Self Attention and Transformers

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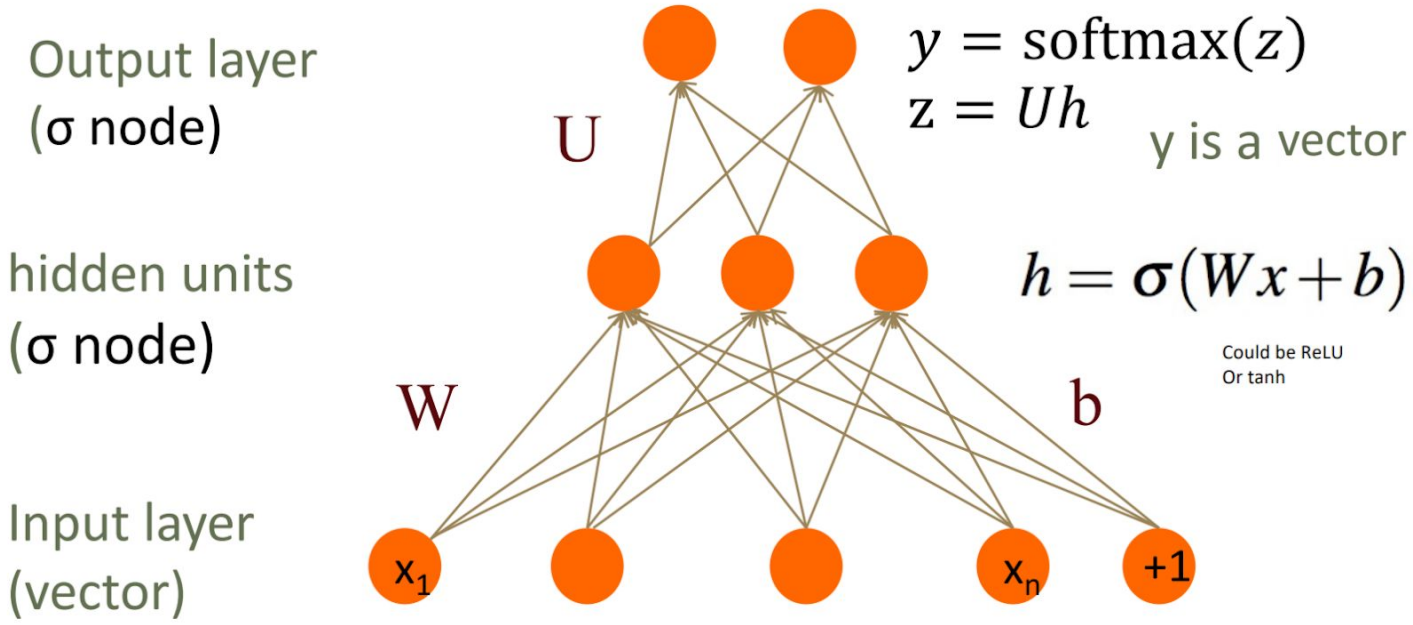
Inspired by slides from Emma Strubell, Graham Neubig

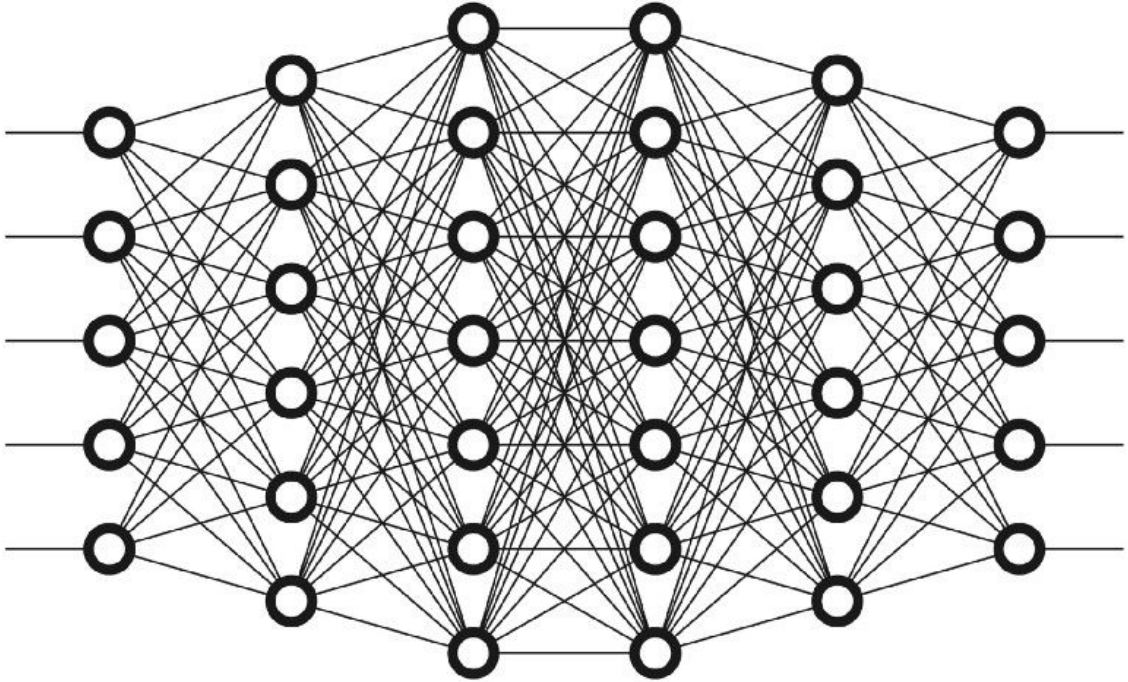
Readings

- Attention Is All You Need
- The Illustrated Transformer
- The Annotated Transformer
- Language Modeling with Transformers and PyTorch

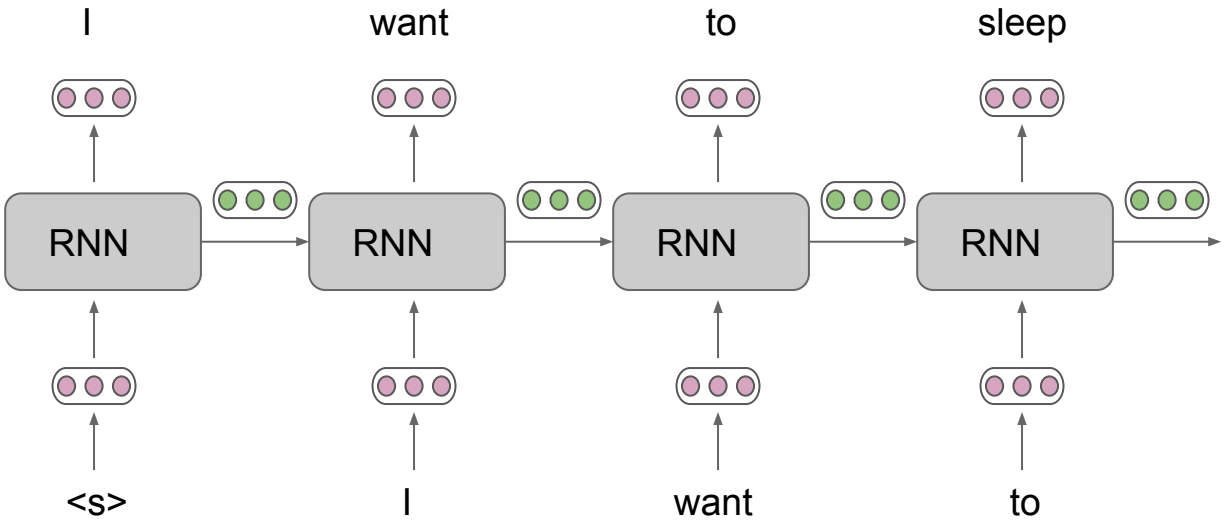
Recap - 2 Layer MLP



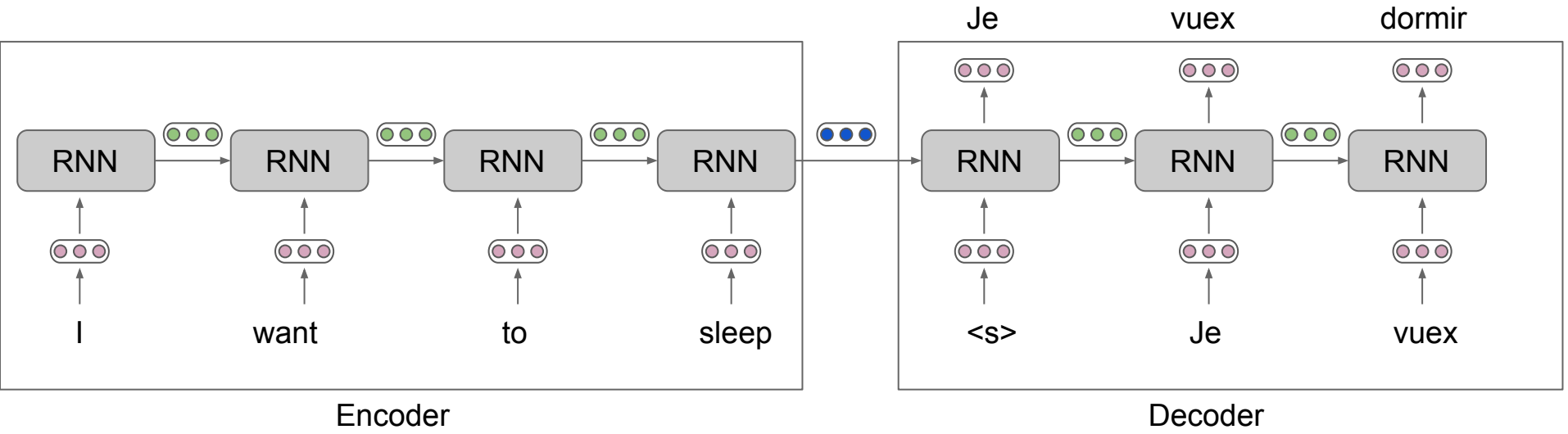
Deep MLP



Recurrent Neural Networks - RNNs



Encoder-Decoder Models



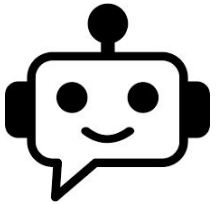
Limitations

- Long Range Dependencies
- Gradient vanishing / explosion
- Long time to converge
- Expensive computation

Long Range Dependencies

I'm want to watch Wicked! How does the weather in NYC look next week?

It looks sunny with some light rain during the weekend.



Oh! But I don't have a rain jacket :(Is there a store nearby?

There's a marshall's a mile away. They have the navy blue jacket you have been eyeing for a while!

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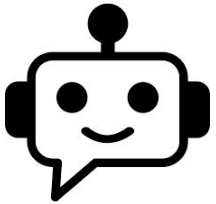
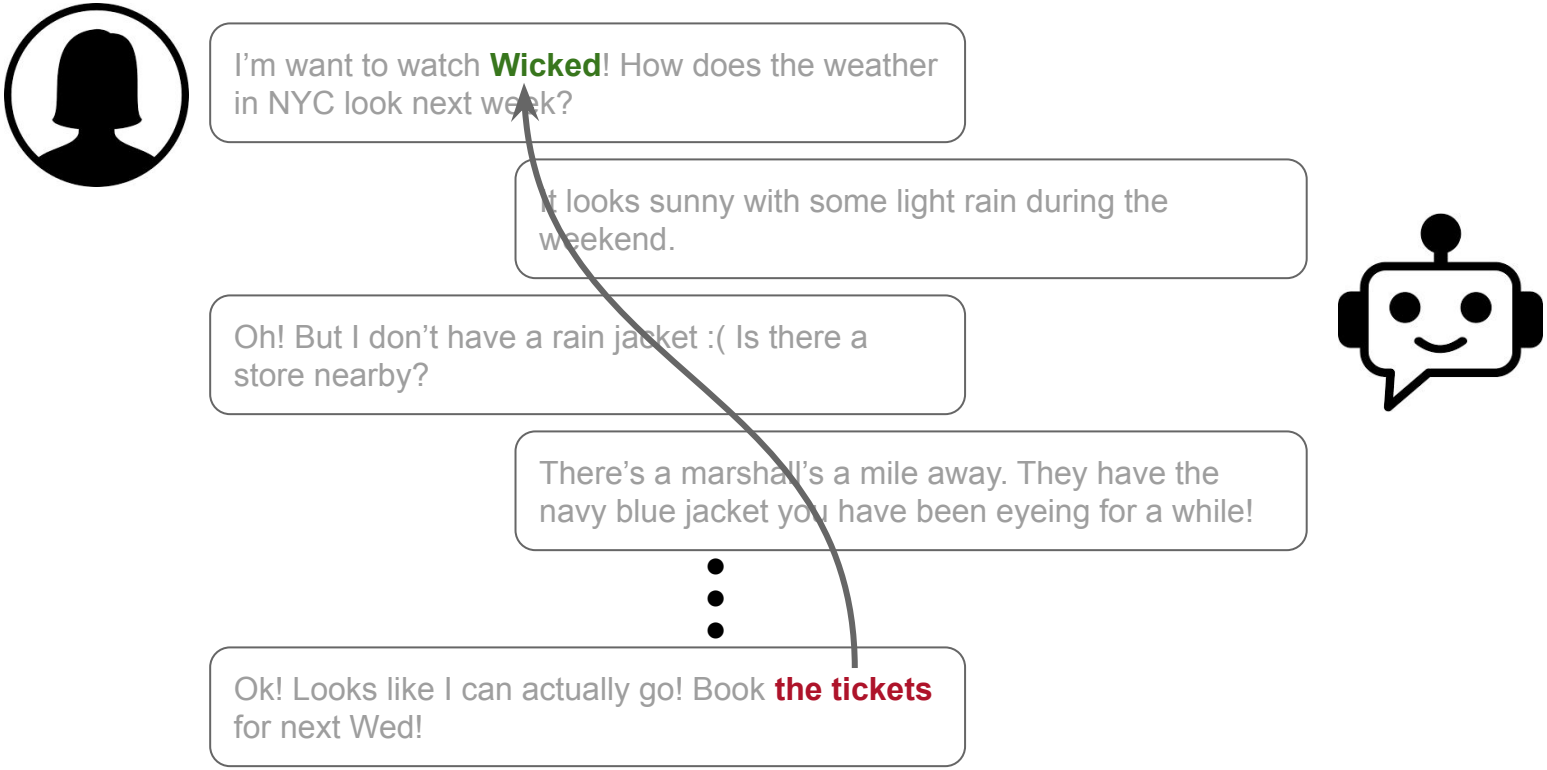


Oh! But I don't have a rain jacket :(Is there a store nearby?

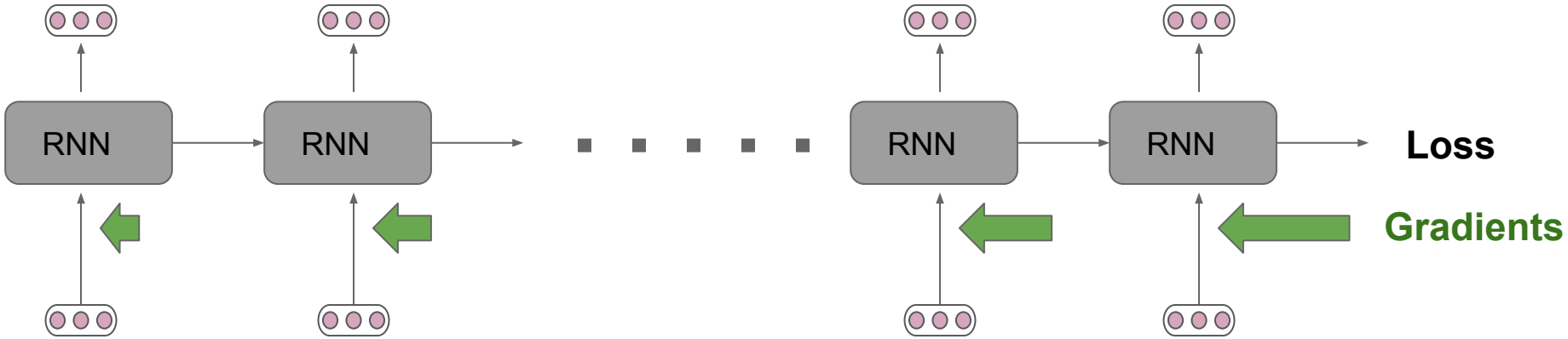
There's a marshall's a mile away. They have the navy blue jacket you have been eyeing for a while!

Ok! Looks like I can actually go! Book **the tickets** for next Wed!

Long Range Dependencies



Gradient vanishing / explosion



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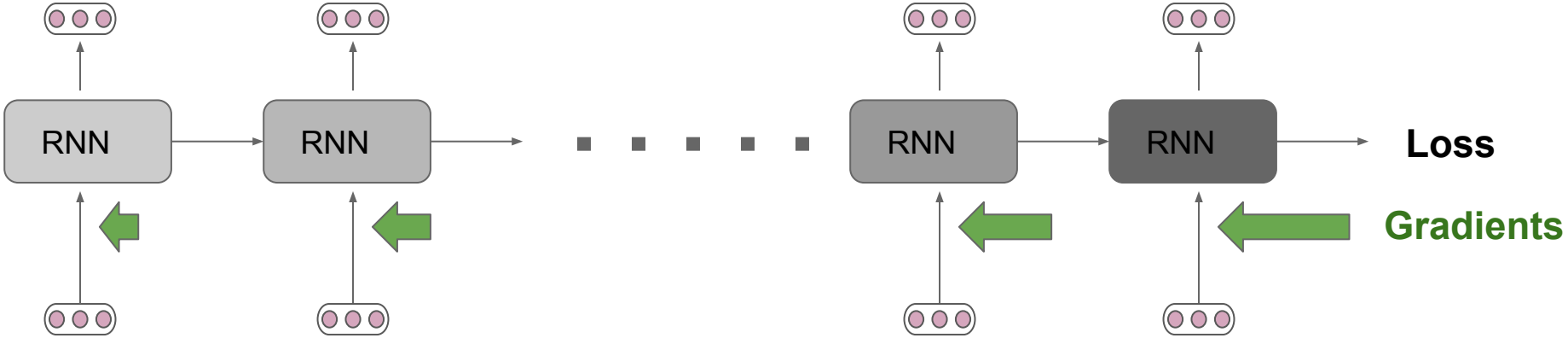

Limitations

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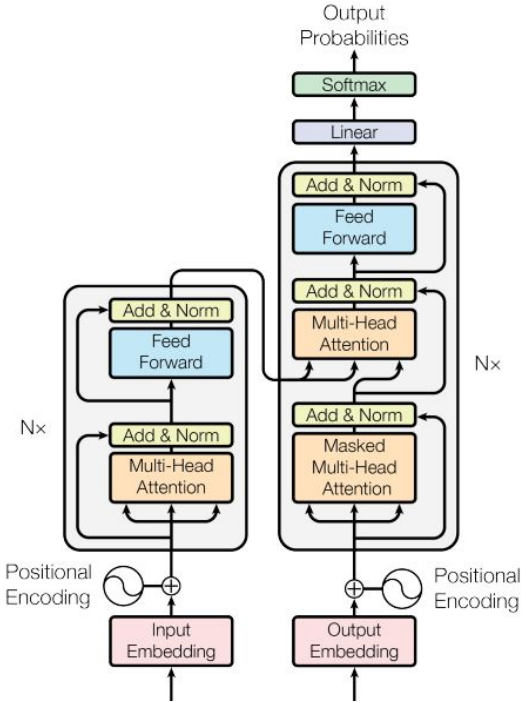
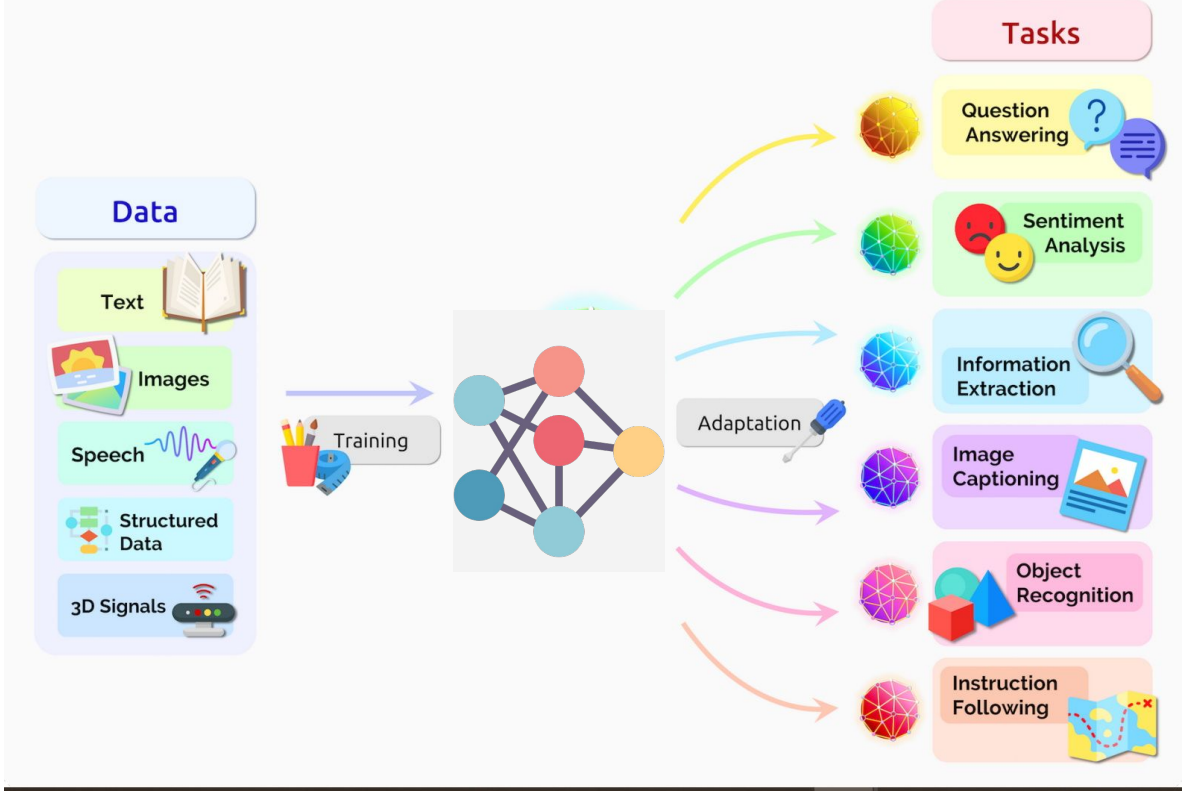
Transformer Model



Google Research

Attention is all you need (Vaswani et.al, 2017)

Wide Applications



https://blogs.nvidia.com/blog/2022/03/25/what-is-a-transformer-model/

Real World Impact

Machine Translation

Smart Assistants

Search Engines

Auto Transcription

google-research/
pegasus

Summarization Engines

Health Record Analysis

and many more ....

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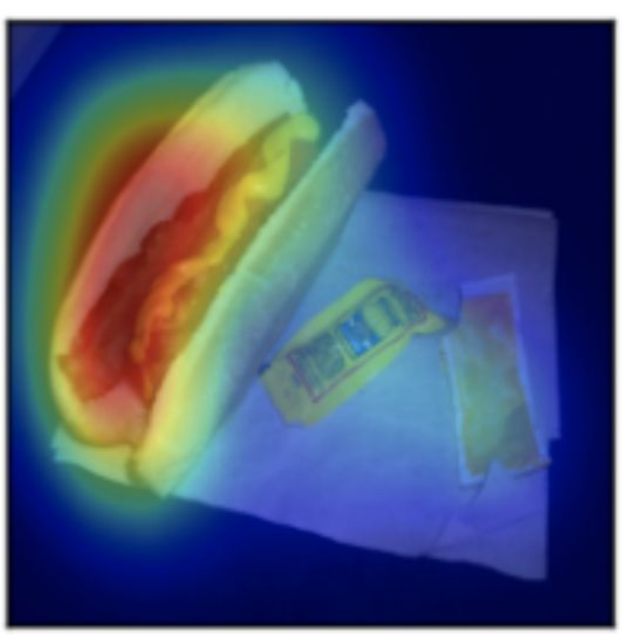
Questions?

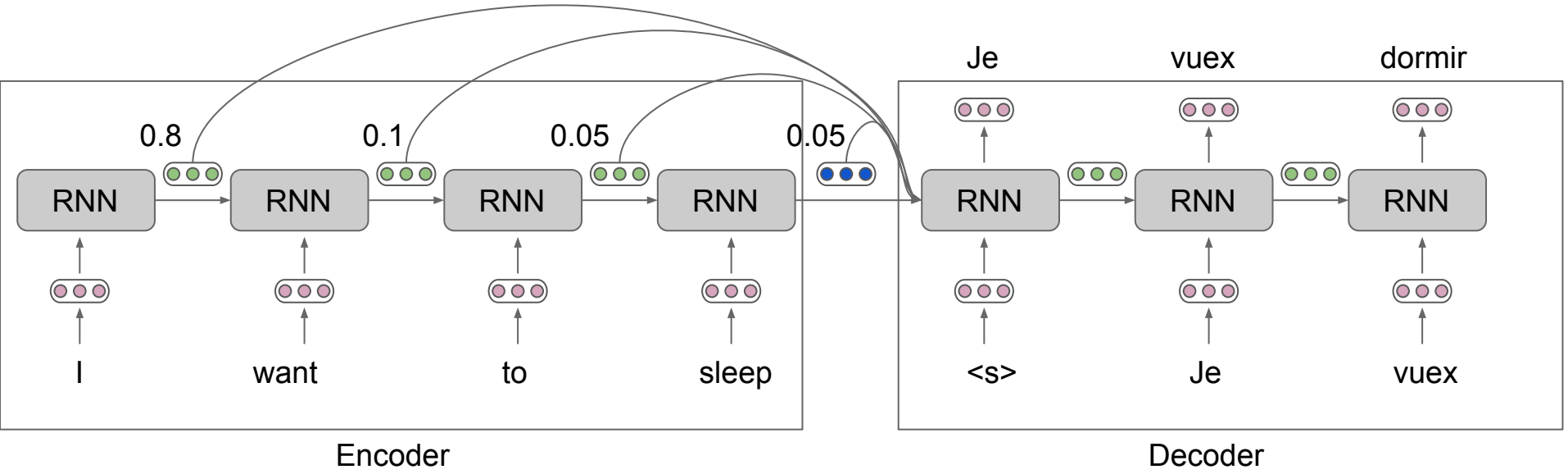
Visual Attention

What toppings are on the hot dog?



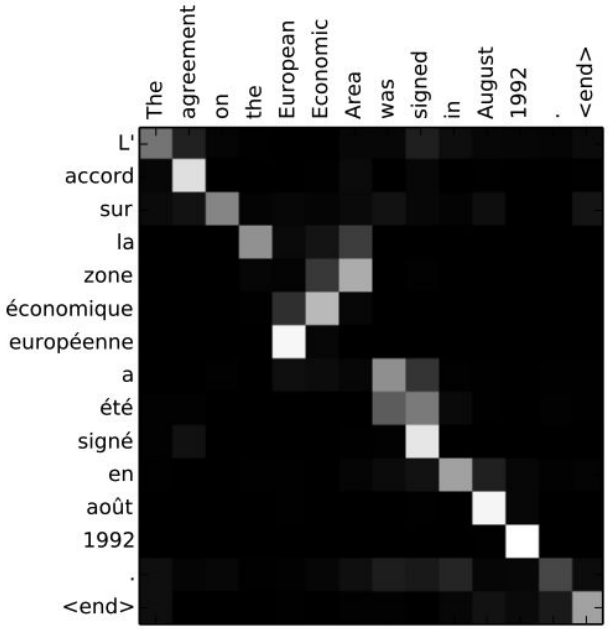
Differential Attention for Visual Question Answering (Patro et.al, 2018)

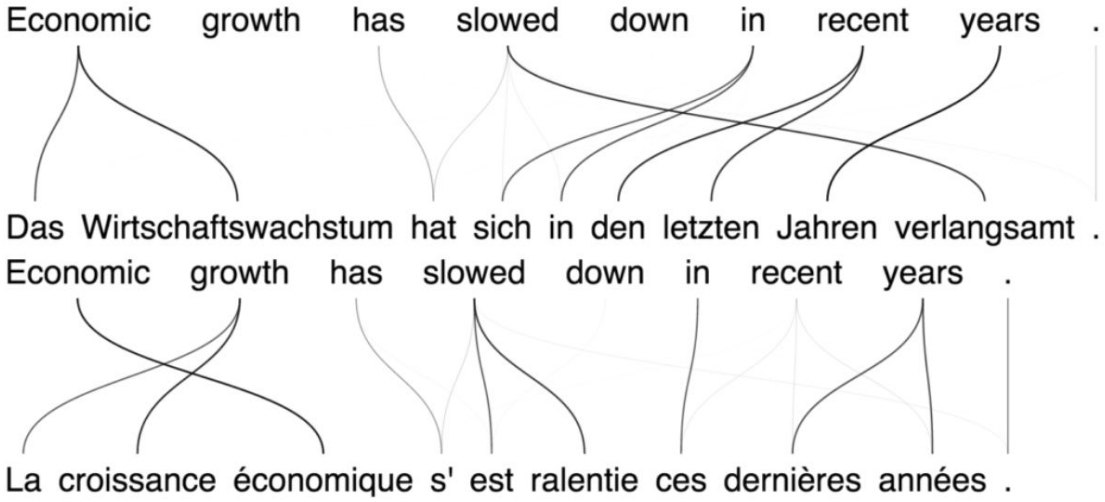
Cross Attention in NMT



Neural Machine Translation by Jointly Learning to Align and Translate. Bahdanau et al, 2015

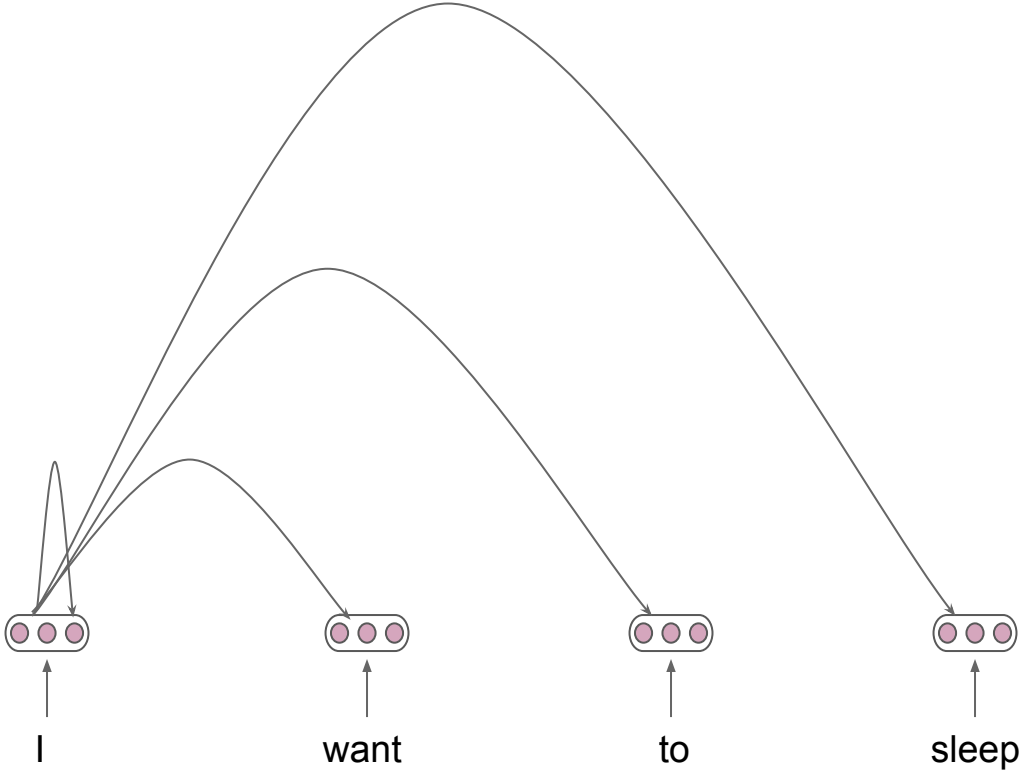
Attention in NMT



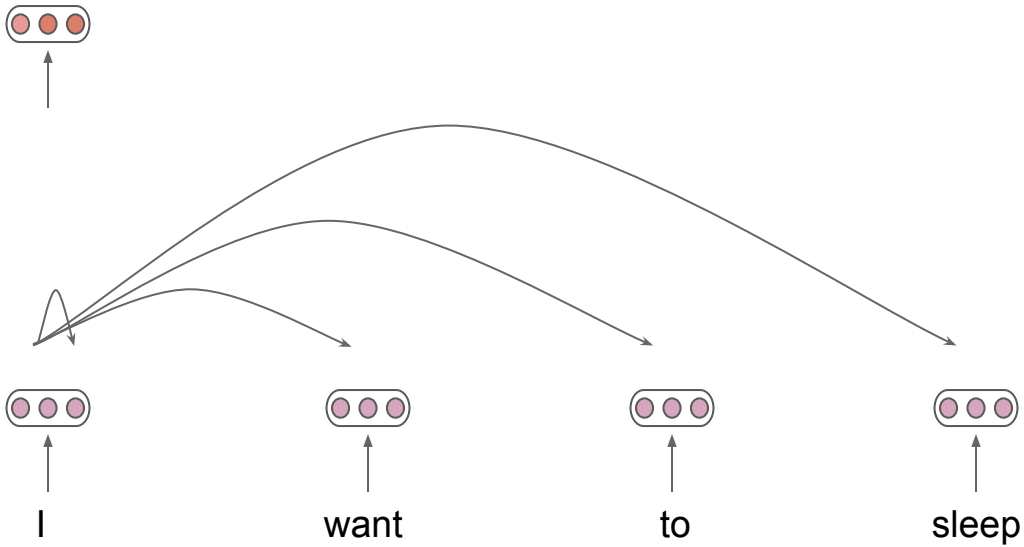


Neural Machine Translation by Jointly Learning to Align and Translate. Bahdanau et al, 2015
https://developer.nvidia.com/blog/introduction-neural-machine-translation-gpus-part-3/

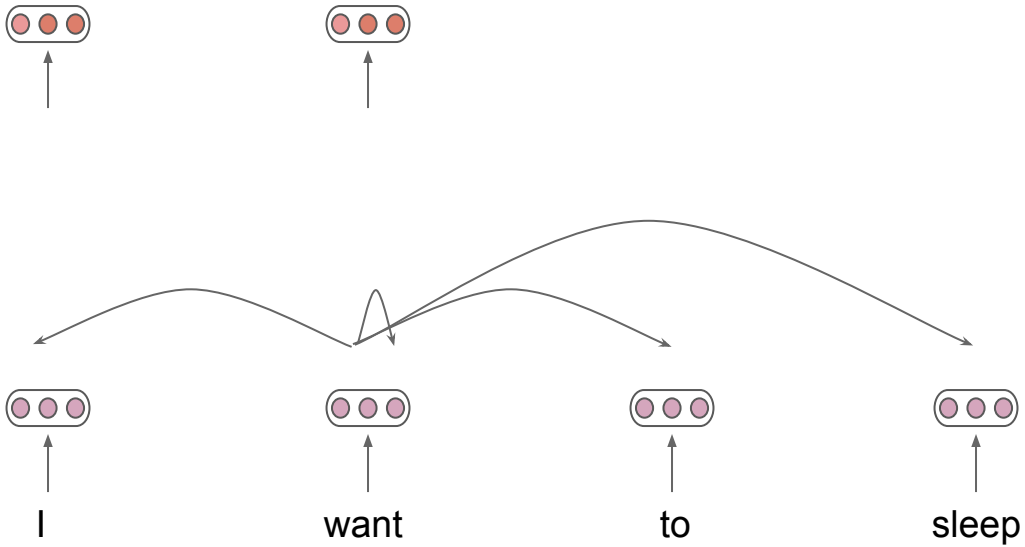
Self Attention



Self Attention - No more recurrence



Self Attention - No more recurrence



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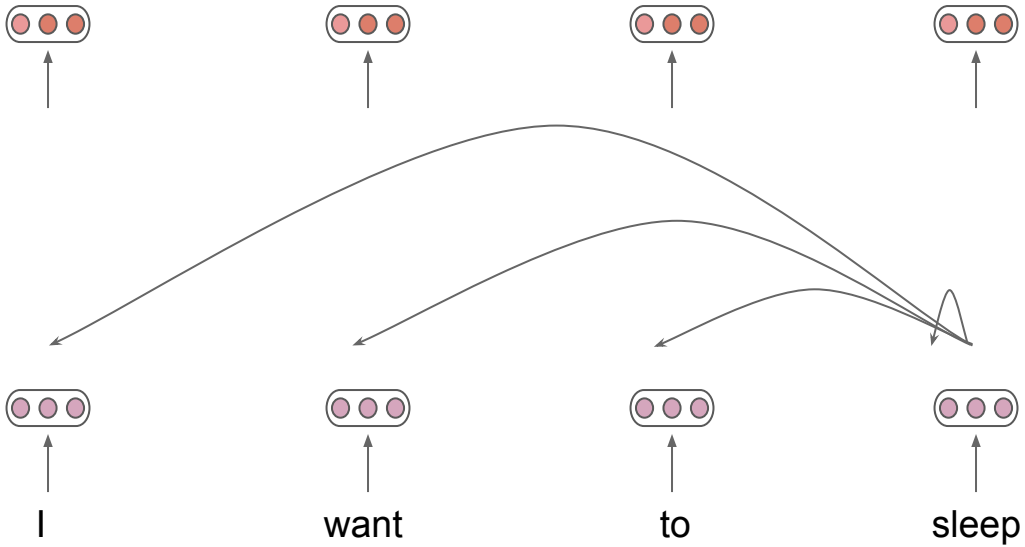
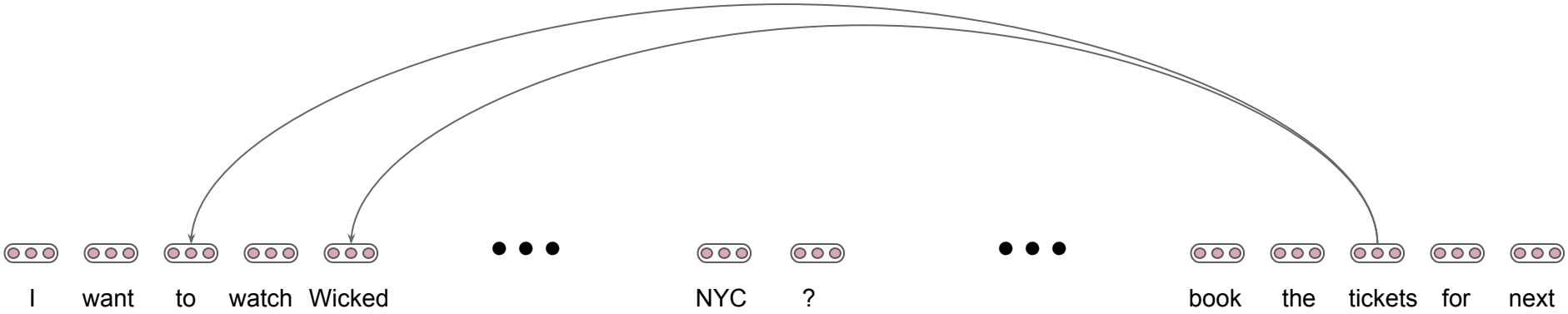
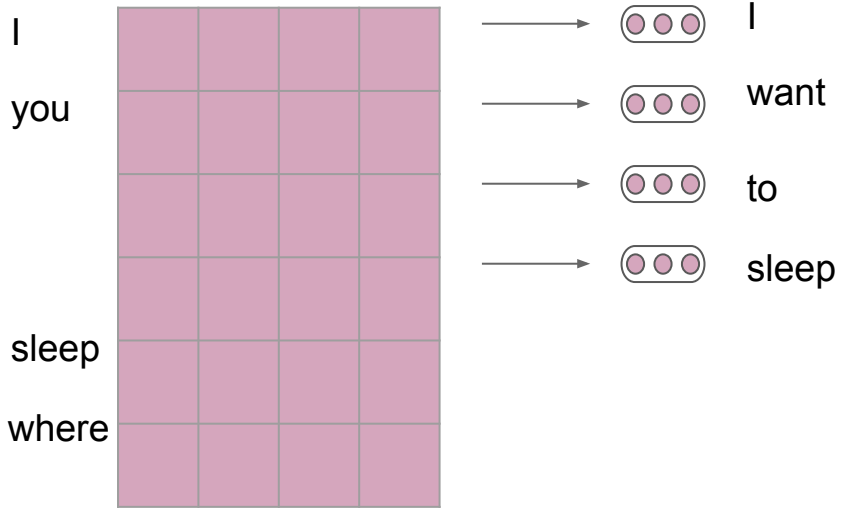
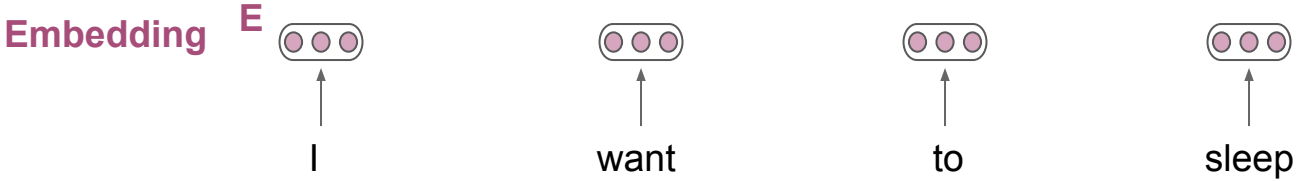


Self Attention for long sequences

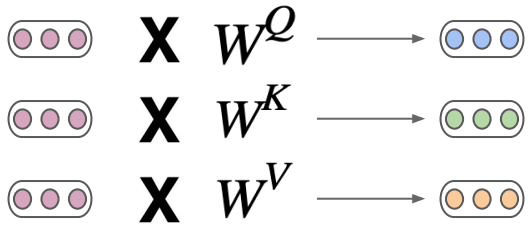


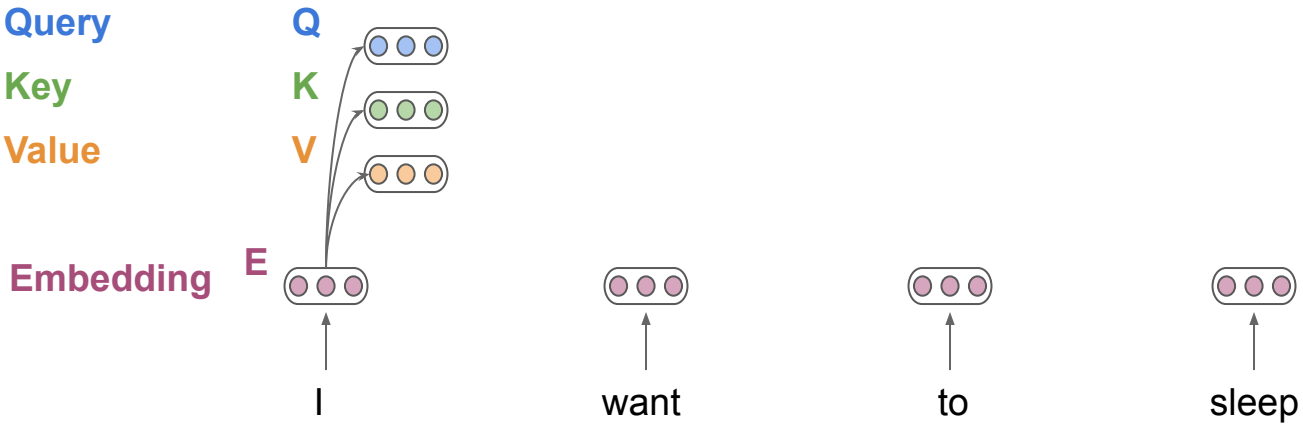
Self Attention - Word Embedding





Self Attention - Projection Layer





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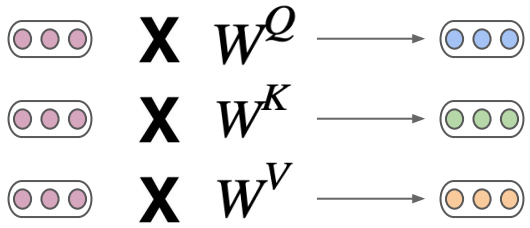
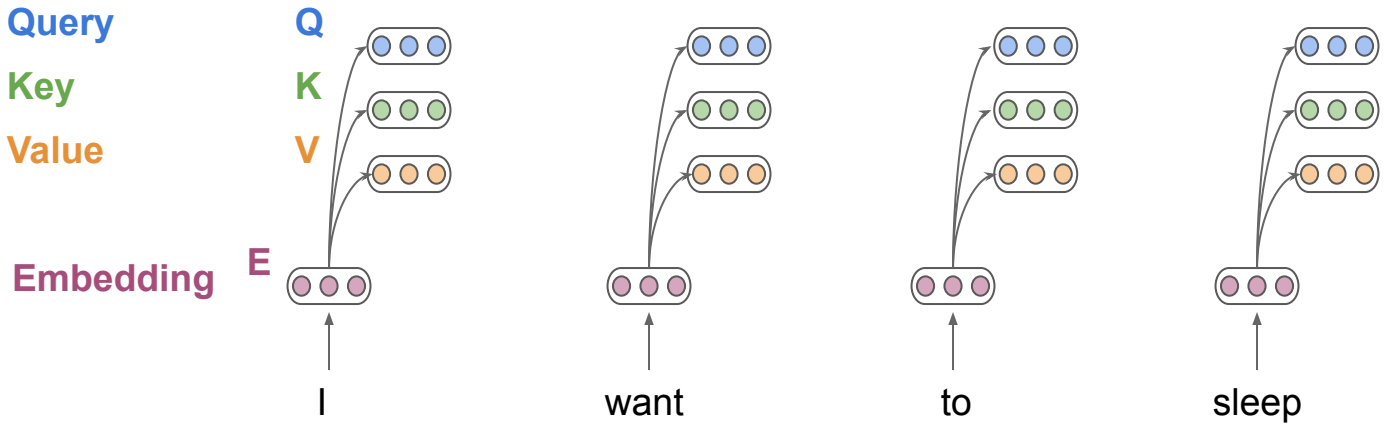
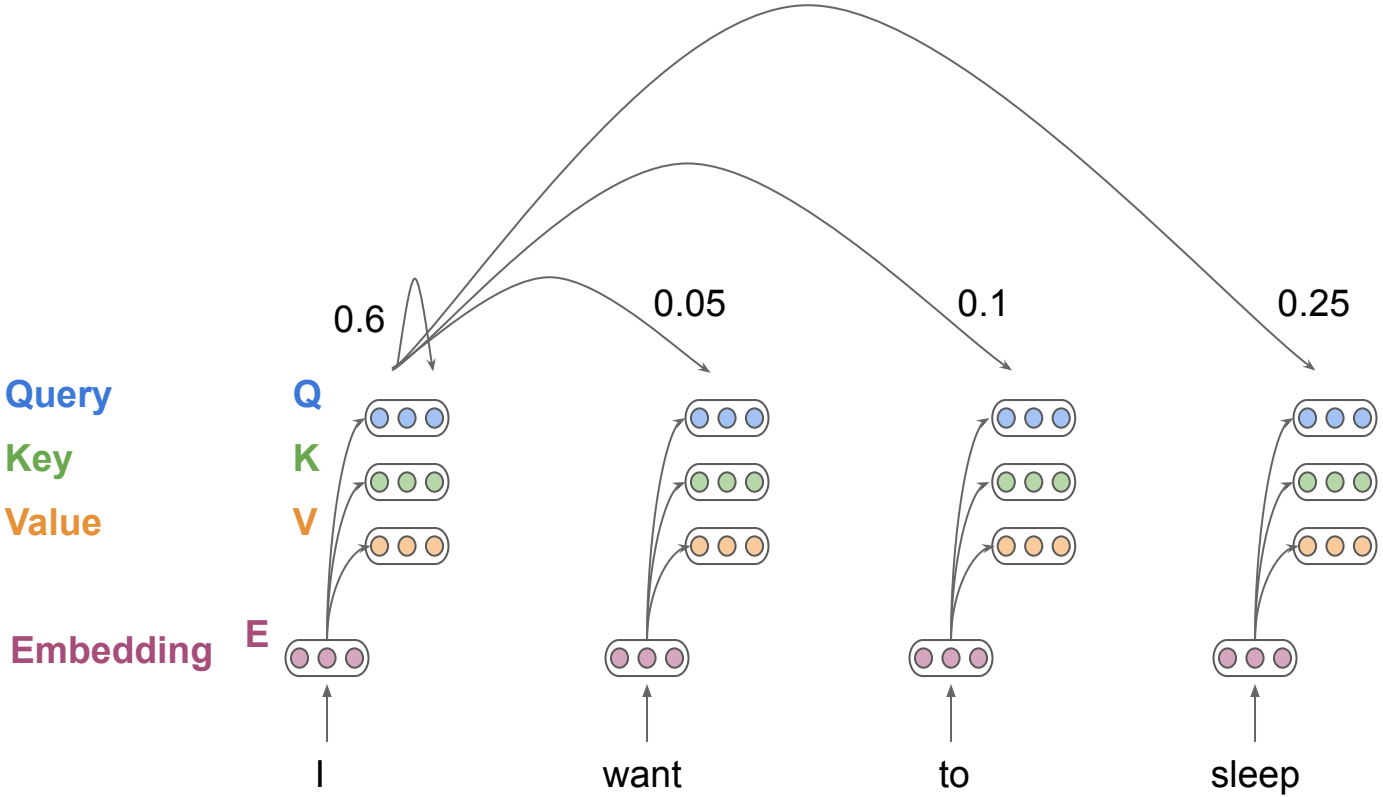
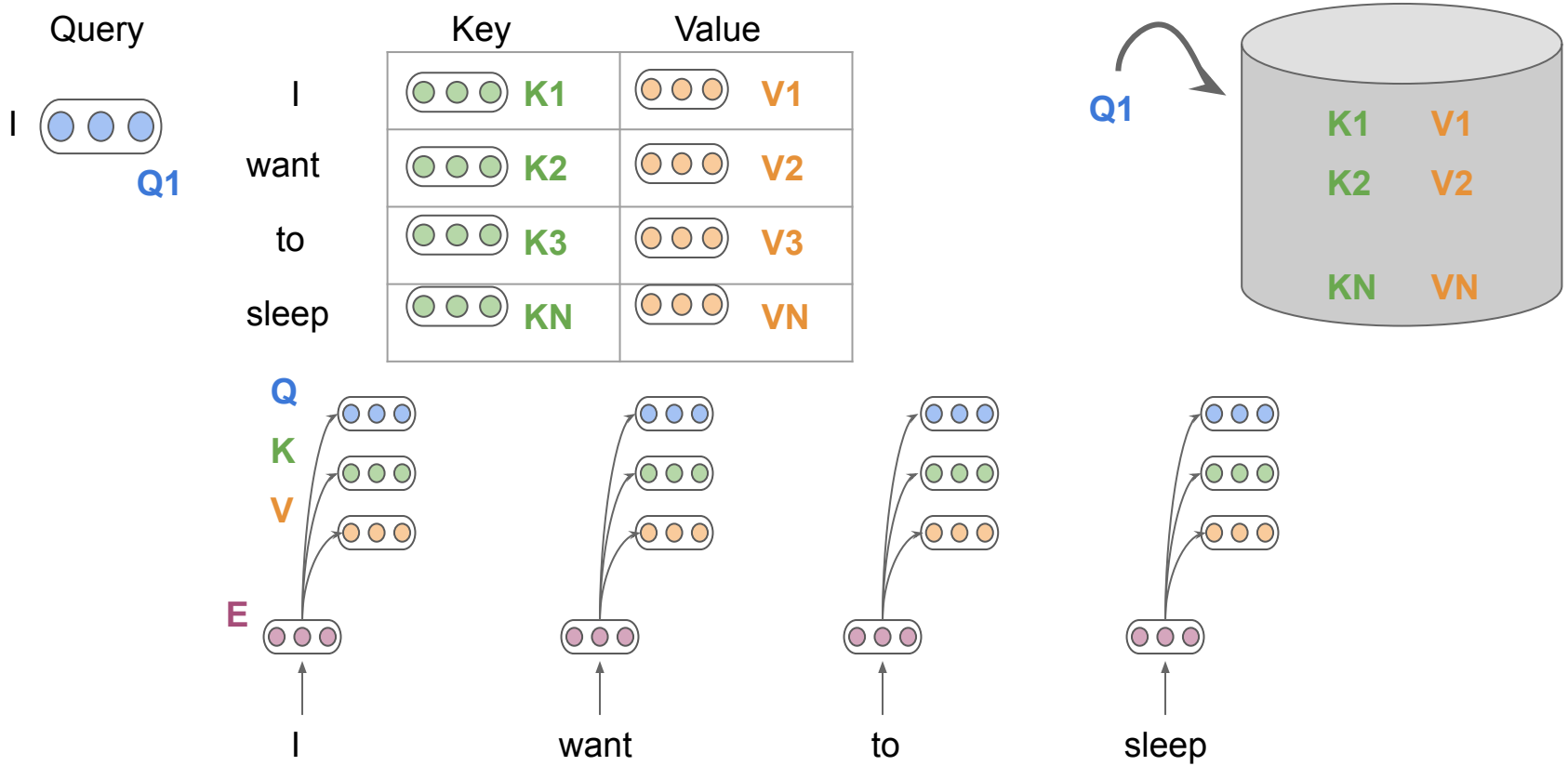




Self Attention - Attention Scores

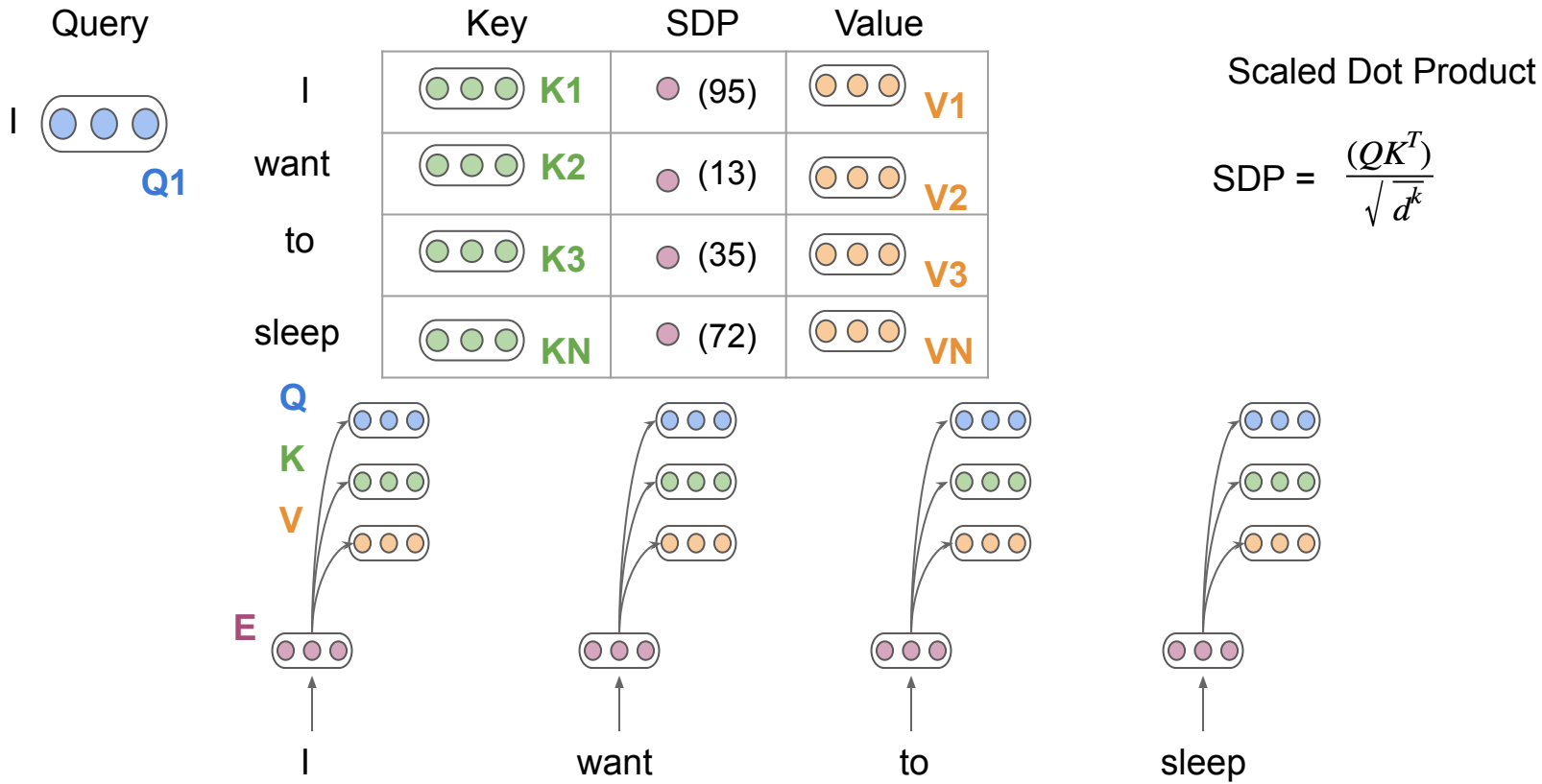


Self Attention

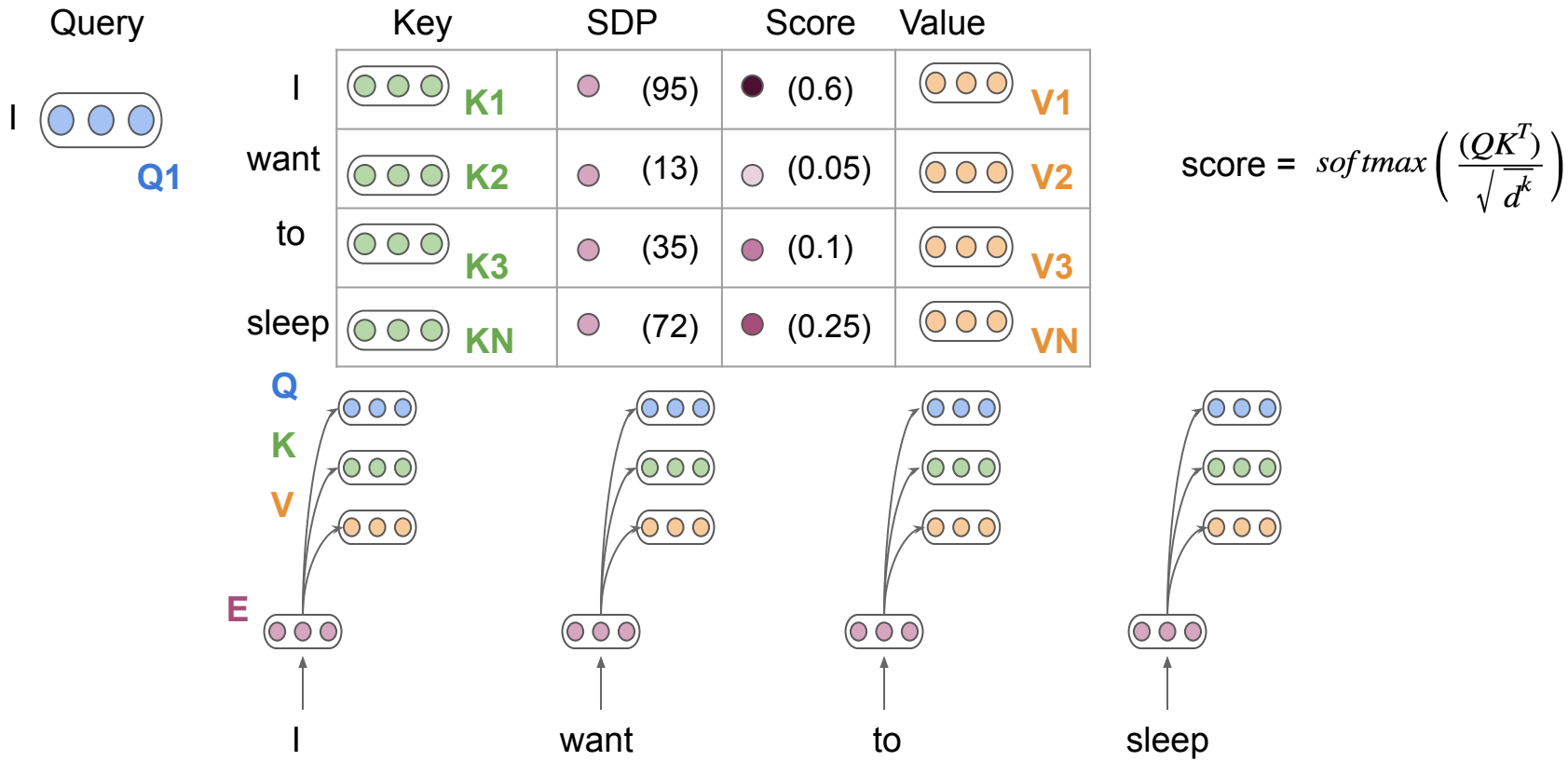


Questions?

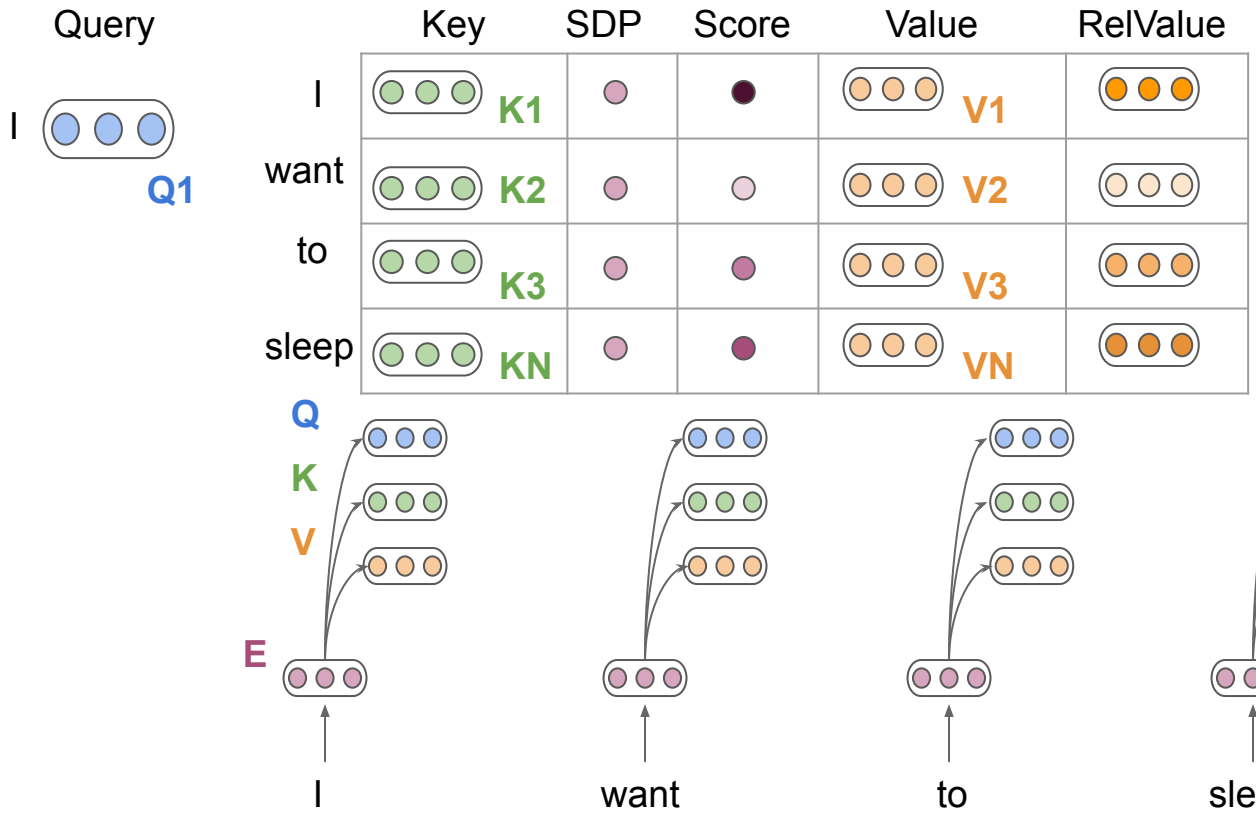
Self Attention - Scaled Dot Product



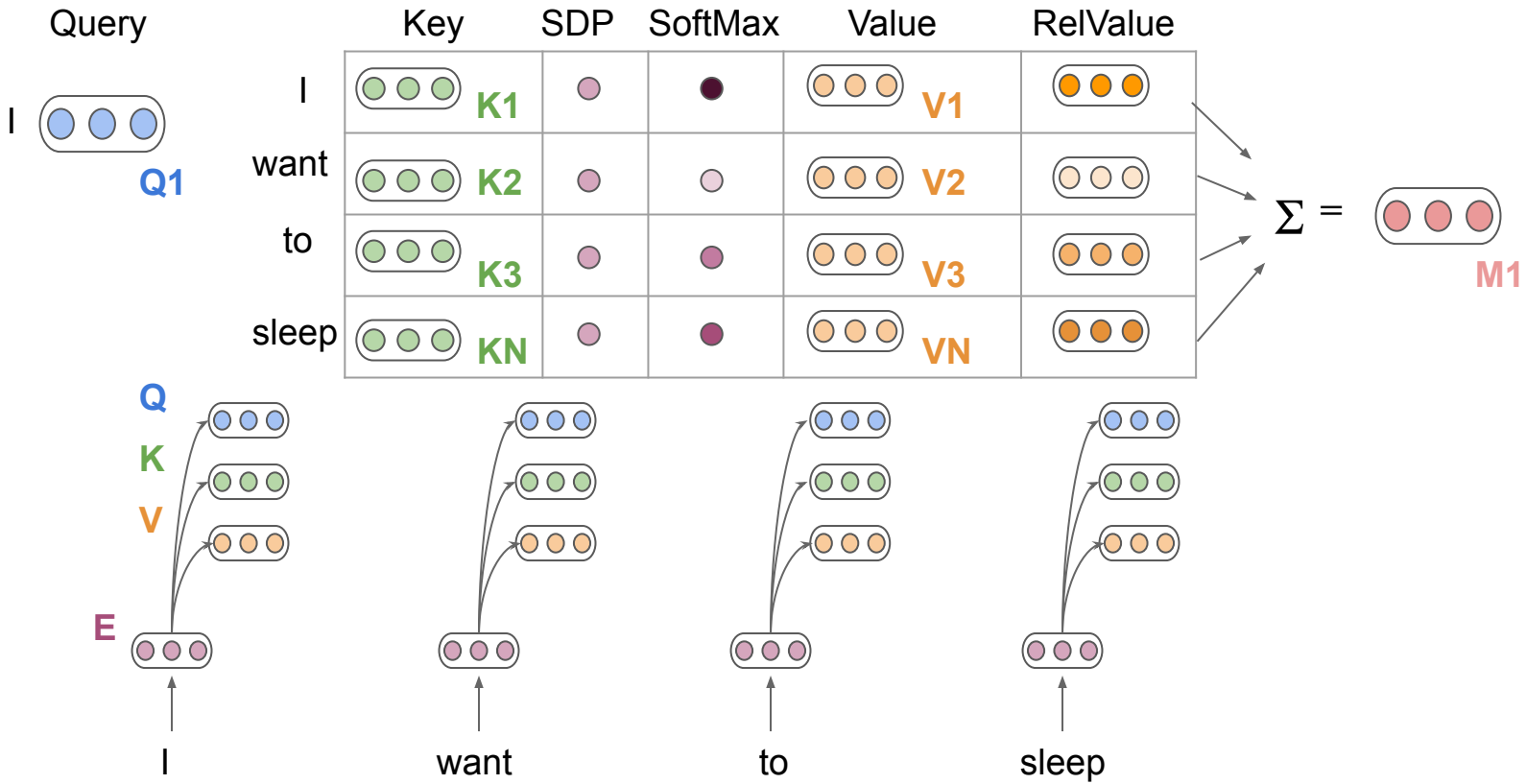
Self Attention - SoftMax



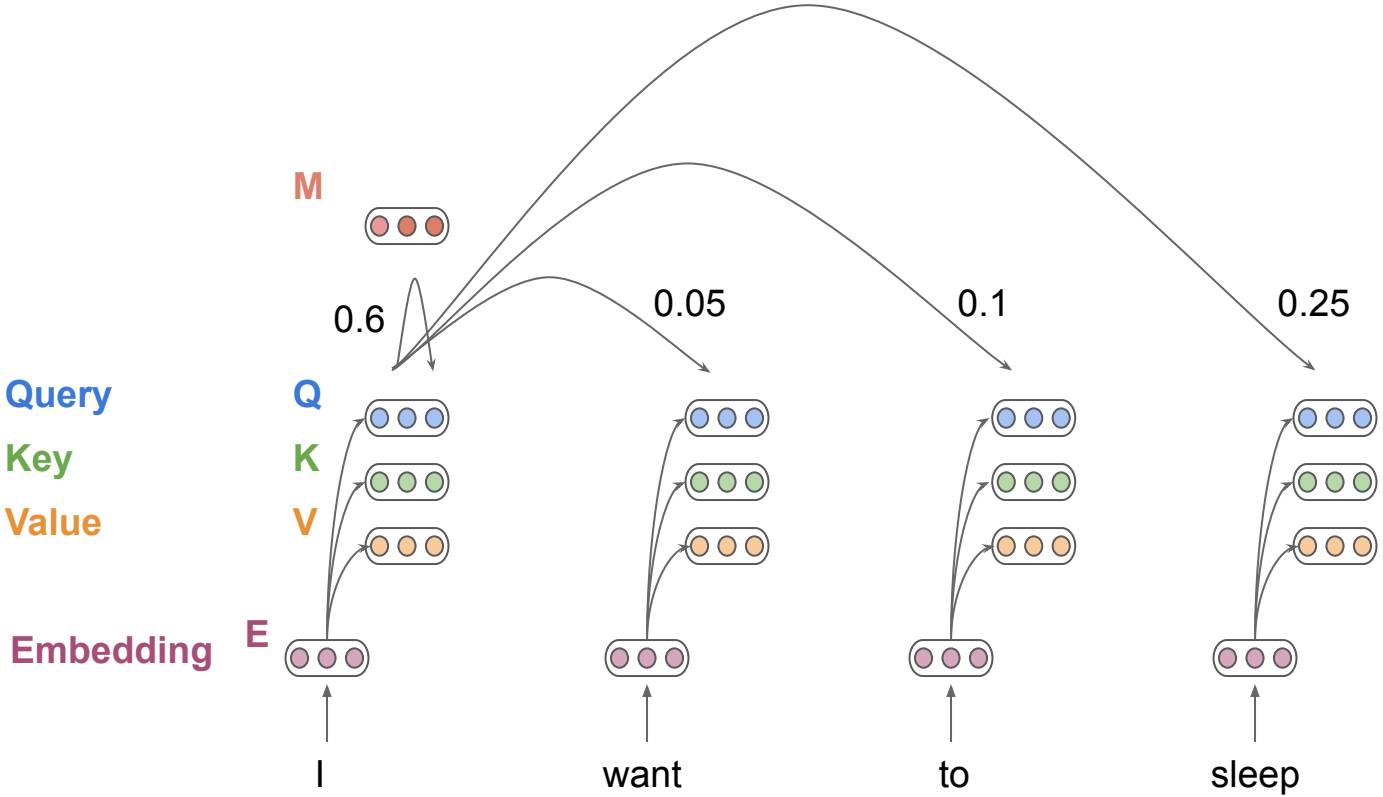
Self Attention - Soft (Relative) Values



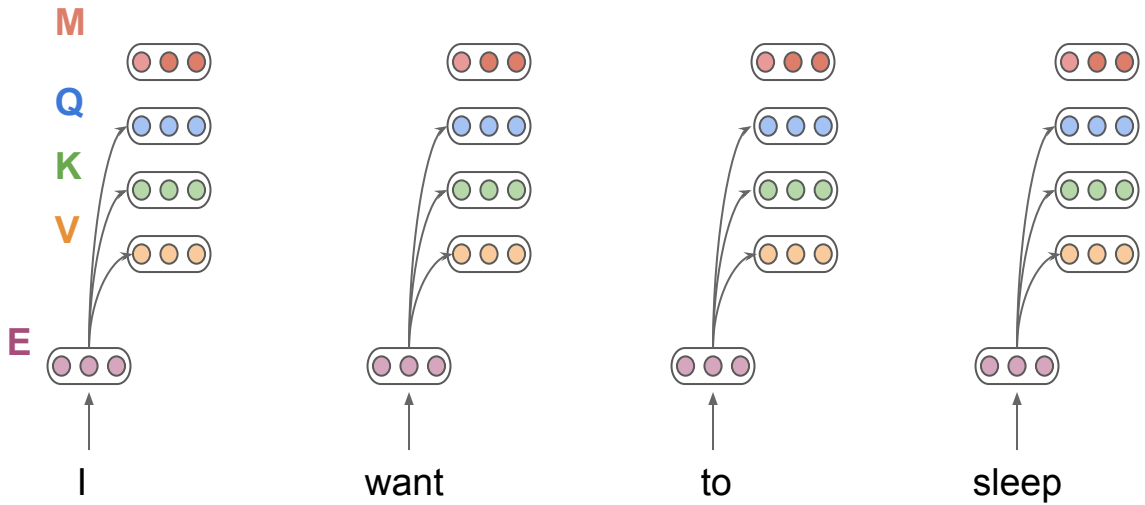
Self Attention - Attended Repr



Self Attention - Attended Contextual Rep



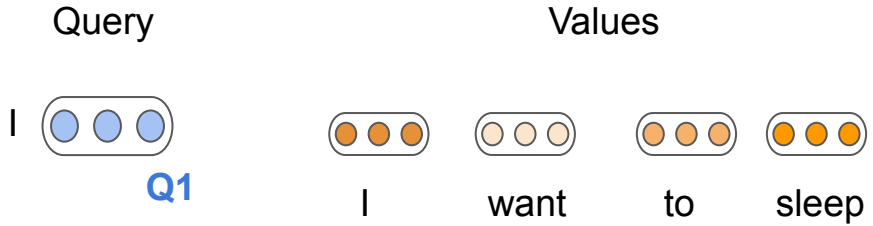
Self Attention - Attended Contextual Rep



Questions?

Problem with Self Attention

- Self Attention can focus heavily on the same word!



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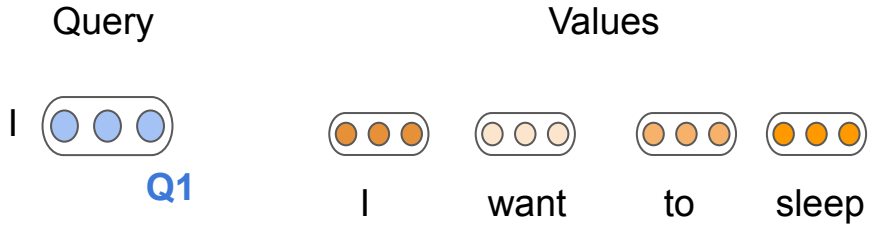


- Single representation

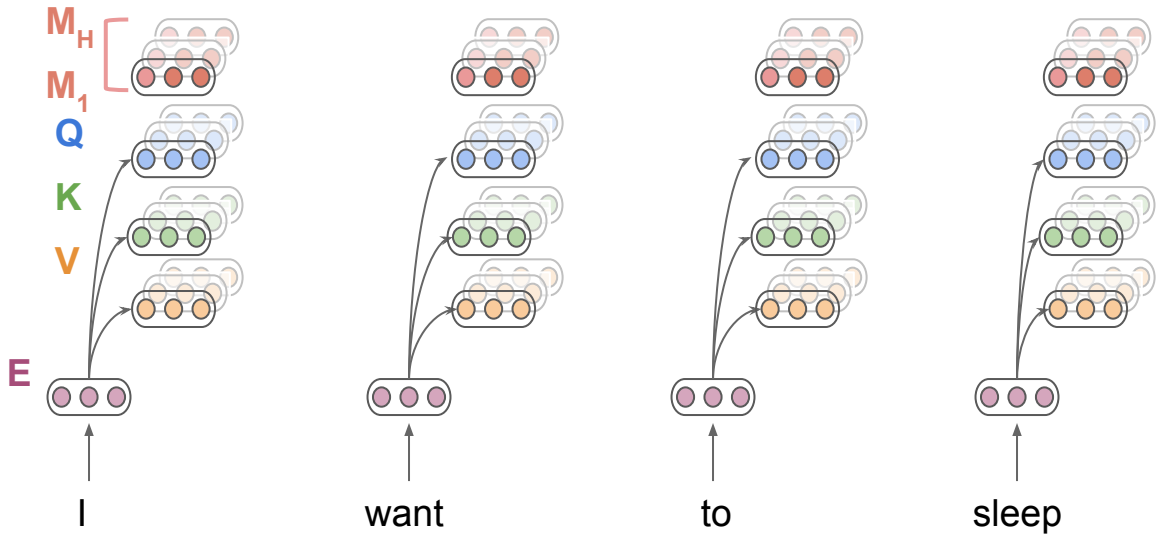
I like **Harry** **Potter** (Book)

v/s

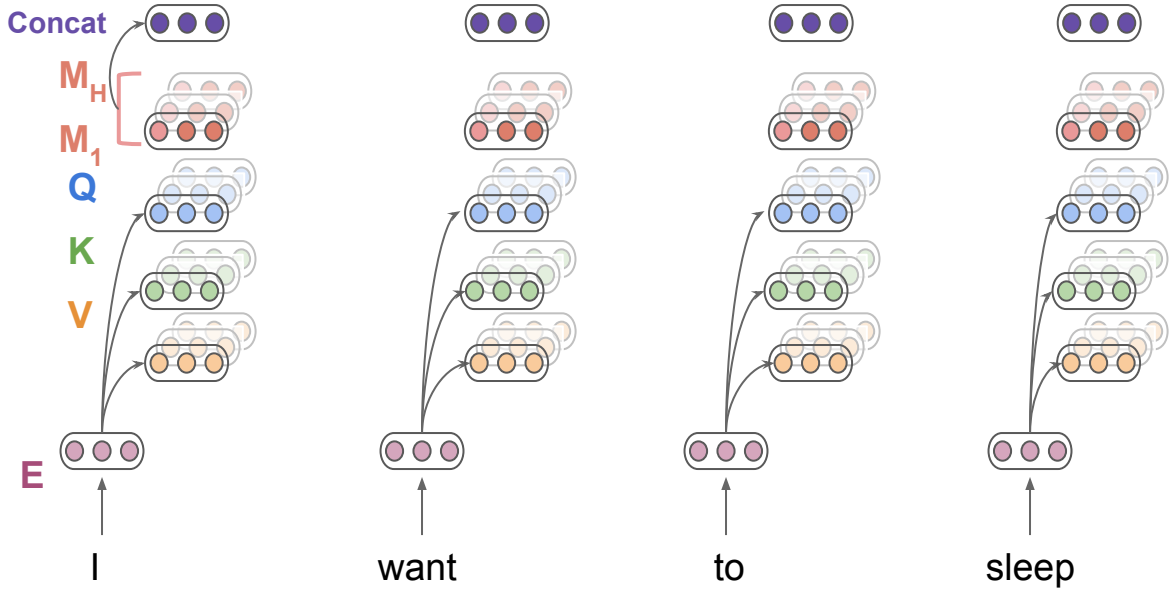
I like **Harry** **Potter** (Movie)

Multi-Headed Self Attention

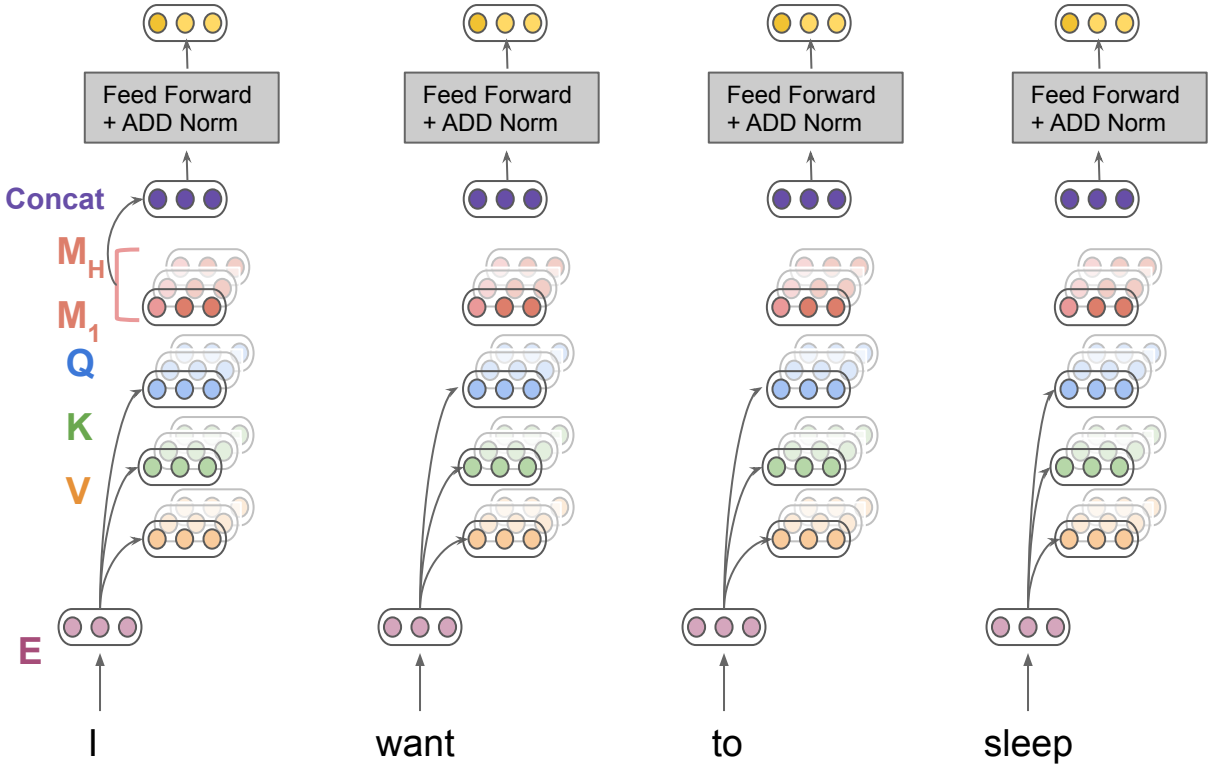
H (no: of heads) Different versions of Q,K,V
Each different repr -> Different attended repr



Multi-Headed Self Attention

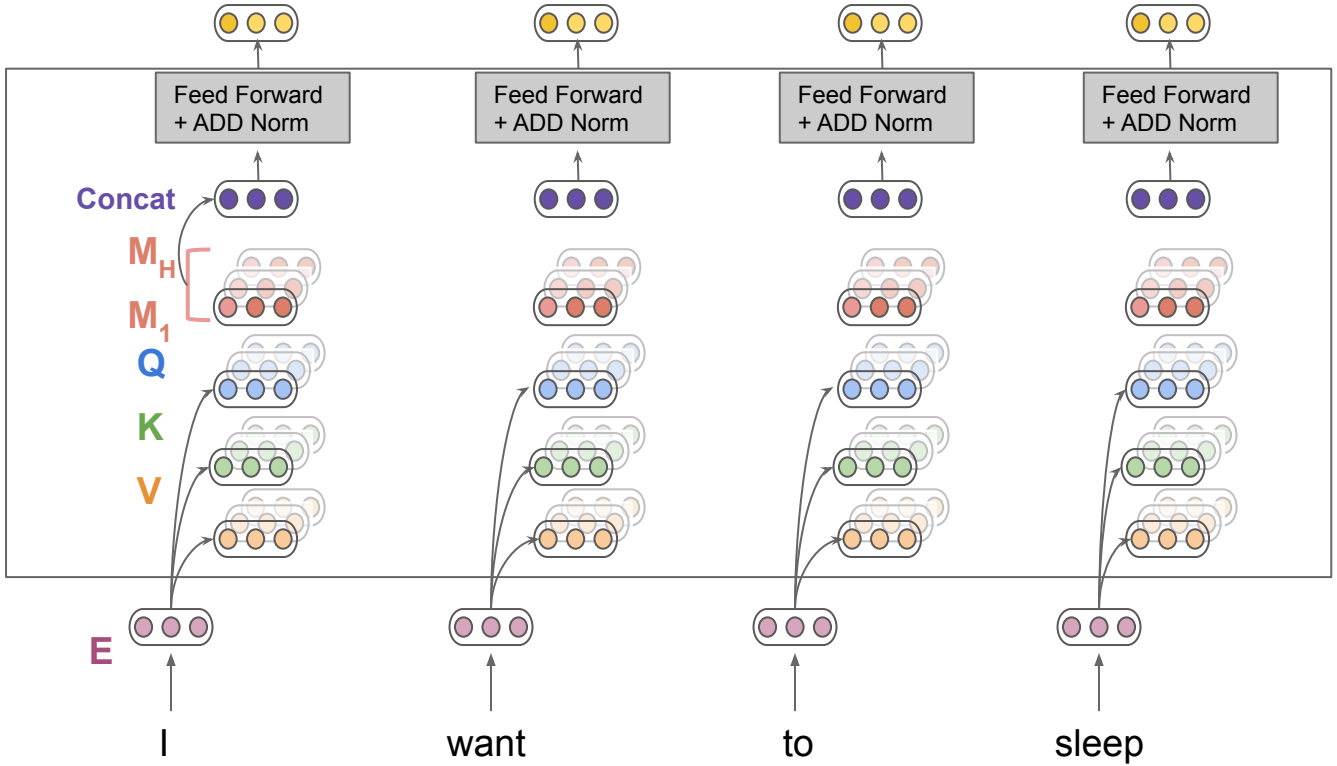


Multi-Headed Self Attention

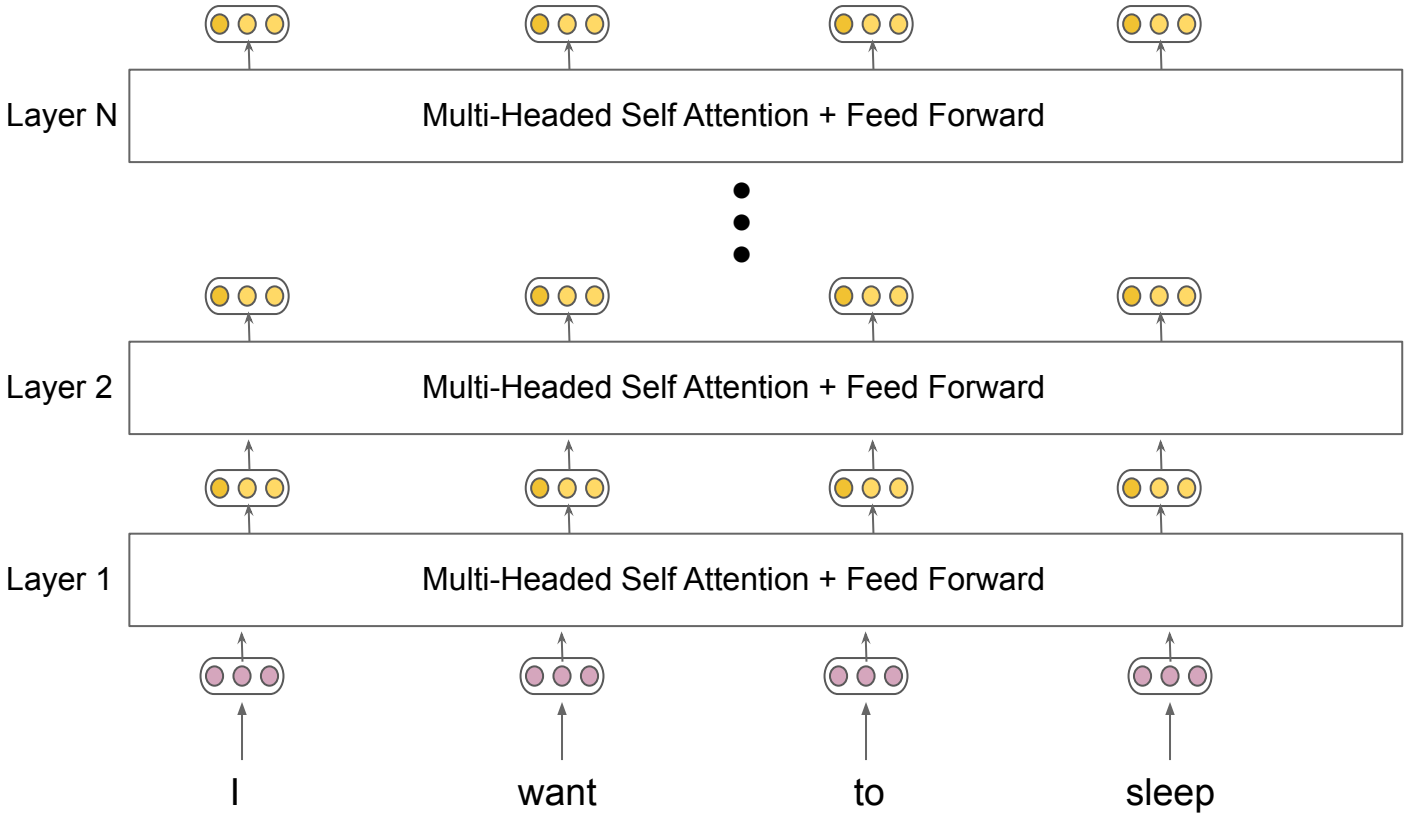


Multi-Headed Self Attention

Multi-Headed Self Attention + Feed Forward

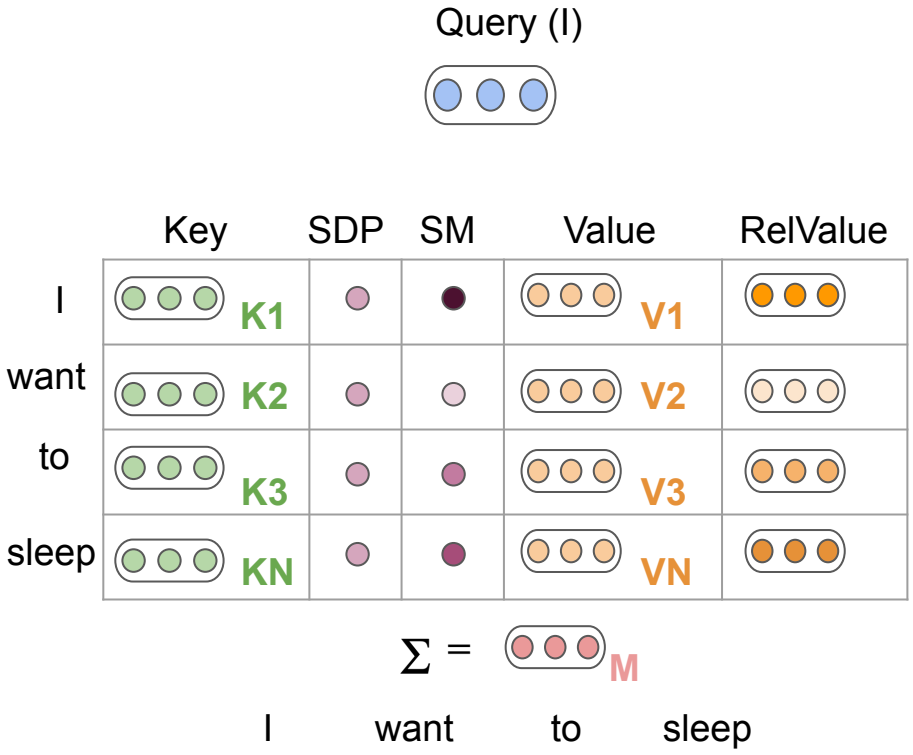


Multi-Headed Self Attention

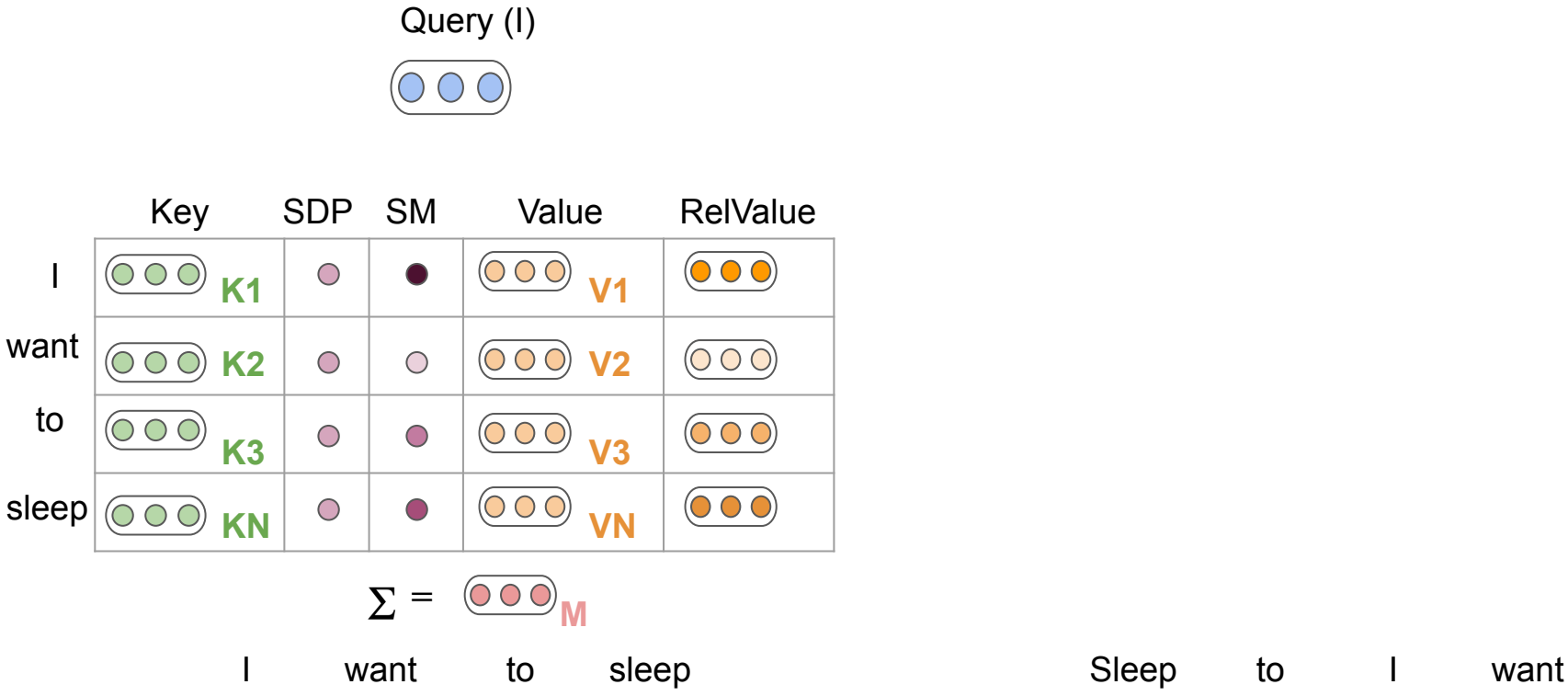


Questions?

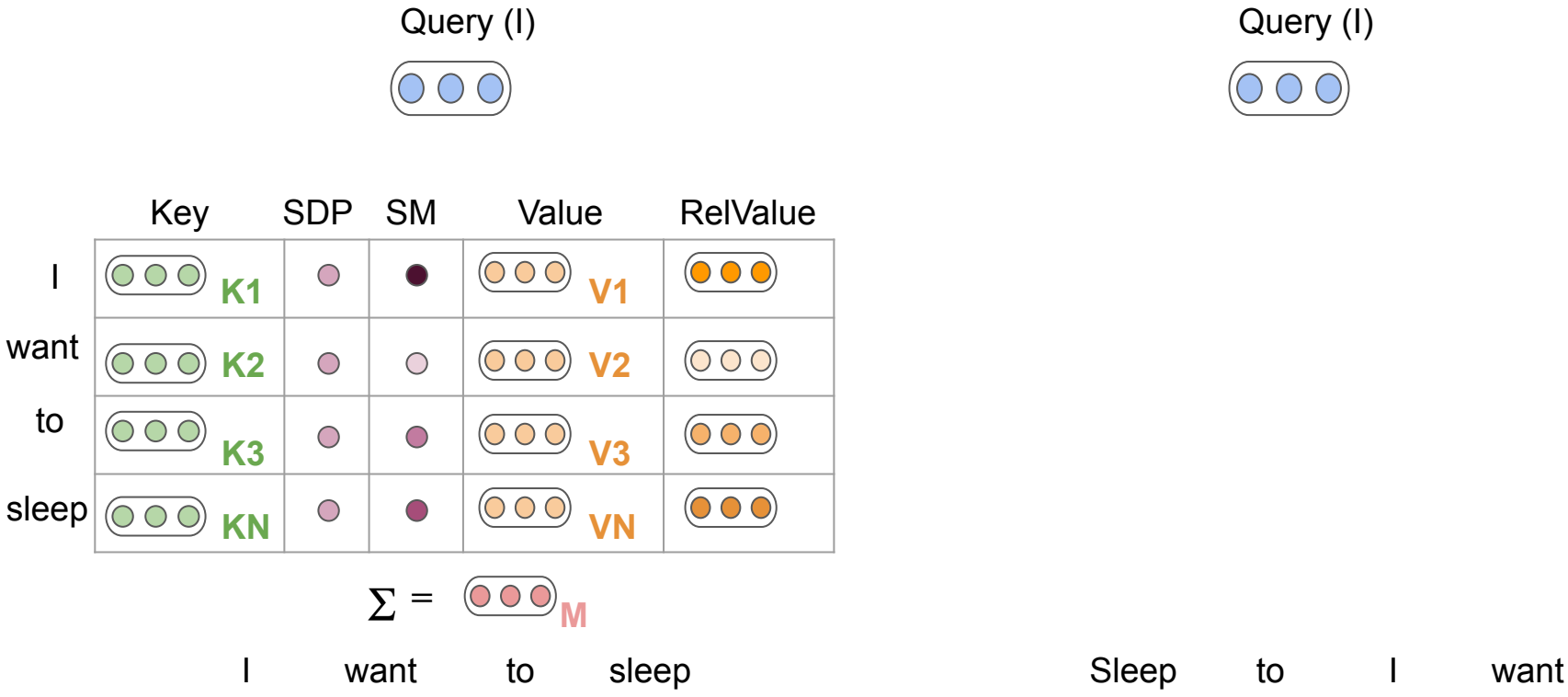
Revisiting Self Attention



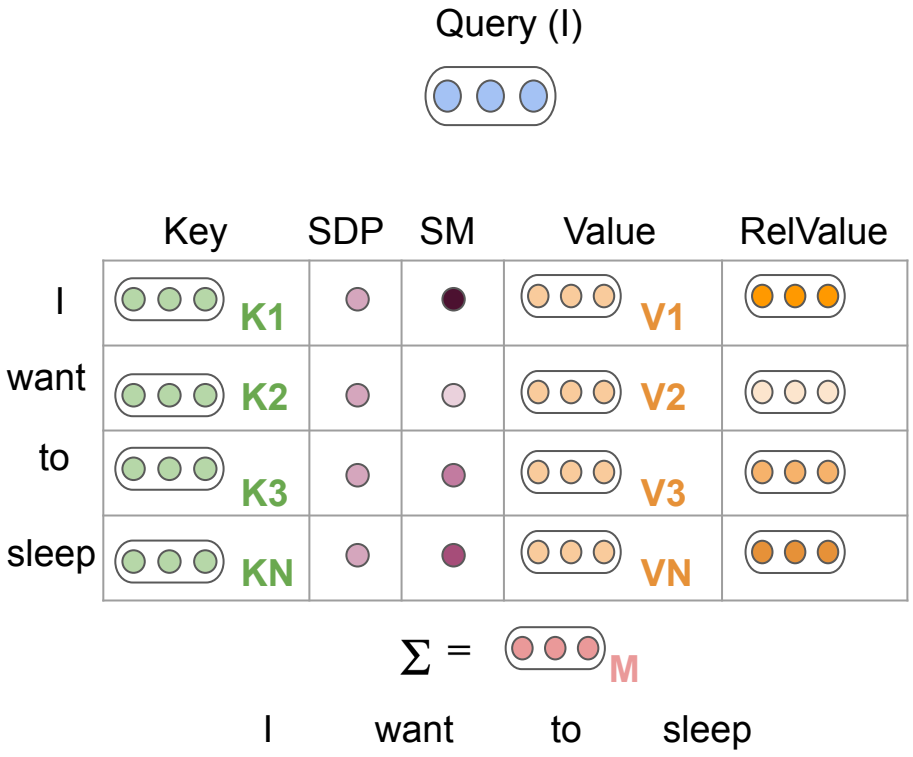
Revisiting Self Attention

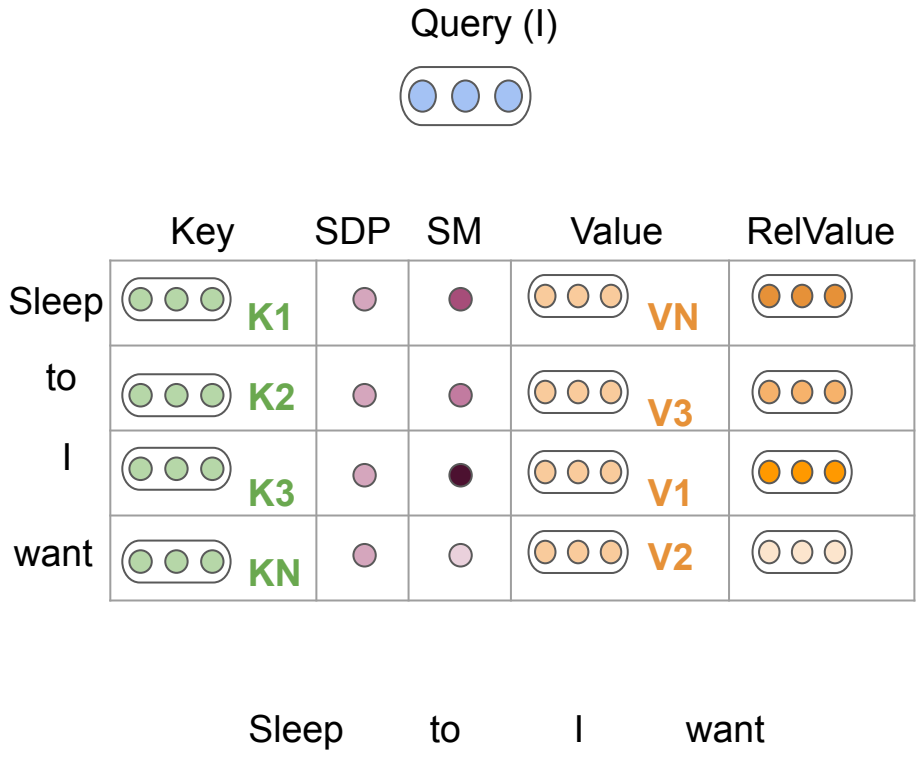


Revisiting Self Attention



Revisiting Self Attention





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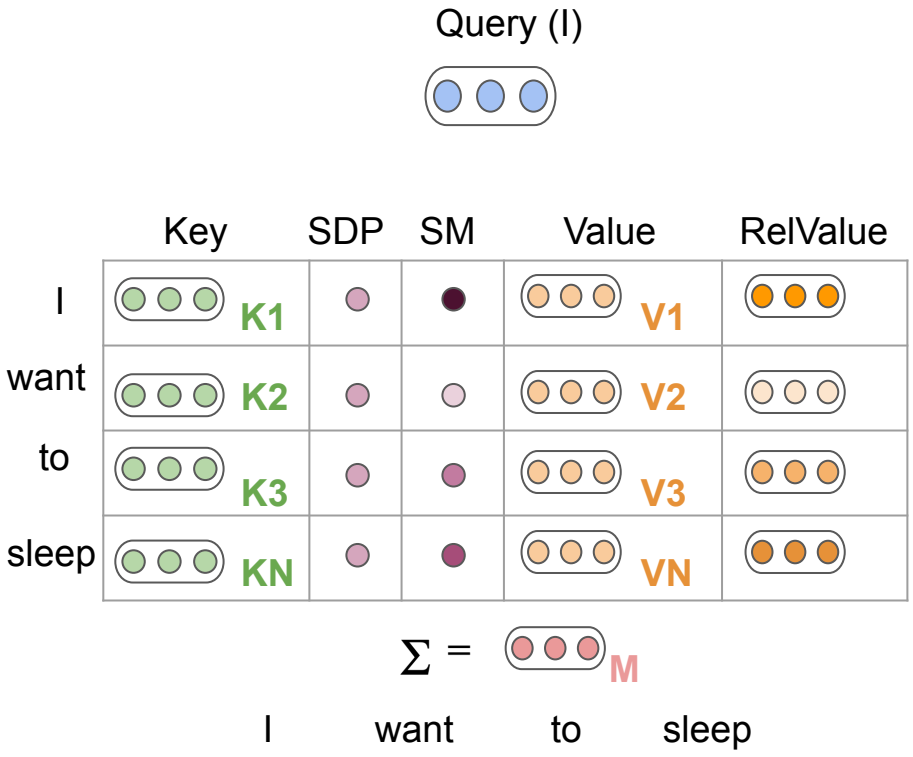

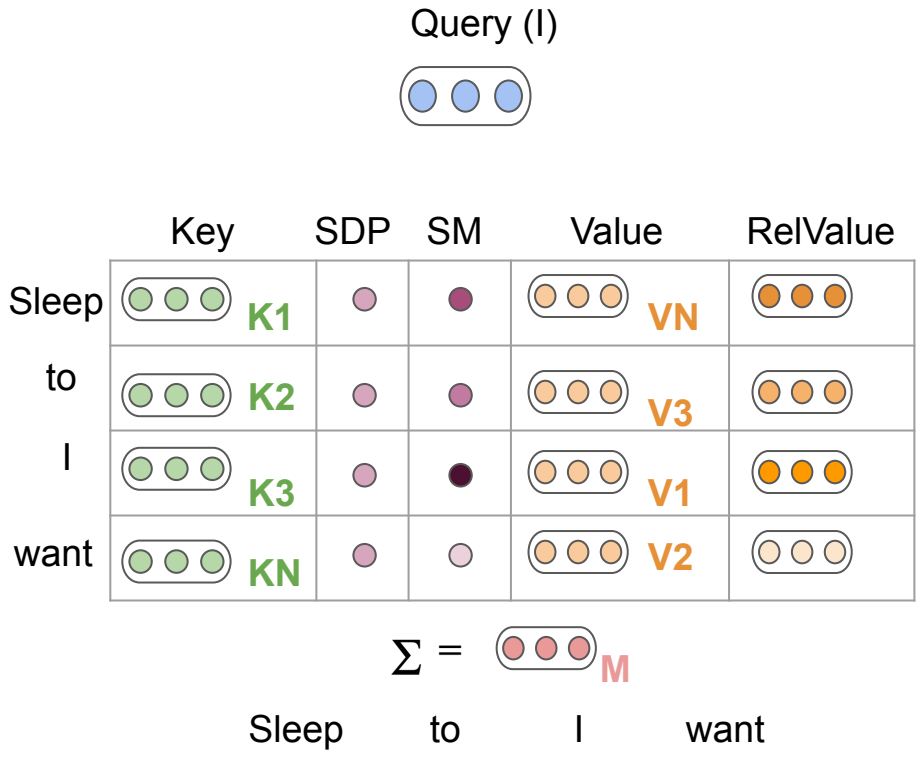

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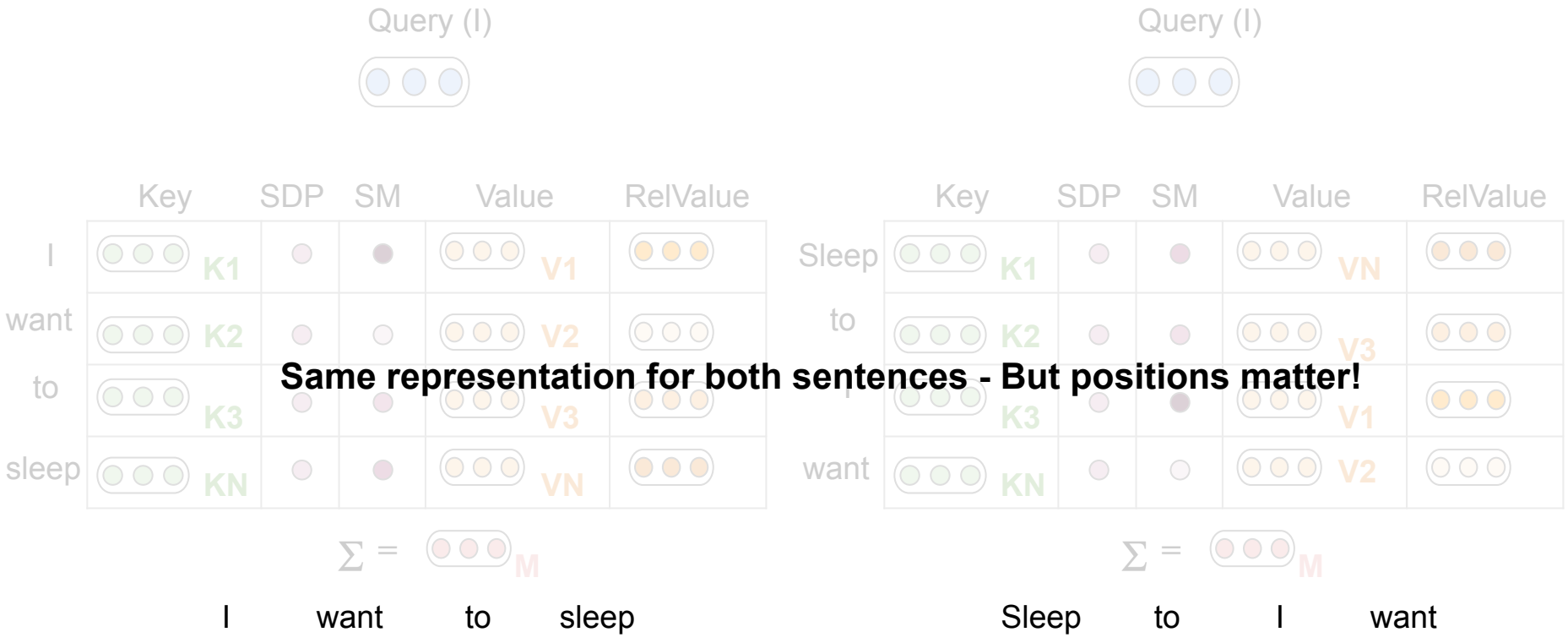
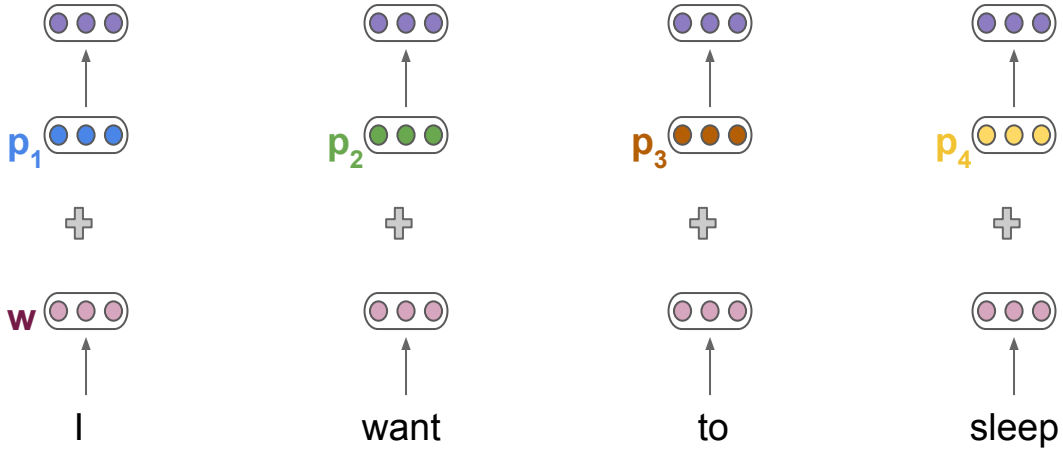


Same representation for both sentences - But positions matter!

Positional Encoding

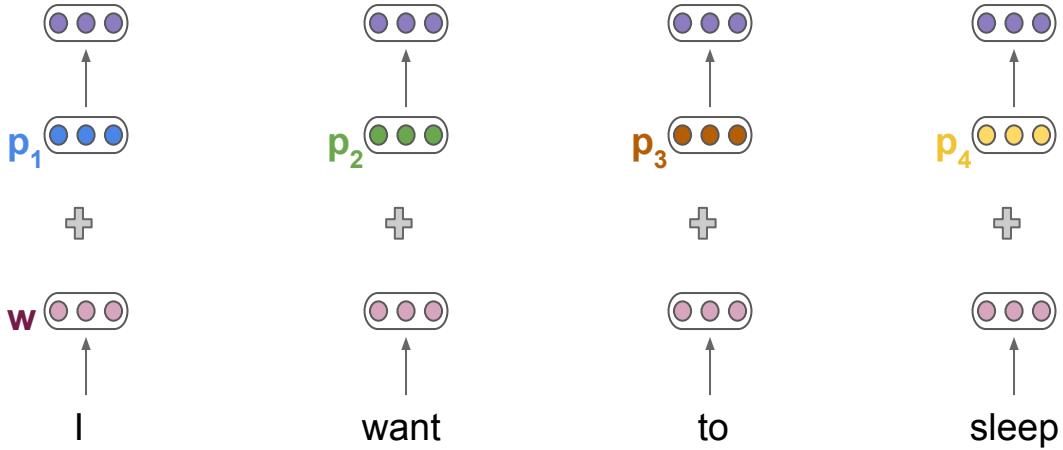
Position embeddings - each position number has an associated embedding



Positional Encoding

Sinusoidal Position embeddings - generalize to any sequence length

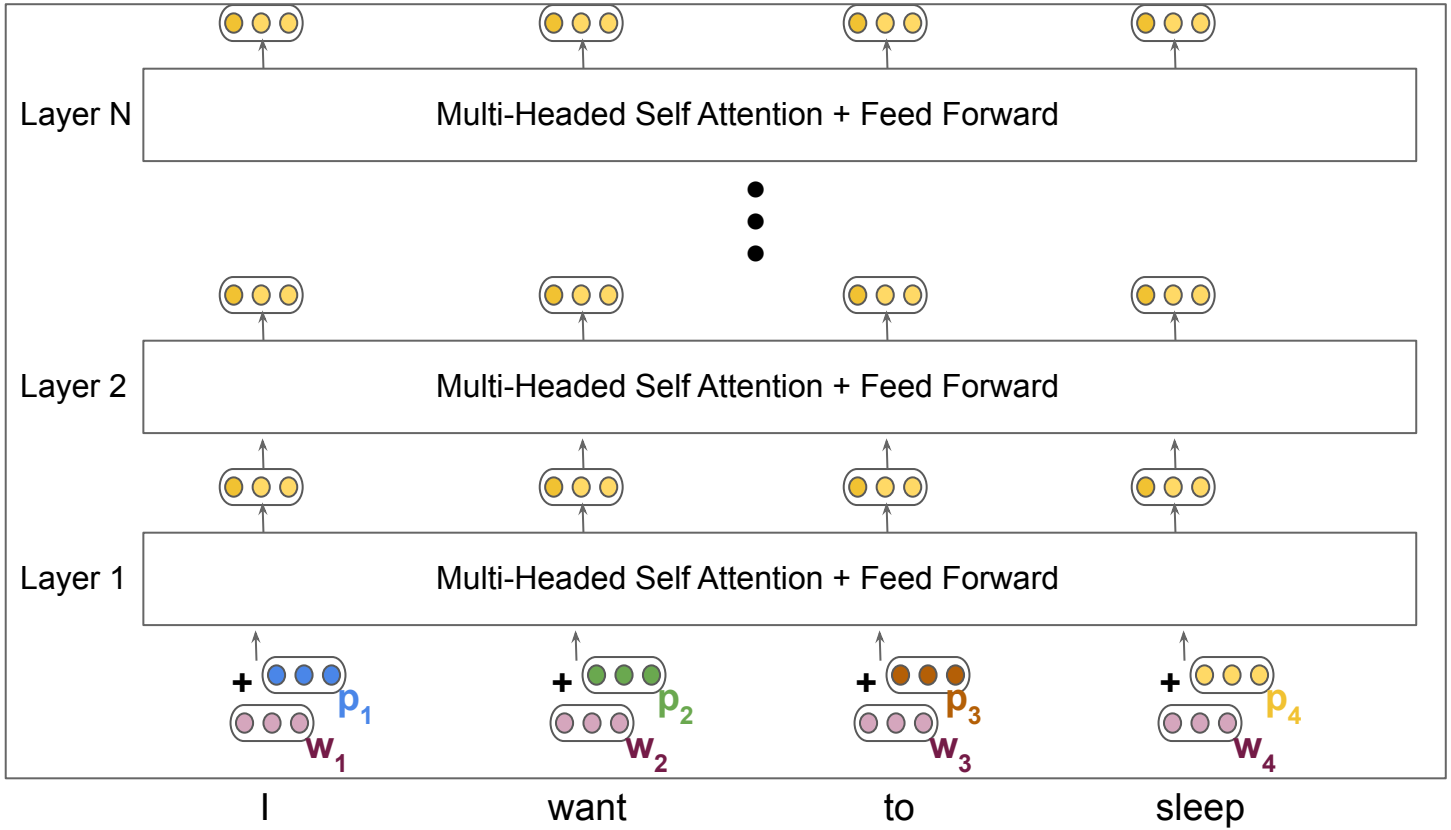
$$p = f(i, t)$$



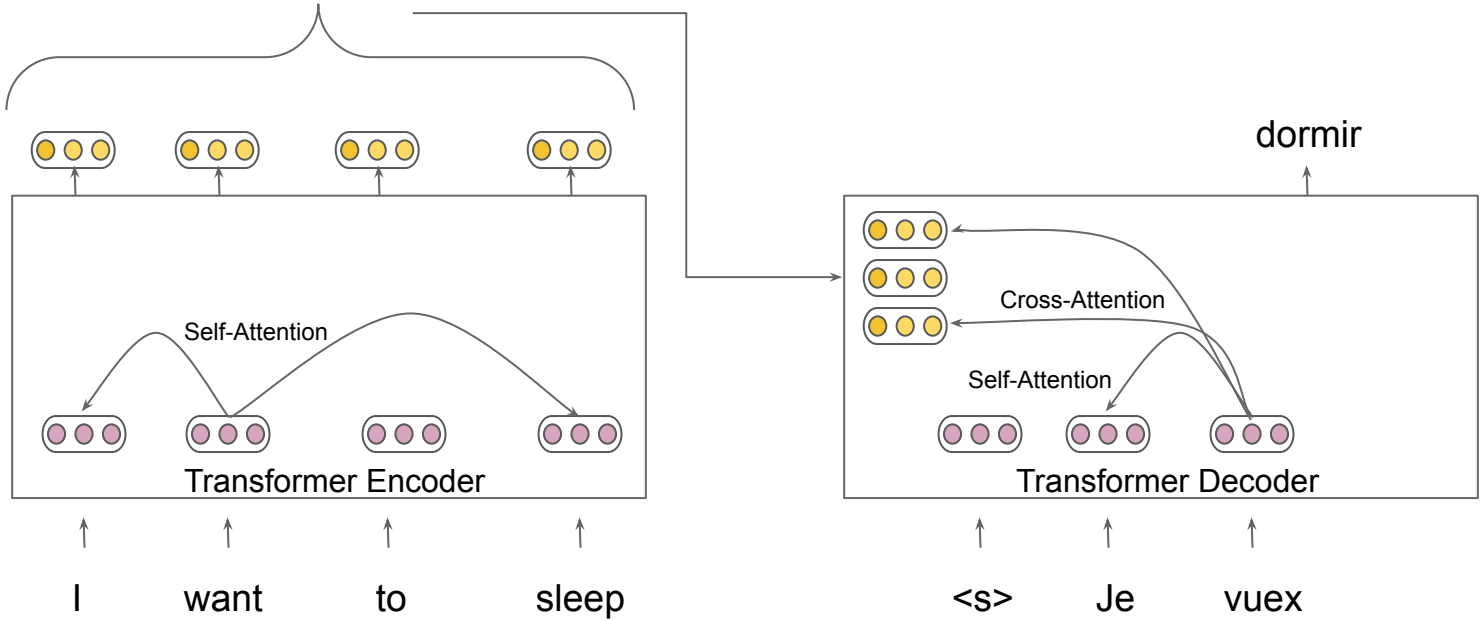
Questions?

Transformer Encoder

N-Layer Transformer Encoder



Transformer Encoder - Decoder

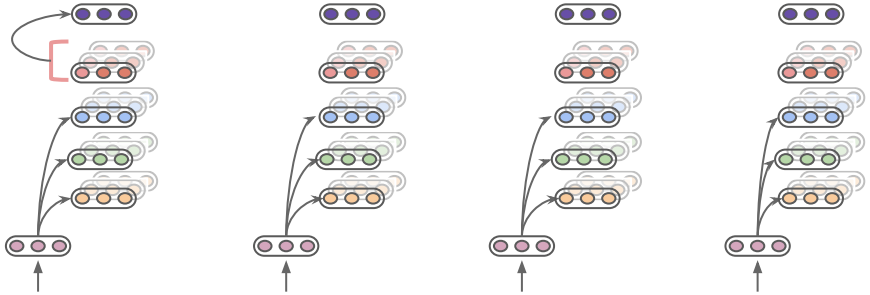


What's so great about Transformers?

- Parallelizable computation
  - Entire sequence, All queries, all attention heads computed in parallel
  - Benefits from fast matrix multiplication on GPUs
- Rich expressive power
  - Every token connected to every other token
  - Can form long range dependencies
- Depth not proportional to seq length
  - Reduces exploding/vanishing gradient problem
  - Converges faster

What's so great about Transformers?

- Parallelizable computation - Entire sequence can be processed in parallel



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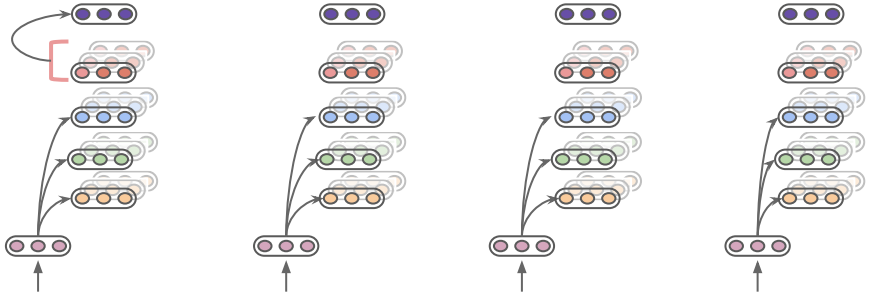
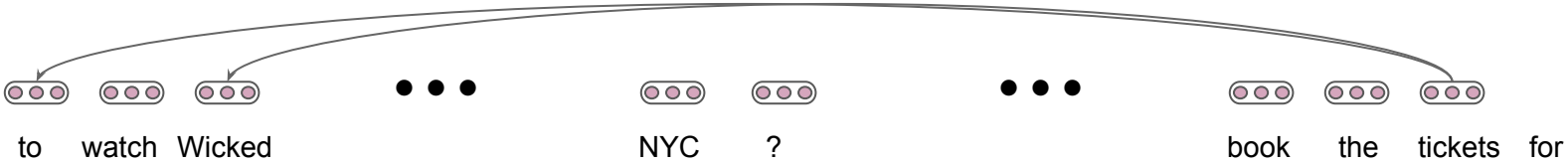
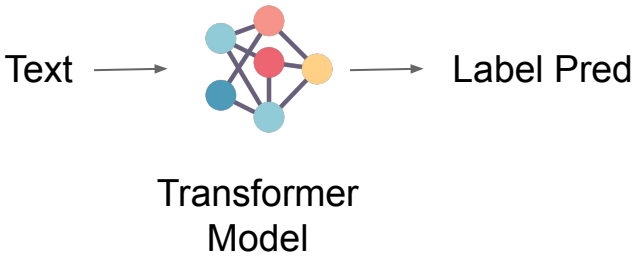


- Rich expressive power - long range dependencies

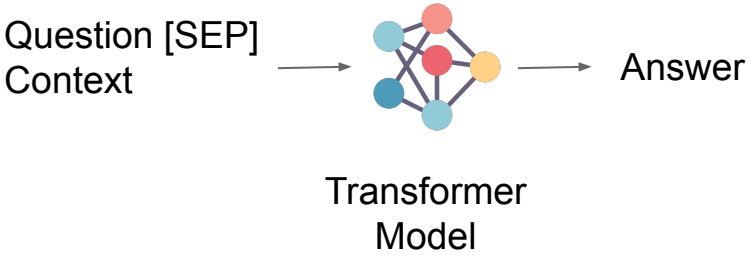


Impact - Wide Applications!

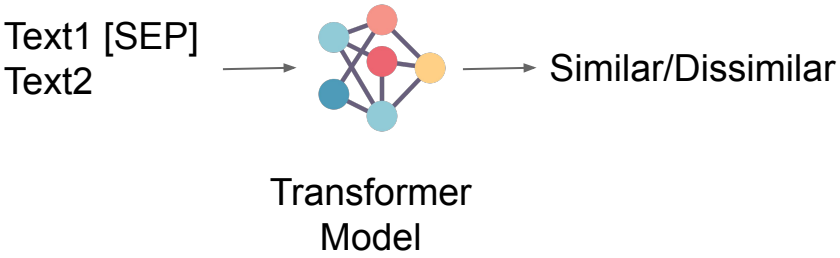
Classification



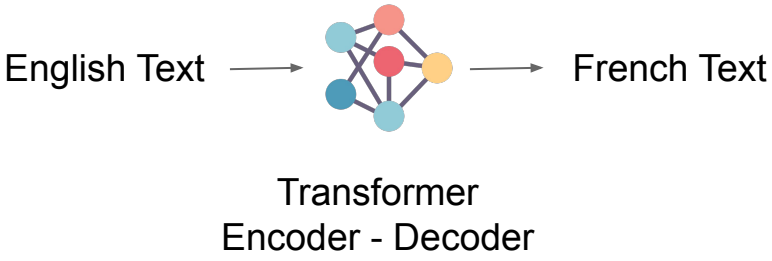
Question Answering



Sentence Similarity

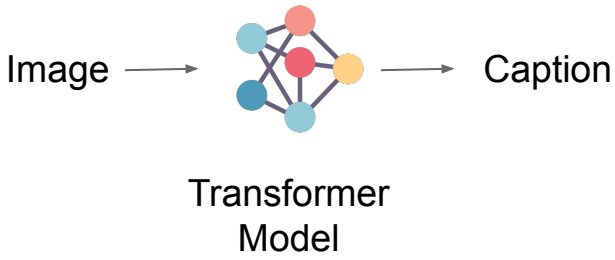


Translation



Impact - Wide Applications!

Captioning



Visual Question Answering

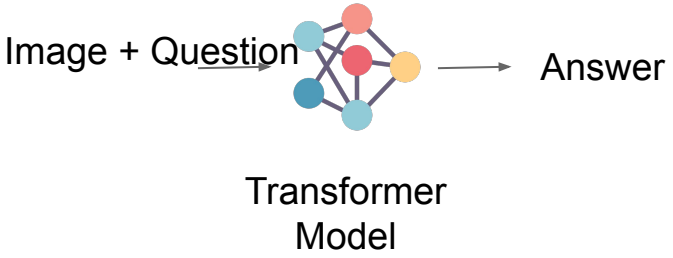
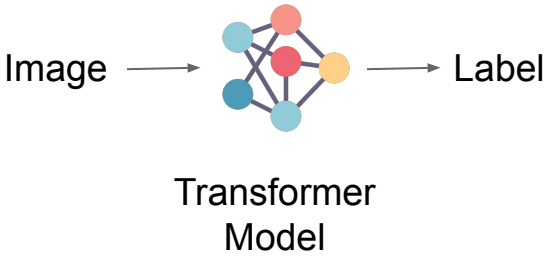
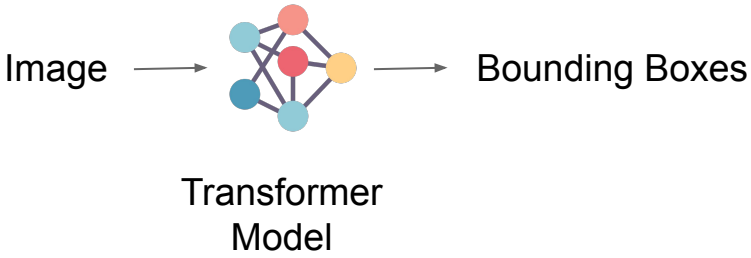


Image Classification

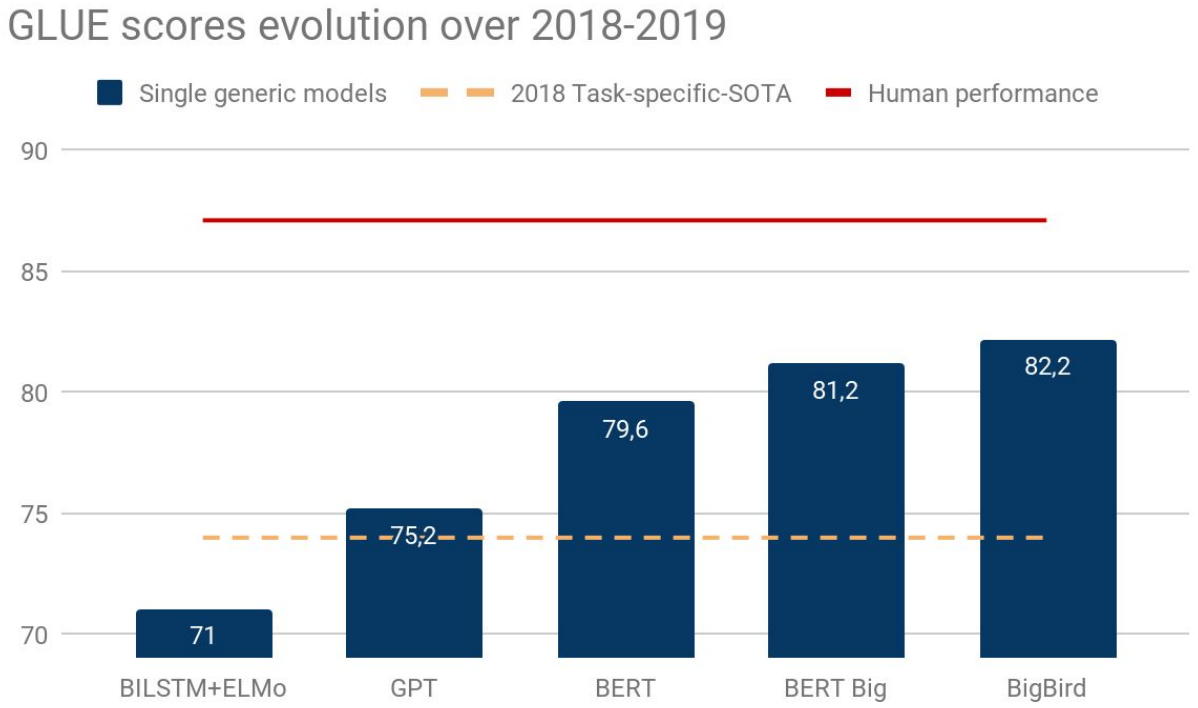


Object Detection

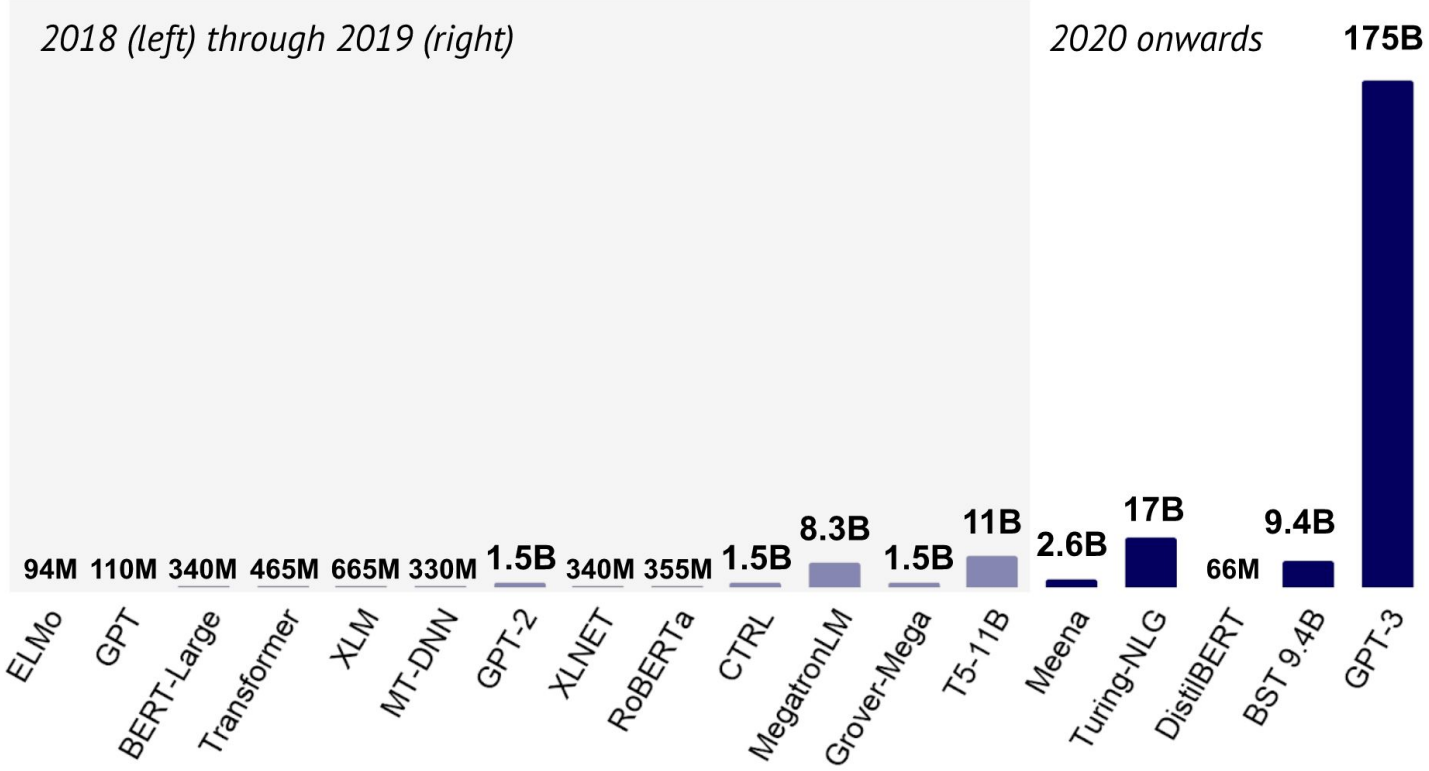


Larger Impact

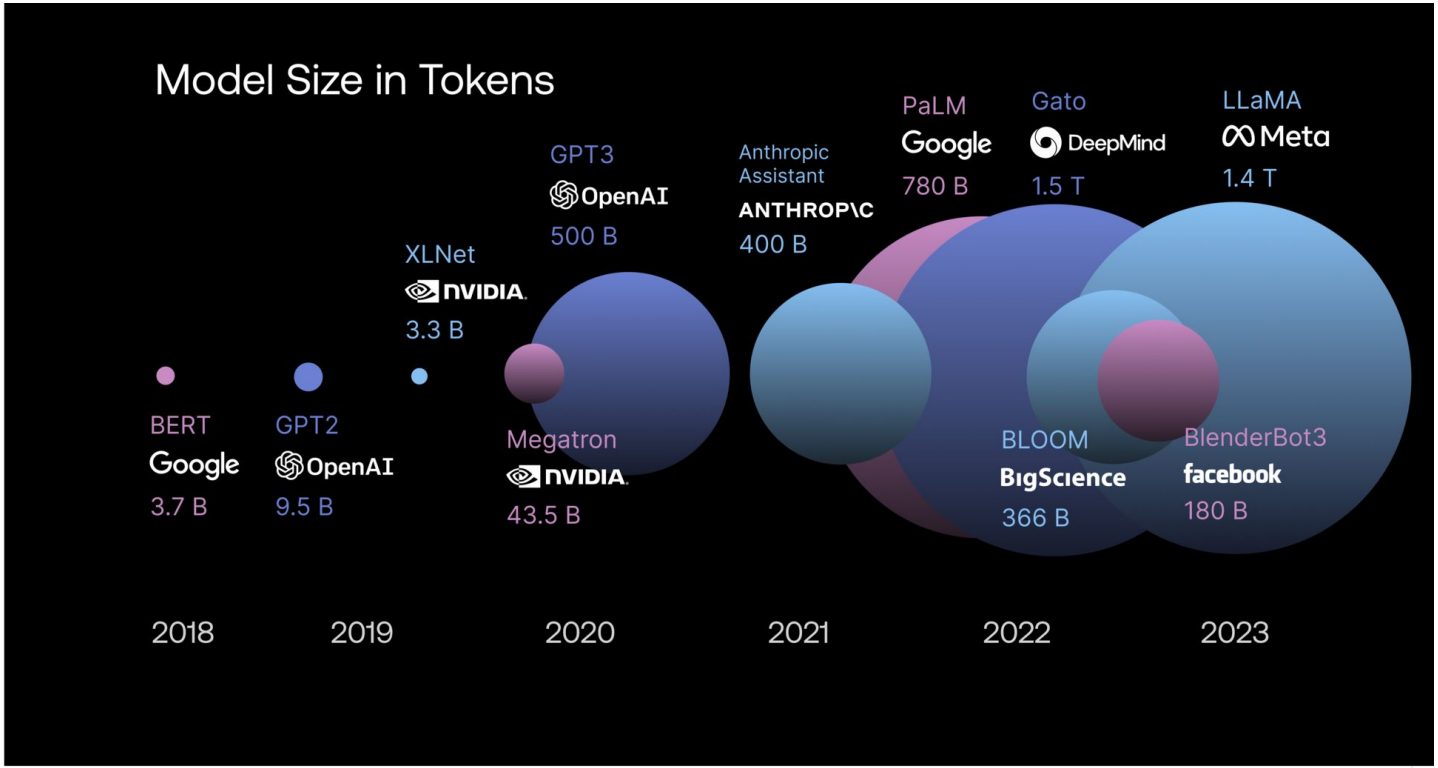
Larger Impact



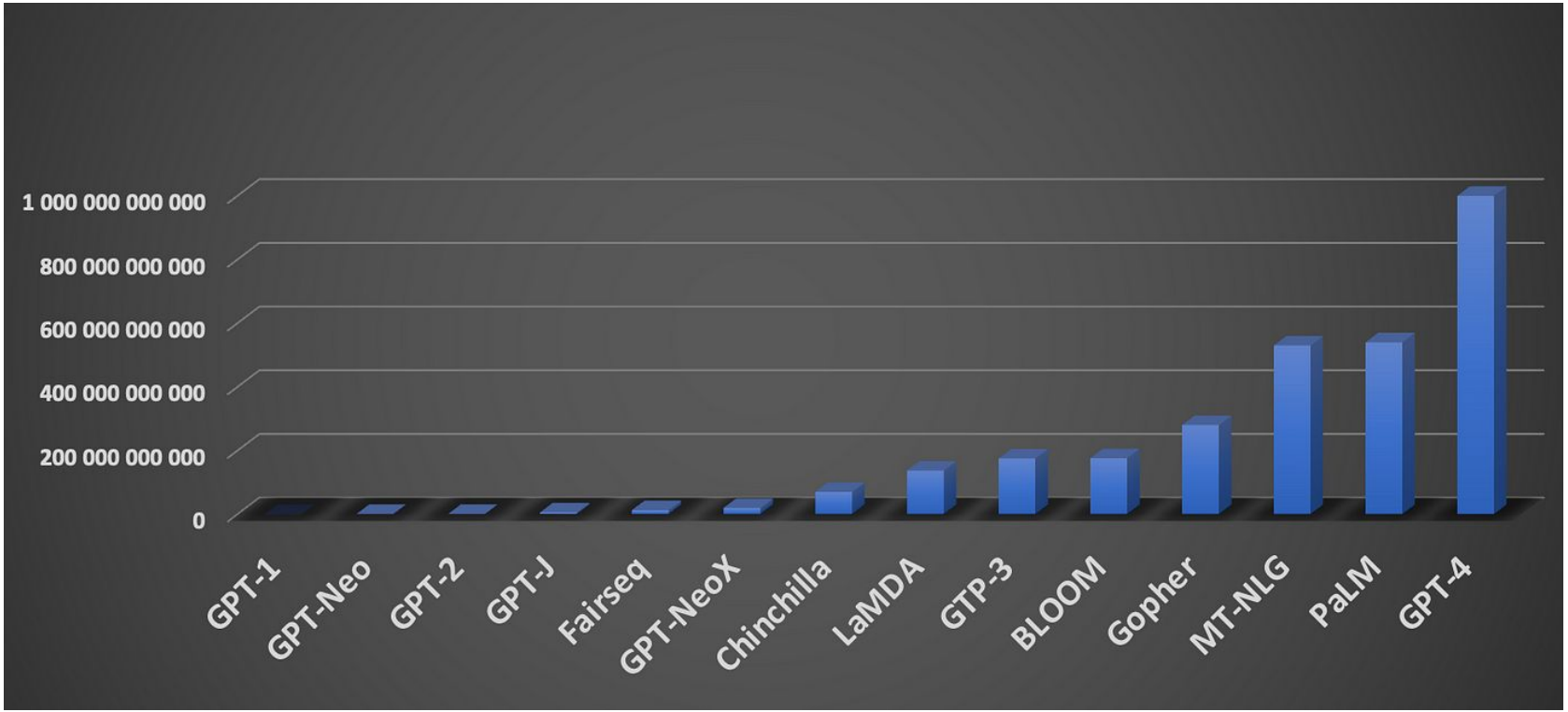
Larger Impact



Larger Impact



Larger Impact



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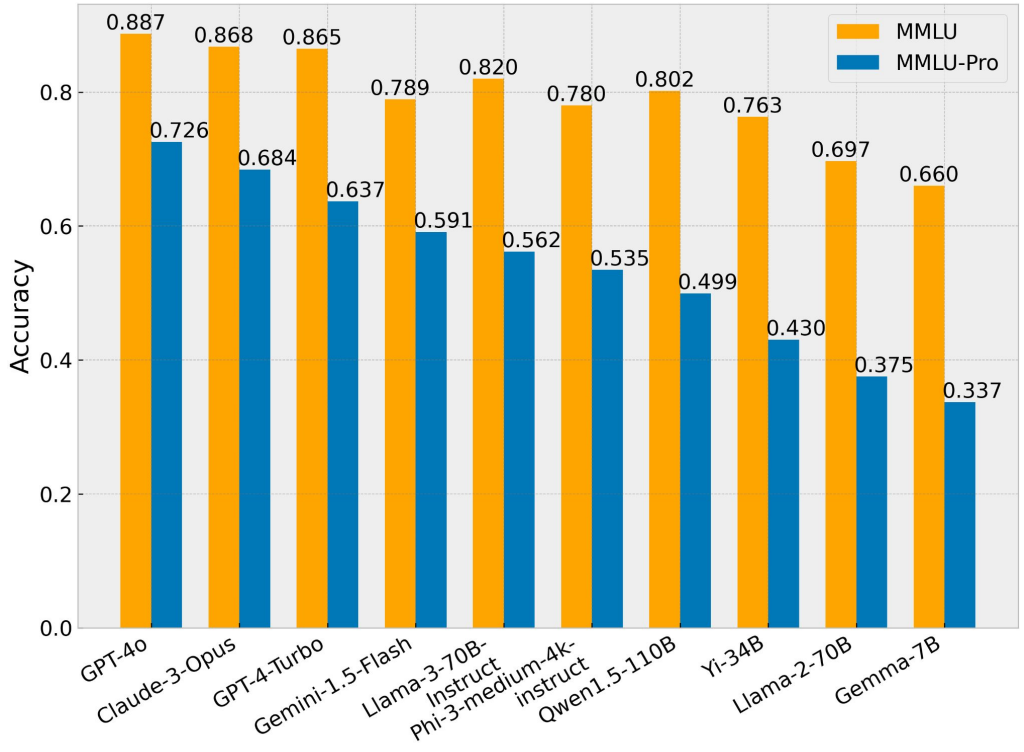

Larger Impact

AI will revolutionise research. But could it transform science altogether?

Announcing Microsoft Copilot, your everyday AI companion

POLITICO

THE FIFTY

More schools want your kids to use ChatGPT. Really.

Education leaders are embracing technology that set off a plagiarism panic just months ago.

How will leveraging AI change the future of legal services?

NYU Langone Health LLM can predict hospital readmissions

GPT-4's potential in shaping the future of radiology

Bing, Bard, and ChatGPT: How AI is rewriting the internet

Thank you!

vidhishab@microsoft.com

Results/Impact

- Improves results, Establishes SOTA in various tasks!
  - Machine Translation
  - Constituency Parsing
  - Language Modeling
  - and more!

- Computationally faster!
  - No sequential computation - Entire sequence processed in parallel