ..)

Open-Ended answers
(natural language text)

- **Demographic stats**
- **Research Findings**
- **Market Insights**

Previous Work on Survey Analysis

Closed-ended answers
(multiple choice, ranges, ..)

- Great to extract quantitative statistics ✓
- Ignore details and nuances ✗

Open-ended answers
(natural language text)

- Very flexible and with detailed information ✓
- Hard to analyse ✗

Closed-vocabulary methods	**Open-vocabulary methods**
Analysis done with a hand-crafted vocabulary and computing word frequencies.	*Discover topics from data rather than from a predefined list of words. Topic Modeling, Clustering (LDA, LSA).*

Our Contribution

We..

1 **Investigate the usage of transformers on the task**:
This enables our approach to extract contextual correlations from the text with high precision compared to traditional methods.

2 **Interpret our model via post-hoc explainability:**
We extract instance-level feature importance (SHAP) as well as high-level concepts learned by the model (ConceptSHAP) to gain a holistic understanding of the model.

3 **Evaluate our methodology on the EMS dataset:**
Our approach delivers promising results on identifying factors influencing student career goals. Insights are derive both from closed- and open-ended answers.

Engineering Major Survey (EMS)

From **2015** to **2019**

7197 surveyed students from **27** US universities

Longitudinal study of college students. Studies how factors from specific topics + open text variables influence their desired career path.

Topic 1: Learning experiences.. **topic 5**: Background.. **topic 8:** Current contextual influences.
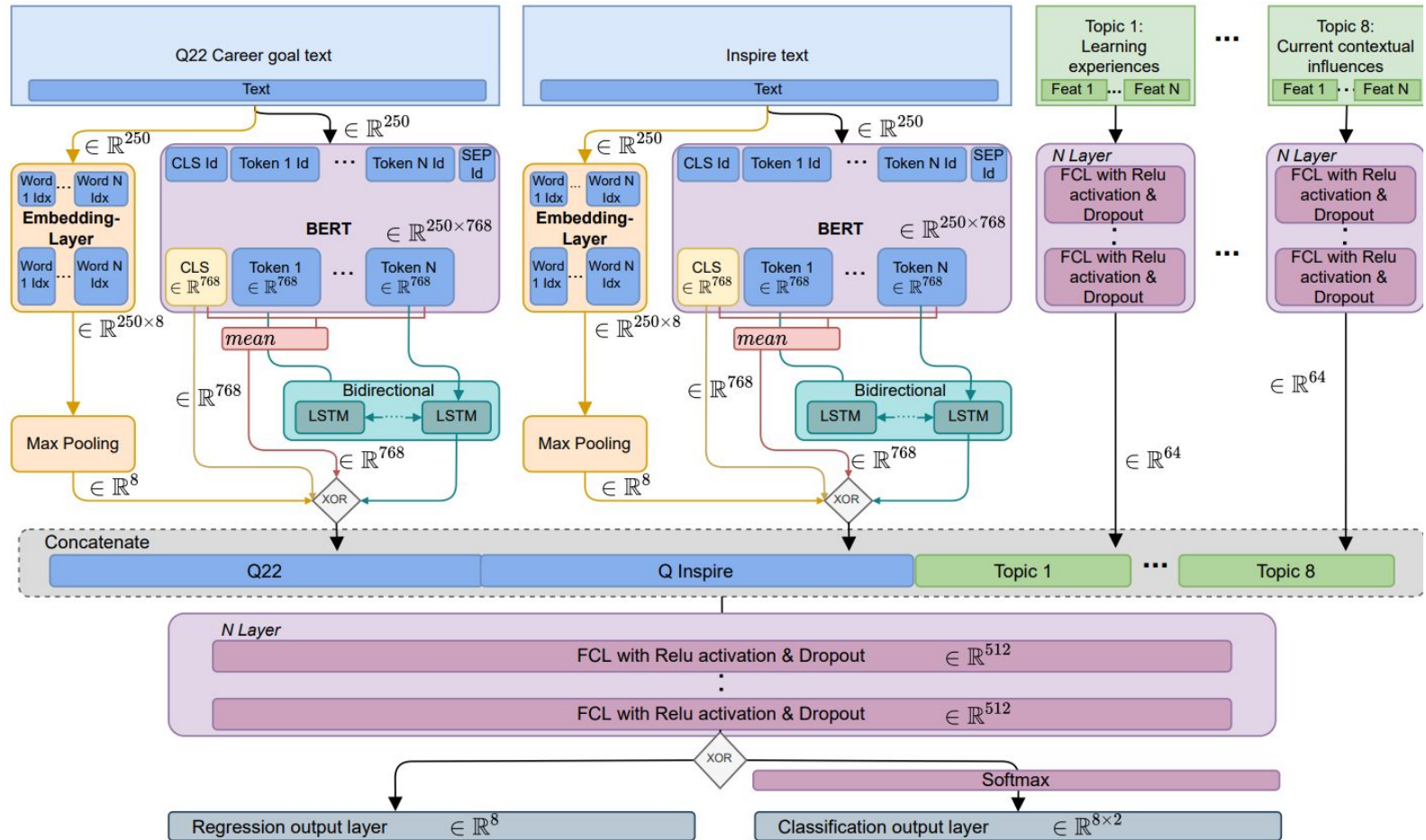
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Q22: *"We have asked a number of questions about your future plans. If you would like to elaborate on what you are planning to do, inthe next five years or beyond, please do so here."*
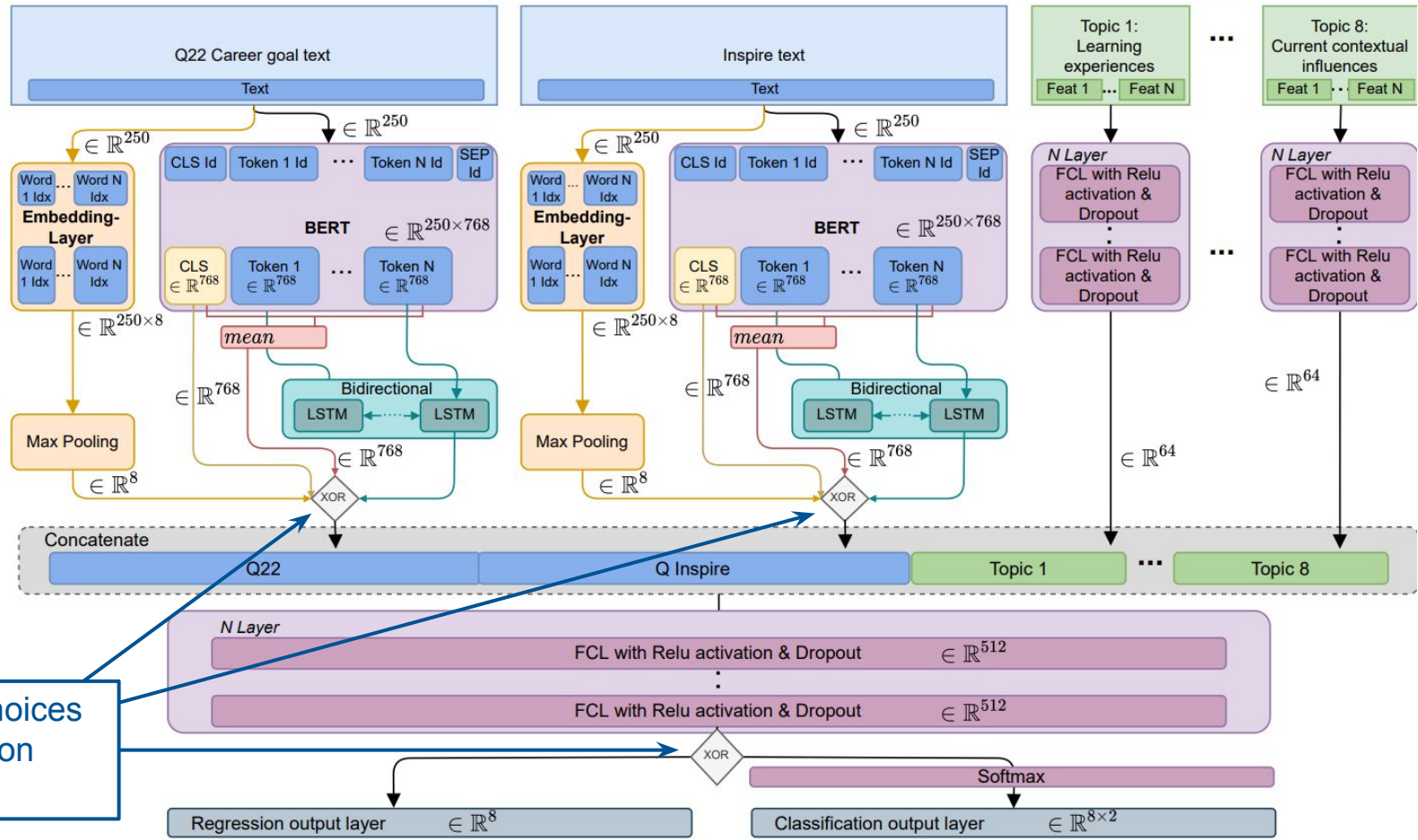**Inspire:** *"To what extent did this survey inspire you to think about your education in new or different ways? Please describe."*

T1: Work for a small business / start-up
T2: Work for a medium/large company
T3: Work for a non-profit organization
T4: Work for the government, military, or public agency.
T5: Work as a teacher in a K-12 school
T6: Work as a faculty member in a college/university
T7: Found your own for-profit organization
T8: Found your own non-profit organization

Gilmartin et al. 2017. *Designing a longitudinal study of engineering students' innovation and engineering interests and plans: The engineering majors survey project. ems 1.0 and 2.0 technical report.* Stanford University Designing Education Lab, Stanford, CA, Technical Report.

Model Architecture

Model Architecture

Task Results and Ablation Study

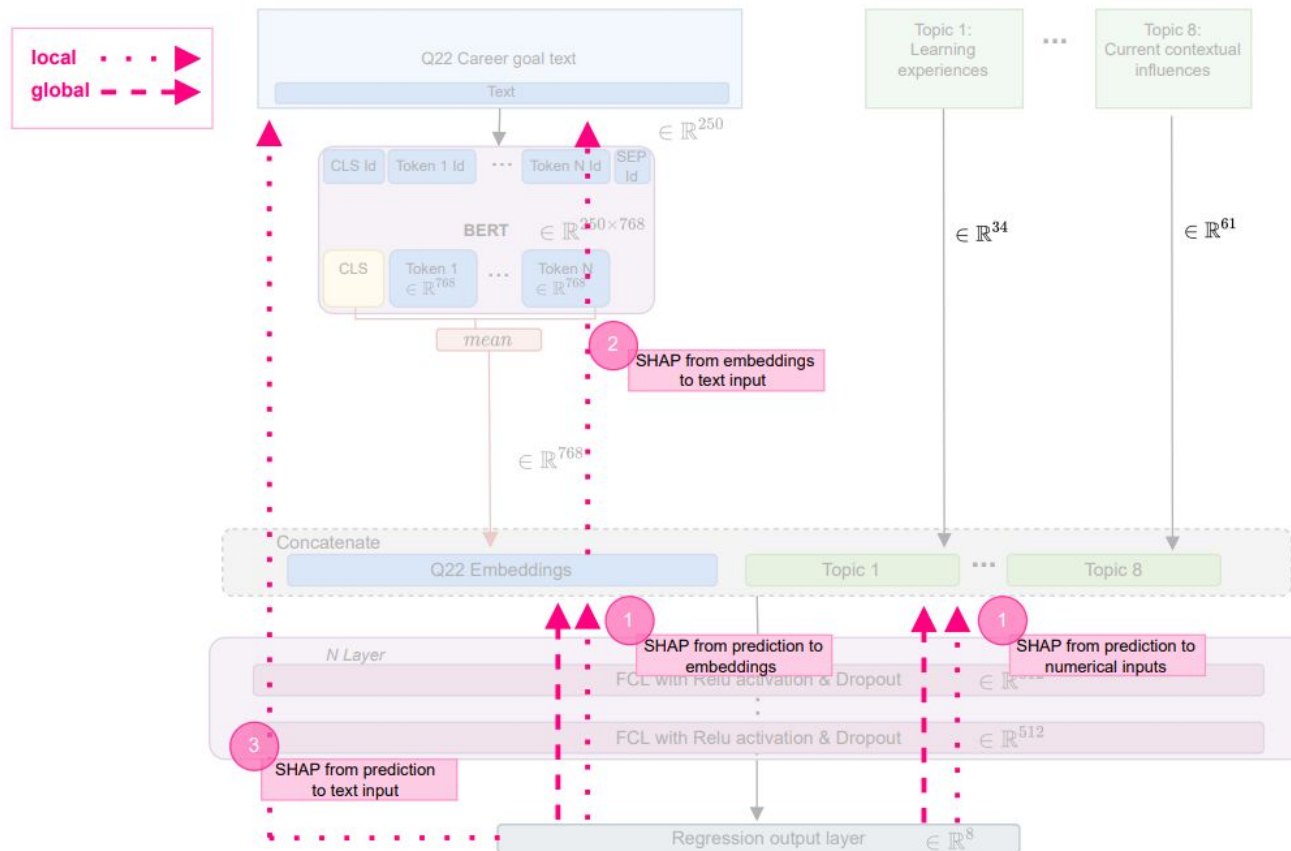| Architecture			T1	T2	T3	T4	T5	T6	T7	T8
Q22	no T	C	51.66	60.10	56.89	44.61	48.40	51.85	52.50	63.70
		R	53.82	51.36	50.82	58.75	43.63	42.24	46.71	62.40
Ins.	no T	C	46.66	38.20	40.68	42.20	50.21	43.48	46.08	42.69
		R	42.26	39.79	36.07	37.77	37.10	41.79	41.88	35.48
Q22+Ins.	no T	C	45.69	59.87	52.31	53.11	47.92	59.71	50.91	51.12
		R	**63.48**	47.46	50.59	45.20	41.06	41.29	39.86	58.73
No text	all T	C	50.85	53.34	61.03	52.40	57.03	**67.88**	61.02	72.65
		R	50.79	54.17	61.58	57.33	**58.94**	56.91	59.08	74.65
Q22	all T	C	63.01	60.74	**63.53**	**60.87**	50.77	57.76	54.90	73.64
		R	59.69	**63.64**	59.59	55.84	56.62	56.03	**62.66**	**76.23**
Ins.	all T	C	57.23	59.08	57.63	54.22	54.68	57.48	65.30	69.24
		R	48.33	47.00	51.49	50.45	48.92	46.12	58.49	72.47
Q22+Ins.	all T	C	58.71	57.52	59.86	55.51	55.16	58.56	62.40	71.55
		R	59.49	54.62	63.27	55.50	56.83	49.58	56.60	73.61

- Closed-ended questions and Q22 improve the model
- Inspire never helps.

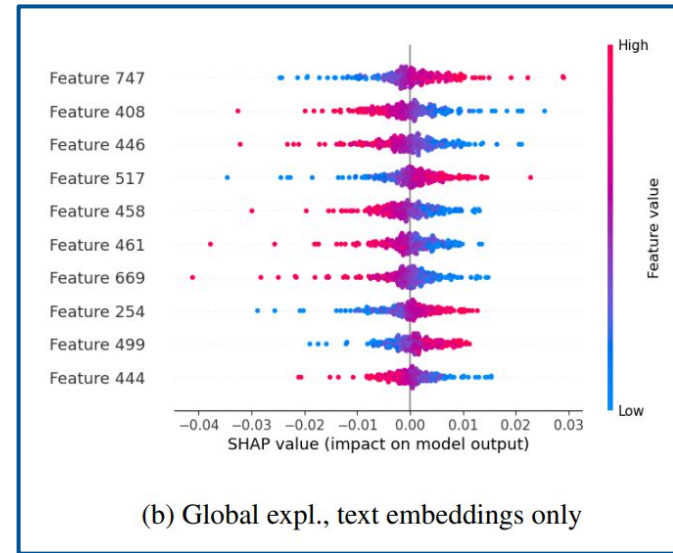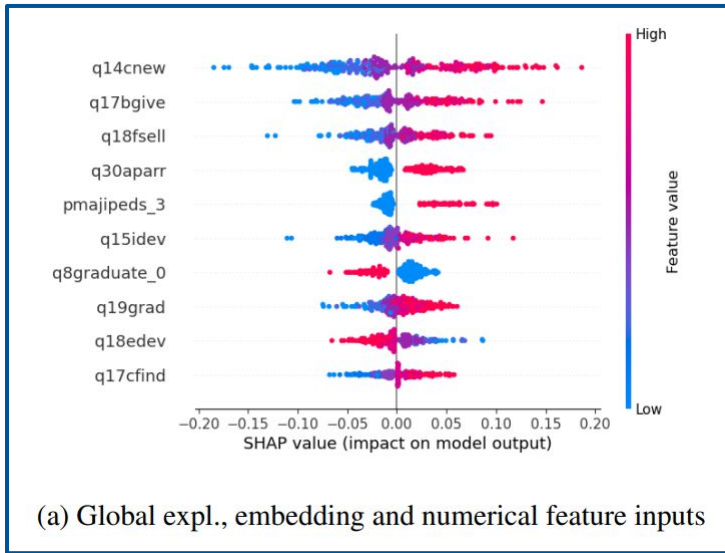- Simple aggregations of BERT embeddings work better than other encodings.

	CLS	Mean	BiLSTM	Embedding
C	60.66	**63.70**	37.88	49.66
R	53.96	62.40	58.18	50.27

Model Explanations – Feature Attribution

Model Explanations – Feature Attribution

(a) Global expl., embedding and numerical feature inputs

(b) Global expl., text embeddings only

1

From output to text and close-ended embeddings.

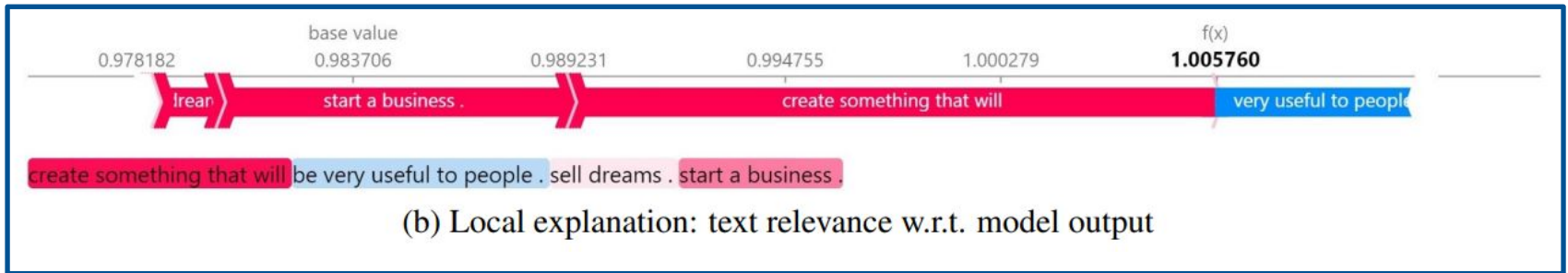(a) Local explanation: all features

(b) Local explanation: text embeddings only

10
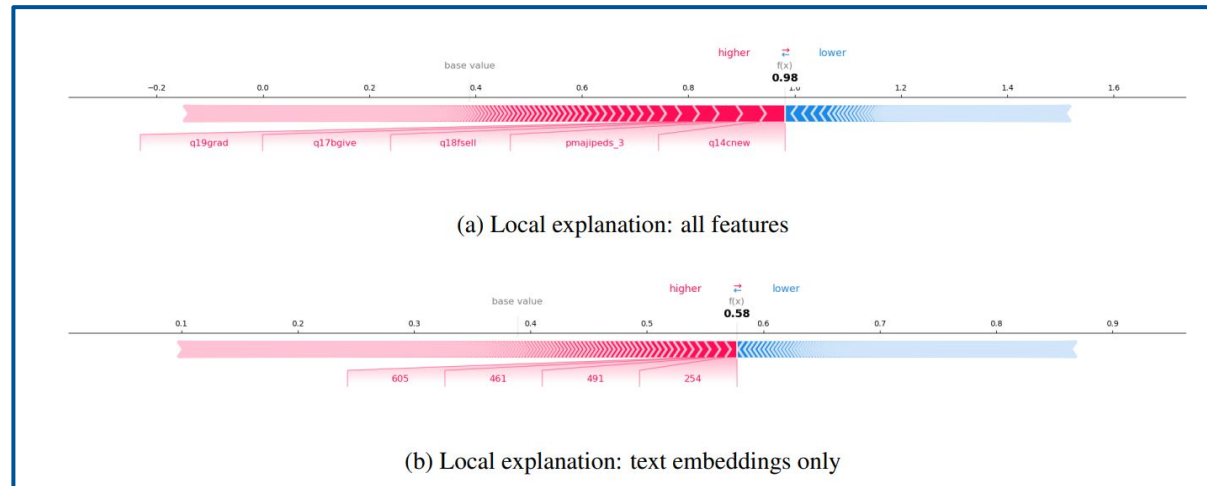
Model Explanations – Feature Attribution

2 From specific neuron to text input

(a) Local explanation: text relevance w.r.t. specific neuron

(b) Local explanation: text relevance w.r.t. model output
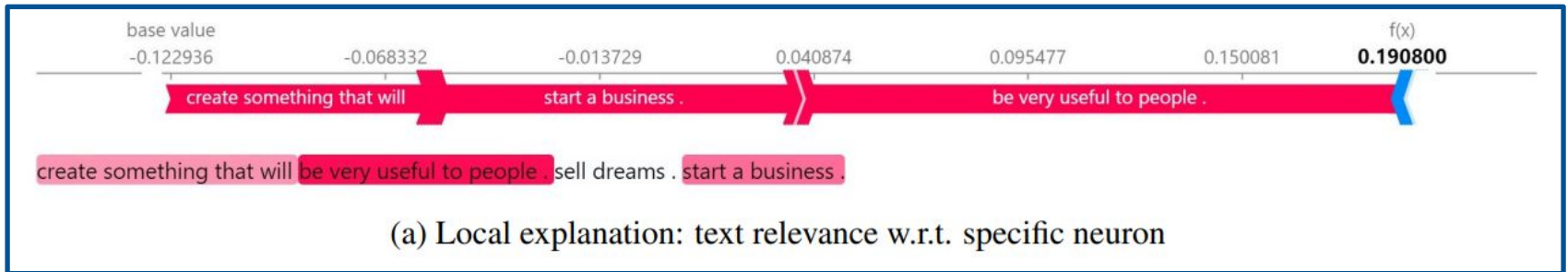
3 From final output to text input

Model Explanations – Learned Concepts

- ConceptSHAP allows the "unsupervised" extraction of concepts.

- For each concept we consider the 100 closest embeddings.

- Added context from corresponding sentences.

Concept	Nearest neighbors	Word cloud	
1	want to be successful. find a job my own business no thanks work hard ill do whatever. no concrete plans yet run my own business. no comments no idea	software (5), my (6), no (17), thanks (6), idea (5), company (5), have (6), work (7)	Lack of specific direction / broad plans
2	i want to attend medical school i plan to find a mechanical i am planning to be a product i plan on working as a i would like to go into manufacturing and continue education with goal i would first like to pursue doctoral degree having my own company i will be starting a career as an seeking law degree, to move into	I (63), my (13), work (10), plan (24), find (5), graduate (8), will (17), be (17), go (7), am (5), career (6), get (6), job (7), would (13), like (14), engineering (7), working (13)	Clear path, self-centeredness, determination
3	business learn skills, turn hobbies into i hope to run my own business start a company overseas earn experience in a small .. either go into industry or go gain experience in the industry. would like to get into management own company when i have the expertise my feet in a start up company early a good paying job at a company that	company (19), my (13), industry (14), work (22), engineering (18), start (12), I (21), business (6), go (12), own (6), job (9), pursue (5), will (8), plan (6), engineer (5), get (7), degree (6), masters (5), working (13), be (5)	Plan type, desired career / work place
4	school within the next two years. work there for 3 years in the next five years i hope work abroad at some point. 5 to 6 years. at least the next two years, i there for at least three years. tentative at that point in time i want in the next five years i field at least once.	at (19), my (13), go (12), industry (14), work (22), engineering (18), start (12), I (21), business (6), engineer (5), be (5), own (6), job (9), pursue (5), will (8), plan (6), get (7), degree (6), masters (5), working (13)	Time planning, distance from goal

Takeaways and Future Work

- Multi-modal + transformers works for jointly analyzing open- and closed-ended survey answers.

- XAI methods can be combined to get a holistic understanding of the model.

- Scales extremely well with the no. of participants

- Task performance highly depends on the data quality and the target variable.

- How to further improve performance?

- Experiments on different survey types.

Thank you!!

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