

How Context Affects Language Models' Factual Predictions

Fabio Petroni, Patrick Lewis, Aleksandra Piktus, Tim Rocktäschel, Yuxiang Wu, Alexander H. Miller, Sebastian Riedel

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FACEBOOK AI



Language models are able to store and retrieve
factual knowledge to some extent

The theory of relativity
was developed by ____.



Einstein

correct

zero-shot cloze-style question answering

Language Models as Knowledge Bases?

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Storing factual knowledge in a fixed number of weights has limitations

Giacomo Tedesco plays
in _____ position .



center

wrong

Giacomo Tedesco

From Wikipedia, the free encyclopedia

Giacomo Tedesco (born February 1, 1976 in [Palermo](#)) is a former Italian [football \(soccer\)](#) midfielder and football manager.

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Club career [edit]

Giacomo Tedesco started his professional career with his hometown club [U.S. Città di Palermo](#) in 1994. He remained in the [Sicilian](#) capital for 3 seasons, making nearly 70 total appearances and scoring 3 goals. In 1997, he moved to [Salernitana](#), where he would go on to make 133 appearances scoring 13 goals between 1997 and 2002. Although he was loaned out to [Napoli](#), for the 2000–2001 season. In six months with the southern Italian club, he played in 14 total games. In 2003, he briefly moved to [Cosenza](#) where he scored a single goal in 14 appearances. Later in 2003, he was sold to [Serie A](#) side [Reggina Calcio](#), where he would spend a solid 4 years in [Calabria](#), all in Italy's top flight. He scored 5 goals for Reggina in a total of over 120 appearances. In 2007, despite having a successful spell in Calabria, Tedesco transferred to Sicilian side [Calcio Catania](#). Since joining Catania, he has made over 50 appearances scoring 4 goals in just two seasons. Under former coaches, [Walter Zenga](#) and [Silvio Baldini](#) Tedesco was consistently part of the starting XI and is always a hard working consistent performer on the left wing. On 9 July 2009, Tedesco was very surprisingly sold to [Bologna FC](#) who have signed the midfielder from Calcio Catania on a two-year deal. On 14 January 2010, Tedesco was sent back to Reggina in an exchange deal for [Antonio Buscè](#).

Giacomo Tedesco

Personal information

Date of birth	February 1, 1976 (age 44)
Place of birth	Palermo , Italy
Height	1.75 m (5 ft 9 in)
Playing position(s)	Midfielder

Senior career*

Years	Team	Apps	(Gls)
1994–1997	Palermo	67	(3)
1997–2002	Salernitana	133	(13)
2000–2001	→ Napoli (<i>loan</i>)	14	(0)
2003	Cosenza	15	(1)
2003–2007	Reggina	121	(5)
2007–2009	Catania	60	(4)
2009	Bologna	8	(0)
2010–2011	Reggina	39	(0)
2011–2013	Trapani	49	(3)

Teams managed

2014–2015	Reggina U19
2015	Reggina
2018	Igea Virtus
2018–2019	Igea Virtus

* Senior club appearances and goals counted for the domestic league only

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Integrate information from a retrieval system
in a purely unsupervised way

Giacomo Tedesco plays
in _____ position .
[SEP]

Giacomo Tedesco is a
former Italian football
(soccer) midfielder and
football manager.



midfielder correct

**RETRIEVAL
SYSTEM**

Contexts

ORA:
oracle

provided in
LAMA

often contains
the true answer
and always
contains related
true information

RET:
retrieved

first paragraph
from DrQA's
retrieval system

often contains
relevant
information

GEN:
generated

1.4B parameters
autoregressive
language model -
purely in-weights
approach

might be related
but not factual

ADV:
adversarial

randomly sample
oracle context
from a different
question that has
the same relation

contains a
distracting and
semantically
plausible answer

LAMA	Relation	B
Google-RE	birth-place	16.1
	birth-date	1.4
	death-place	14.0
	Total	10.5
T-REx	1-1	74.5
	$N-1$	34.2
	$N-M$	24.3
	Total	32.3
SQuAD		17.4
<i>weighted average</i>		30.5

Results

LAMA	Relation	B
Google-RE	birth-place	16.1
	birth-date	1.4
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- dramatic improvement on the LAMA probe for BERT

- unsupervised machine reading capabilities of pre-trained LMs

B-ORA
70.6
98.1
65.1
78.0
91.1
67.3
52.4
62.6
61.7
63.6

LAMA	Relation	B
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BERT + IR
match a
supervised
baseline

<i>rain sourced context</i>		
DRQA	B-RET	B-ORA
48.6	43.5	<i>70.6</i>
42.9	43.1	<i>98.1</i>
38.4	35.8	<i>65.1</i>
43.3	40.8	<i>78.0</i>
55.2	81.2	<i>91.1</i>
30.4	47.5	<i>67.3</i>
15.4	32.0	<i>52.4</i>
25.8	43.1	<i>62.6</i>
37.5	34.3	<i>61.7</i>
27.2	42.8	<i>63.6</i>

LAMA	Relation	B	B-ADV	<i>open domain sourced context</i>			B-ORA
				B-GEN	DRQA	B-RET	
Google-RE	birth-place	16.1	14.5	8.5	48.6	43.5	<i>70.6</i>
	birth-date	1.4	1.4	1.4	42.9	43.1	<i>98.1</i>
	death-place	14.0	12.6	6.0	38.4	35.8	<i>65.1</i>
	Total	10.5	9.5	5.3	43.3	40.8	<i>78.0</i>
T-REx	1-1	74.5	74.5	71.3	55.2	81.2	<i>91.1</i>
	<i>N-1</i>	34.2	33.8	32.7	30.4	47.5	<i>67.3</i>
	<i>N-M</i>	24.3	23.6	23.8	15.4	32.0	<i>52.4</i>
	Total	32.3	31.8	31.1	25.8	43.1	<i>62.6</i>
SQuAD		17.4	17.4	15.8	37.5	34.3	<i>61.7</i>
<i>weighted average</i>		30.5	30.0	29.0	27.2	42.8	<i>63.6</i>

BERT's next-sentence prediction is an effective unsupervised mechanism to exploit context

Segment A

Giacomo Tedesco plays
in _____ position .
[SEP]

Giacomo Tedesco is a
former Italian football
(soccer) midfielder and
football manager.

Segment B



masked language model



midfielder correct

next sentence prediction



NSP = 1

ORACLE

BERT's next-sentence prediction is an effective unsupervised mechanism to ignore noisy contexts

Segment A

Giacomo Tedesco plays
in _____ position .
[SEP]

Mauricio Antonio
Robles is a
former Venezuelan
baseball pitcher.

Segment B



masked language model



center

wrong

equivalent to zero-context prediction

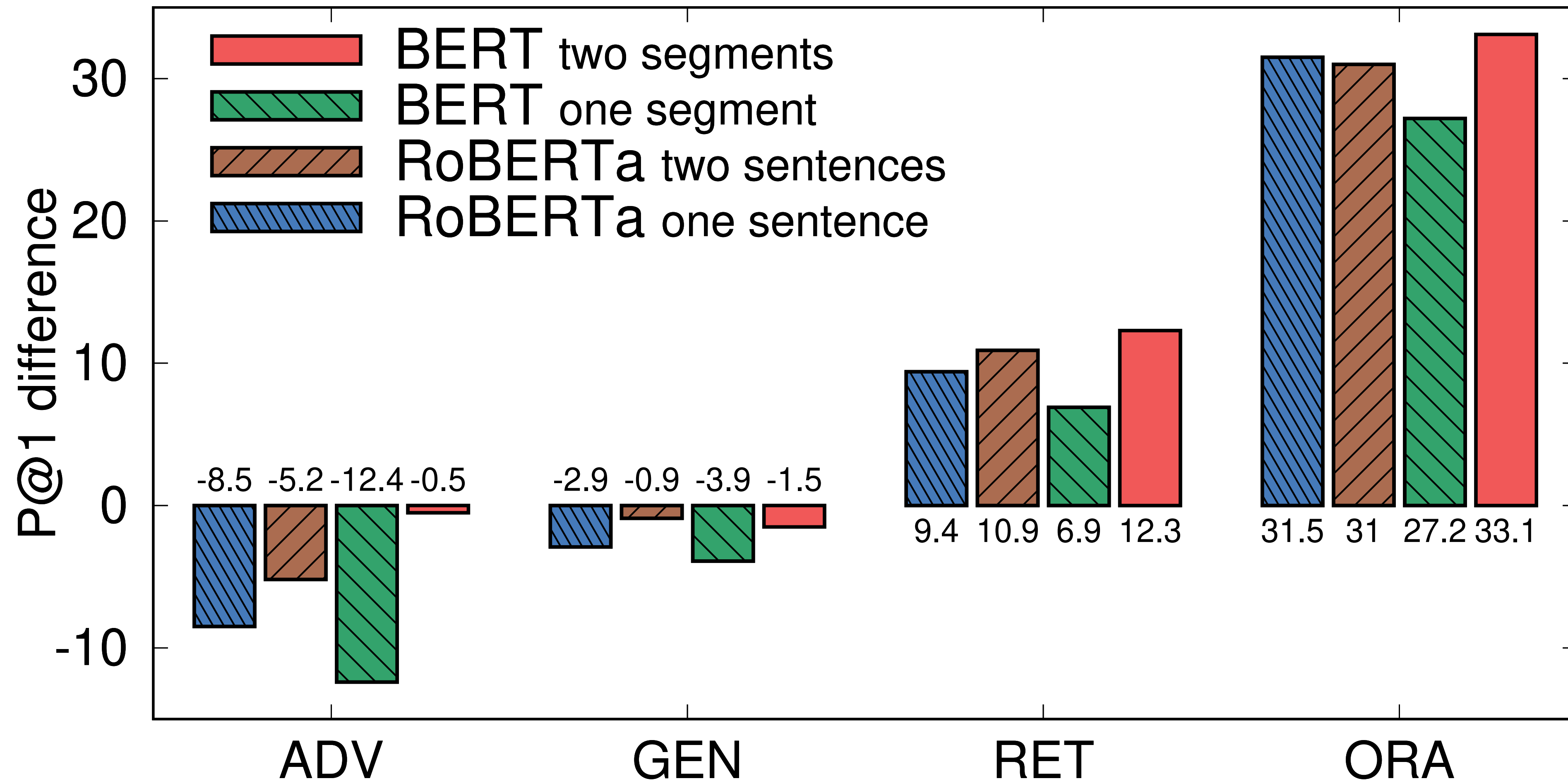
next sentence prediction



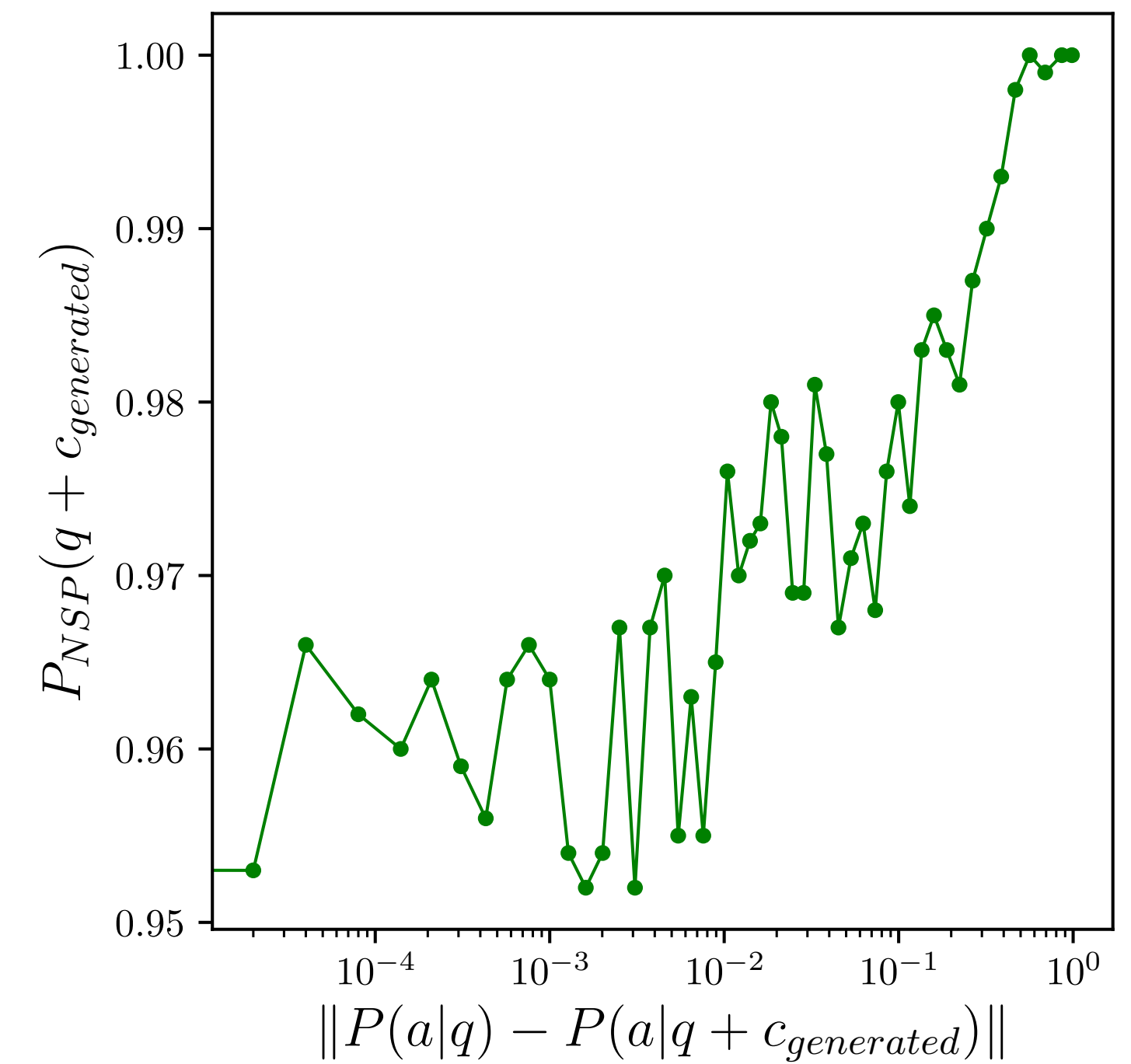
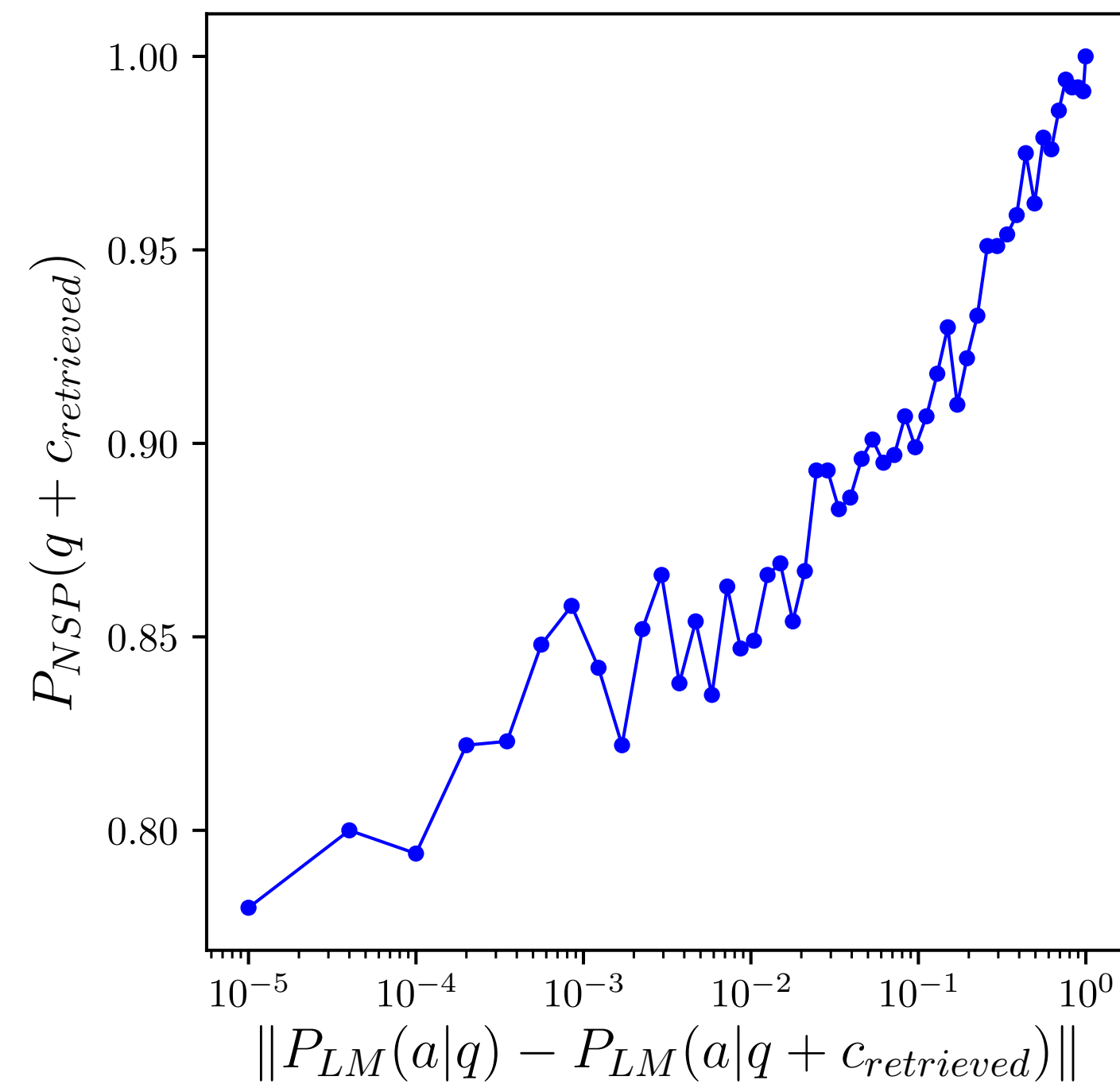
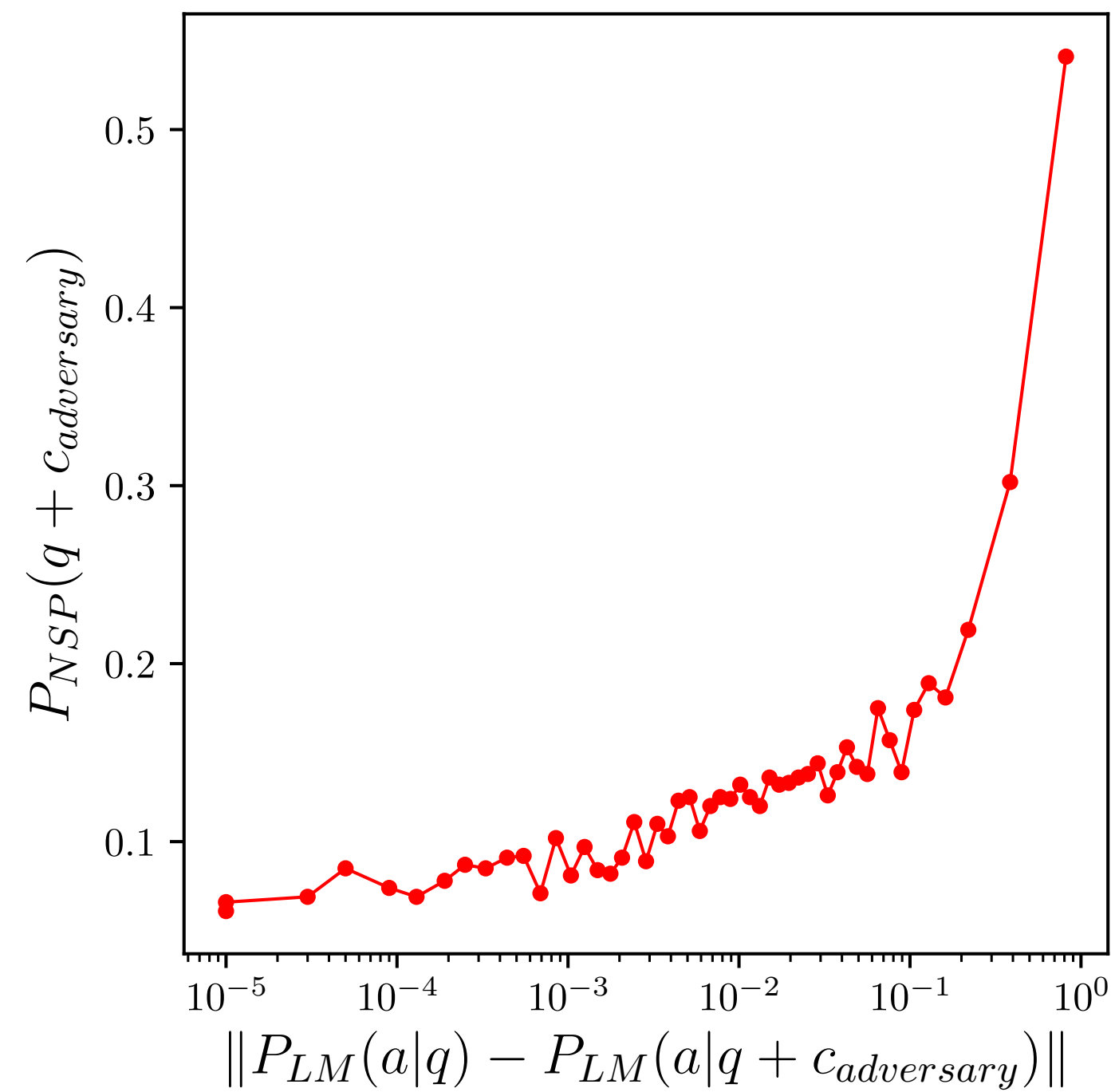
NSP = 0

ADVERSARIAL

Change in P@1 relative to zero context



The more relevant that BERT thinks the context is, the more we see an increase to the likelihood of the true answer



Percentage of times BERT changes its output for the better or worse

P@1	<i>answer in ctx</i>	B-ADV	B-GEN	B-RET	B-ORA
<i>better</i>	<i>present</i>	0.9	4.6	14.0	32.6
	<i>absent</i>	2.4	2.5	3.2	1.4
	Total	3.3	7.0	17.2	34.0
<i>worse</i>	<i>present</i>	0.6	2.0	2.4	3.5
	<i>absent</i>	3.1	6.2	3.9	0.1
	Total	3.7	8.2	6.3	3.6
<i># better rel.</i>		11	13	34	39

- Autoregressive language models can generate relevant context and potentially serve as unsupervised IR systems
- BERT is unable to filter generated irrelevant or factually wrong information

For BERT the generation is always a plausible continuation of the question

Segment A

Giacomo Tedesco plays
in _____ position .
[SEP]

How much does he
play? He can play
fullback, wing or centre.
He can also play ...

Segment B



masked language model



fullback

wrong

next sentence prediction



NSP = 1

GENERATED

It is not necessary to have the answer in the context
to get a correct prediction

Segment A

Giacomo Tedesco plays
in _____ position .
[SEP]

Giovanni Tedesco has
two brothers who are
also football players,
Salvatore and Giacomo.

Segment B



masked language model



midfielder

correct

next sentence prediction



NSP = 1

RETRIEVED

Conclusion

- **Re-examining NSP:** it is important for robust exploitation of retrieved context for unsupervised tasks.
- **Comparison with DrQA:** extractive while BERT is abstractive. Single-token limitation of the LAMA probe.
- **Unsupervised Question Answering:** powerful and flexible unsupervised QA systems could soon be a reality.

THANK YOU



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Artificial Intelligence Research