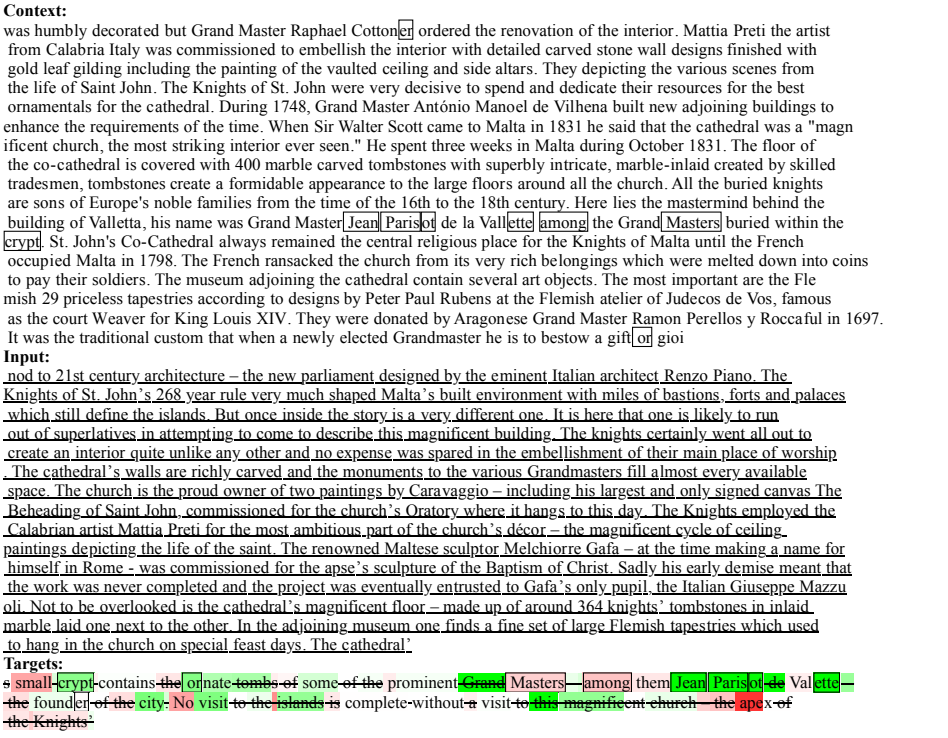
Appendix

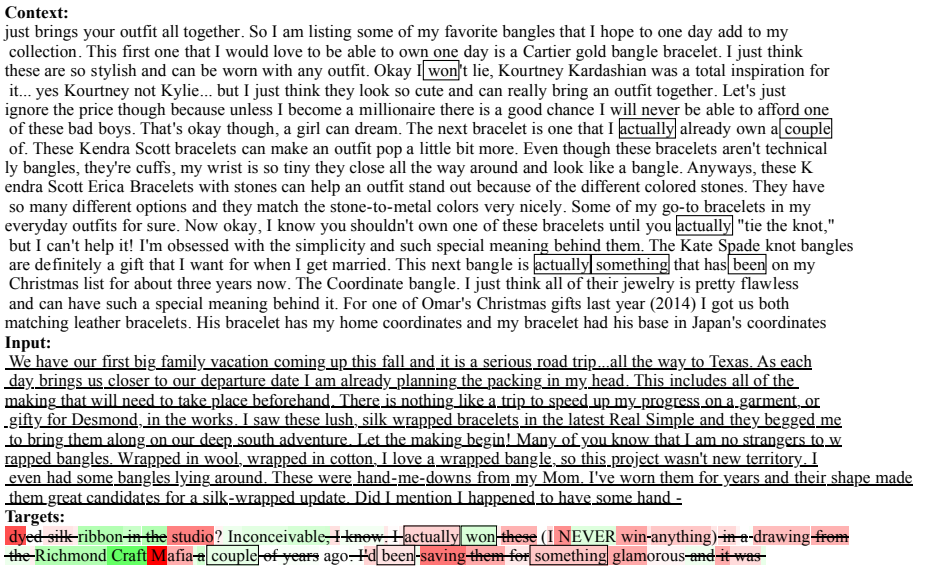
Appendix A Full data on POS tags and percentage of improvement on the log likelihood score.

	Not in context, not in input	Not in context, in input	In context, not in input	In context, in input	Occurrence
NN	0.157771	0.698062	16.197878	5.578312	23639620
NNP	0.020258	0.527689	35.891013	8.141562	16840255
IN	-0.169446	-0.187711	3.308690	1.816983	13603903
JJ	0.400632	1.011774	13.077988	5.019096	12885333
DT	0.224373	0.196791	3.253798	2.453526	11128747
NNS	0.131760	0.594879	17.203110	5.242418	10088414
.	0.074150	-0.292448	7.026237	0.411417	6330229
RB	0.692010	0.897788	5.454908	2.711667	6174253
VB	0.384166	0.659601	9.219075	3.491015	5390427
,	0.731329	0.710795	3.420206	2.353697	5245713
PRP	-0.260621	-0.006360	3.305721	1.998650	5219071
CC	0.055603	0.277403	3.446472	2.634180	4463355
VBZ	0.355881	0.093804	5.872791	0.625349	3895160
VBG	0.588187	0.913552	11.268538	4.581329	3834853
VBN	0.260189	0.650080	12.332930	4.213668	3646850
VBD	0.312395	0.378780	6.878956	2.758350	3377739
VBP	0.333019	0.362408	5.038212	1.873432	3308882
TO	0.000127	-0.183880	3.921325	1.767642	3205519
CD	0.619997	1.148265	20.414486	5.950232	2723028
PRP$	0.040851	0.269473	4.617825	2.683837	1942225
MD	-0.115006	0.047148	3.572827	2.559091	1590480
:	-0.729198	-0.690925	5.812855	3.404822	650535
WDT	0.455384	0.571508	3.444940	1.234093	576220
WRB	0.638024	0.921696	5.063341	3.163921	572072
JJR	1.010684	1.612511	7.880883	4.808698	483001
(	0.226634	0.602507	3.785168	2.695342	450846
WP	1.296407	1.746595	5.018384	3.681695	437709
RP	0.347023	0.406551	5.269570	3.544124	416556
POS	-1.028733	0.472410	8.667241	2.427072	387925
)	0.200041	0.019679	4.084305	1.586972	369449
JJS	0.499507	0.790719	7.975327	4.348411	342354
NNPS	-0.206552	0.327515	30.412756	6.301600	233250
EX	0.793452	1.222533	4.670563	3.714079	201943
RBR	1.037655	2.046677	5.190104	4.050341	192250
PDT	0.604735	1.509266	3.752347	3.438381	84221
RBS	0.114155	0.759014	4.438339	4.140244	83746
FW	0.779163	0.560080	13.321369	4.776943	80379
$	-0.071967	0.671289	18.502472	5.415212	63854
UH	0.154138	0.207683	7.501694	3.188253	45710
”	0.967397	1.077652	17.579383	2.770341	30181
WP$	2.702986	3.293384	6.577276	3.215185	18004
#	0.767495	4.536762	31.027920	14.052459	14969
SYM	0.343766	-3.428490	20.566550	3.729796	5532
“	1.352541	4.927900	35.315082	16.644833	2998
LS	3.417315	-1.039910	57.893078	8.573192	836

Appendix B Visualization of context and change in token log likelihood



(a) Sampled from context-input-target triplet with top 1% of context utility.



(b) Randomly sampled.

Figure 1: Visualize the difference in log-likelihood for each target token with and without context.

Visualize the delta log-likelihood for each target token with and without context. The color of each target token is determined by $\log P(y_i|y_{<i}, \mathbf{x}, \mathbf{c}, \theta) - \log P(y_i|y_{<i}, \mathbf{x}, \theta')$. The color is green if the difference is positive (context helped). The color is red if the difference is negative (context harmed). We put a box around a target token if it only appeared in the context, but not input. We put a strike-through on a token if it appeared in the input. We show two examples here. Figure 1a is sampled from the context-input-target triplet with top 1% of context utility. Figure 1b is randomly sampled from the whole C4 train split. We provide more examples in the supplementary materials. They are interactive HTML files that you can mouse-over the tokens to see the difference in log-likelihood.

Appendix C Model training steps per second

Model Size	Steps/Sec	Training Devices	Number of Steps	Batch size
C4 Language Modeling				
`113M`	3.3	64 TPUv3	1,100,000	512
`409M`	2.2	64 TPUv3	1,100,000	512
`1560M`	1.5	128 TPUv3	1,100,000	512
Natural Question				
`409M`	212.5	64 TPUv3	40,000	64
`1560M`	74.6	64 TPUv3	40,000	64

Appendix D License for assets used in this work

Name	License	Link
C4 English Dataset	ODC-By-1.0	https://commoncrawl.org
Natural Question	CC BY-SA 3.0	https://github.com/google-research-datasets/natural-questions/tree/master/nq_open
T5X	Apache-2.0	https://github.com/google-research/t5x
mT5	Apache-2.0	https://github.com/google-research/multilingual-t5
T5 Retrieval	Apache-2.0	https://github.com/google-research/t5x_retrieval