A Appendices

A.1 Estimating Summary Oracles

We describe our method to estimate extractive and compressive oracle summaries prior to training using two types of *oracles*. We build these oracles in order to train our model with a supervised objective by minimizing a negative log-likelihood function. We create documents annotated with sentence-level and word-level extraction labels, which correspond to the gold values of both variables z_i and y_{ij} respectively.

Extractive Oracle. We followed Narayan et al. (2018c) and identified the set of sentences which collectively give the highest ROUGE (Lin and Hovy, 2003) with respect to the gold summary. More concretely, we assembled candidate summaries efficiently by first selecting p sentences from the document which on their own have high ROUGE scores. We then generated all possible combinations of p sentences subject to maximum length m (3 for CNN and 4 for DailyMail) and evaluated them against the gold summary. We select the summary with the highest mean of ROUGE-1, ROUGE-2, and ROUGE-L F1 scores.

Compressive Oracle. The primary challenge in building a compressive oracle lies in preserving the grammaticality of compressed sentences. Following the sentence compression literature (McDonald, 2006; Clarke and Lapata, 2008; Berg-Kirkpatrick et al., 2011; Filippova and Altun, 2013; Filippova et al., 2015), we train a supervised neural model to annotate spans in every sentence that can be dropped. In particular, we trained a supervised sentence labeling classifier adapted from Lample et al. (2016). To train our classifier, we used the publicly released set of 10,000 sentence-compression pairs from the Google sentence compression dataset (Filippova et al., 2015; Filippova and Altun, 2013). We removed the first 1,000 sentences as the development set and used the remaining ones as the training set.

After training our classifier for 30 epochs, it achieved a per-sentence accuracy of 21%, a word-based F-1 score of 78% and a compression ratio of 0.38. The parameters for the model were: 2 layers, dropout of 0.1, hidden dimension of size 400, action dimension of 20 and relation dimension of 20. We used the One Billion Word Benchmark corpus (Chelba et al., 2013) to train word embeddings with the skip-gram model (Mikolov et al.,

EXTRACTIVE ORACLE
• Wijnaldum - who has netted 16 goals in all competitions for the Dutch giants this season - has been linked with a move to Manchester United, Arsenal and Newcastle. • The PSV captain could help his club help end their seven-year wait for the Eredivisie title if they beat Heerenveen at home on Saturday.

COMPRESSIVE ORACLE
• ~~PSV Eindhoven midfielder~~ Georginio Wijnaldum ~~has fueled speculation that he~~ is eyeing a move to the Premier League in the summer. • Wijnaldum — who has netted 16 goals in all competitions for the Dutch giants this season - has been linked with a move to Manchester United, Arsenal and Newcastle.

BOW ORACLE (Baseline)
• Wijnaldum — ~~who~~ has ~~netted~~ 16 goals in all competitions for ~~the~~ Dutch giants this ~~season~~ has been linked with a ~~move~~ to Manchester United , Arsenal and Newcastle • ~~The~~ PSV ~~captain could help his club help end~~ their ~~seven-year wait~~ for ~~the~~ Eredivisie title ~~if they beat~~ Heerenveen ~~at home~~ on Saturday

GOLD
• Georginio Wijnaldum is set to guide PSV to their first title in seven years • Dutch giants can win Eredivisie with a win over Heerenveen on Saturday • Manchester United, Arsenal and Newcastle have been linked with him • Midfielder has scored 16 goals in all competitions for PSV this term

EXTRACTIVE ORACLE
• Wrap a filter around the centre of an ice-cream cone to keep little hands clean from ice-cream mess. • Apply a dab of your favourite shoe polish on the filter and use it as an applicator. • As they are lint-free coffee filters can be used to polish glass, and clean mirrors.

COMPRESSIVE ORACLE
• Keep celery crispy ~~by storing them with a coffee filter, which are far more absorbent than kitchen roll, and will absorb moisture from the vegetables~~. • Wrap a filter around the centre of an ice-cream cone to keep ~~little~~ hands clean from ice-cream mess. • Use it as a bouquet garni holder ~~the next time you're~~ ~~making soup or stews~~. • Keep clothes smelling fresh
• Coffee filters are perfect for polishing leather shoes ~~as they are lint-free and so won't leave unsightly streak marks on your shoes~~.

BOW ORACLE (Baseline)
• ~~Stop messy ice-cream spillage~~ Wrap a ~~filter~~ around ~~the centre~~ of ~~an ice-cream cone~~ to keep ~~little hands clean from ice-cream mess~~ • ~~Apply a dab~~ of ~~your favourite shoe~~ polish ~~on the filter~~ and ~~use~~ it as ~~an applicator~~ • ~~As they~~ are ~~lint-free coffee~~ filters ~~can be used~~ to polish ~~glass~~, and ~~clean mirrors~~

GOLD
• Lint-free and tear resistant filters are good for a range of household tasks • Wrap one sheet around celery stalks when storing in fridge to keep crisp • Use it to polish shoes, keep laundry smelling fresh and even as a plate

Figure 6: Examples of our estimated oracle summaries along with the reference summary for the CNN and DailyMail datasets. For illustration, the compressive oracle shows the removed spans strike-through.

2013) using context window size 6, negative sampling size 10, and hierarchical softmax 1. Same embeddings were used to train our summarization model also. For details of the evaluation metrics, please see Filippova et al. (2015).

After tagging all sentences in the CNN and DailyMail corpora using this compression model, we generated oracle compressive summaries based on the best average of ROUGE-1 and ROUGE-2 F_1 scores from the combination of all possible sen-

Models	CNN			DailyMail			Newsroom Ext.			Newsroom Mixed			Newsroom Abs.		
	R1	R2	RL	R1	R2	RL	R1	R2	RL	R1	R2	RL	R1	R2	RL
EXCONSUMM Extractive	32.5	12.6	28.5	**42.8**	**19.3**	**38.9**	**69.4**	**64.3**	**68.3**	31.9	**16.3**	26.9	17.2	**3.1**	13.6
EXCONSUMM BOW	**33.5**	12.4	**30.0**	42.5	17.8	38.8	68.7	59.8	67.6	**32.0**	15.2	**27.3**	**19.1**	2.8	**16.5**
EXCONSUMM Compressive	32.5	**12.7**	29.2	41.7	18.5	38.4	68.4	62.9	67.3	31.7	16.1	27.0	17.1	**3.1**	14.1

Table 6: Comparison of BOW model against Extractive and Compressive models. Most of the numbers are repeated from Table 2.

Figure 7: Summaries produced by the EXCONSUMM Extractive, BoW compressive and compressive methods. For illustration, BoW and compressive summaries show the removed spans strike-through.

tences with all combinations of removals of the marked compression chunks. To solve this combinatorial problem, our algorithm recursively selects the n possible sentences with the best accumulated score. Due to performance reasons, we used a simplified algorithm which uses unigrams and bigrams overlap computed incrementally at each recursion level, instead of the official ROUGE metric (Lin and Hovy, 2003). We only allow a maximum of seven compressed sentences per oracle. Our compressive oracle achieves much better scores than the extractive oracle because of its capability to make summaries concise (see Table 1 in the paper). Moreover, the linguistic quality of these oracles was preserved due to the tagging of the entire span by the sentence compressor. See Figure 6 for examples of our oracle summaries.

Baseline BOW Oracle. Additionally, we also experimented with a *bag-of-words oracle* (BOW oracle), that serves as a baseline for creating a compressive oracle, in which labels are generated by simply dropping words if they do not appear

in the gold summary. Unsurprisingly, oracle sentences compressed with this method are often ungrammatical (see Figure 6).

Our model EXCONSUMM trained with the BOW oracle (EXCONSUMM BOW) often score higher than the scores of the compressive model as shown in Table 6. However, looking at the example summaries in Figure 7, we find that the BOW compressive model is incapable of generating a fluent or grammatical summary. The EXCONSUMM Compressive summary, on the other hand, is fluent and grammatical. Our summary LSTMs (WordStates and SentStates) can preserve the fluency of the summaries if trained with the fluent Compressive oracle. This is not guaranteed when using the BOW oracle.

A.2 Human Evaluation Experiment Design

The main assumption behind this evaluation is that the gold summary highlights the most important content of the document. Based on this assumption, the questions are written using the GOLD summary. For this study, we used the same 20 documents (10 from CNN and 10 from DailyMail testsets) with an accompanying set of questions based on the gold summary from Narayan et al. (2018c).[12] We examined how many questions participants were able to answer by reading system summaries alone, without access to the article. The more questions a system can help to answer, the better it is at summarizing the document as a whole. We collected answers from five different participants for each summary and system pair. We marked a correct answer with a score of one, partially correct answers with a score of 0.5, and zero otherwise, the final score is an average of all these scores. Answers were elicited using Amazon's Mechanical Turk crowd-sourcing platform. Examples of systems summaries used for this evaluation are shown in Figures 5, 8, 9, 10, 11, 12 and 13.

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[12]The test set for the QA evaluation is publicly available at https://github.com/EdinburghNLP/Refresh.

LEAD
- (CNN) Seven people–including Illinois State University associate men's basketball coach Torrey Ward and deputy athletic director Aaron Leetch–died when their small plane crashed while heading back from the NCAA tournament final.
- The aircraft went down overnight Monday about 2 miles east of the Central Illinois Regional Airport in Bloomington, McLean County Sheriff's Office Sgt. Bill Tate said.
- That's about 5 miles from the campus of Illinois State, where Ward and Leetch both worked.

REFRESH
- (CNN) Seven people–including Illinois State University associate men's basketball coach Torrey Ward and deputy athletic director Aaron Leetch–died when their small plane crashed while heading back from the NCAA tournament final.
- The aircraft went down overnight Monday about 2 miles east of the Central Illinois Regional Airport in Bloomington, McLean County Sheriff's Office Sgt. Bill Tate said.
- The plane was coming back from the NCAA Final Four championship game in Indianapolis, according to Illinois State athletics spokesman John Twork.

LATENT
- (CNN) Seven people–including Illinois State University associate men's basketball coach Torrey Ward and deputy athletic director Aaron Leetch–died when their small plane crashed while heading back from the NCAA tournament final.
- The plane was coming back from the NCAA Final Four championship game in Indianapolis, according to Illinois State athletics spokesman John Twork.
- The aircraft went down overnight Monday about 2 miles east of the Central Illinois Regional Airport in Bloomington, McLean County Sheriff's Office Sgt. Bill Tate said .

EXCONSUMM Extractive
- (CNN) Seven people–including Illinois State University associate men's basketball coach Torrey Ward and deputy athletic director Aaron Leetch–died when their small plane crashed while heading back from the NCAA tournament final.
- The plane was coming back from the NCAA Final Four championship game in Indianapolis, according to Illinois State athletics spokesman John Twork.

EXCONSUMM Compressive
- Seven people died their small plane crashed while heading back from the NCAA tournament final.
- The aircraft went down overnight Monday about 2 miles east of the Central Illinois Regional Airport in Bloomington.
- The plane was coming back from the NCAA Final Four championship game.

Pointer+Coverage
- Illinois State University associate men's basketball coach Torrey ward and deputy athletic director Aaron Leetch died when their small plane crashed while heading back from the NCAA tournament final.
- The aircraft went down overnight Monday about 2 miles east of the Central Illinois Regional Airport in Bloomington, iIlinois.
- It was not immediately known who else was on the aircraft, which the National Transportation Safety Board tweeted was a Cessna 414.
- There's also a picture of a small plane with the words, "my ride to the game was n't bad #indy2015f4".

GOLD
- The crashed plane was a Cessna 414, National Transportation Safety Board reports
- Coach Torrey Ward, administrator Aaron Leetch among the 7 killed in the crash
- The plane crashed while coming back from the NCAA title game in Indianapolis

Question-Answer Pairs
- What type of plane crashed? (Cessna 414)
- Who are confirmed dead in the crash? (Coach Torrey Ward and administrator Aaron Leetch)
- How many people in total died in the crash? (7 people)
- The plane crashed while coming back from where? (The NCAA title game in Indianapolis)

Figure 8: Example output summaries on the CNN/DailyMail dataset, gold standard summary, and corresponding questions.

LEAD
- A hedgehog sniffing around in the dusk was once a common sight - but experts warn it may soon become a thing of the past.
- One in five people have never seen a hedgehog in their gardens, according to a wildlife survey.
- And of those who do spot the tiny animals, only a quarter see them frequently, the RSPB found.
- The startling figures confirm fears that the small British mammal is suffering a huge decline.

REFRESH
- One in five people have never seen a hedgehog in their gardens, according to a wildlife survey.
- And of those who do spot the tiny animals, only a quarter see them frequently, the RSPB found.
- The startling figures confirm fears that the small British mammal is suffering a huge decline.
- There are thought to be less than 1 million hedgehogs living in this country today, an estimated 30 per cent drop since 2013.

LATENT
- There are thought to be less than 1 million hedgehogs living in this country today, an estimated 30 per cent drop since 2013.
- One in five people have never seen a hedgehog in their gardens, according to a new wildlife survey.
- The startling figures confirm fears that the small British mammal is suffering a huge decline.

EXCONSUMM Extractive
- One in five people have never seen a hedgehog in their gardens, according to a wildlife survey.
- And of those who do spot the tiny animals , only a quarter see them frequently, the RSPB found.
- The startling figures confirm fears that the small British mammal is suffering a huge decline.
- There are thought to be less than 1 million hedgehogs living in this country today, an estimated 30 per cent drop since 2013.

EXCONSUMM Compressive
- One in five people have never seen a hedgehog in their gardens.
- And of those who do spot the tiny animals, only a quarter see them frequently, the RSPB found.
- The small British mammal is suffering a huge decline.
- There are thought to be less than 1 million hedgehogs living in this country today, an estimated 30 per cent drop since 2013.

Pointer+Coverage
- One in five people have never seen a hedgehog in their gardens.
- Of those who do spot the tiny animals, only a quarter see them frequently.
- The startling figures confirm fears that the small British mammal is suffering a huge decline.

GOLD
- One in five people have never seen a hedgehog in their back gardens
- Only a quarter of those who do admitted seeing the animals frequently
- Wildlife survey suggested the small British mammal is in huge decline
- There are thought to be less than 1 million hedgehogs in the country

Question-Answer Pairs
- How many people have never seen a hedgehog in their back gardens? (One in five people)
- Who conducted this survey? (Wildlife survey)
- How many hedgehogs are thought to be left in the country? (less than 1 million)

Figure 9: Example output summaries on the CNN/DailyMail dataset, gold standard summary, and corresponding questions.

LEAD
- (CNN) Blinky and Pinky on the Champs Elysees?
- Inky and Clyde running down Broadway?
- Power pellets on the Embarcadero?

REFRESH
- Leave it to Google to make April Fools' Day into throwback fun by combining Google Maps with Pac-Man.
- The massive tech company is known for its impish April Fools' Day pranks, and Google Maps has been at the center of a few, including a Pokemon Challenge and a treasure map.
- This year the company was a day early to the party, rolling out the Pac-Man game Tuesday.

LATENT
- Leave it to Google to make April Fools' Day into throwback fun by combining Google Maps with Pac-Man.
- (CNN) Blinky and Pinky on the Champs Elysees? Inky and Clyde running down Broadway? Power pellets on the Embarcadero?
- Twitterers have been tickled by the possibilities, playing Pac-Man in Manhattan, on the University of Illinois quad, in central London and down crooked Lombard Street in San Fran cisco, among many locations:.

EXCONSUMM Extractive
- Leave it to Google to make April Fools' Day into throwback fun by combining Google Maps with Pac-Man.
- It's easy to play: Simply pull up Google Maps on your desktop browser, click on the Pac-Man icon on the lower left, and your map suddenly becomes a Pac-Man course.

EXCONSUMM Compressive
- Leave it to Google to make April Fools Day into throwback fun by combining Google Maps with Pac-Man.
- The tech company is known for its April Fools Day pranks.

Pointer+Coverage
- The massive tech company is known for its impish April fools' day pranks, and Google Maps has been at the center of a few, including a Pokemon challenge and a treasure map.
- It's easy to play : simply pull up Google Maps on your desktop browser.

GOLD
- Google Maps has a temporary Pac-Man function
- Google has long been fond of April Fools' Day pranks and games
- Many people are turning their cities into Pac-Man courses

Question-Answer Pairs
- What function does Google Maps have? (Pac-Man)
- What has Google been long fond of? (April Fools' Day pranks and games)
- What are many people turning their cities into? (Pac-Man courses)

Figure 10: Example output summaries on the CNN/DailyMail dataset, gold standard summary, and corresponding questions.

LEAD
- (CNN) Somewhere over the rainbow, people on the Internet are losing their minds.
- Is it real?
- After the New York area received a large amount of rain, four rainbows stretched across the early morning sky on Tuesday.

REFRESH
- (CNN) Somewhere over the rainbow, people on the Internet are losing their minds.
- After the New York area received a large amount of rain, four rainbows stretched across the early morning sky on Tuesday.
- Amanda Curtis, CEO of a fashion company in New York, snapped the lucky shot.

LATENT
- Amanda Curtis, CEO of a fashion company in New York, snapped the lucky shot.
- After the New York area received a large amount of rain, four rainbows stretched across the early morning sky on Tuesday.
- CNN iReporter Yosemitebear Vasquez posted a video to YouTube in 2010 reacting to a double rainbow he spotted in Yosemite National Park. The video has since garnered over 40 million views.

EXCONSUMM Extractive
- After the New York area received a large amount of rain, four rainbows stretched across the early morning sky on Tuesday.
- Amanda Curtis, CEO of a fashion company in New York, snapped the lucky shot.
- The video has since garnered over 40 million views.

EXCONSUMM Compressive
- Four rainbows stretched across the early morning sky on Tuesday.
- Amanda Curtis, CEO of a fashion company in New York, snapped the lucky shot.
- The video has since garnered over 40 million views.

Pointer+Coverage
- Amanda Curtis, CEO of a fashion company in New York, snapped the lucky shot.
- She posted the picture to Twitter, and within a few hours, it had already received hundreds of retweets.

GOLD
- Amanda Curtis, CEO of a fashion company in New York, posted a picture of four rainbows to Twitter
- "I had a small moment of awe," she said

Question-Answer Pairs
- Who posted a picture to Twitter? (Amanda Curtis)
- What did the picture show? (four rainbows)
- What is the profession of the person who posted this picture? (CEO of a fashion company in New York)

Figure 11: Example output summaries on the CNN/DailyMail dataset, gold standard summary, and corresponding questions.

LEAD
- The Fulham fans in the Jimmy Steed Stand applauded their team at the final whistle.
- It was not the victory manager Kit Symons had called for but a point away to Charlton probably secures their future in the Championship next season.
- They are eight points clear of Millwall and bar a miraculous resurgence from one of the bottom three sides will stay up but the fact relegation is still mathematically feasible for a club that were in the Premier League last season is alarming.
- A vertiginous decline, just one victory in their last seven games had seen them dragged back into a relegation battle and after a painful 4-1 trouncing by bitter rivals Brentford last week, Symons was looking for a quick response from his players.

REFRESH
- The Fulham fans in the Jimmy Steed Stand applauded their team at the final whistle.
- It was not the victory manager Kit Symons had called for but a point away to Charlton probably secures their future in the Championship next season.
- They are eight points clear of Millwall and bar a miraculous resurgence from one of the bottom three sides will stay up but the fact relegation is still mathematically feasible for a club that were in the Premier League last season is alarming.
- He got it with Ross McCormack giving them the lead after eight minutes.

LATENT
- Johann Gudmundsson celebrates his first-half effort as Charlton come from behind to earn a point.
- Ross McCormack headed over a stranded Stephen Henderson with just eight minutes played in London.
- Fulham now sit 20th in the table eight points clear of fellow London rivals Millwall, but Symons is refusing to relax just yet.

EXCONSUMM Extractive
- The Fulham fans in the Jimmy Steed Stand applauded their team at the final whistle.
- It was not the victory manager Kit Symons had called for but a point away to Charlton probably secures their future in the Championship next season .

EXCONSUMM Compressive
- The Fulham fans in the Jimmy Steed Stand applauded their team at the final whistle.
- It was not the victory manager Kit Symons had called for but a point away.
- They are eight points clear of Millwall and bar a miraculous resurgence.
- Fulham sit 20th in the table eight points clear of fellow London rivals, but Symons is refusing to relax just yet.

Pointer+Coverage
- Fulham fans in the Jimmy Steed Stand applauded their team at the final whistle.
- It was not the victory manager Kit Symons had called for but a point away to Charlton probably secures their future in the Championship next season.
- They are eight points clear of Millwall and bar a miraculous resurgence.

GOLD
- Ross McCormack gave Fulham the lead after eight minutes at The Valley
- But Johann Gudmundsson leveled the scores less than ten minutes later
- Scott Parker was booed on his return to club, 11 years after he left
- Share of the points in London leaves Charlton in 11th and Fulham in 20th

Question-Answer Pairs
- Who gave Fulham the lead after eight minutes at The Valley? (Ross McCormack)
- Who leveled the scores less than ten minutes later? (Johann Gudmundsson)
- Who was booed on his return to club, 11 years after he left? (Scott Parker)
- What is Charlton's place after the share of the points in London? (11th)
- What is Fulham's place after the share of the points in London? (20th)

Figure 12: Example output summaries on the CNN/DailyMail dataset, gold standard summary, and corresponding questions.

LEAD
- (CNN) You probably never knew her name, but you were familiar with her work.
- Betty Whitehead Willis, the designer of the iconic "Welcome to Fabulous Las Vegas" sign, died over the weekend.
- She was 91.

REFRESH
- Betty Whitehead Willis, the designer of the iconic "Welcome to Fabulous Las Vegas" sign, died over the weekend.
- Willis played a major role in creating some of the most memorable neon work in the city.
- Willis visited the Neon Museum in 2013 to celebrate her 90th birthday.

LATENT
- Betty Whitehead Willis, the designer of the iconic "Welcome to Fabulous Las Vegas" sign, died over the weekend. She was 91.
- The Neon Museum also credits her with designing the signs for Moulin Rouge Hotel and Blue Angel Motel.
- Willis visited the Neon Museum in 2013 to celebrate her 90th birthday.

EXCONSUMM Extractive
- Betty Whitehead Willis, the designer of the iconic "Welcome to Fabulous Las Vegas" sign, died over the weekend.
- Willis visited the Neon Museum in 2013 to celebrate her 90th birthday.

EXCONSUMM Compressive
- Betty Whitehead Willis died over the weekend.
- Willis played a major role in creating some of the most memorable neon work in the city.
- Willis visited the Neon Museum in 2013 to celebrate her 90th birthday.

Pointer+Coverage
- Betty Whitehead Willis, the designer of the iconic "Welcome to Fabulous Las Vegas, died over the weekend.
- She was 91.
- Willis never trademarked her most-famous work, calling it "my gift to the city".

GOLD
- Willis never trademarked her most-famous work, calling it "my gift to the city"
- She created some of the city's most famous neon work

Question-Answer Pairs
- What was Willis' most-famous work called? (my gift to the city)
- What did Willis create in the city? (City's most famous neon work)

Figure 13: Example output summaries on the CNN/DailyMail dataset, gold standard summary, and corresponding questions.