Pre-training Text-to-Text Transformers for Concept-centric Common Sense

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* equal contribution
Commonsense Reasoning with PTLMs

What do you fill with ink to write notes on a piece of copy paper?

(A) Fountain pen
(B) Pencil case
(C) Printer
(D) Notepad
What do you fill with ink to write notes on a piece of copy paper?

(A) **Fountain pen**
(B) Pencil case
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(D) Notepad
What do you fill with ink to write notes on a piece of copy paper?

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Fails to reason with the **concept-centric knowledge**
Current PTLMs

… **Copy paper** is thinner than **printer** paper, which doesn’t make a huge difference when you’re printing text, but it does when you’re printing large images. Images require a lot of **ink** and because **copy paper** has a thinner structure, the **ink** will need to spread out more for the **paper** to absorb it all. …

The model may be **sensitive** to the **co-occurrence** (ink, copy, paper)
How can we teach PTLMs to **write** and **reason** with **Common sense Concepts**?

What do you **fill** with **ink** to **write** notes on a piece of **copy paper**?

(A) **Fountain pen**
(B) **Pencil case**
(C) **Printer**
(D) **Notepad**

fill, ink, write, copy paper

Fountain Pen
Our idea: Novel Self-supervised Objectives to improve common sense reasoning ability.

Generate a sentence with the following concepts:
Hold Woman Position

She was the first woman to hold the position.

Generative Objective: Concept-to-Sentence Generation (C2S)
Ask model to recover the original sentence given only a few unordered keywords of the sentence.
Our idea: Novel Self-supervised Objectives to improve common sense reasoning ability.

Generate a sentence with the following concepts:
Hold Woman Position

Correct the order of the following sentence:
Tree grows on the apple

She was the first woman to hold the position.

Apple grows on the tree

Generative Objective: Concept Order Recovering (COR)
Ask model to recover the original sentence given order-of-concept shuffled sentence.
Our idea: Novel Self-supervised Objectives to improve common sense reasoning ability.

- **Generate a sentence with the following concepts:** Hold Woman Position
- **Correct the order of the following sentence:** Tree grows on the apple
- **Which sentence is correct?**
  1. Tree grows on the apple
  2. Apple grows on the tree

Text-to-Text Transformer

- She was the first woman to hold the position.
- Apple grows on the tree
- Apple grows on the tree

**Discriminative Objective:** Generative QA
Ask model to distinguish the real sentence from a concept-distracted sentence.
CALM: Concept-Aware Language Model

Original Sentence $x$

She was the first woman to hold the position.

Extract Concept Set $C$

$(\text{woman, hold, position})$

(1) Given an input sentence $x$ (“She was the first woman to hold the position.”), extract concept-set $C$ $(\text{woman, hold, position})$. 
(1) Given an input sentence $x$ (“She was the first woman to hold the position.”), extract concept-set $C$ (woman, hold, position).
(1) Given $x$ and $C$, produce corrupted source sentence $x'$ either for C2S and COR
(1) Given an input sentence $x$ ("She was the first woman to hold the position.") extract concept-set $C$ (woman, hold, position).
(1) Given $x$ and $C$, produce corrupted source sentence $x'$ either for C2S and COR
(2) The generator trained with C2S and COR recovers sentence $x'$ to distractor $x$
CALM: Concept-Aware Language Model

Given an input sentence $x$ ("She was the first woman to hold the position."), extract concept-set $C$ (woman, hold, position).

Given $x$ and $C$, produce corrupted source sentence $x'$ either for C2S and COR

The generator trained with C2S and COR recovers sentence $x'$ to distractor $x''$

The discriminator is trained to distinguish truth sentence from distractor $x''$

Original Sentence $x$

She was the first woman to hold the position.

Extract Concept Set $C$

(woman, hold, position)

She was the first position to hold the woman.

Discriminator

She was the first woman to hold the position.

Generator

C2S

Woman holds the position.

COR

She was the first woman to position the hold.

She was the first woman to hold the position.
Given an input sentence $x$ (“She was the first woman to hold the position.”), extract concept-set $C$ (woman, hold, position).

Given $x$ and $C$, produce corrupted source sentence $x'$ either for C2S and COR.

The generator trained with C2S and COR recovers sentence $x'$ to distractor $x''$.

The discriminator is trained to distinguish truth sentence from distractor $x''$. 

She was the first woman to hold the position.

Weight Sharing

Generator

C2S

COR

Discriminator

She was the first woman to hold the position.

Woman holds the position.

Woman holds the position.

She was the first position to hold the woman.
Is CALM reason with concepts? Yes!

<table>
<thead>
<tr>
<th>Methods</th>
<th>CSQA</th>
<th>OBQA</th>
<th>PIQA</th>
<th>aNLI</th>
</tr>
</thead>
<tbody>
<tr>
<td>T5-base</td>
<td>61.88(±0.08)</td>
<td>58.20(±1.0)</td>
<td>68.14(±0.73)</td>
<td>61.10(±0.38)</td>
</tr>
<tr>
<td>T5-base w/ additional epochs</td>
<td>61.92(±0.45)</td>
<td>58.10(±0.9)</td>
<td>68.19(±0.77)</td>
<td>61.15(±0.52)</td>
</tr>
<tr>
<td>T5-base + SSM</td>
<td>62.08(±0.41)</td>
<td>58.30(±0.8)</td>
<td>68.27(±0.71)</td>
<td>61.25(±0.51)</td>
</tr>
<tr>
<td>CALM (Generative-Only)</td>
<td>62.28(±0.36)</td>
<td>58.90(±0.4)</td>
<td>68.91(±0.88)</td>
<td>60.95(±0.46)</td>
</tr>
<tr>
<td>CALM (Contrastive-Only)</td>
<td>62.73(±0.41)</td>
<td>59.30(±0.3)</td>
<td>70.67(±0.98)</td>
<td>61.35(±0.06)</td>
</tr>
<tr>
<td>CALM (Mix-only)</td>
<td>63.02(±0.47)</td>
<td>60.40(±0.4)</td>
<td>70.07(±0.98)</td>
<td>62.79(±0.55)</td>
</tr>
<tr>
<td>CALM (w/o Mix warmup)</td>
<td>62.18(±0.48)</td>
<td>59.00(±0.5)</td>
<td>69.21(±0.57)</td>
<td>61.25(±0.55)</td>
</tr>
<tr>
<td>CALM</td>
<td><strong>63.32(±0.35)</strong></td>
<td><strong>60.90(±0.4)</strong></td>
<td><strong>71.01(±0.61)</strong></td>
<td><strong>63.20(±0.52)</strong></td>
</tr>
</tbody>
</table>

Experimental results on commonsense reasoning dataset.

CALM consistently and significantly outperforms the backbone T5-base model.
Is CALM reason with concepts? Yes!

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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Accuracy (official dev)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BERT-large</td>
<td>57.06(±0.12)</td>
<td>60.40(±0.6)</td>
<td>67.08(±0.61)</td>
<td>66.75(±0.61)</td>
</tr>
<tr>
<td>T5-large</td>
<td>69.81(±1.02)</td>
<td>61.40(±1.0)</td>
<td>72.19(±1.09)</td>
<td>75.54(±1.22)</td>
</tr>
<tr>
<td>CALM-large (Mix-only)</td>
<td>70.26(±0.23)</td>
<td>62.50(±1.0)</td>
<td>73.70(±1.09)</td>
<td>75.99(±1.26)</td>
</tr>
<tr>
<td>CALM-large</td>
<td>71.31(±0.04)</td>
<td><strong>66.00(±1.0)</strong></td>
<td>75.11(±1.65)</td>
<td>77.12(±0.34)</td>
</tr>
</tbody>
</table>

Effective in Large Models.

Performance of compared models fine-tuned with different fraction of the dataset

Performance is consistent in large model & different fraction of the dataset.
Is CALM *write* with concepts? Yes!

<table>
<thead>
<tr>
<th>Methods</th>
<th>Params</th>
<th>CommonGen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BLEU-4</td>
</tr>
<tr>
<td>GPT-2 (Radford et al., 2019)</td>
<td>774M</td>
<td>21.10</td>
</tr>
<tr>
<td>UniLM (Dong et al., 2019)</td>
<td>340M</td>
<td>27.70</td>
</tr>
<tr>
<td>BART (Lewis et al., 2020)</td>
<td>406M</td>
<td>26.30</td>
</tr>
<tr>
<td>T5-Base (Raffel et al., 2019)</td>
<td>220M</td>
<td>16.40</td>
</tr>
<tr>
<td>T5-Large (Raffel et al., 2019)</td>
<td>770M</td>
<td>28.60</td>
</tr>
<tr>
<td>KG-BART (Liu et al., 2020)</td>
<td>406M</td>
<td><strong>30.90</strong></td>
</tr>
<tr>
<td><strong>Our T5-Base</strong></td>
<td>220M</td>
<td>24.90</td>
</tr>
<tr>
<td><strong>CALM</strong></td>
<td>220M</td>
<td>26.40</td>
</tr>
</tbody>
</table>

(Left): Comparison between PTLMs (Below): Comparison on generated sentences with same concept-set

<table>
<thead>
<tr>
<th>Concept-set</th>
<th>T5-base</th>
<th>CALM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass, Dog, Ball, Chase Net, Cast, Boat, Water Hole, Tree, Plant, Dig Ingredient, Add, Pan, Fry Water, Hold, Hand, Walk Place, Use, Metal tool Hair, Wax, Apply, Remove Sidewalk, Dog, Walk, Leash</td>
<td>a dog is chased by a ball on the grass. fishing boat casts a net in the water. a man digs a hole in a tree to plant a new tree. he digs the a pan filled with ingredients adds a touch of spice to the fry. A man holding a hand and walking in the water. A man is holding water. A man uses a metal tool to make a piece of metal. remove the wax from your hair and apply it to your hair. A dog walking on a leash on the sidewalk.</td>
<td>dog chasing a ball in the grass. fisherman casts a net into the water from a fishing boat. man digging a hole to plant a tree. add the ingredients to a pan and fry. man holding a bottle of water in his hand as he walks down the street. woman uses a metal tool to make a piece of jewelry. woman applies wax to her hair and then removes it with a comb. dog walking on a sidewalk with a leash.</td>
</tr>
</tbody>
</table>
Summary

- **Novel self-supervised strategies** for concept-centric Common Sense
  - Concept to Sentence
  - Concept Order Recovering
  - Generative QA

- **Two-stage training strategy**
  - Generator and Discriminator

Text-to-Text models can be pre-trained with **better parameter** and **sample efficiency** by carefully designed **self-supervised objectives** that focus on the ability required by target tasks.