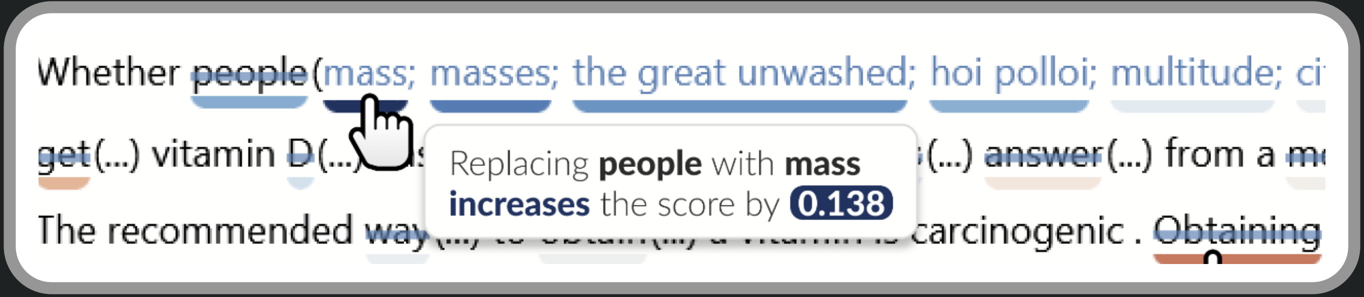
iScore

Visual Analytics for Interpreting How **Language Models** Automatically Score Summaries

Adam **Coscia**, Langdon **Holmes**, Wesley **Morris**, Joon Suh **Choi**, Scott **Crossley**, Alex **Endert**

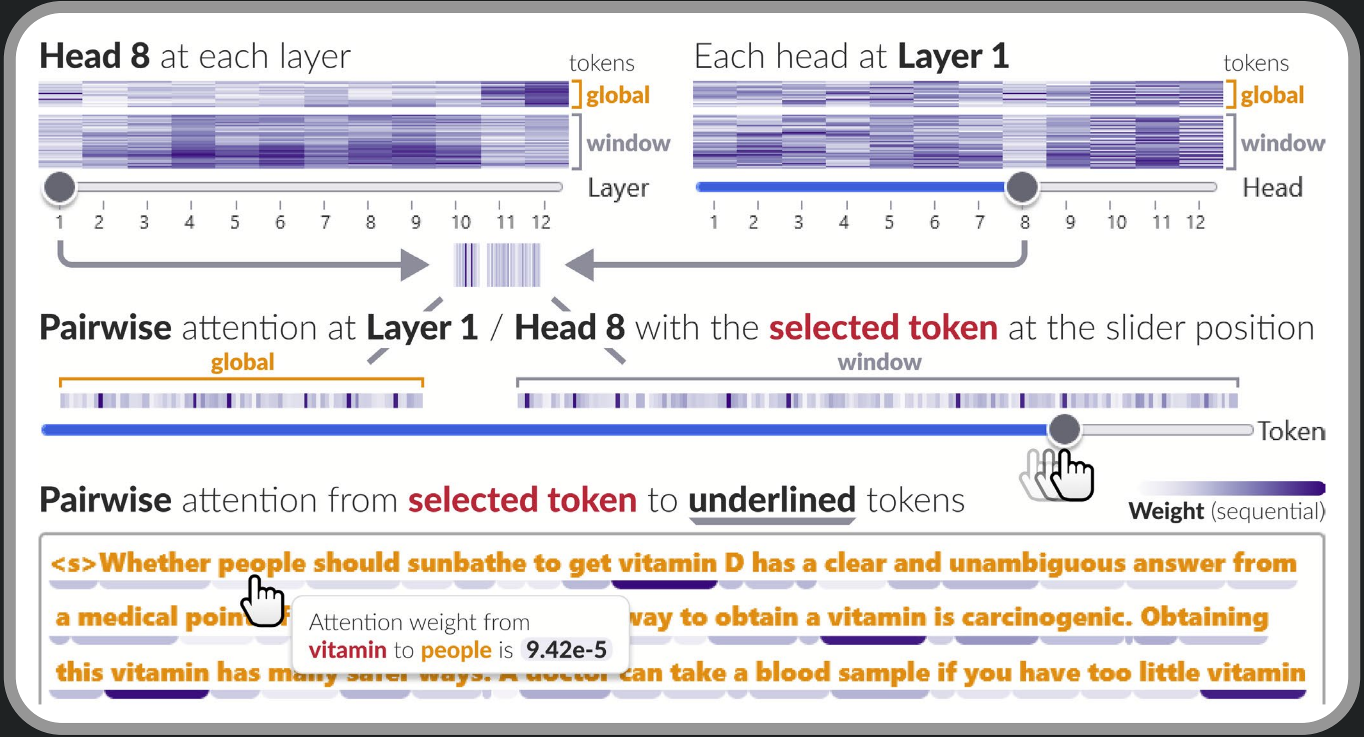


Whether ~~people~~ (mass; masses; the great unwashed; hoi polloi; multitude; ci

get(...) vitamin D(...) (...) answer(...) from a me

The recommended way (...) carcinogenic . Obtaining

Replacing **people** with **mass** **increases** the score by **0.138**



Pairwise attention at **Layer 1** / **Head 8** with the **selected token** at the slider position

Pairwise attention from **selected token** to **underlined** tokens

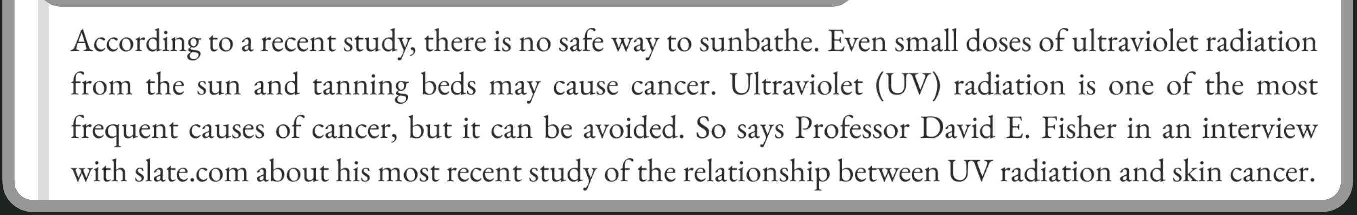
<s>Whether people should sunbathe to get vitamin D has a clear and unambiguous answer from a medical poin[...] way to obtain a vitamin is carcinogenic. Obtaining this vitamin has many safer ways. A doctor can take a blood sample if you have too little vitamin

Attention weight from **vitamin** to **people** is **9.42e-5**

Visual Analytics Lab @ Georgia Tech

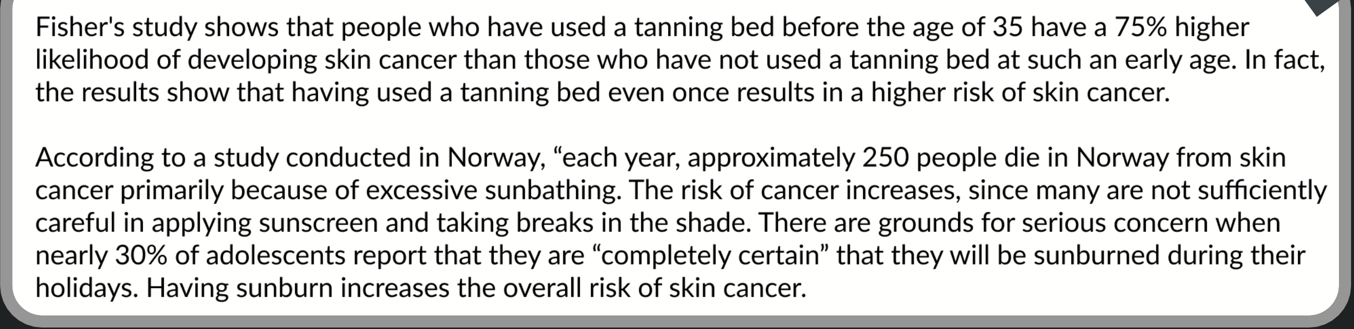
Summary writing helps students learn

Textbook Source



According to a recent study, there is no safe way to sunbathe. Even small doses of ultraviolet radiation from the sun and tanning beds may cause cancer. Ultraviolet (UV) radiation is one of the most frequent causes of cancer, but it can be avoided. So says Professor David E. Fisher in an interview with slate.com about his most recent study of the relationship between UV radiation and skin cancer.

Learner Summaries



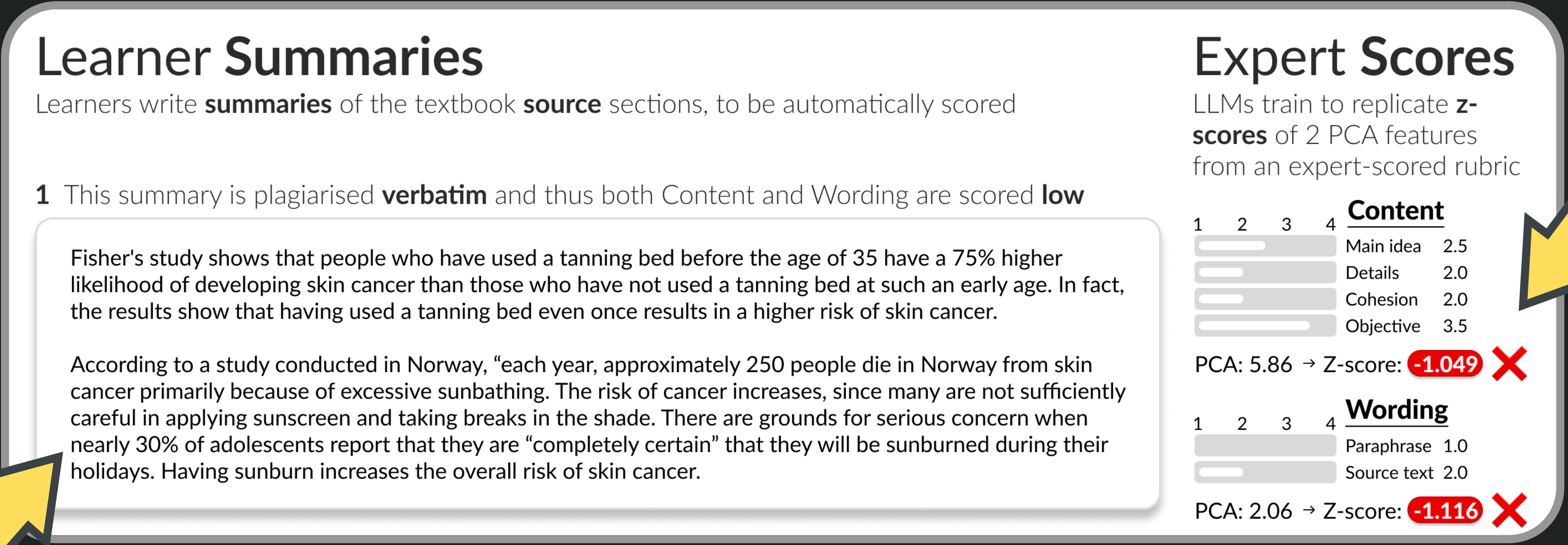
Fisher's study shows that people who have used a tanning bed before the age of 35 have a 75% higher likelihood of developing skin cancer than those who have not used a tanning bed at such an early age. In fact, the results show that having used a tanning bed even once results in a higher risk of skin cancer.

According to a study conducted in Norway, “each year, approximately 250 people die in Norway from skin cancer primarily because of excessive sunbathing. The risk of cancer increases, since many are not sufficiently careful in applying sunscreen and taking breaks in the shade. There are grounds for serious concern when nearly 30% of adolescents report that they are “completely certain” that they will be sunburned during their holidays. Having sunburn increases the overall risk of skin cancer.

Learning engineers trained LLMs that score student **summaries** of **textbook sources**

✅ **LLMs** can help score summary writing, making it scalable!

Unclear how LLMs score summaries



Learner Summaries

Learners write **summaries** of the textbook **source** sections, to be automatically scored

1 This summary is plagiarised **verbatim** and thus both Content and Wording are scored **low**

Fisher's study shows that people who have used a tanning bed before the age of 35 have a 75% higher likelihood of developing skin cancer than those who have not used a tanning bed at such an early age. In fact, the results show that having used a tanning bed even once results in a higher risk of skin cancer.

According to a study conducted in Norway, “each year, approximately 250 people die in Norway from skin cancer primarily because of excessive sunbathing. The risk of cancer increases, since many are not sufficiently careful in applying sunscreen and taking breaks in the shade. There are grounds for serious concern when nearly 30% of adolescents report that they are “completely certain” that they will be sunburned during their holidays. Having sunburn increases the overall risk of skin cancer.

Expert Scores

LLMs train to replicate **z-scores** of 2 PCA features from an expert-scored rubric

Content

Main idea	2.5
Details	2.0
Cohesion	2.0
Objective	3.5

PCA: 5.86 → Z-score: -1.049 ✗

Wording

Paraphrase	1.0
Source text	2.0

PCA: 2.06 → Z-score: -1.116 ✗

✗ Hard to characterize **relationship** between **summary** and **source**

✗ How will LLMs score **summaries** they have **never seen before?**

Our Goal

Build an **interactive** tool for **engineers** to evaluate **qualitative** relationships that LLMs have **learned** before deploying them!

How to **evaluate** LLMs at scale?

Interpreting LLM behaviors 🔍

- Hard to identify factors (synonyms, grammar, etc.)
- Track changes in LLM scores across summaries

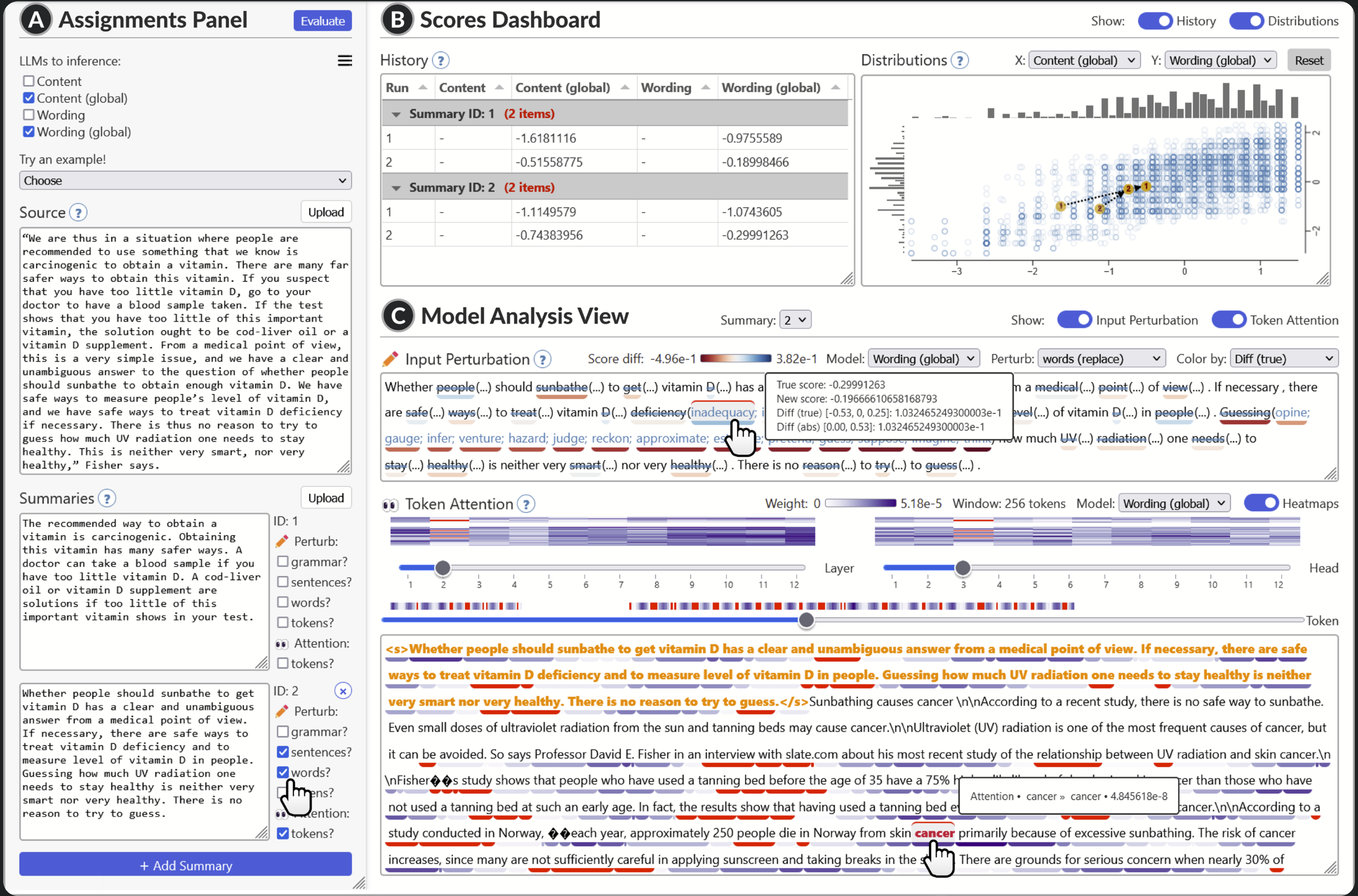
Analyzing LLM data 📈

- Too many tokens / parameters to analyze at once
- Unique architectures require new analysis tools

Our solution: iScore!

✅ **Run** multiple LLMs in real-time

✅ **Input** a source text and any number summaries



A Assignments Panel Evaluate

LLMs to inference:

- ☐ Content
- ☑ Content (global)
- ☐ Wording
- ☑ Wording (global)

Try an example!

Choose

Source ? Upload

```
"We are thus in a situation where people are
recommended to use something that we know is
carcinogenic to obtain a vitamin. There are many far
safer ways to obtain this vitamin. If you suspect
that you have too little vitamin D, go to your
doctor to have a blood sample taken. If the test
shows that you have too little of this important
vitamin, the solution ought to be cod-liver oil or a
vitamin D supplement. From a medical point of view,
this is a very simple issue, and we have a clear and
unambiguous answer to the question of whether people
should sunbathe to obtain enough vitamin D. We have
safe ways to measure people's level of vitamin D,
and we have safe ways to treat vitamin D deficiency
if necessary. There is thus no reason to try to
guess how much UV radiation one needs to stay
healthy. This is neither very smart, nor very
healthy," Fisher says.
```

Summaries ? Upload

```
The recommended way to obtain a
vitamin is carcinogenic. Obtaining
this vitamin has many safer ways. A
doctor can take a blood sample if you
have too little vitamin D. A cod-liver
oil or vitamin D supplement are
solutions if too little of this
important vitamin shows in your test.
```

ID: 1
Perturb:
- ☐ grammar?
- ☐ sentences?
- ☐ words?
- ☐ tokens?

Attention:
- ☐ tokens?

```
Whether people should sunbathe to get
vitamin D has a clear and unambiguous
answer from a medical point of view.
If necessary, there are safe ways to
treat vitamin D deficiency and to
measure level of vitamin D in people.
Guessing how much UV radiation one
needs to stay healthy is neither very
smart nor very healthy. There is no
reason to try to guess.
```

ID: 2 ×
Perturb:
- ☐ grammar?
- ☑ sentences?
- ☑ words?
- ☐ tokens?

Attention:
- ☑ tokens?

+ Add Summary

B Scores Dashboard Show: History Distributions

History ?

Run	Content	Content (global)	Wording	Wording (global)
Summary ID: 1 (2 items)				
1	-	-1.6181116	-	-0.9755589
2	-	-0.51558775	-	-0.18998466
Summary ID: 2 (2 items)				
1	-	-1.1149579	-	-1.0743605
2	-	-0.74383956	-	-0.29991263

Distributions ? X: Content (global) Y: Wording (global) Reset

C Model Analysis View Summary: 2 Show: Input Perturbation Token Attention

Input Perturbation ? Score diff: -4.96e-1 3.82e-1 Model: Wording (global) Perturb: words (replace) Color by: Diff (true)

Whether ~~people~~(...) should ~~sunbathe~~(...) to ~~get~~(...) vitamin ~~D~~(...) has a … m a ~~medical~~(...) ~~point~~(...) of ~~view~~(...) . If necessary , there are ~~safe~~(...) ~~ways~~(...) to ~~treat~~(...) vitamin ~~D~~(...) ~~deficiency~~(inadequacy; i … ~~evel~~(...) of vitamin ~~D~~(...) in ~~people~~(...) . ~~Guessing~~(opine; gauge; infer; venture; hazard; judge; reckon; approximate; es … e; pretend; guess; suppose; imagine; think) w much ~~UV~~(...) ~~radiation~~(...) one ~~needs~~(...) to ~~stay~~(...) ~~healthy~~(...) is neither very ~~smart~~(...) nor very ~~healthy~~(...) . There is no ~~reason~~(...) to ~~try~~(...) to ~~guess~~(...) .

True score: -0.29991263
New score: -0.19666610658168793
Diff (true) [-0.53, 0, 0.25]: 1.032465249300003e-1
Diff (abs) [0.00, 0.53]: 1.032465249300003e-1

Token Attention ? Weight: 0 5.18e-5 Window: 256 tokens Model: Wording (global) Heatmaps

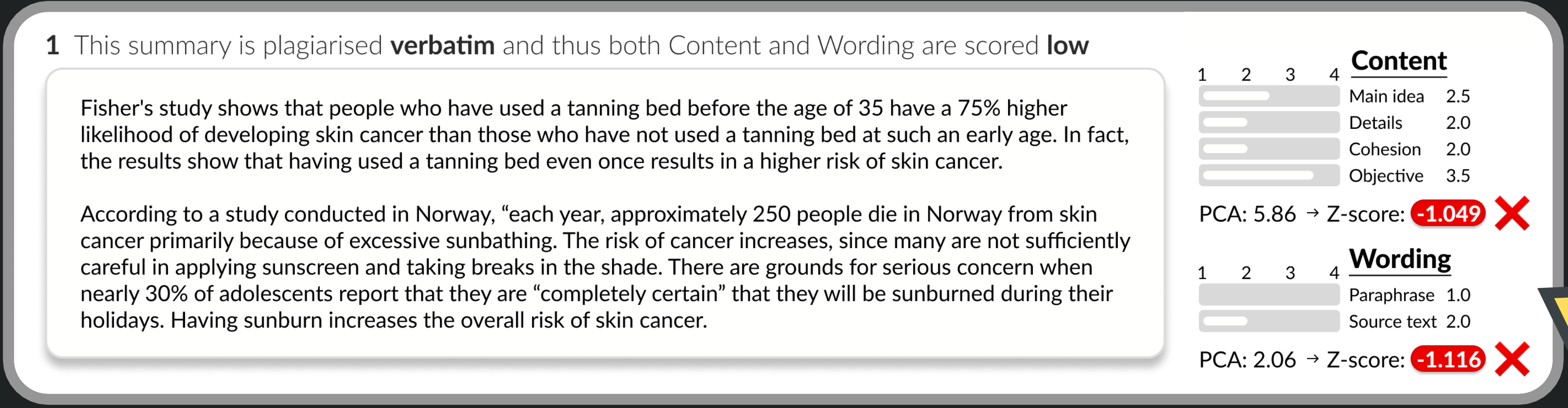
<s>Whether people should sunbathe to get vitamin D has a clear and unambiguous answer from a medical point of view. If necessary, there are safe ways to treat vitamin D deficiency and to measure level of vitamin D in people. Guessing how much UV radiation one needs to stay healthy is neither very smart nor very healthy. There is no reason to try to guess.</s>Sunbathing causes cancer \n\nAccording to a recent study, there is no safe way to sunbathe. Even small doses of ultraviolet radiation from the sun and tanning beds may cause cancer.\n\nUltraviolet (UV) radiation is one of the most frequent causes of cancer, but it can be avoided. So says Professor David E. Fisher in an interview with slate.com about his most recent study of the relationship between UV radiation and skin cancer.\n \nFisher��s study shows that people who have used a tanning bed before the age of 35 have a 75% h … er than those who have not used a tanning bed at such an early age. In fact, the results show that having used a tanning bed e … ancer.\n\nAccording to a study conducted in Norway, ��each year, approximately 250 people die in Norway from skin **cancer** primarily because of excessive sunbathing. The risk of cancer increases, since many are not sufficiently careful in applying sunscreen and taking breaks in the s … There are grounds for serious concern when nearly 30% of

Attention • cancer » cancer • 4.845618e-8

Track ✅ changes in scores over time

Perturb ✅ model inputs and **analyze** model outputs

Example: Why are scores **different?**



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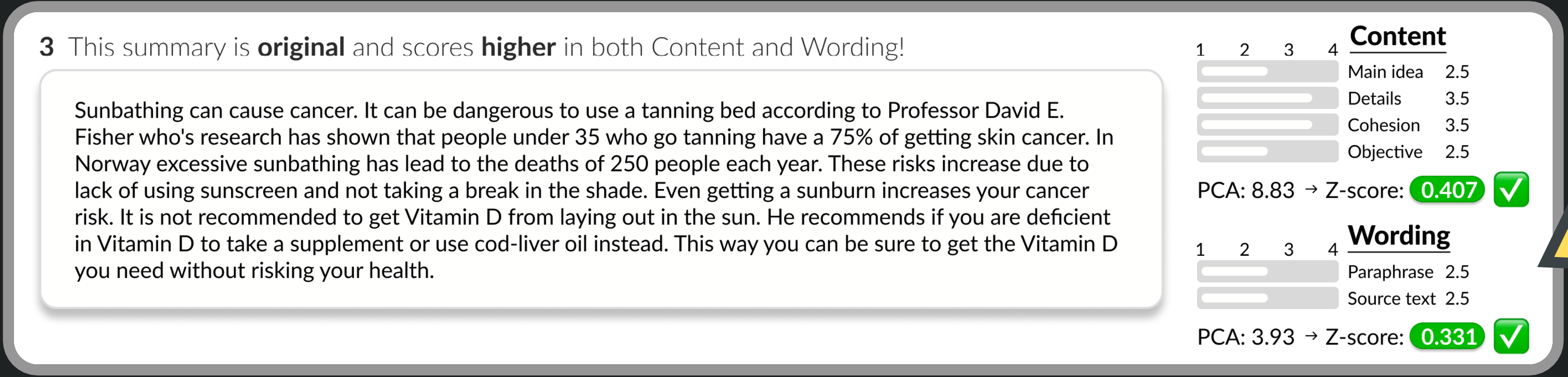


3 This summary is **original** and scores **higher** in both Content and Wording!

Sunbathing can cause cancer. It can be dangerous to use a tanning bed according to Professor David E. Fisher who's research has shown that people under 35 who go tanning have a 75% of getting skin cancer. In Norway excessive sunbathing has lead to the deaths of 250 people each year. These risks increase due to lack of using sunscreen and not taking a break in the shade. Even getting a sunburn increases your cancer risk. It is not recommended to get Vitamin D from laying out in the sun. He recommends if you are deficient in Vitamin D to take a supplement or use cod-liver oil instead. This way you can be sure to get the Vitamin D you need without risking your health.

Content

Main idea	2.5
Details	3.5
Cohesion	3.5
Objective	2.5

PCA: 8.83 → Z-score: 0.407 ✓

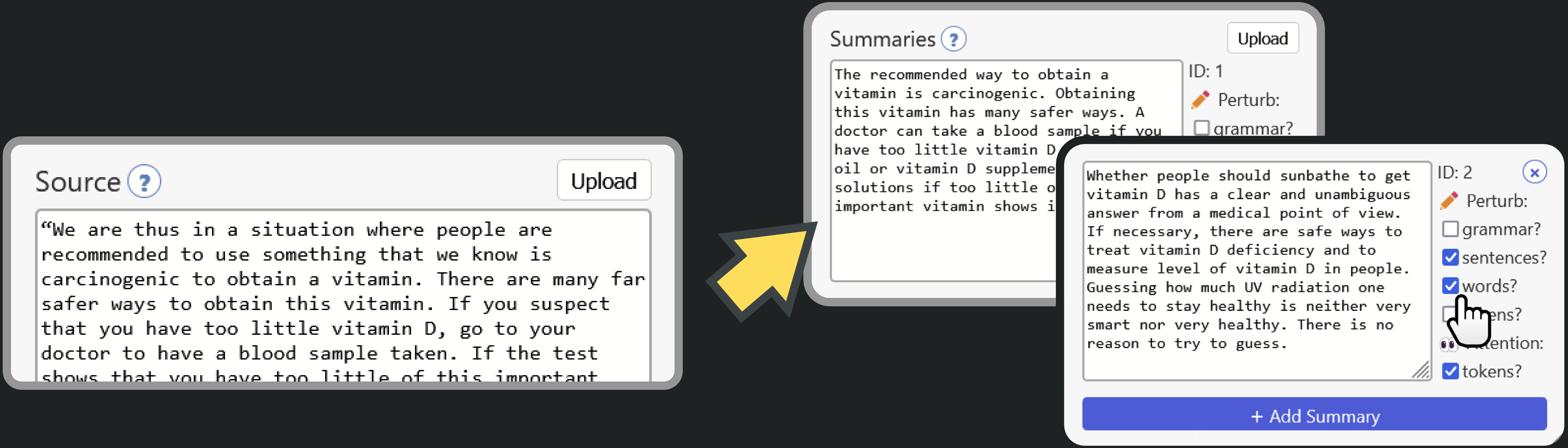
Wording

Paraphrase	2.5
Source text	2.5

PCA: 3.93 → Z-score: 0.331 ✓

✗ How to **identify** decision criteria, **compare** summaries, **analyze** weights?

Assignments Panel



Source ?

“We are thus in a situation where people are recommended to use something that we know is carcinogenic to obtain a vitamin. There are many far safer ways to obtain this vitamin. If you suspect that you have too little vitamin D, go to your doctor to have a blood sample taken. If the test shows that you have too little of this important

Summaries ?

The recommended way to obtain a vitamin is carcinogenic. Obtaining this vitamin has many safer ways. A doctor can take a blood sample if you have too little vitamin D
oil or vitamin D suppleme
solutions if too little o
important vitamin shows i

ID: 1

Perturb:

□ grammar?

Whether people should sunbathe to get vitamin D has a clear and unambiguous answer from a medical point of view. If necessary, there are safe ways to treat vitamin D deficiency and to measure level of vitamin D in people. Guessing how much UV radiation one needs to stay healthy is neither very smart nor very healthy. There is no reason to try to guess.

ID: 2

Perturb:

□ grammar?

☑ sentences?

☑ words?

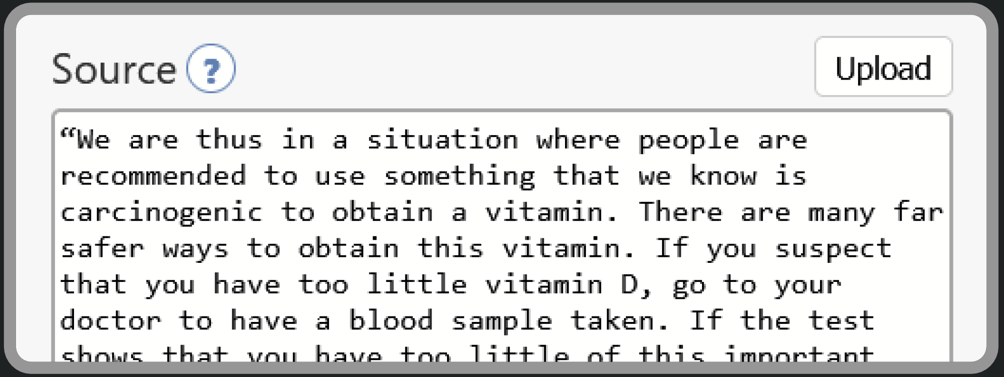
□ ens?

entention:

☑ tokens?

- Input a **source** text and multiple **summaries** to compare

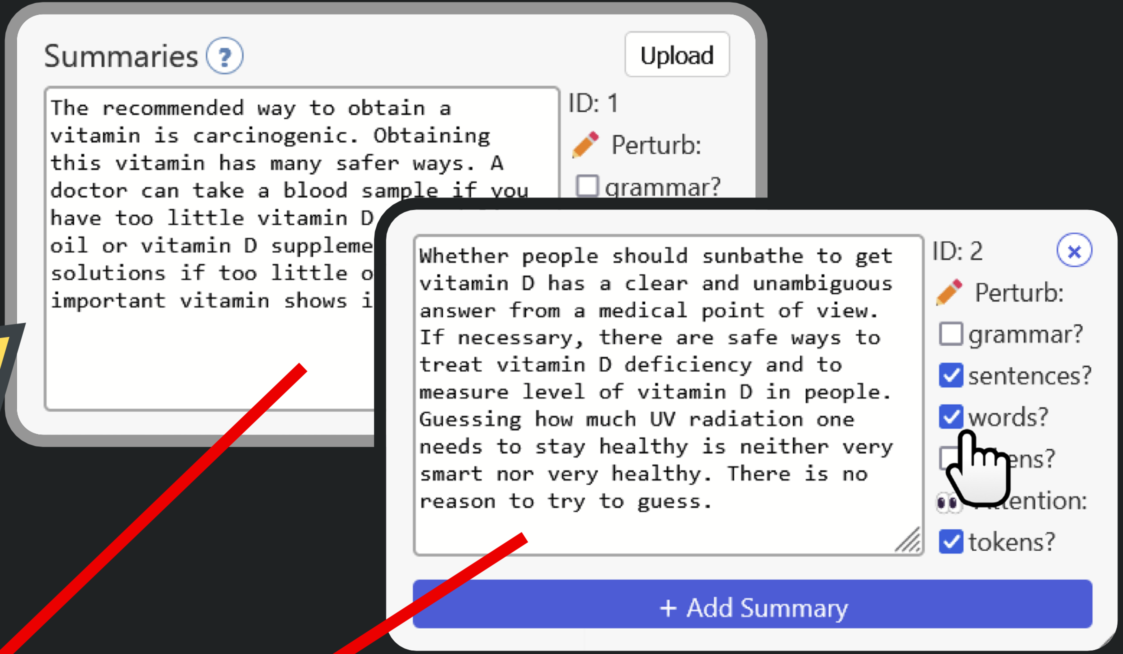
Assignments Panel



Source ?

Upload

"We are thus in a situation where people are recommended to use something that we know is carcinogenic to obtain a vitamin. There are many far safer ways to obtain this vitamin. If you suspect that you have too little vitamin D, go to your doctor to have a blood sample taken. If the test shows that you have too little of this important



Summaries ?

Upload

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ID: 1

Perturb:

☐ grammar?

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ID: 2

Perturb:

☐ grammar?

☑ sentences?

☑ words?

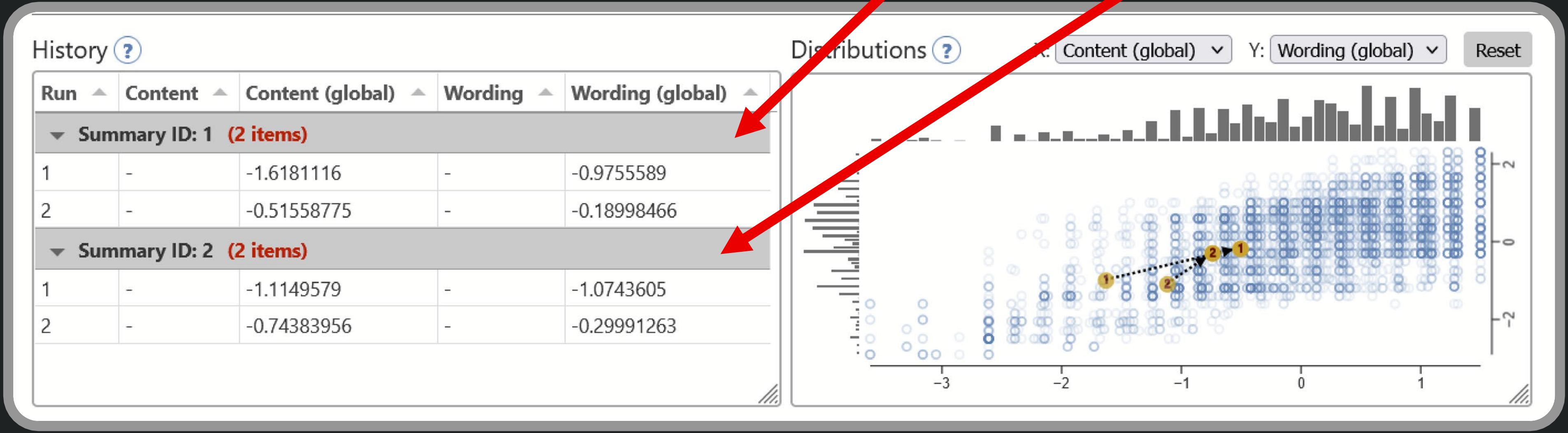
ens?

ention:

☑ tokens?

+ Add Summary

Scores Dashboard



History ?

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Distributions ?

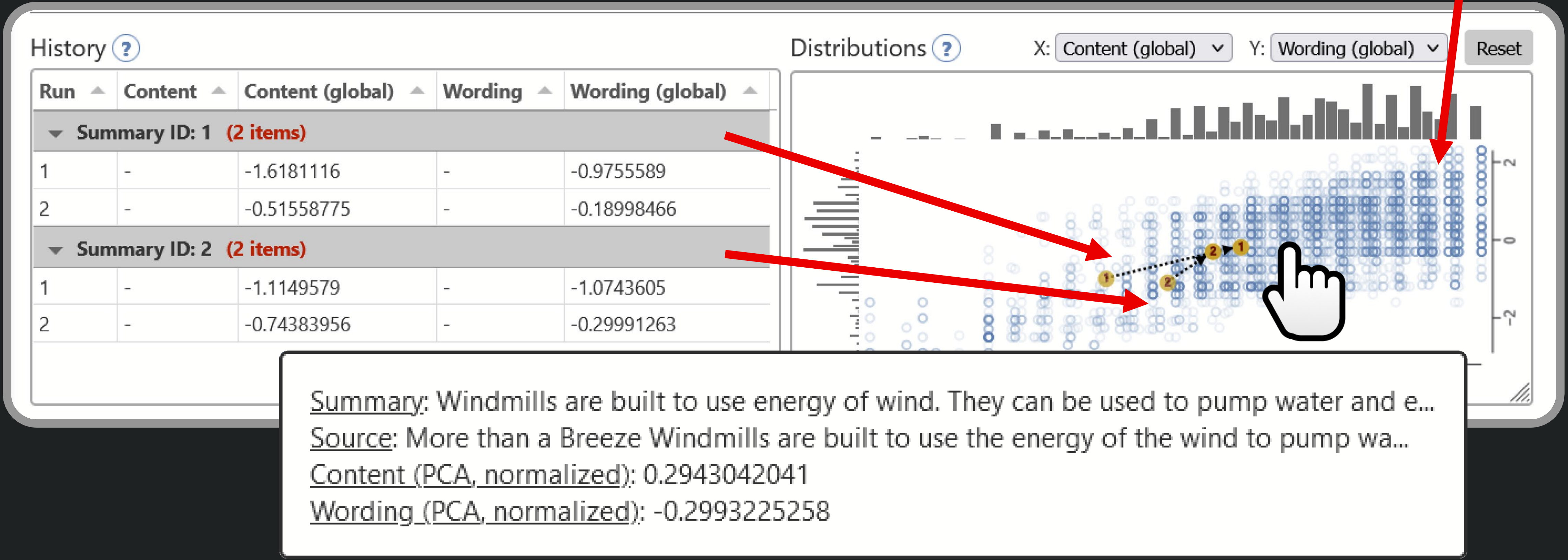
X: Content (global)

Y: Wording (global)

Reset

Scores Dashboard

LLM training data (expert-scored)



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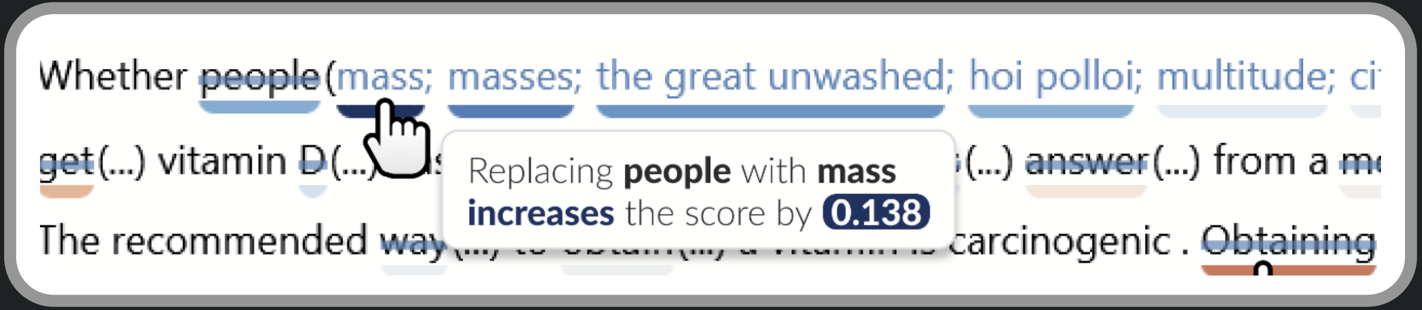
1	-	-1.1149579	-	-1.0743605
2	-	-0.74383956	-	-0.29991263

Summary: Windmills are built to use energy of wind. They can be used to pump water and e...
Source: More than a Breeze Windmills are built to use the energy of the wind to pump wa...
Content (PCA, normalized): 0.2943042041
Wording (PCA, normalized): -0.2993225258

- Track changes in scores across **runs** (i.e., each time the LLMs are run)
- Show LLM scores in context of **expert training data**

Qualitative Model Analysis

Input Perturbation



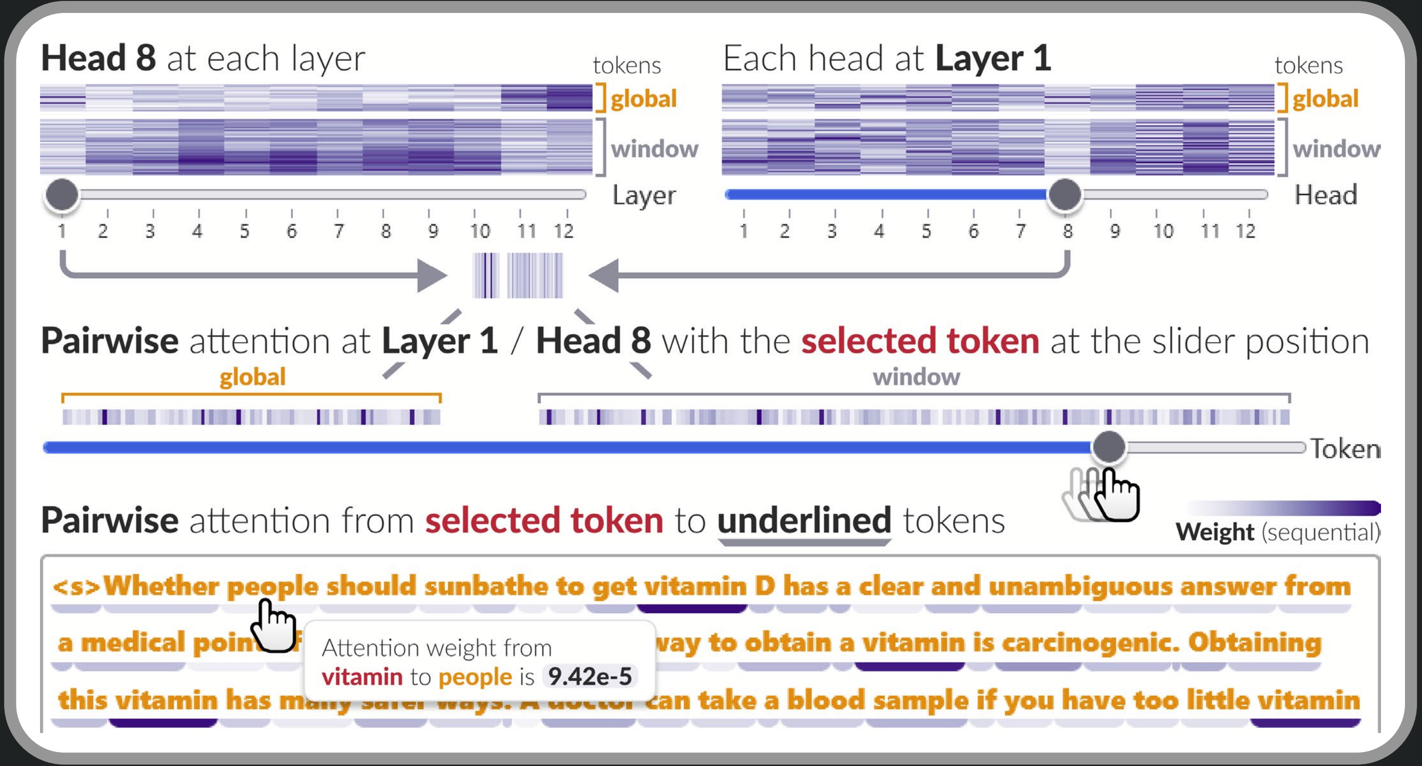
Whether ~~people~~(mass; masses; the great unwashed; hoi polloi; multitude; ci

~~get~~(...) vitamin ~~D~~(...) s (...) ~~answer~~(...) from a m

The recommended ~~way~~(...) carcinogenic . ~~Obtaining~~

Replacing **people** with **mass** **increases** the score by **0.138**

Attention Visualization



<s>Whether people should sunbathe to get vitamin D has a clear and unambiguous answer from a medical poin... ...way to obtain a vitamin is carcinogenic. Obtaining this vitamin has many safer ways. A doctor can take a blood sample if you have too little vitamin

Attention weight from **vitamin** to **people** is **9.42e-5**

Input Perturbation

Token / word / sentence revisions are **automatically** applied to the summary and **re-scored**. The revisions are underlined and colored by the **difference** in score between the original summary and the revised summary. In the example summary below, the original Content score is **0.682**

Original

This is a bad summary.

Content : -0.186

Wording : -0.425

Perturbation

This is a ~~bad~~ **better** summary ~~.~~**!**

✅ **Content** : 0.223 **(+0.409)** ▲

❌ **Wording** : -0.599 **(-0.174)** ▼

Input Perturbation

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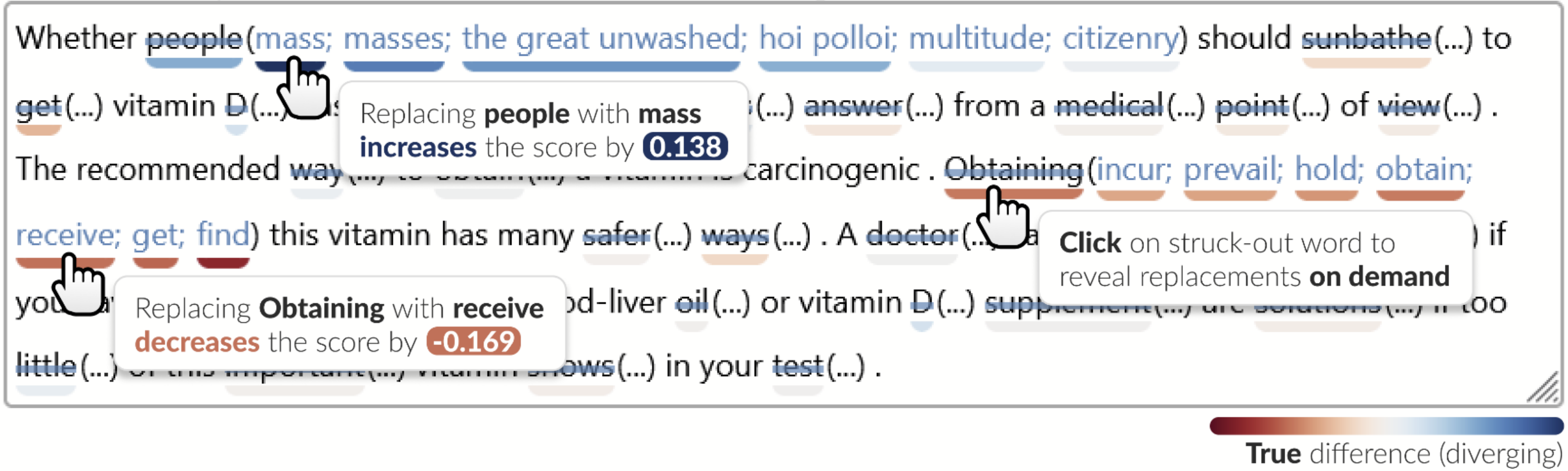
Words - Replace words with **synonyms** using word tokenizer and WordNet



Whether ~~people~~(mass; masses; the great unwashed; hoi polloi; multitude; citizenry) should ~~sunbathe~~(...) to

~~get~~(...) vitamin ~~D~~(...) (...) ~~answer~~(...) from a ~~medical~~(...) ~~point~~(...) of ~~view~~(...) .

The recommended ~~way~~ carcinogenic . ~~Obtaining~~(incur; prevail; hold; obtain;

receive; get; find) this vitamin has many ~~safer~~(...) ~~ways~~(...) . A ~~doctor~~( ) if

you od-liver ~~oil~~(...) or vitamin ~~D~~(...) too

~~little~~(...) ows(...) in your ~~test~~(...) .

Replacing **people** with **mass** **increases** the score by **0.138**

Click on struck-out word to reveal replacements **on demand**

Replacing **Obtaining** with **receive** **decreases** the score by **-0.169**

Input Perturbation

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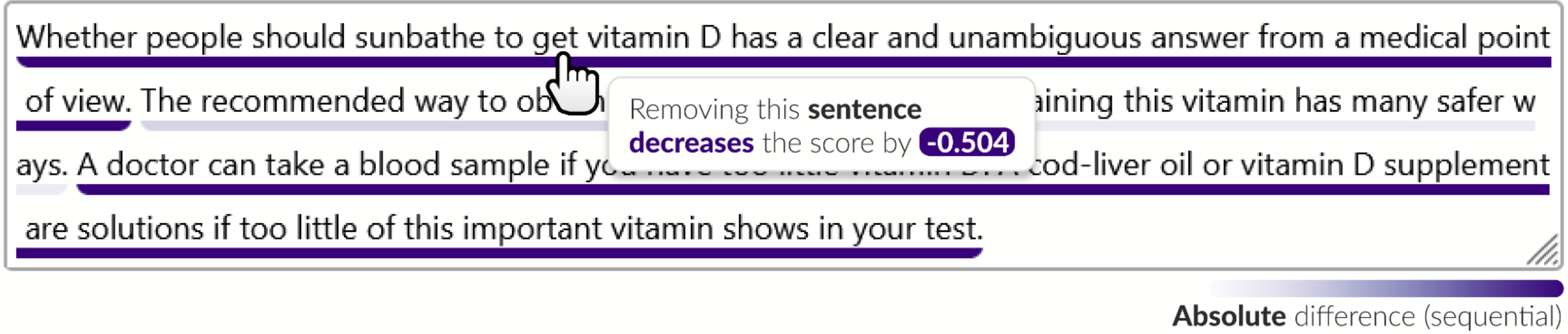
Sentences - Remove sentences using sentence tokenizer



Whether people should sunbathe to get vitamin D has a clear and unambiguous answer from a medical point
of view. The recommended way to ob
aining this vitamin has many safer w
ays. A doctor can take a blood sample if yo
cod-liver oil or vitamin D supplement
are solutions if too little of this important vitamin shows in your test.

Removing this **sentence** **decreases** the score by **-0.504**

Absolute difference (sequential)

Input Perturbation

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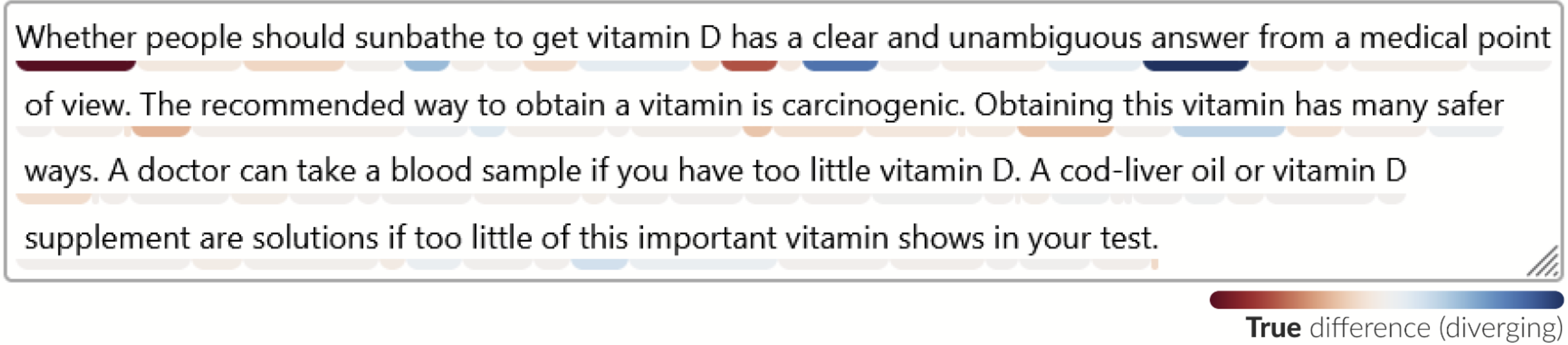
Tokens - Mask tokens using LLM tokenizer



Whether people should sunbathe to get vitamin D has a clear and unambiguous answer from a medical point of view. The recommended way to obtain a vitamin is carcinogenic. Obtaining this vitamin has many safer ways. A doctor can take a blood sample if you have too little vitamin D. A cod-liver oil or vitamin D supplement are solutions if too little of this important vitamin shows in your test.

Input Perturbation

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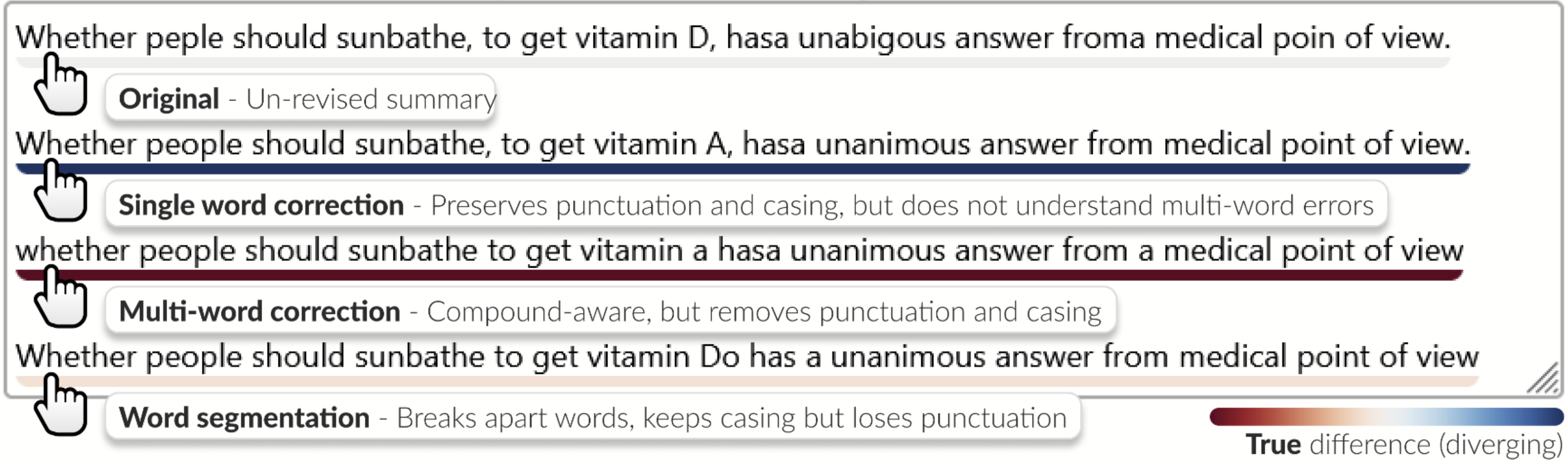
Grammar - Correct **spelling** automatically using SymSpellPy



Whether peple should sunbathe, to get vitamin D, hasa unabigous answer froma medical poin of view.

Original - Un-revised summary

Whether people should sunbathe, to get vitamin A, hasa unanimous answer from medical point of view.

Single word correction - Preserves punctuation and casing, but does not understand multi-word errors

whether people should sunbathe to get vitamin a hasa unanimous answer from a medical point of view

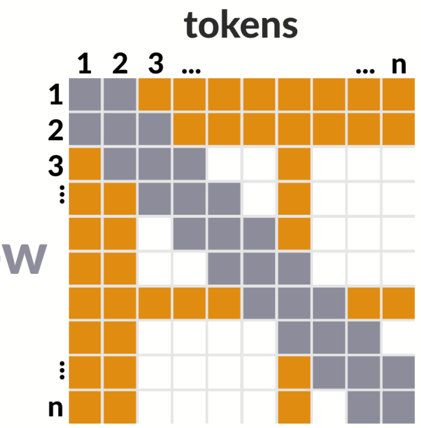
Multi-word correction - Compound-aware, but removes punctuation and casing

Whether people should sunbathe to get vitamin Do has a unanimous answer from medical point of view

Word segmentation - Breaks apart words, keeps casing but loses punctuation

Token Attention

Transformers independently arrange **heads** in sequential **layers**. Heads compute weights called **attention** between all pairs of tokens for the next layer. Longformers use a unique **sliding attention window** to compute weights between tokens only inside the window. **Global** tokens are assigned attention between all other tokens, as usual.



How are Longformers different from other LLMs?

- Can process **4096 token inputs** (more than most LLMs!)
- Use **sliding window** (i.e., not every token has attention!)

❌ How to **scale** visualizations between layers, heads, and window?

Token Attention

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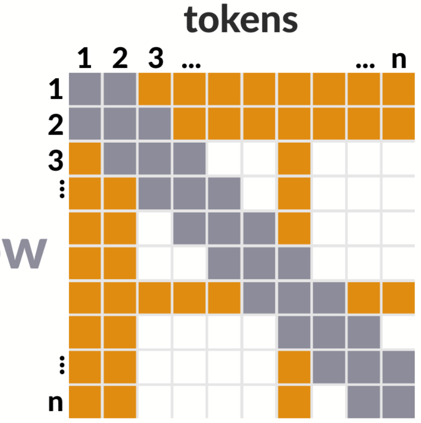
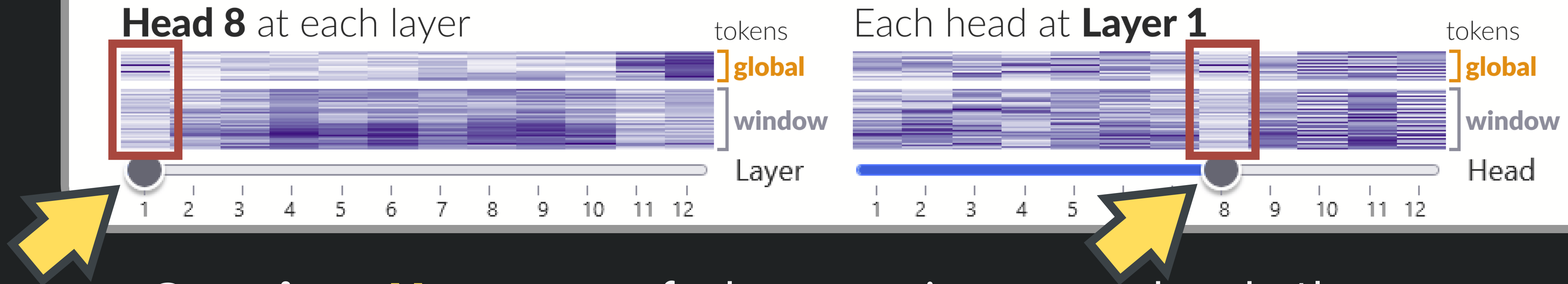


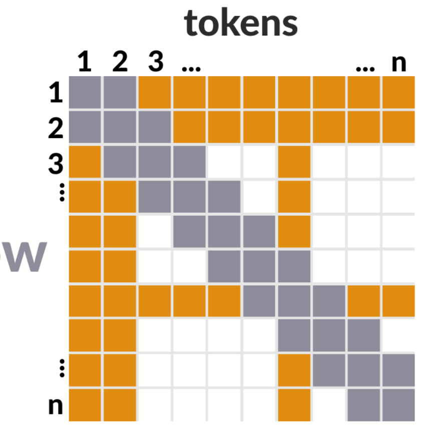


- **Overview : Heat maps** of token attentions across heads / layers

✅ Use **fluid interaction** principles!

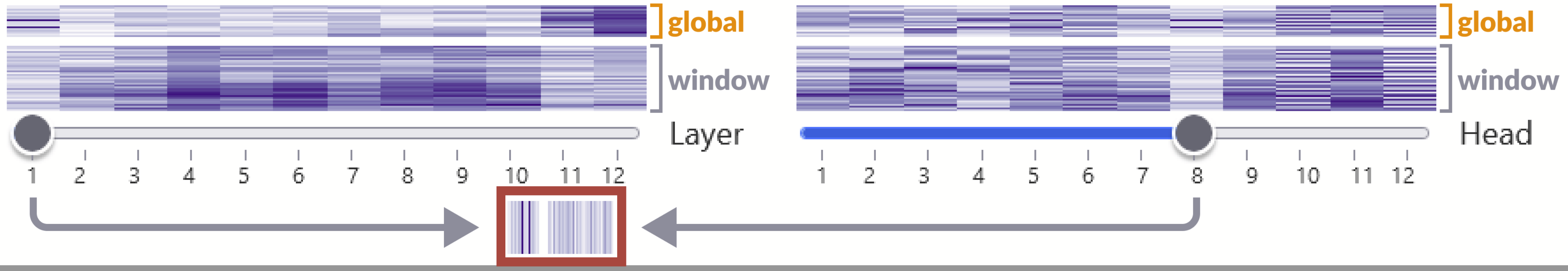
Token Attention

Transformers independently arrange **heads** in sequential **layers**. Heads compute weights called **attention** between all pairs of tokens for the next layer. Longformers use a unique **sliding attention window** to compute weights between tokens only inside the window. **Global** tokens are assigned attention between all other tokens, as usual.

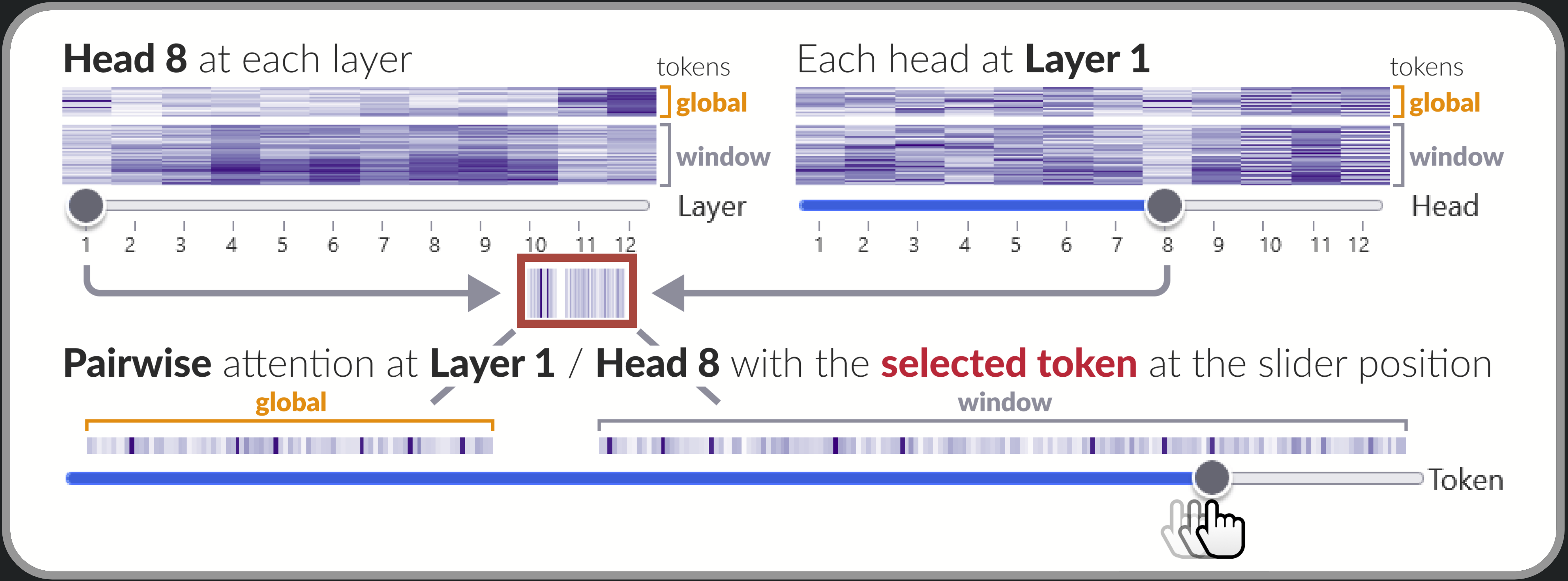


Head 8 at each layer

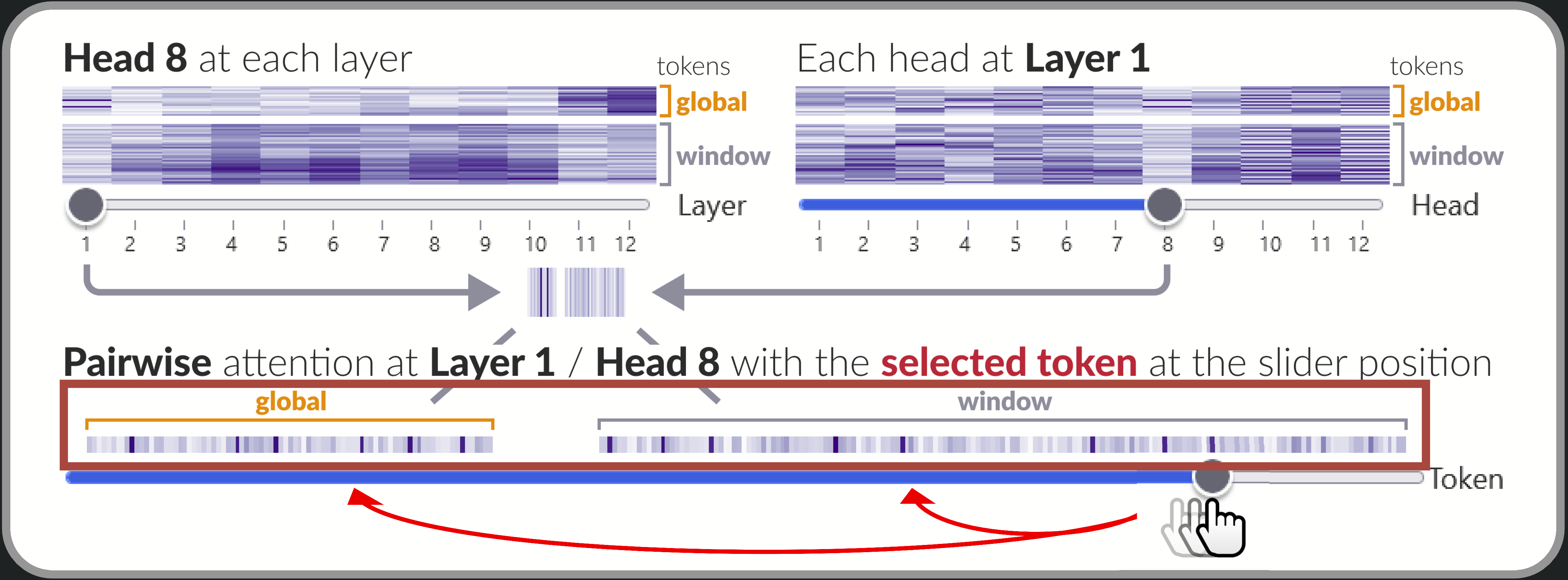
Each head at **Layer 1**



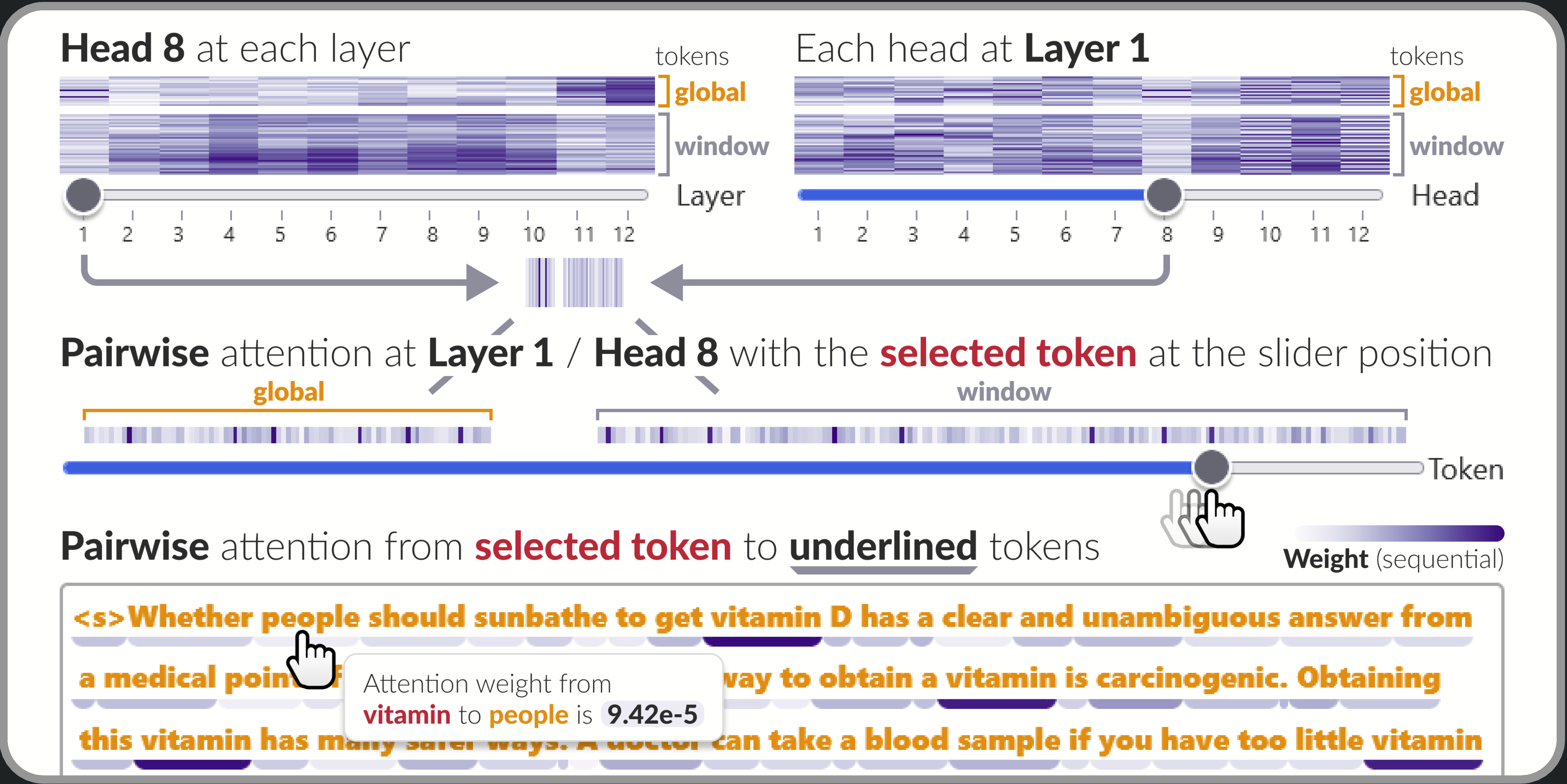
- **Drill down :** Select heat map at single head + layer



- **Drill down : Rug plot** of token attentions at single head + layer



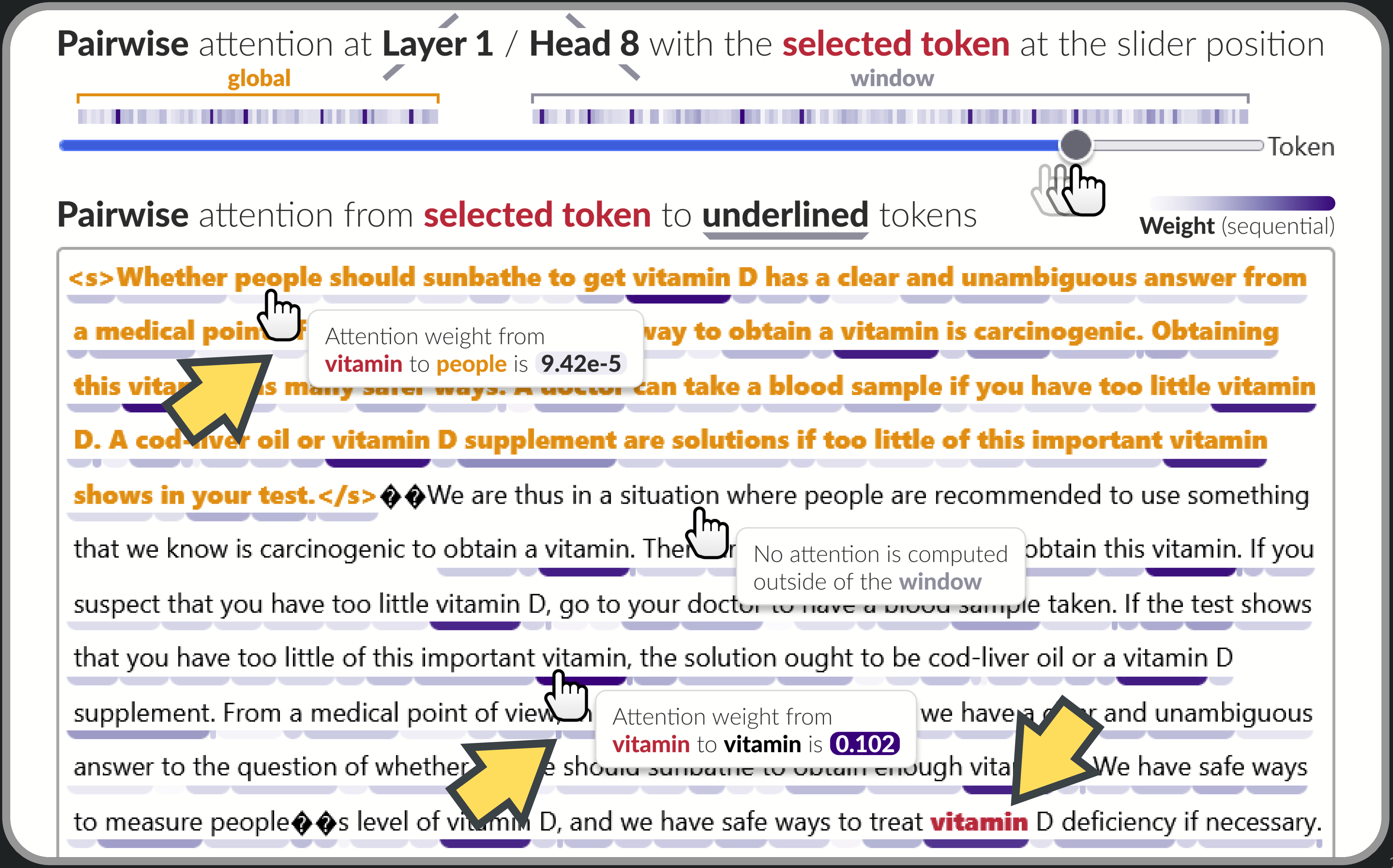
- **Drill down : Rug plot** of token attentions at single head + layer
    - Attention from **selected token** to all other **tokens**



<s>Whether people should sunbathe to get vitamin D has a clear and unambiguous answer from a medical poin f way to obtain a vitamin is carcinogenic. Obtaining this vitamin has many safer ways. A doctor can take a blood sample if you have too little vitamin

Attention weight from **vitamin** to **people** is **9.42e-5**

- **Details : Underline** attention weights and **compare** tokens inline!



Pairwise attention at **Layer 1** / **Head 8** with the **selected token** at the slider position

Pairwise attention from **selected token** to **underlined** tokens

<s>Whether people should sunbathe to get vitamin D has a clear and unambiguous answer from a medical poin f … way to obtain a vitamin is carcinogenic. Obtaining this vita … s many safer ways. A doctor can take a blood sample if you have too little vitamin D. A cod-liver oil or vitamin D supplement are solutions if too little of this important vitamin shows in your test.</s>��We are thus in a situation where people are recommended to use something that we know is carcinogenic to obtain a vitamin. Ther r … obtain this vitamin. If you suspect that you have too little vitamin D, go to your doctor to have a blood sample taken. If the test shows that you have too little of this important vitamin, the solution ought to be cod-liver oil or a vitamin D supplement. From a medical point of view, … we have a … r and unambiguous answer to the question of whether … e should sunbathe to obtain enough vita … We have safe ways to measure people��s level of vitamin D, and we have safe ways to treat **vitamin** D deficiency if necessary.

Attention weight from **vitamin** to **people** is **9.42e-5**

No attention is computed outside of the **window**

Attention weight from **vitamin** to **vitamin** is **0.102**

Case Study

Discovered **surprising** LLM behaviors

- Removing first sentence **dropped scores** by 90%
- LLMs **weight punctuation** high in final layers
- Visually seeing **lack of attention** in summary text

Insights led to **re-training** LLM

- Improved **model accuracy** in training by 3%!

Expert Interviews

“How did iScore enable you to…”

Understand LLMs?

Evaluate LLMs?

Trust LLMs?

Expert Interviews

Understanding LLMs

- How decisions are made from LLM parameters
- Whether LLMs use context around words
- “Seeing” what is going on inside models

> *“There is always anxiety or tension around **whether an outcome is just a fluke**.”*

> *“While **[topic sentences]** could be important for writing summaries, **it may not be the way the model is operating**.”*

Expert Interviews

Evaluating LLMs

- Closing the loop of model development
- Quickly profile the best-performing models
- Generate examples to add to LLM training data

> *"I used Input Perturbations to see* ***whether adversarial attacks can trick models****."*

> *"I often train* ***multiple models*** *for a task and* ***want to compare them****. I like to switch between the models* ***on the fly****."*

Expert Interviews

Trusting LLMs

- Several requirements
  - Reproducibility
  - Address biases
  - Show limitations
  - Include teachers

> *"The aspects of iScore that can test variations* ***[Assignments Panel, Input Perturbations]*** *allow us to* ***demonstrate what happens*** *with changes in summaries. This can broadly allow us to* ***improve trust in these systems****."*

Implications for Design

Structure evaluation using visual hierarchies

- **Upload / Compare** multiple text/LLMs at once
- **Arrange** for comparison (group by topic, etc.)
- **Visualize** “ground truth” training data to compare

Scale interpretability methods to large inputs

- **Fluid interaction** b/w levels of aggregation
- **Inline visuals** reveal semantic/syntactic patterns

Future Work

Responsible and Ethical AI for Education

- Stereotypes / biases, Multilingual, Tools for Teachers

LLM Generalizability

- LLM-generated Summaries (GPT, LLaMa, Claude)

Mixed Methods LLM Evaluation

- Gradient Attribution (SHAP), Hypothesis Testing (χ^2)

iScore

Visual Analytics for Interpreting How **Language Models** Automatically Score Summaries

Adam **Coscia**, Langdon **Holmes**, Wesley **Morris**, Joon Suh **Choi**, Scott **Crossley**, Alex **Endert**

Whether people (mass; masses; the great unwashed; hoi polloi; multitude; ci

get(...) vitamin D(...) Replacing **people** with **mass** (...) answer(...) from a m

a medical poin... Attention weight from vitamin to people is 9.42e-5 ...way to obtain a vitamin is carcinogenic. Obtaining

this vitamin has many safer ways. A doctor can take a blood sample if you have too little vitamin

All code and models are **open source!**

bit.ly/iscore-paper

Visual Analytics Lab
@ Georgia Tech