Group-wise Contrastive Learning for Neural Dialogue Generation

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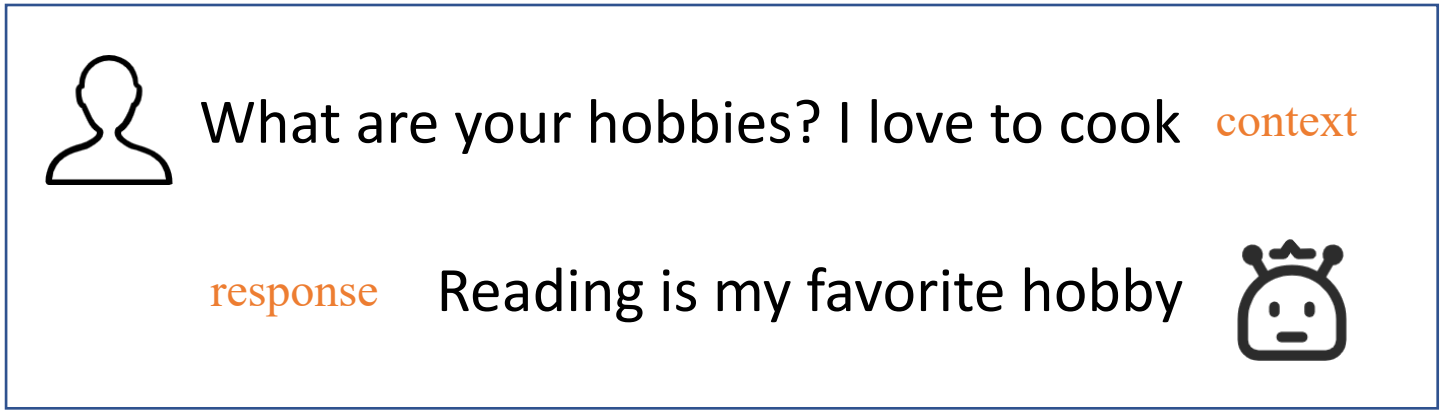
Task

- Neural Dialogue Generation



Problem

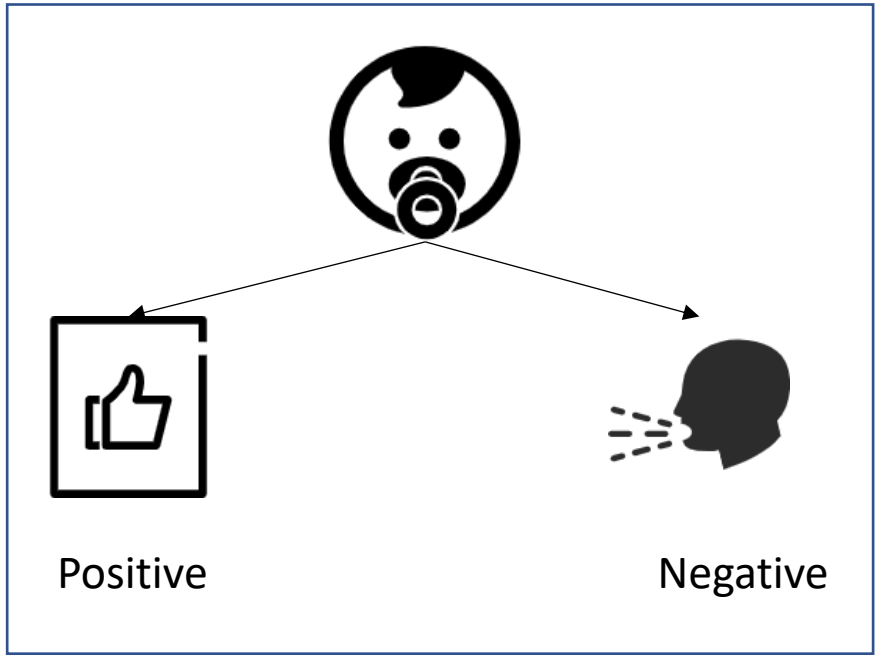
- Maximum Likelihood Estimation (MLE) Objective
  - relatively high frequencies in conversational datasets

I don’t know

Safe but Dull and Vacuous

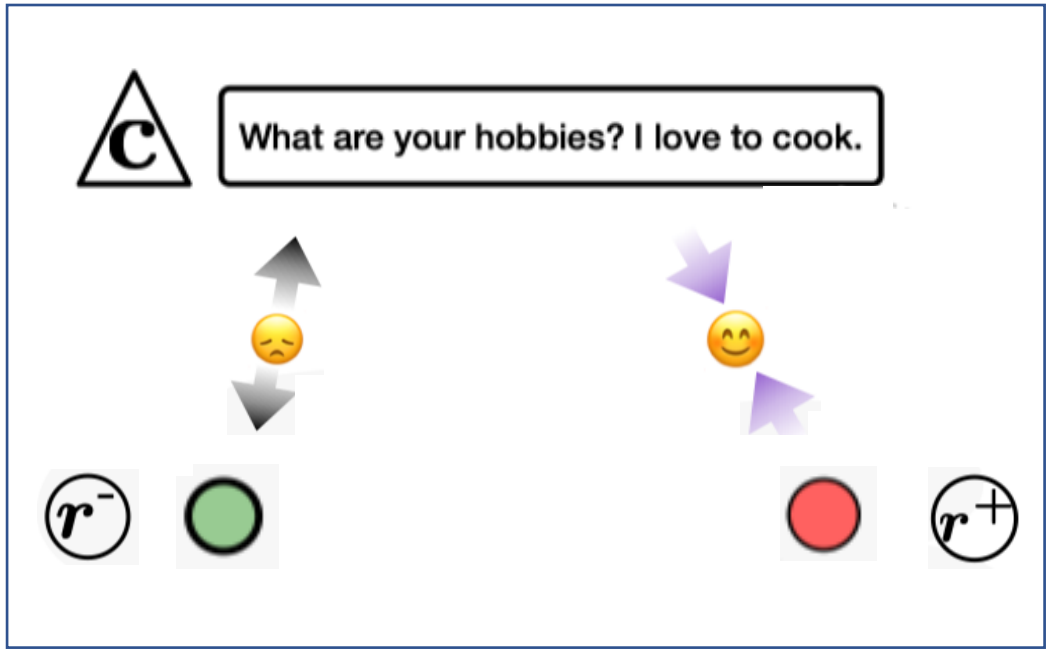
Motivation

- Humans not only learn from the positive signals but also benefit from correcting behaviors of undesirable actions.



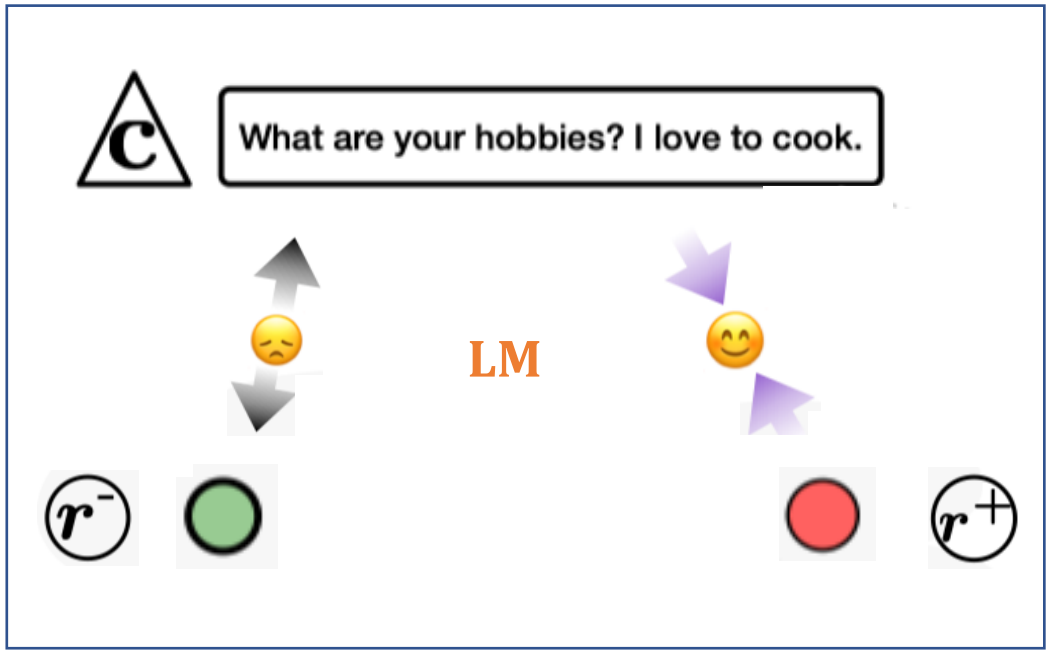
Method

- Contrastive Learning



Method

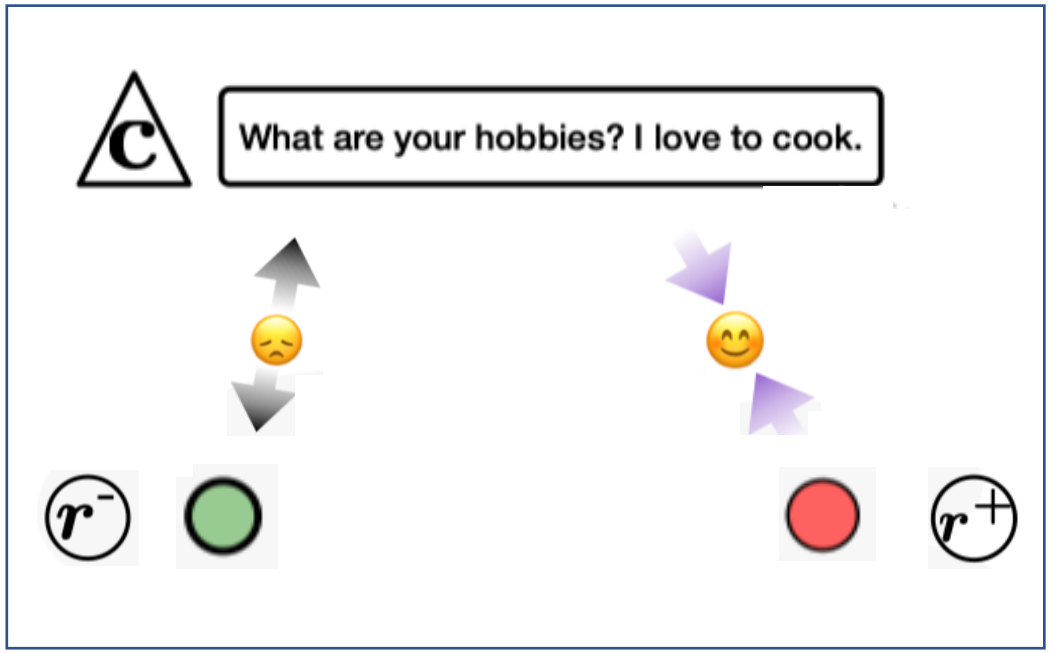
- Contrastive Learning



$$\mathcal{L}''(\boldsymbol{\theta}; \mathbb{D}) =$$
$$-\frac{1}{N}\sum_{(\boldsymbol{c},\boldsymbol{r})\in\mathbb{D}} \log\sigma(\text{LM}[(\boldsymbol{c},\boldsymbol{r})^+;\boldsymbol{\theta}])$$
$$-\frac{1}{N}\sum_{(\boldsymbol{c},\boldsymbol{r})\in\mathbb{D}} \log[1-\sigma(\text{LM}[(\boldsymbol{c},\boldsymbol{r})^-;\boldsymbol{\theta}])]$$

Method

- Contrastive Learning



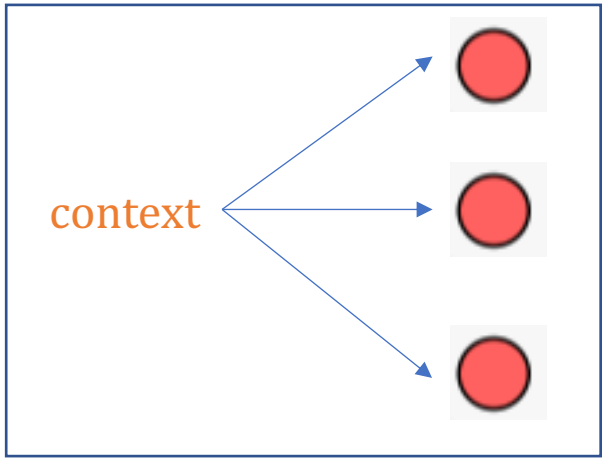
$$\mathcal{D}((\boldsymbol{c},\boldsymbol{r});\boldsymbol{\theta},\boldsymbol{\phi}) = \log \frac{p_m(\boldsymbol{r}|\boldsymbol{c},\boldsymbol{\theta})}{p_n(\boldsymbol{r}|\boldsymbol{c},\boldsymbol{\phi})}$$

pretrained baseline model

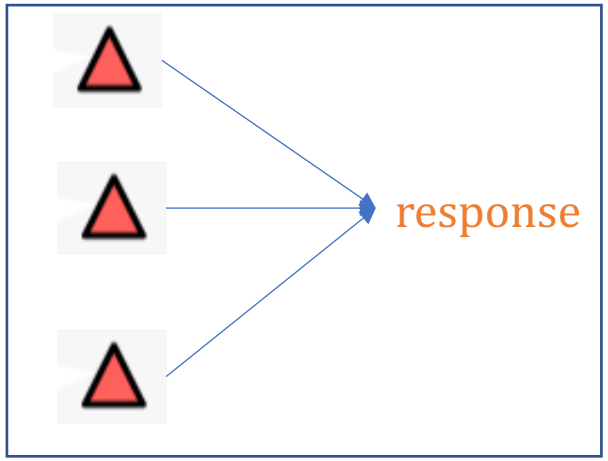
$$\mathcal{L}''(\boldsymbol{\theta};\mathbb{D},\boldsymbol{\phi}) =$$
$$-\frac{1}{N}\sum_{(\boldsymbol{c},\boldsymbol{r})\in\mathbb{D}} \log\sigma(\mathcal{D}((\boldsymbol{c},\boldsymbol{r})^{+};\boldsymbol{\theta},\boldsymbol{\phi}))$$
$$-\frac{1}{N}\sum_{(\boldsymbol{c},\boldsymbol{r})\in\mathbb{D}} \log\left[1-\sigma(\mathcal{D}((\boldsymbol{c},\boldsymbol{r})^{-};\boldsymbol{\theta},\boldsymbol{\phi}))\right]$$

Problem

- multi-mapping relations



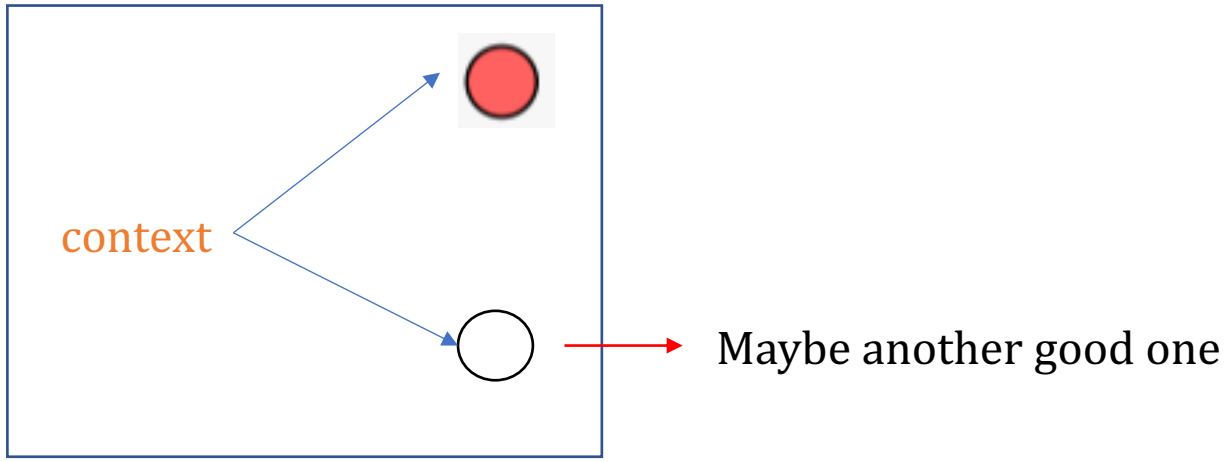
one-to-many



many-to-one

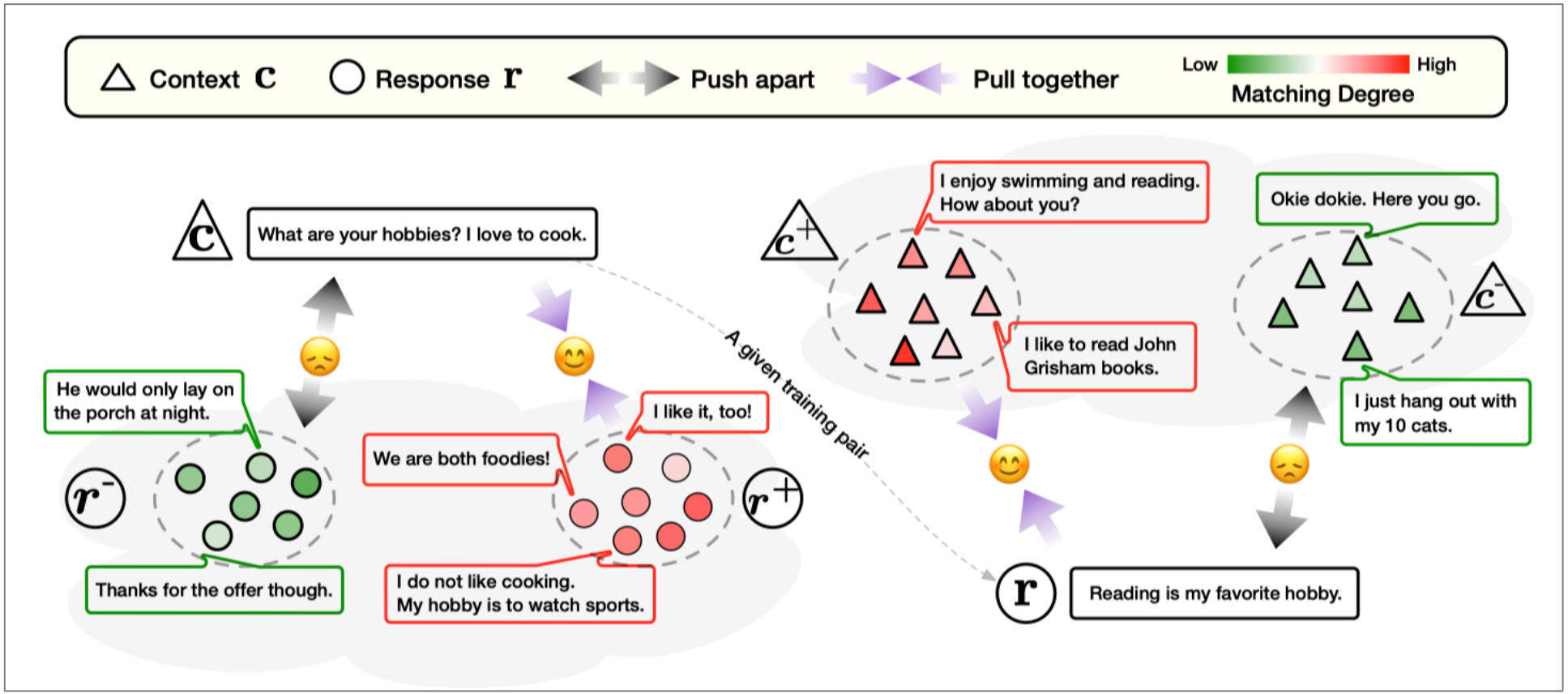
Problem

- Single pair contrastive learning



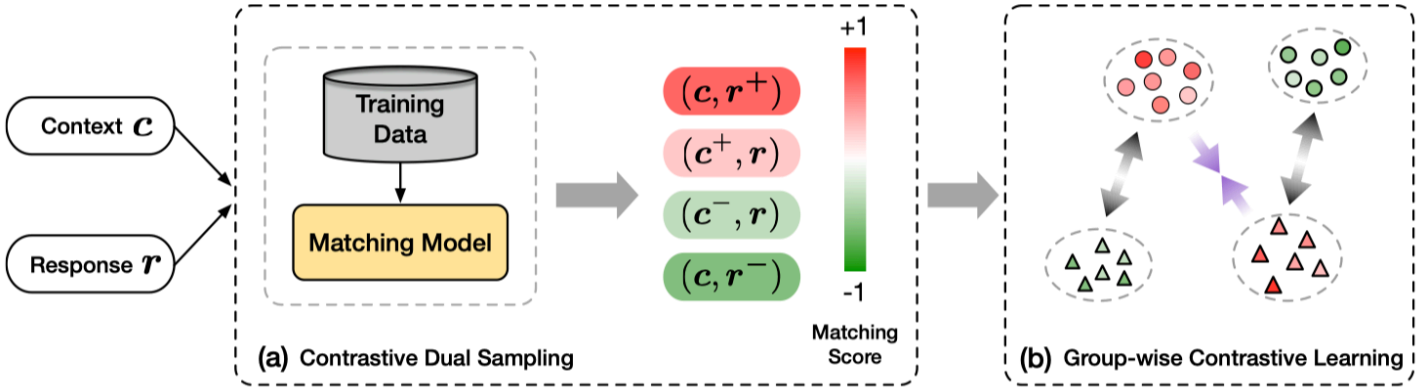
Method

- Contrastive Dual Sampling



Method

- Group-wise Contrastive Learning



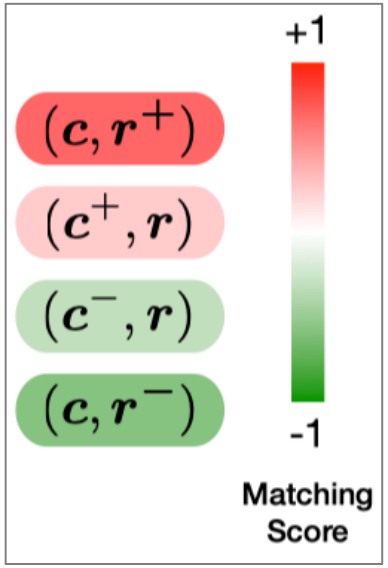
$$\mathcal{L}'(\boldsymbol{\theta}; \mathbb{D}, \boldsymbol{\phi}) =$$

$$-\frac{1}{N}\sum_{(\boldsymbol{c},\boldsymbol{r})\in\mathbb{D}}\frac{1}{2\boldsymbol{k}+1}\sum_{i=1}^{2\boldsymbol{k}+1}\log\sigma(\mathcal{D}((\boldsymbol{c},\boldsymbol{r})_i^+;\boldsymbol{\theta},\boldsymbol{\phi}))$$

$$-\frac{1}{N}\sum_{(\boldsymbol{c},\boldsymbol{r})\in\mathbb{D}}\frac{1}{2\boldsymbol{k}}\sum_{i=1}^{2\boldsymbol{k}}\log\left[1-\sigma(\mathcal{D}((\boldsymbol{c},\boldsymbol{r})_i^-;\boldsymbol{\theta},\boldsymbol{\phi}))\right]$$

Method

- Weighted Group-wise Contrastive Learning



$$\mathcal{L}(\boldsymbol{\theta}; \mathbb{D}, \boldsymbol{\phi}) =$$

$$-\frac{1}{N}\sum_{(\boldsymbol{c},\boldsymbol{r})\in\mathbb{D}}\frac{1}{2\boldsymbol{k}+1}\sum_{i=1}^{2\boldsymbol{k}+1}\log\left[\boldsymbol{s}_i^+\cdot\sigma(\mathcal{D}((\boldsymbol{c},\boldsymbol{r})_i^+;\boldsymbol{\theta},\boldsymbol{\phi}))\right]$$

$$-\frac{1}{N}\sum_{(\boldsymbol{c},\boldsymbol{r})\in\mathbb{D}}\frac{1}{2\boldsymbol{k}}\sum_{i=1}^{2\boldsymbol{k}}\log\left[1+\boldsymbol{s}_i^-\cdot\sigma(\mathcal{D}((\boldsymbol{c},\boldsymbol{r})_i^-;\boldsymbol{\theta},\boldsymbol{\phi}))\right]$$

Experiments

	PersonaChat	Douban	OpenSubtitles
#context-response pairs	140,248	218,039	353,046
Avg. #turns per context	2.69	3.94	3.79
Avg. #words per utterance	11.96	15.28	6.85
Training Pairs	113,558	198,039	293,129
Validation Pairs	13,602	10,000	29,960
Test Pairs	13,088	10,000	29,957
#Tokens	18,029	40,000	40,000

Table 1: Data statistics for PersonaChat, Douban and OpenSubtitles datasets.

Results

	Models	BLEU-1 / 2 / 3 / 4	Dist-1	Dist-2	Dist-3	Avg.	Ext.	Gre.	Coh.	Ent-1 / 2
(a)	SEQ2SEQ	12.040 / 3.9950 / 0.8815 / 0.2312	0.4309	2.045	4.303	36.33	28.66	63.64	41.66	6.891 / 10.81
	SEQ2SEQ (►)	**13.660 / 4.9160 / 1.5970 / 0.6122**	**0.8492**	**5.093**	**12.000**	**39.76**	**31.74**	**64.76**	**49.39**	**7.016 / 10.90**
	HRED	12.410 / 3.8360 / 0.8455 / 0.2364	0.4744	2.546	6.127	36.52	28.37	64.12	39.08	6.792 / 10.66
	HRED (►)	**13.180 / 4.3220 / 1.0360 / 0.3274**	**0.7130**	**4.468**	**11.220**	**38.54**	**29.65**	**64.26**	**44.07**	**6.931 / 10.84**
	TRANSFORMER	11.460 / 3.2080 / 0.5389 / 0.1476	0.4813	2.544	6.146	35.72	27.38	63.61	38.02	6.804 / 10.55
	TRANSFORMER (►)	**12.660 / 3.8920 / 0.8406 / 0.2577**	**0.7859**	**4.562**	**10.950**	**37.42**	**28.95**	**64.02**	**41.96**	**6.918 / 10.80**
	HRAN	12.190 / 3.8290 / 0.7752 / 0.2171	0.5074	2.883	7.104	36.53	28.08	63.58	40.22	**6.964** / 10.83
	HRAN (►)	**13.430 / 4.5030 / 1.0630 / 0.3513**	**0.7713**	**4.974**	**12.380**	**39.04**	**30.08**	**64.48**	**46.63**	6.942 **/ 10.87**
(b)	SEQ2SEQ	5.585 / 0.7887 / 0.1008 / 0.0296	1.1610	6.105	13.100	46.75	36.80	**53.52**	52.13	7.225 / 11.13
	SEQ2SEQ (►)	**5.821 / 0.7910 / 0.1053 / 0.0377**	**1.3010**	**7.935**	**18.070**	**46.96**	**36.99**	53.41	**53.40**	**7.464 / 11.66**
	HRED	**5.899** / 0.7925 / 0.0786 / 0.0206	0.8334	5.147	14.160	48.12	36.50	**54.20**	49.99	7.107 / 10.90
	HRED (►)	5.778 **/ 0.7968 / 0.0996 / 0.0387**	**1.2910**	**7.461**	**19.450**	**48.23**	**36.51**	53.34	**50.31**	**7.436 / 11.10**
	TRANSFORMER	5.229 / 0.6443 / 0.0764 / 0.0240	1.1140	5.658	13.830	45.45	35.45	53.04	48.04	7.084 / 11.15
	TRANSFORMER (►)	**5.386 / 0.6460 / 0.0889 / 0.0274**	**1.3280**	**6.723**	**15.800**	**45.96**	**36.11**	**53.33**	**48.92**	**7.238 / 11.16**
	HRAN	5.366 / 0.7229 / **0.0860** / 0.0182	1.0960	6.679	17.250	47.44	36.35	**53.93**	50.25	7.202 / **11.15**
	HRAN (►)	**5.541 / 0.7424** / 0.0723 **/ 0.0194**	**1.6630**	**10.030**	**24.240**	**48.01**	**36.99**	53.46	**51.81**	**7.394** / 10.94
(c)	SEQ2SEQ	5.666 / 1.0870 / **0.2471** / 0.0416	0.2880	2.110	5.566	54.22	46.11	63.96	56.82	6.685 / 10.54
	SEQ2SEQ (►)	**5.696 / 1.1290** / 0.2199 **/ 0.0476**	**0.4495**	**3.681**	**10.860**	**54.32**	**47.13**	**64.54**	**58.60**	**6.792 / 10.80**
	HRED	5.489 / 0.9953 / 0.2206 / 0.0711	0.3020	2.179	6.355	**54.61**	**54.36**	67.91	56.45	6.699 / 10.74
	HRED (►)	**5.670 / 1.0930 / 0.2461 / 0.0828**	**0.4490**	**3.099**	**8.949**	54.19	**54.36**	**68.16**	**57.26**	**6.722 / 10.80**
	TRANSFORMER	4.619 / **0.8294** / 0.1500 / 0.0307	0.3470	2.038	5.028	52.29	44.21	63.16	53.40	6.677 / 10.40
	TRANSFORMER (►)	**4.712** / 0.8197 **/ 0.1744 / 0.0314**	**0.3897**	**2.437**	**6.188**	**52.34**	**45.12**	**63.52**	**54.11**	**6.722 / 10.50**
	HRAN	5.090 / 0.8424 / 0.1665 / 0.0405	0.3205	2.604	8.188	**54.74**	54.52	68.16	56.58	6.556 / 10.53
	HRAN (►)	**5.423 / 0.9192 / 0.1913 / 0.0529**	**0.5034**	**3.935**	**11.920**	54.40	**54.54**	**68.30**	**57.48**	**6.699 / 10.89**

Results

Learning Approaches	BLEU-1 / 2 / 3 / 4	Dist-1	Dist-2	Dist-3	Avg.	Ext.	Gre.	Coh.	Ent-1 / 2
ADVERSARIAL	12.190 / 4.0060 / 0.8950 / 0.2644	0.6269	3.357	7.374	35.93	29.00	63.65	42.38	6.980 / 10.88
MMI	**14.030** / 4.6460 / 1.3340 / 0.5022	0.4734	2.443	5.515	39.34	30.92	**64.84**	45.16	6.874 / 10.65
DEEPRL	12.660 / 4.0150 / 1.0140 / 0.3314	0.6838	3.838	8.581	37.23	29.68	64.30	44.13	6.885 / 10.85
CVAE	11.570 / 2.8100 / 0.6357 / 0.1714	0.2876	2.326	7.506	39.29	30.61	63.67	41.76	6.869 / 10.82
DIALOGWAE	11.430 / 2.9260 / 0.5676 / 0.1436	**0.9936**	5.080	9.928	38.68	28.70	63.39	41.06	7.009 / **11.09**
Ours	13.660 / **4.9160 / 1.5970 / 0.6122**	0.8492	**5.093**	**12.000**	**39.76**	**31.74**	64.76	**49.39**	**7.016 /** 10.90

Table 3: Performance (%) of our approach instantiated on naive SEQ2SEQ and baseline approaches on PersonaChat.

Results

- Human Evaluation
  - fluency, informativeness, coherence and engagingness.

Opponent	Win	Loss	Tie	Kappa
Ours *vs.* VANILLA MLE	53%	10%	37%	0.5750
Ours *vs.* ADVERSARIAL	47%	15%	38%	0.5495
Ours *vs.* MMI	43%	12%	45%	0.5863
Ours *vs.* DEEPRL	40%	22%	38%	0.6036
Ours *vs.* CVAE	40%	15%	45%	0.5510
Ours *vs.* DIALOGWAE	45%	18%	37%	0.4216

Table 4: The results of human evaluation on the test set of PersonaChat.

Results

Framework variants	BLEU-1 / 2 / 3 / 4	Dist-1	Dist-2	Dist-3	Avg.	Ext.	Gre.	Coh.	Ent-1 / 2
(a) *w/o* group-wise sampling	12.870 / 4.102 / 0.9564 / 0.2308	0.3965	2.070	4.633	36.52	29.09	64.21	42.40	6.836 / 10.62
(b) *w/o* group-wise positive sampling	13.120 / 4.800 / 1.4180 / 0.5967	0.4632	2.270	5.002	38.26	31.18	64.66	43.03	6.812 / 10.49
(c) *w/o* group-wise negative sampling	13.210 / 4.698 / 1.3970 / 0.5587	0.7175	3.532	7.473	38.23	30.96	64.62	46.27	6.911 / 10.68
(d) *w/o* response-side sampling	13.340 / 4.730 / 1.4820 / 0.5779	0.8487	4.964	11.340	39.31	31.51	64.66	48.35	6.938 / 10.75
(e) *w/o* context-side sampling	13.170 / 4.539 / 1.4160 / 0.5308	0.8455	4.892	11.210	39.57	**31.81**	64.56	47.19	6.904 / 10.66
(f) *w/o* impact of matching scores	13.560 / 4.359 / 1.1140 / 0.3823	0.6086	3.809	9.037	38.78	30.35	64.44	46.88	6.952 / **10.90**
Full version	**13.660 / 4.916 / 1.5970 / 0.6122**	**0.8492**	**5.093**	**12.000**	**39.76**	31.74	**64.76**	**49.39**	**7.016 / 10.90**

Table 5: Ablation test (%) using SEQ2SEQ with different framework variants on PersonaChat.

Results

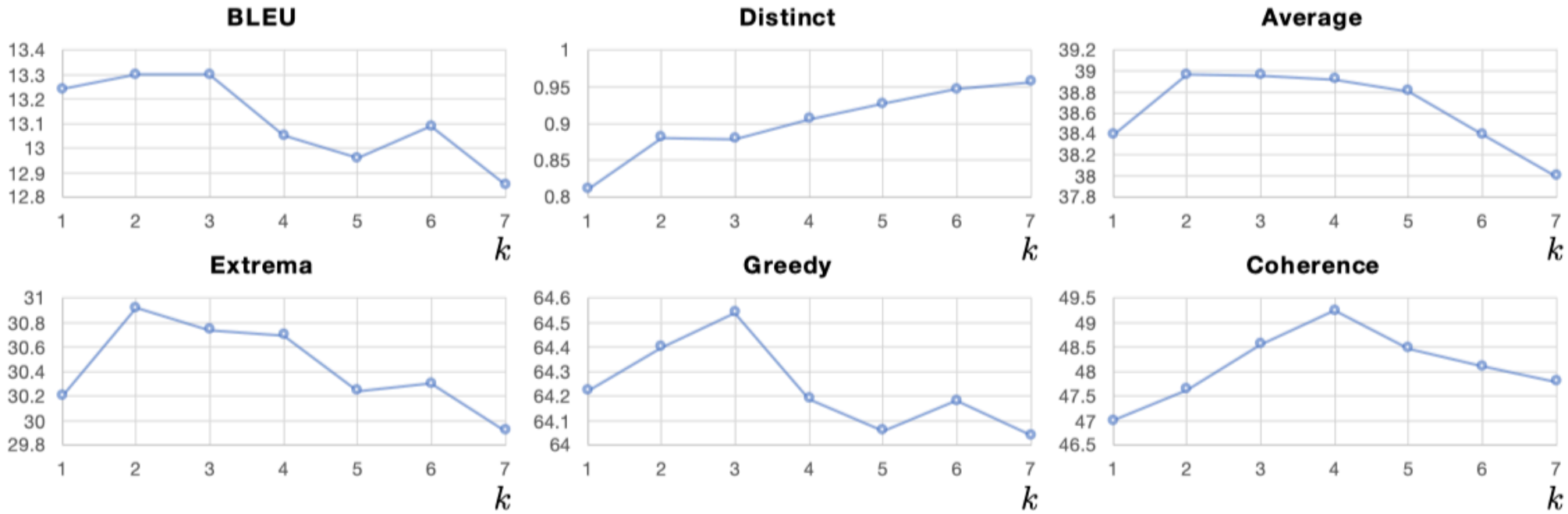


Figure 3: Evaluation results (%) with different group size k on the validation set of PersonaChat using the proposed framework instantiated on SEQ2SEQ. BLEU-1 and Dist-1 are denoted as "BLEU" and "Distinct", respectively.

Conclusion

- Introduce contrastive learning to dialogue generation.
- Dual Sampling and Weighted Group-wise contrastive learning.
- Extensive Experiments and Good Results.