Pre-training on high-resource speech recognition improves low-resource speech-to-text translation

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Natural Language Processing

Current systems

Spanish Audio:

English text: *?*

Current systems

Spanish Audio:

Spanish text: *ola mi nombre es hodor*

English text: *?*

Automatic Speech Recognition

Current systems

Spanish Audio:

Spanish text: *ola mi nombre es hodor*

English text: *hi my name is hodor*

Automatic Speech Recognition

Machine Translation

~100 languages supported by Google Translate …

Unwritten languages

Mboshi:

Bantu language, Republic of Congo, ~160K speakers

~3000 languages with no writing system

~~Mboshi text:~~   ~~*not available*~~   ~~**Automatic Speech Recognition**~~

Unwritten languages

Mboshi:

paired with French translations (Godard et al. 2018)

~3000 languages with no writing system

Efforts to collect speech and translations using mobile apps

    ○   *Aikuma*: Bird et al. 2014, *LIG-Aikuma*: Blachon et al. 2016
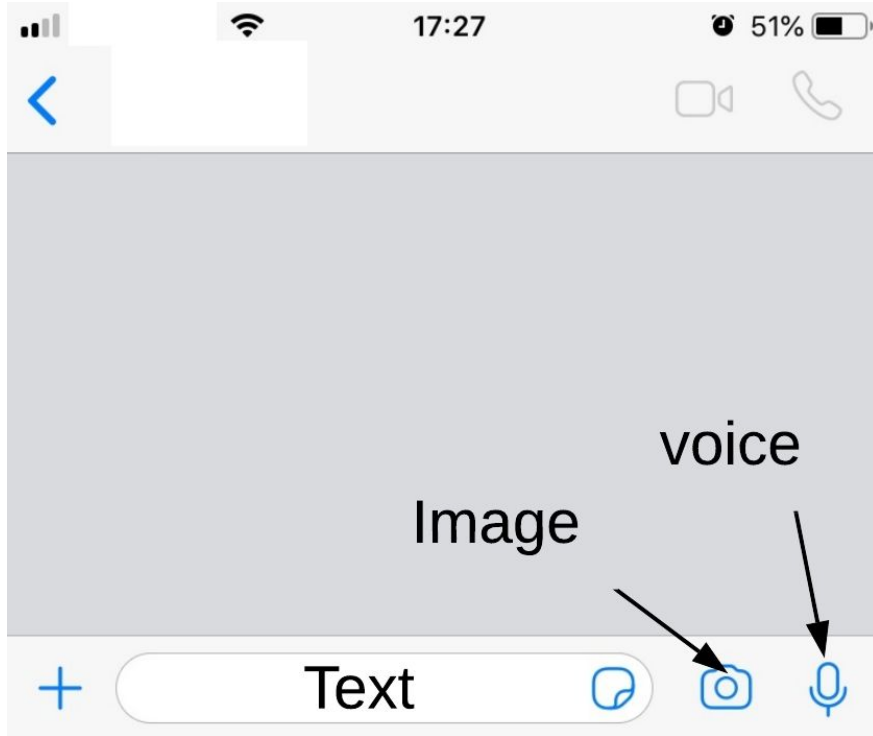
Haiti Earthquake, 2010

Survivors sent text messages to helpline

Moun kwense nan Sakre Kè nan Pòtoprens

People trapped in Sacred Heart Church, PauP

- International rescue teams face language barrier
- No automated tools available
- Volunteers from global Haitian diaspora help create parallel text corpora in short time
  [Munro 2010]

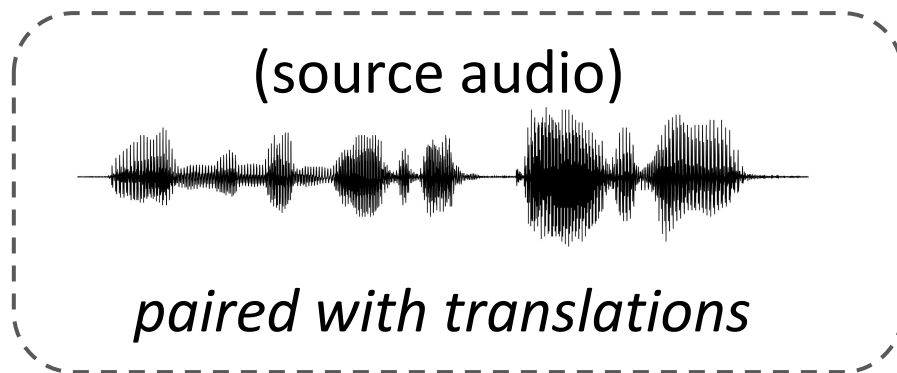# Are we better prepared in 2019?

Moun kwense nan Sakre Kè nan Pòtoprens

People trapped in Sacred Heart Church, PauP

Voice messages

Can we build a speech-to-text translation (**ST**) system?

… given as training data:

(source audio)

paired with translations

- Tens of hours of speech paired with text translations
- No source text available
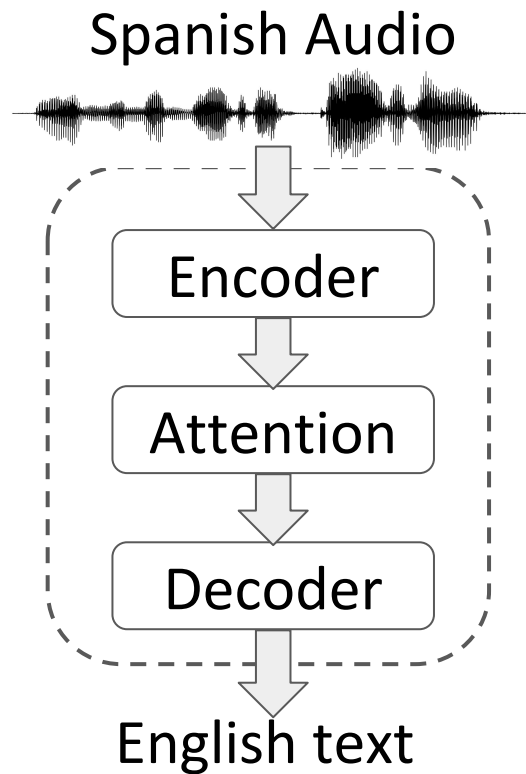
Neural models ...

Spanish Audio:

Sequence-to-Sequence   *Weiss et al. (2017)*

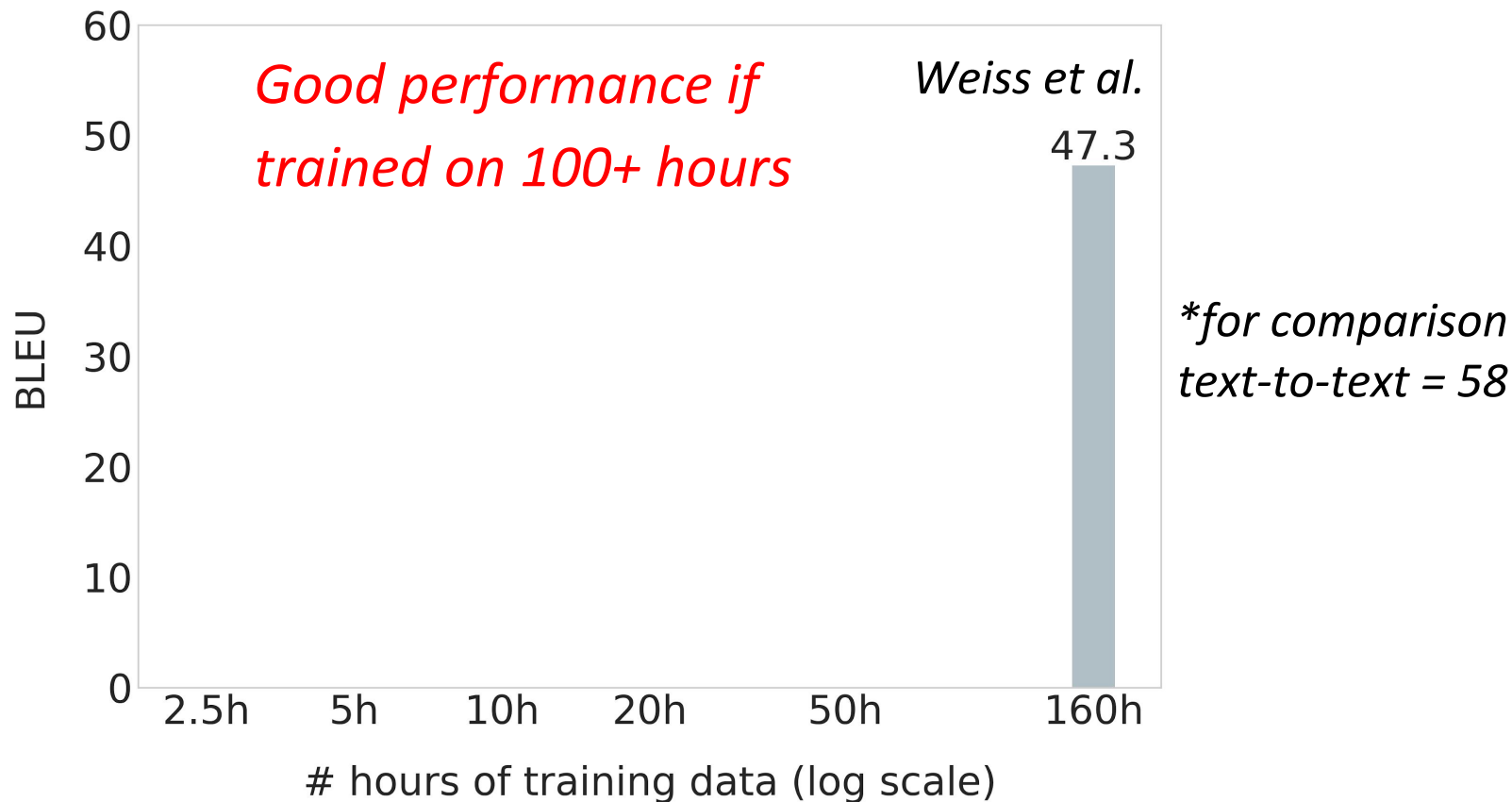English text: *hi my name is hodor*

Directly translate speech

Spanish speech to English text

Spanish Audio

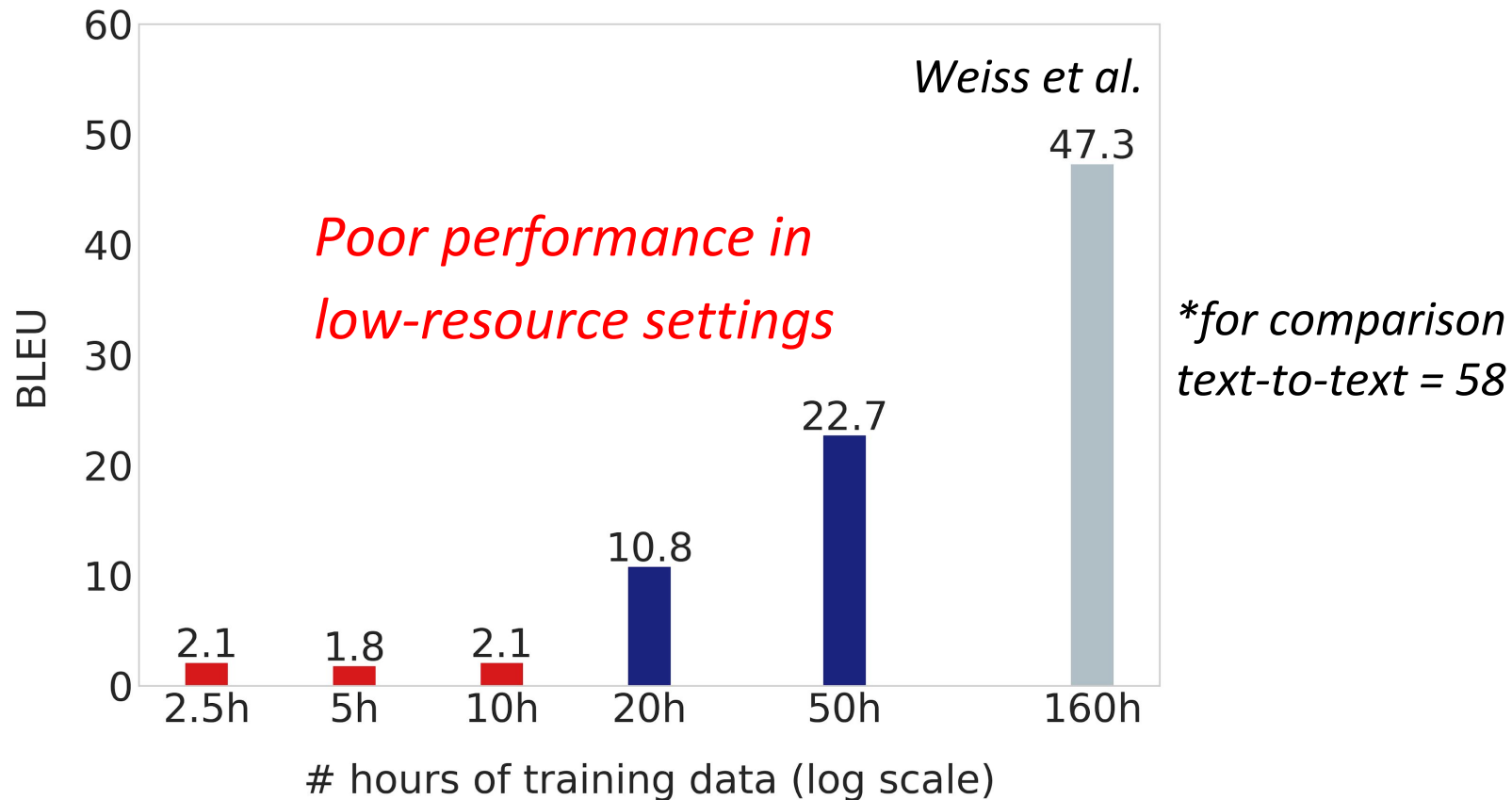Encoder

Attention

Decoder

English text

- telephone speech (unscripted)
- realistic noise conditions
- multiple speakers and dialects
- crowdsourced English text translations

Closer to real-world conditions

Spanish speech to English text

Good performance if trained on 100+ hours

Weiss et al.

47.3

*for comparison text-to-text = 58

BLEU (y-axis): 0, 10, 20, 30, 40, 50, 60

hours of training data (log scale): 2.5h, 5h, 10h, 20h, 50h, 160h

But …

Poor performance in low-resource settings

Weiss et al.

*for comparison text-to-text = 58

Goal: to improve translation performance

Goal: to improve translation performance

… without labeling more low-resource speech

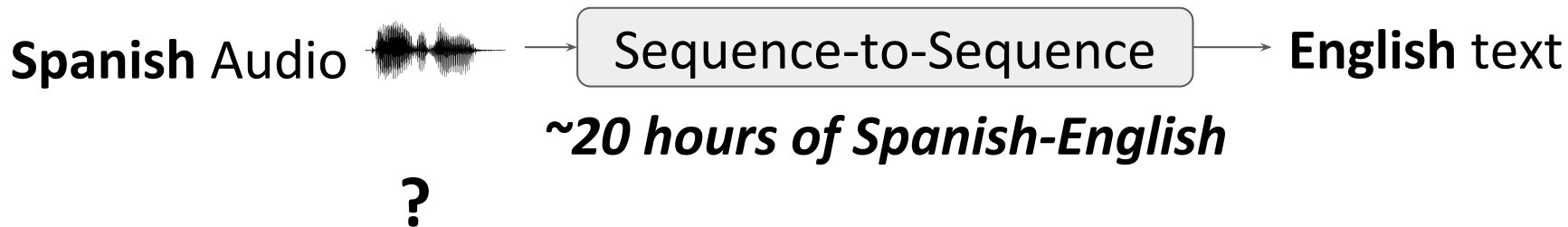100s of hours of **monolingual** speech paired with text available
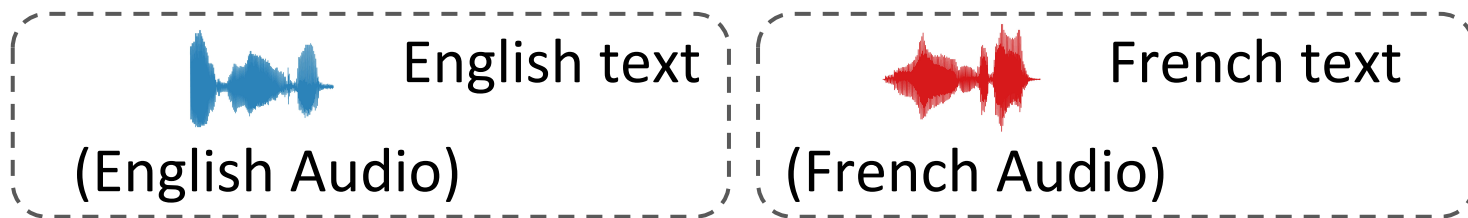
… typically used to train ASR systems

English text

(English Audio)

French text

(French Audio)
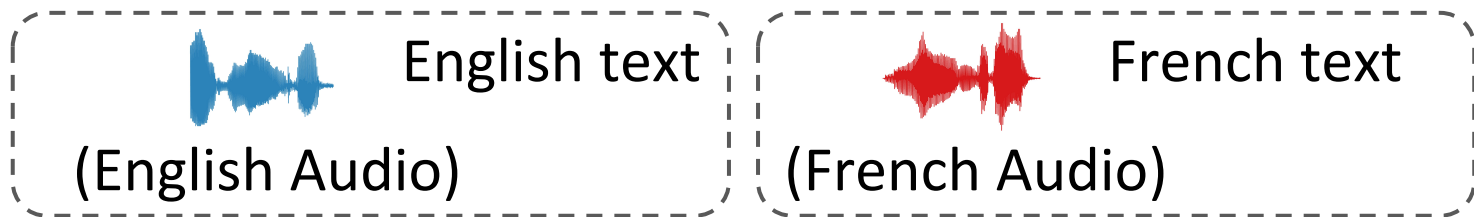
Key idea: leverage monolingual data from a different high-resource language

100s of hours of **monolingual** speech paired with text available
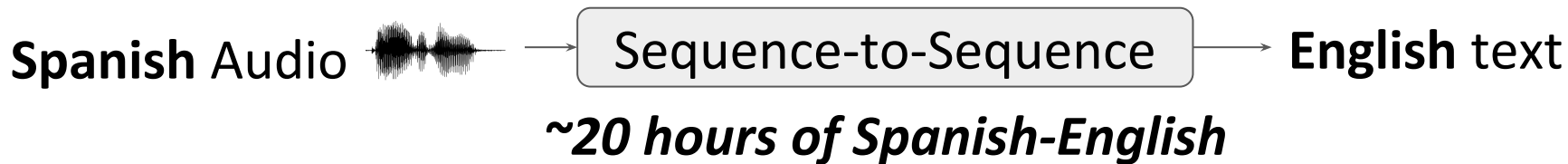
… typically used to train ASR systems

English text

(English Audio)

French text

(French Audio)

Spanish Audio → Sequence-to-Sequence → **English** text

~20 hours of Spanish-English

?

100s of hours of **monolingual** speech paired with text available

… typically used to train ASR systems

Spanish text

(Spanish Audio)
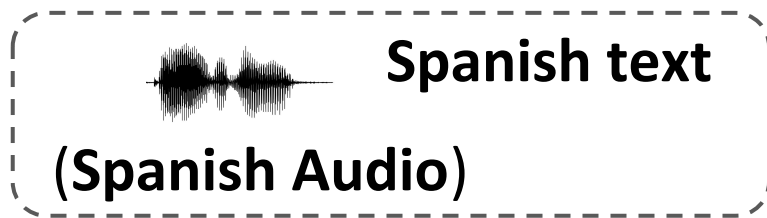
Weiss et al. 2017
Anastasopoulos and Chiang 2018
Bérard et al. 2018
Sperber et al. 2019

Spanish Audio ⟶ Sequence-to-Sequence ⟶ **English** text

~20 hours of Spanish-English

100s of hours of **monolingual** speech paired with text available

… typically used to train ASR systems

English text

(English Audio)

French text

(French Audio)

Spanish Audio → Sequence-to-Sequence → **English** text

~20 hours of Spanish-English

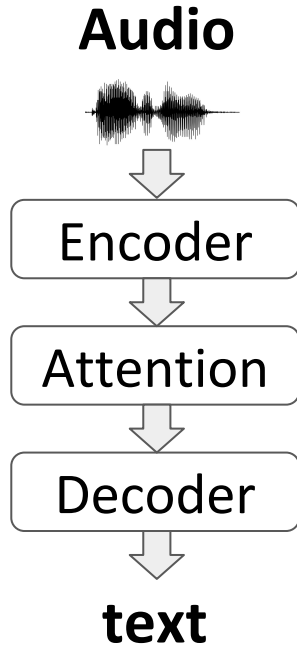**?**
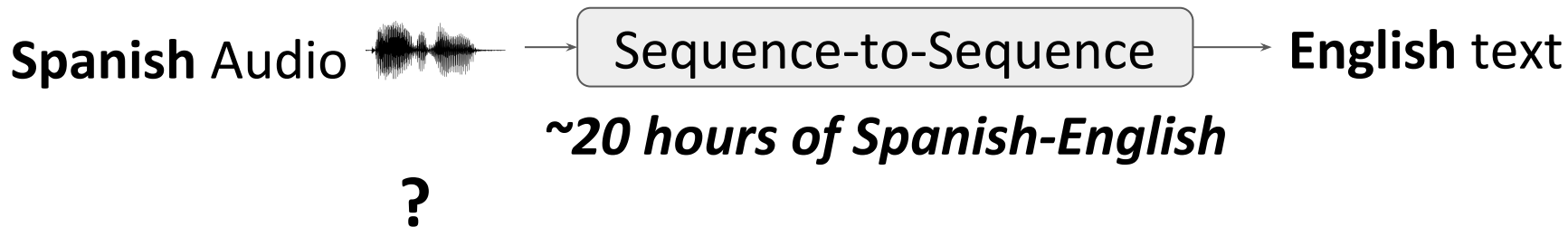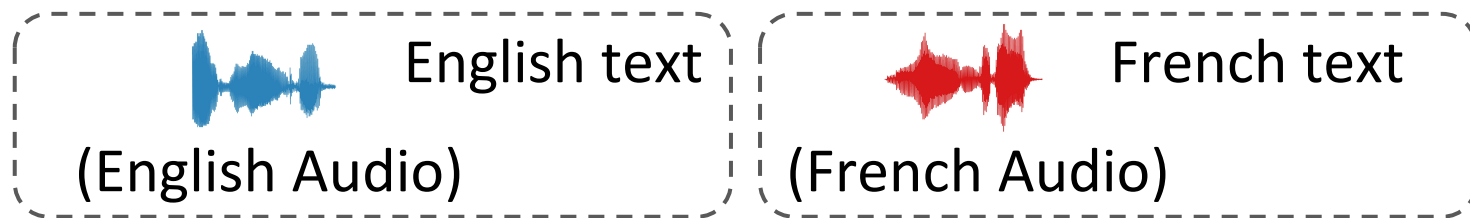
Why Spanish-English?

Why Spanish-English?

simulate low-resource settings and test our method

Why Spanish-English?

simulate low-resource settings and test our method

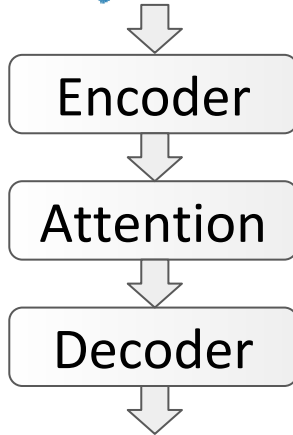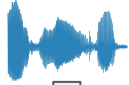**Later:** results on truly low-resource language ---
Mboshi to French

Method

Audio

Encoder

Attention

Decoder

text

Same model architecture for ASR and ST

*randomly initialized parameters
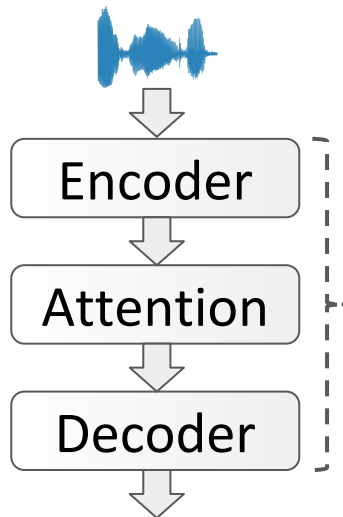
Pretrain on high-resource

English audio

Encoder

Attention

Decoder

English text

300 hours of English audio and text

*train until convergence

Fine-tune on low-resource

20 hours Spanish-English

English audio

Encoder
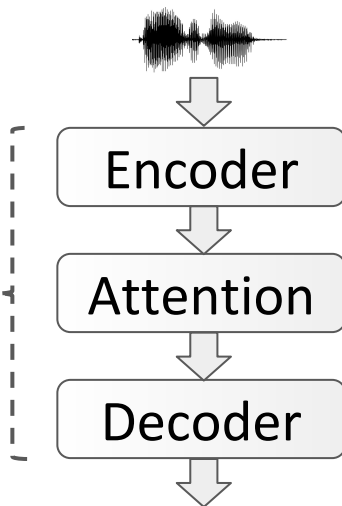
Attention

Decoder

English text

transfer from English ASR

Spanish audio

Encoder

Attention

Decoder

English text

Fine-tune on low-resource

20 hours Spanish-English

Spanish audio

Encoder
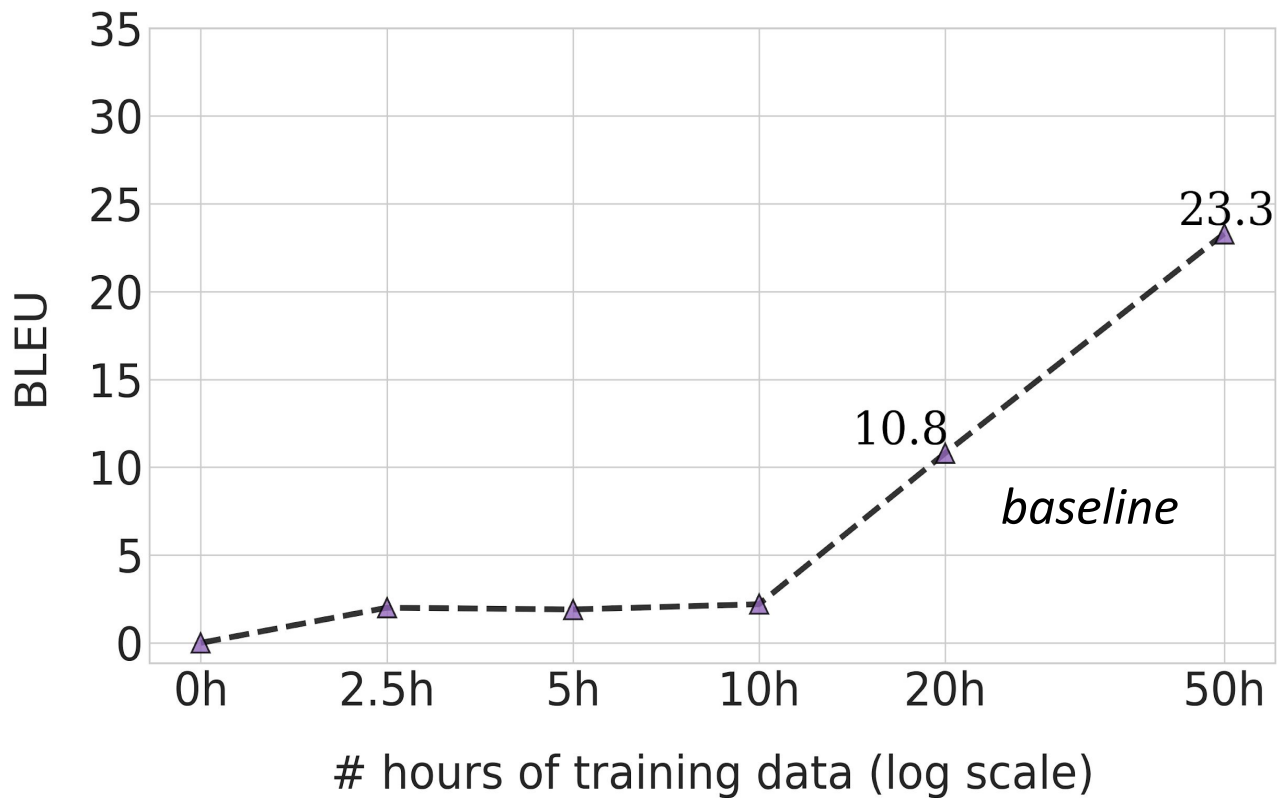
Attention

Decoder

English text
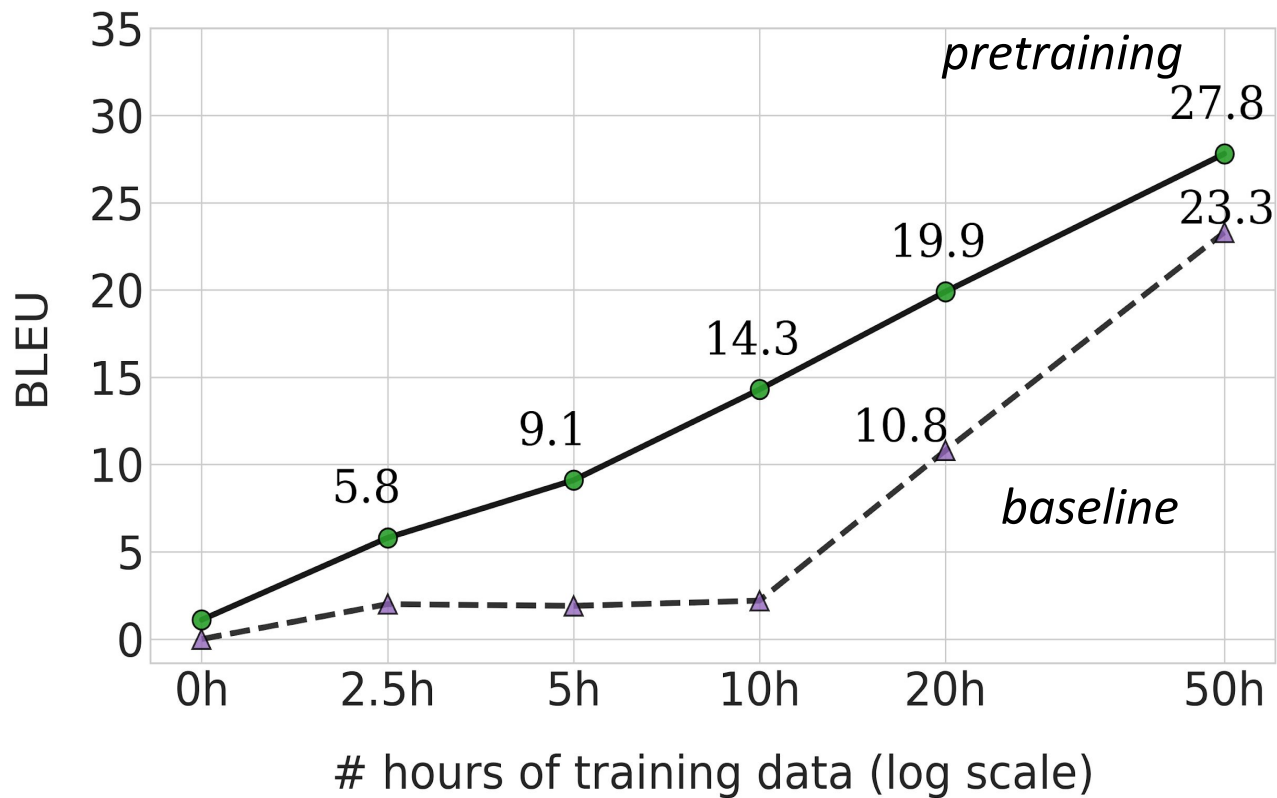
*train until convergence

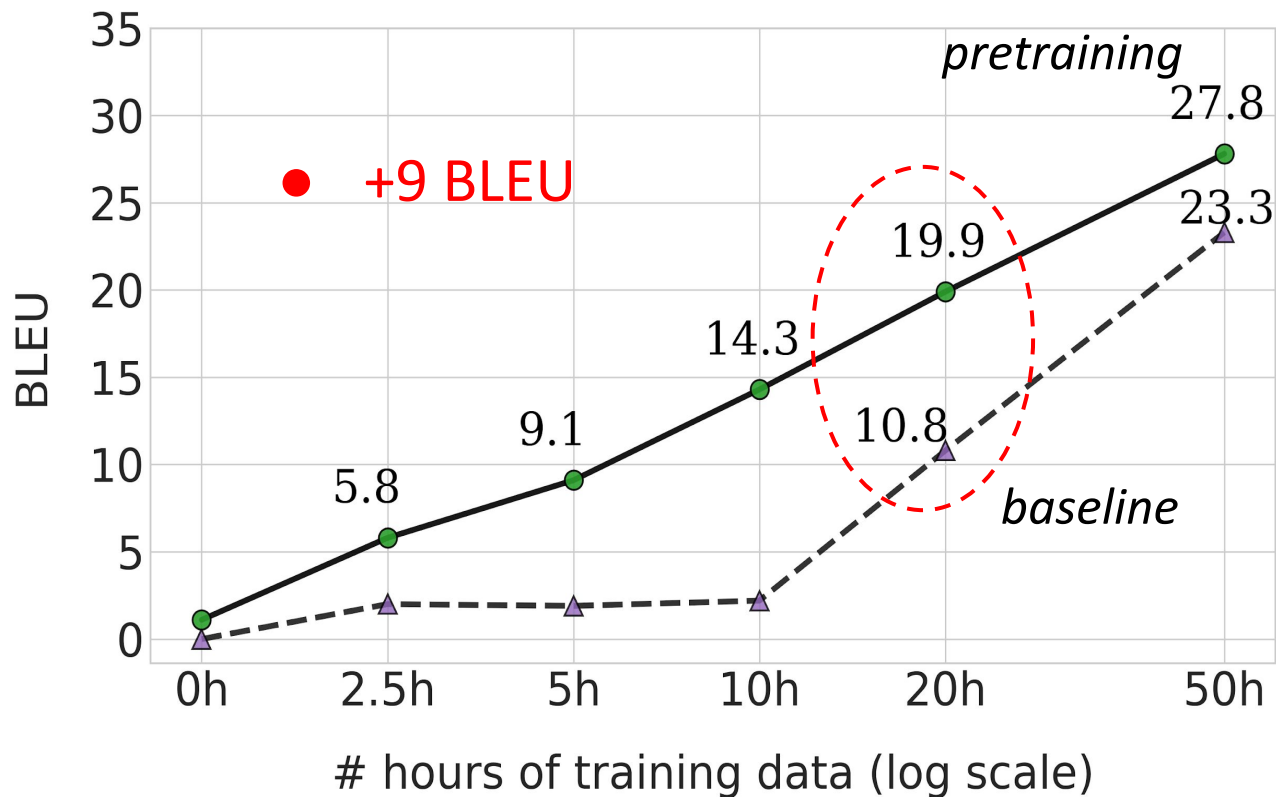# Will this work?

Spanish-English BLEU scores

*for comparison
Weiss et al. = 47.3*

Spanish-English BLEU scores

*for comparison
Weiss et al. = 47.3*

Spanish-English BLEU scores

Spanish-English BLEU scores
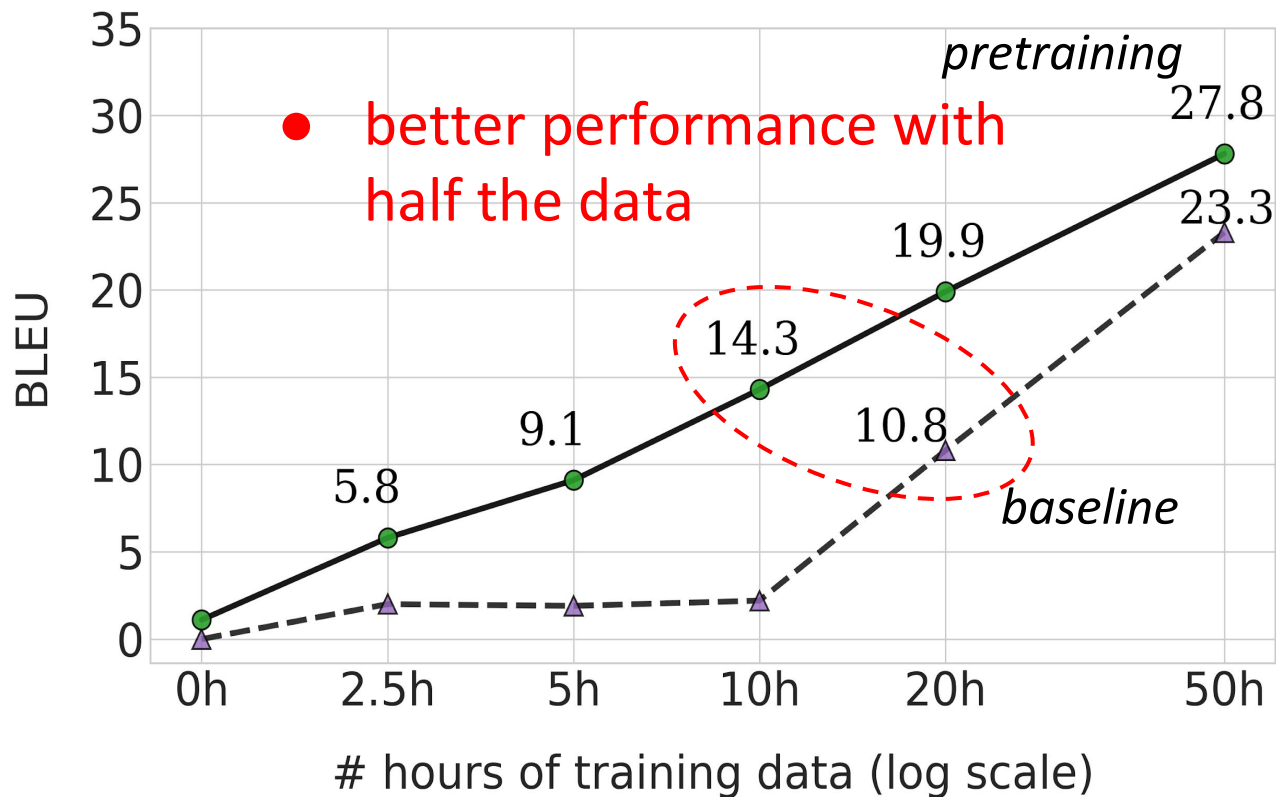
*for comparison
Weiss et al. = 47.3*

Further analysis

20 hours Spanish-English
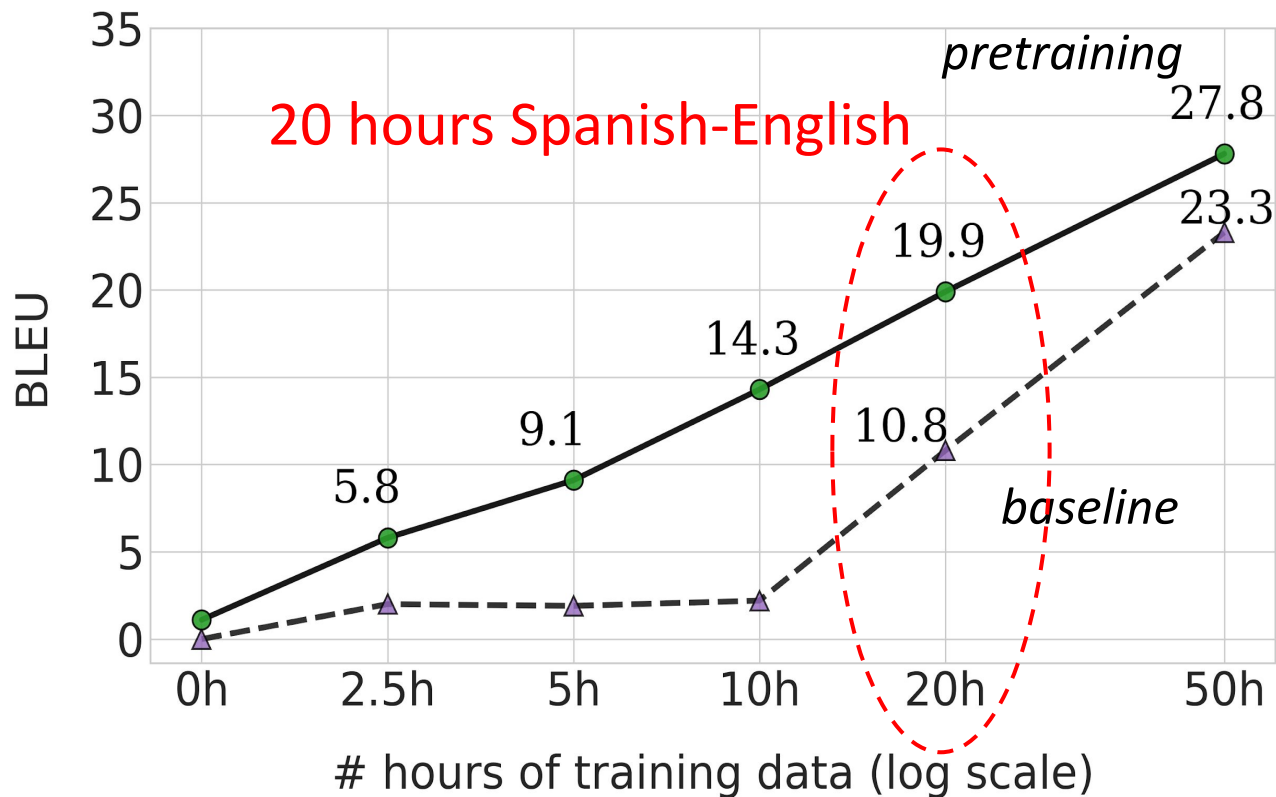
*for comparison
Weiss et al. = 47.3*

Faster training time

pretraining
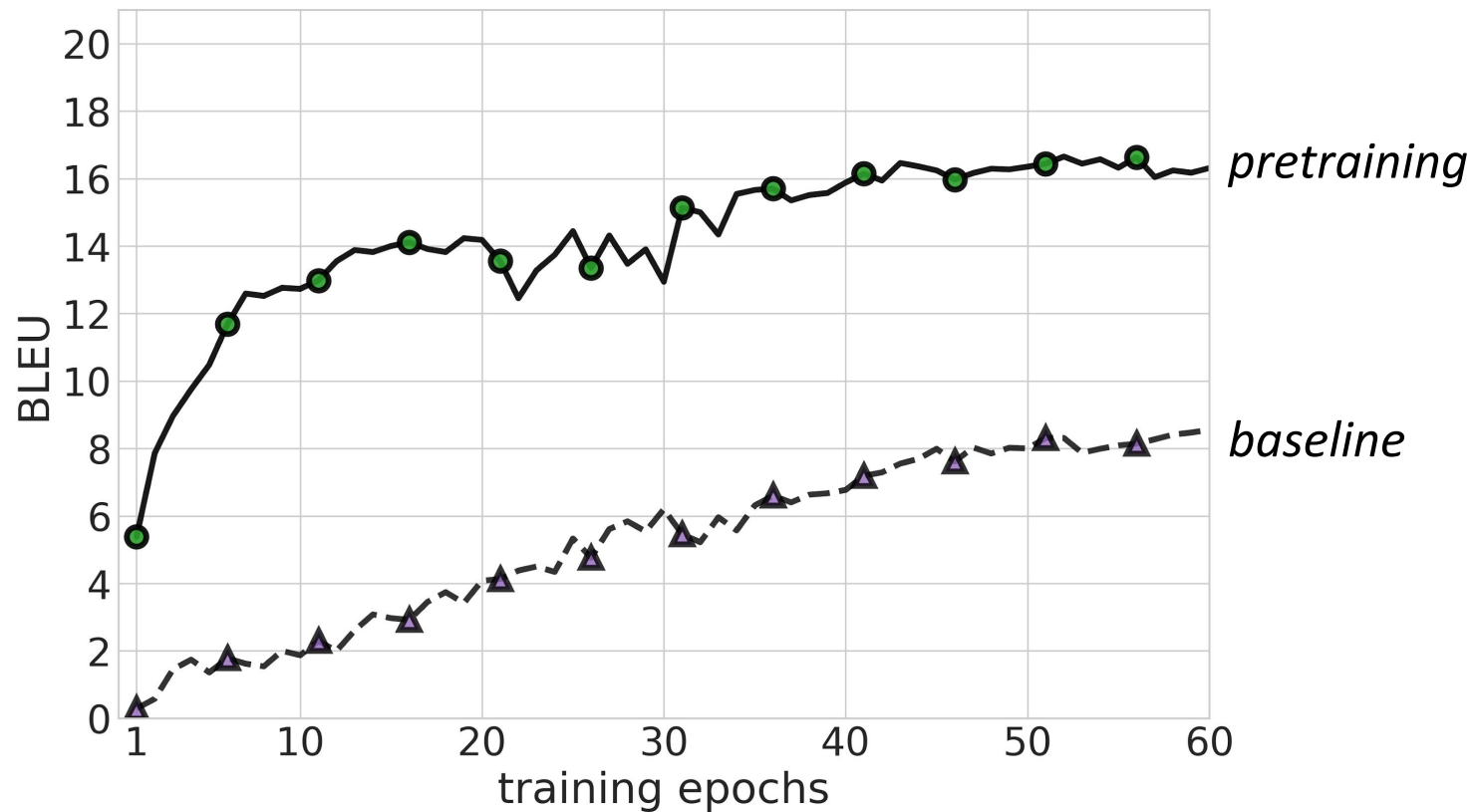
baseline

Faster training time
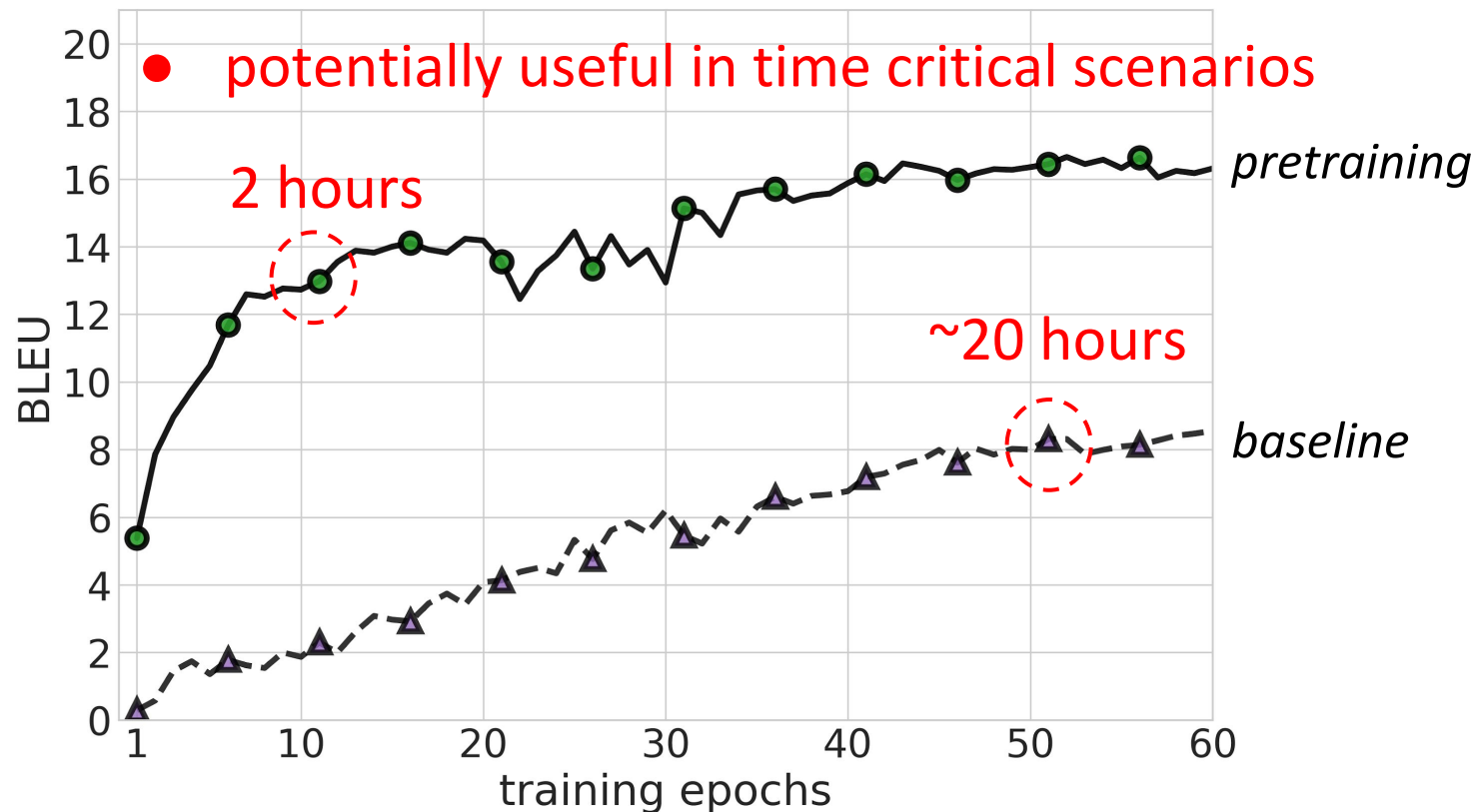
Ablation: model parameters

Spanish to English, *N* = 20 hours

	BLEU
baseline	10.8
+English ASR	19.9

Ablation: model parameters

Spanish to English, N = 20 hours

	BLEU
baseline	10.8
+English ASR	19.9
+English ASR: decoder	10.5

English

Spanish

Encoder

random

Encoder

Attention

Attention

Decoder

Decoder

English text

English text

Ablation: model parameters

Spanish to English, *N* = 20 hours

	BLEU
baseline	10.8
+English ASR	19.9
+English ASR: decoder	10.5
+English ASR: encoder	16.6

English

Spanish

Encoder → Encoder

Attention

random

Attention

Decoder

Decoder

English text

English text

Ablation: model parameters

Spanish to English, N = 20 hours

	BLEU
baseline	10.8
+English ASR	19.9
+English ASR: decoder	10.5
+English ASR: encoder	16.6

English

Spanish

Encoder → Encoder

Attention

Attention

random
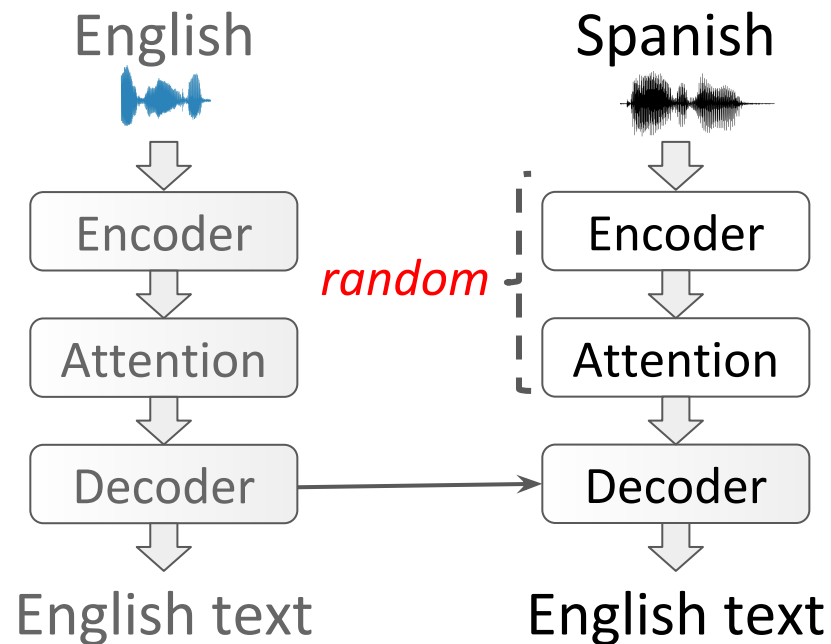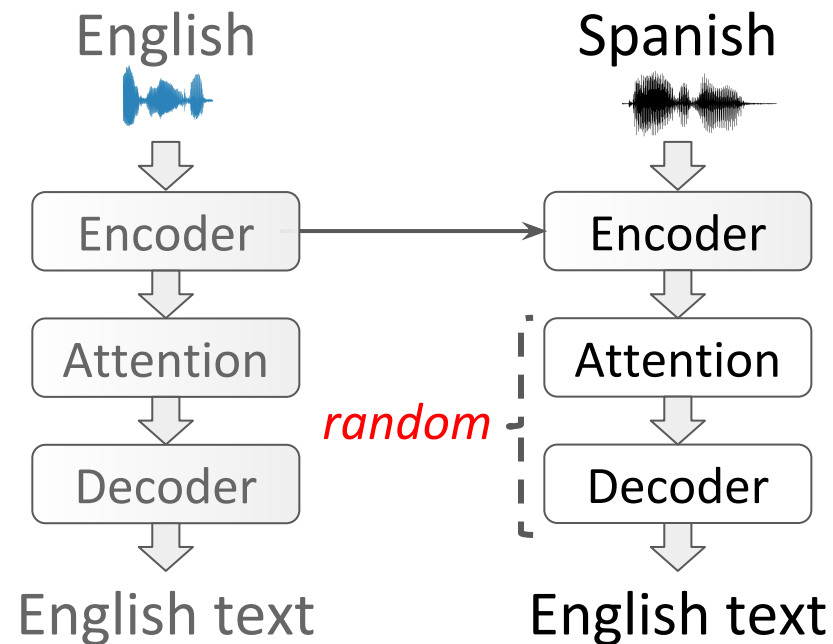
Decoder

Decoder

English text

English text

… transferring encoder only parameters works well!

Ablation: model parameters

Spanish to English, *N* = 20 hours

	BLEU
baseline	10.8
+English ASR	19.9
+English ASR: decoder	10.5
+English ASR: encoder	16.6

English

Encoder → Encoder

Attention

Decoder

English text

Spanish

Encoder

Attention

Decoder

English text

random
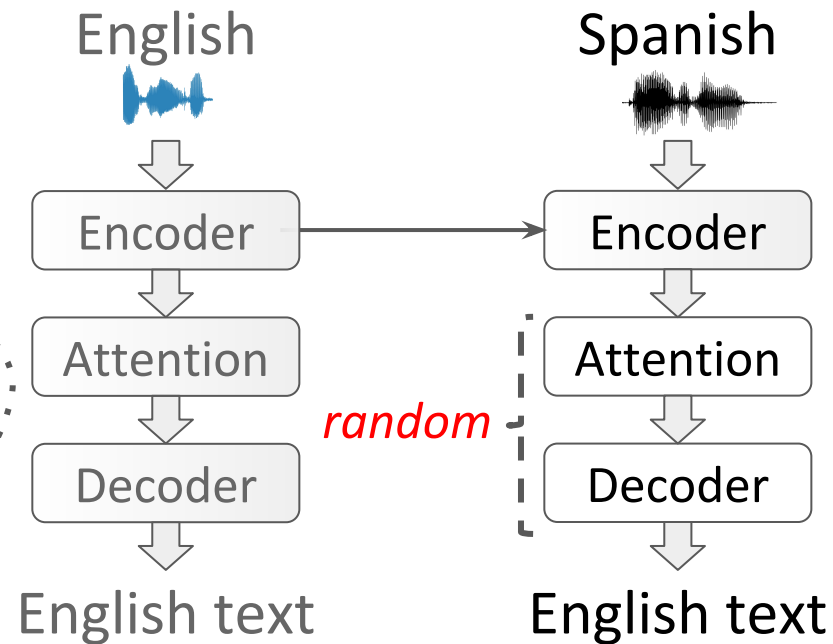
… can pretrain on a language different from
both source and target in ST pair

Pretraining on French

Spanish to English, *N* = 20 hours

	BLEU
baseline	10.8
+English ASR	19.9
+English ASR: encoder	16.6
+French ASR: encoder	?

*only 20 hours of French ASR

French

Spanish

Encoder → Encoder

Attention

Attention

random

Decoder

Decoder

French text

English text

Pretraining on French

Spanish to English, N = 20 hours

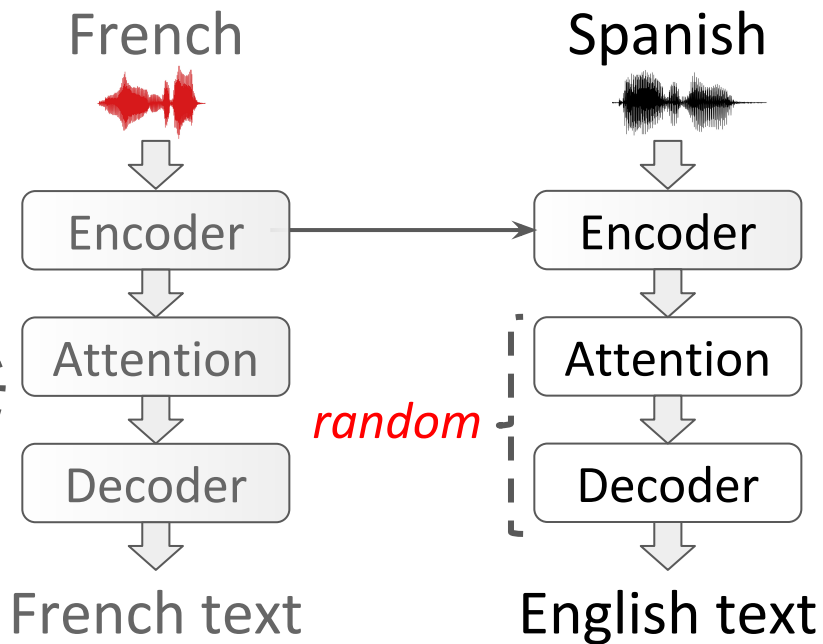|	BLEU
baseline	10.8
+English ASR	19.9
+English ASR: encoder	16.6
+French ASR: encoder	**12.5**
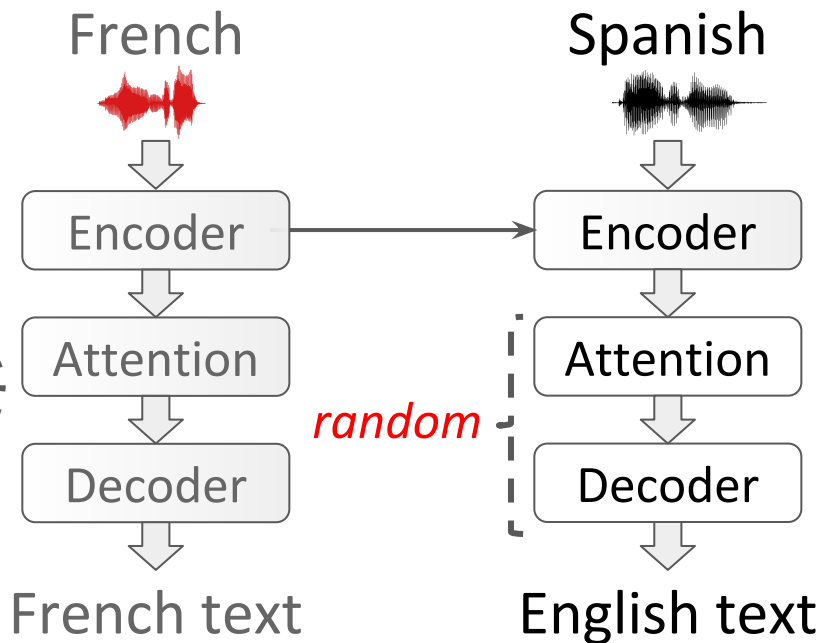
French ASR helps Spanish-English ST

French

Spanish

Encoder → Encoder

Attention

Attention

random

Decoder

Decoder

French text

English text

Takeaways

- Pretraining on a different language helps
- transfer all model parameters for best gains
- encoder parameters account for most of these

  … useful when target vocabulary is different

… Mboshi-French ST

Mboshi-French ST

- ST data by Godard et al. 2018
  - **~4 hours** of speech, paired with French translations

- Mboshi
  - Bantu language, Republic of Congo
  - Unwritten
  - ~160K speakers

Mboshi-French: Results

Mboshi to French, *N* = 4 hours

	BLEU
baseline	?

Mboshi

Encoder

Attention

Decoder

French text
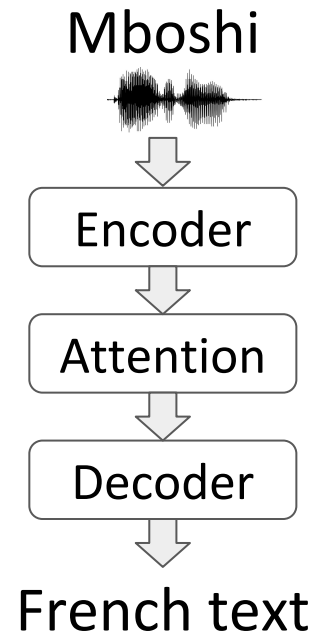
Mboshi-French: Results

Mboshi to French, N = 4 hours

	BLEU
baseline	3.5

👎

*outperformed by a naive baseline
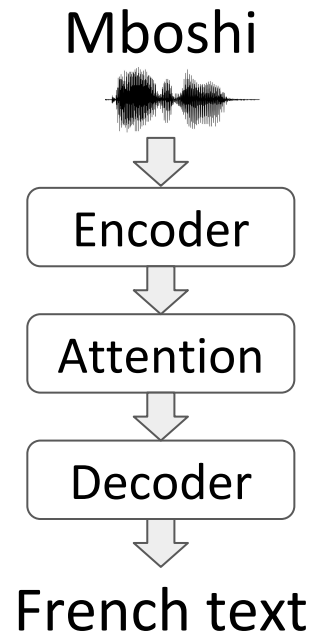
Mboshi

Encoder

Attention

Decoder

French text

Pretraining on French ASR

Mboshi to French, N = 4 hours

	BLEU
baseline	3.5
+French ASR: all	?

French

Encoder

Attention

Decoder

French text

Mboshi

Encoder

Attention

Decoder

French text

transfer all parameters

Pretraining on French ASR

Mboshi to French, N = 4 hours

	BLEU
baseline	3.5
+French ASR: all	5.9

French

Mboshi

Encoder → Attention → Decoder

French text

Encoder → Attention → Decoder

French text
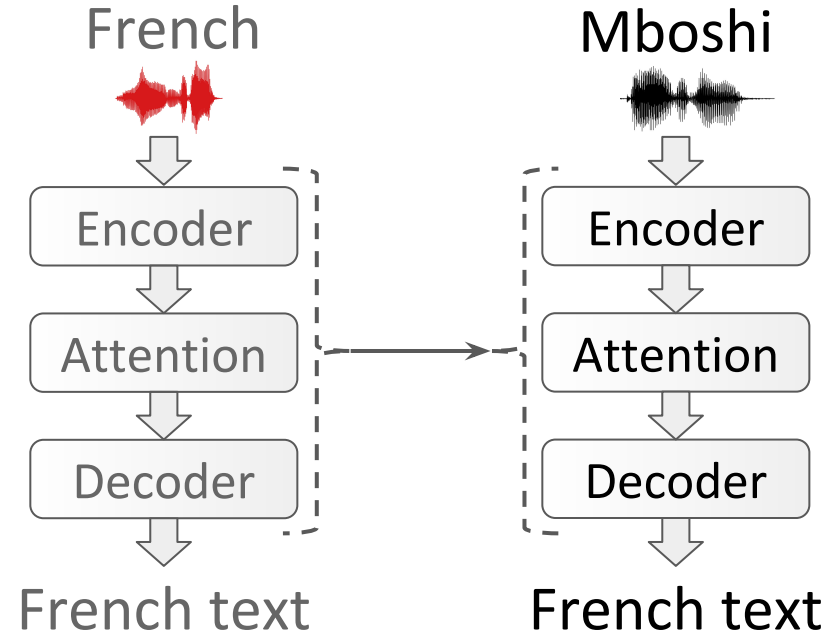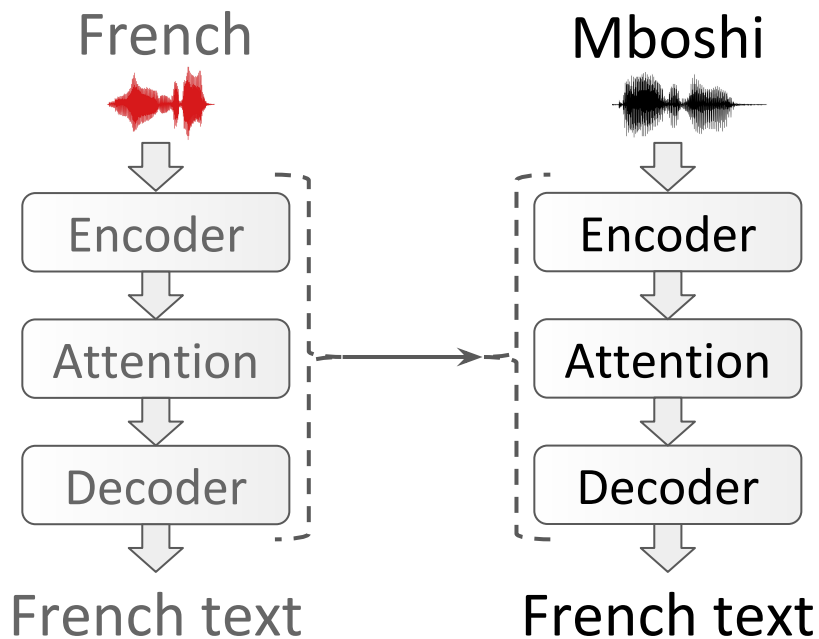
French ASR helps Mboshi-French ST

Pretraining on French ASR

Mboshi to French, N = 4 hours

	BLEU
baseline	3.5
+French ASR: all	5.9

French ASR helps Mboshi-French ST

Pretraining on English ASR

Mboshi to French, N = 4 hours

	BLEU
baseline	3.5
+French ASR: all	5.9
+English ASR: encoder	?

English · Mboshi

Encoder → Encoder

Attention · *random* · Attention

Decoder · Decoder

English text · French text
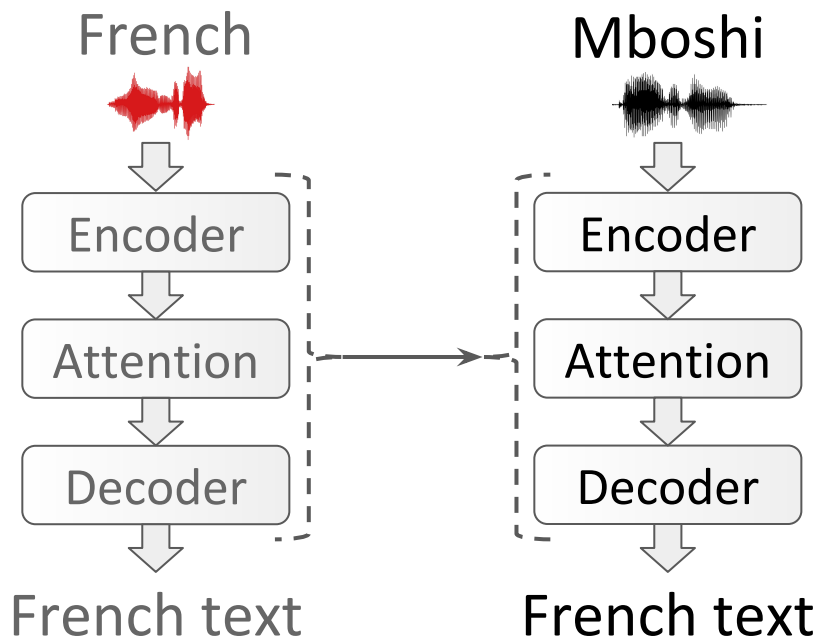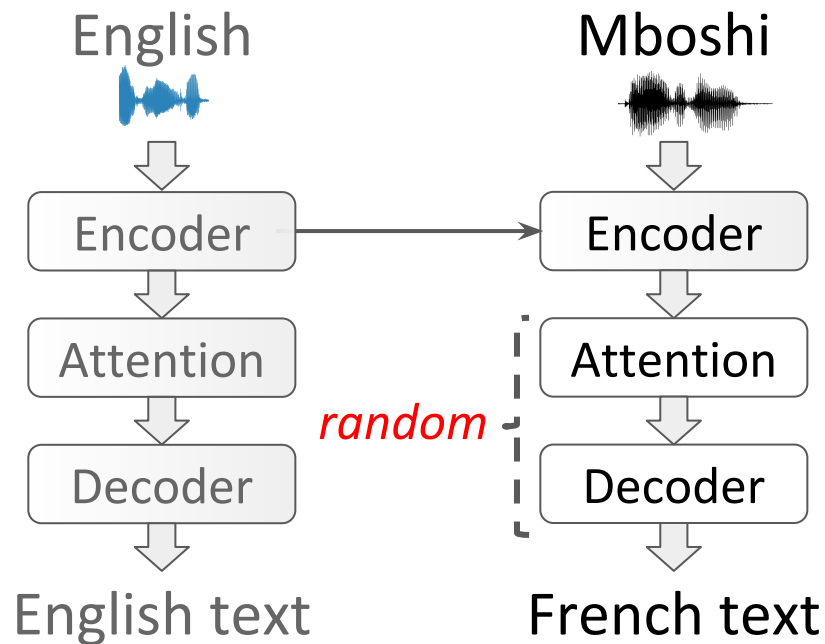
using encoder trained on a lot more data

Pretraining on English ASR

Mboshi to French, *N* = 4 hours

	BLEU
baseline	3.5
+French ASR: all	5.9
+English ASR: encoder	5.3

English

Encoder → Encoder

Attention

Decoder

random

English text

Mboshi

Encoder

Attention

Decoder

French text

English ASR helps Mboshi-French ST
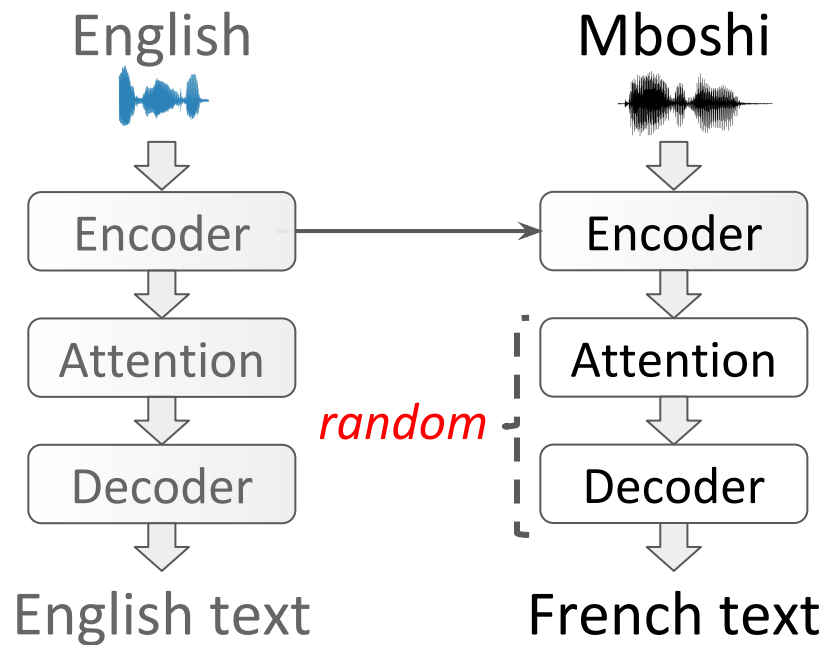
Pretraining on French ASR: can transfer all parameters

… but only 20 hours of data

Pretraining on English ASR: trained on a lot more data (300 hours)

… but can only transfer encoder parameters

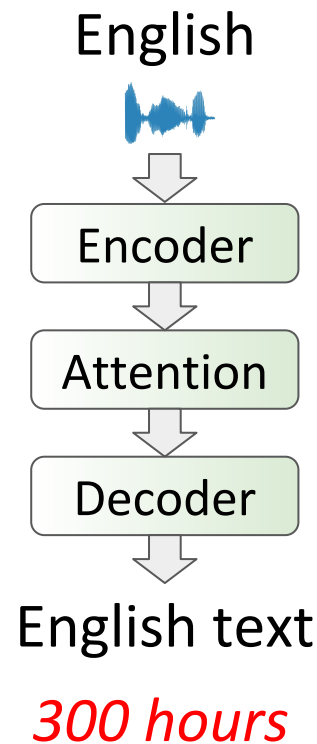**Pretraining on French ASR**: can transfer all parameters
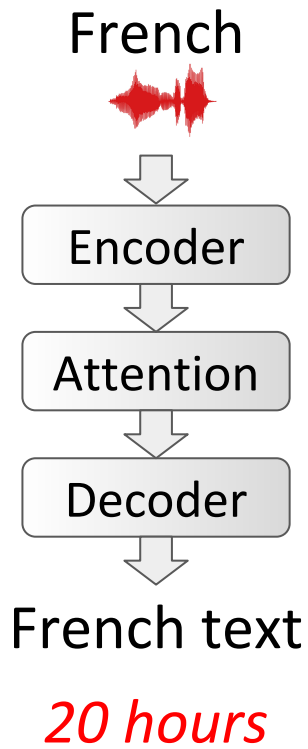
… but only 20 hours of data

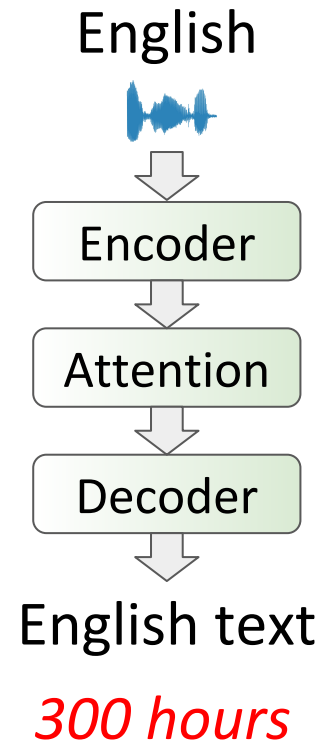**Pretraining on English ASR**: trained on a lot more data (300 hours)

… but can only transfer encoder parameters

… combine both?

Pretraining on French and English ASR

French

Encoder

Attention

Decoder

French text

20 hours

English

Encoder

Attention

Decoder

English text

300 hours

Pretraining on French and English ASR

Pretraining on French and English ASR

French   Mboshi   English

French	Mboshi	English
Encoder	Encoder	Encoder
Attention	Attention	Attention
Decoder	Decoder	Decoder
French text	French text	English text
20 hours	*4 hours*	*300 hours*

Pretraining on English ASR

Mboshi to French, *N* = 4 hours

	BLEU
baseline	3.5
+French ASR: all	5.9
+English ASR: encoder	5.3
+English ASR: encoder +French ASR: remaining	?

Mboshi

Encoder ← From English ASR

Attention

Decoder ⎤ From French ASR

French text
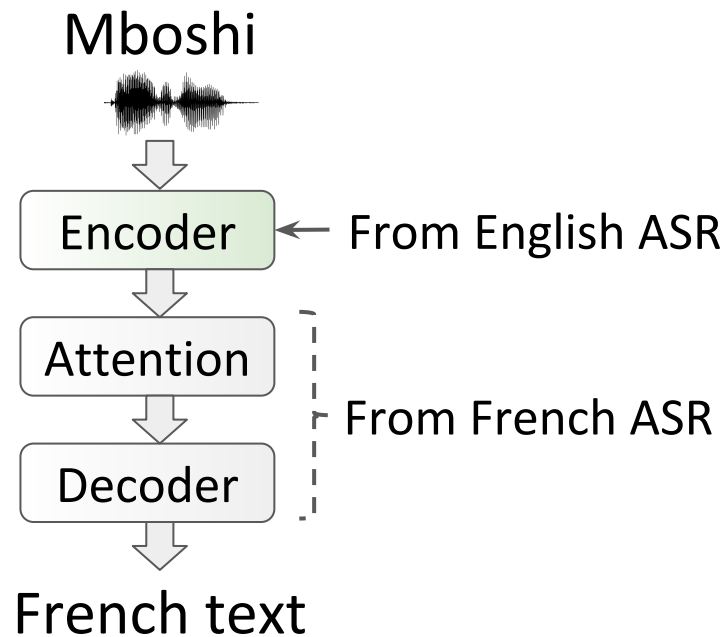
Pretraining on English ASR

Mboshi to French, N = 4 hours

	BLEU
baseline	3.5
+French ASR: all	5.9
+English ASR: encoder	5.3
+English ASR: encoder +French ASR: remaining	7.1

combining gives the best gains
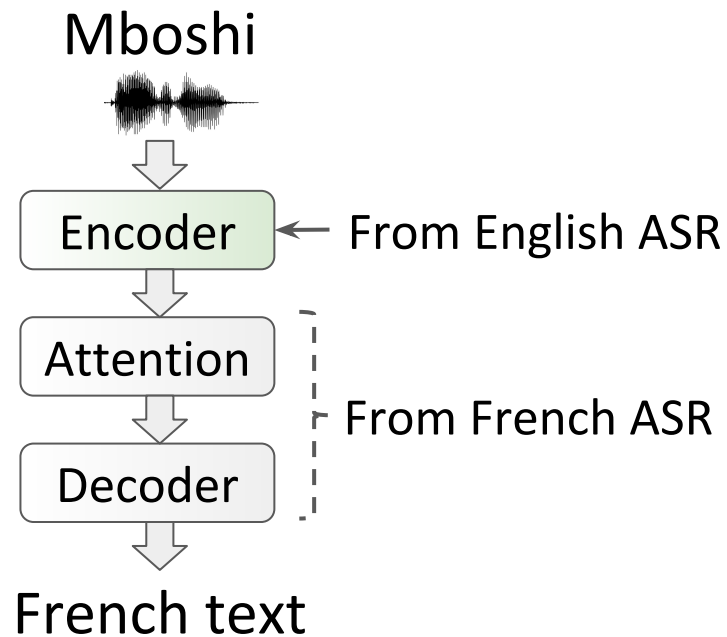
Mboshi

Encoder ← From English ASR

Attention

Decoder ⌐ From French ASR

French text

Pretraining on English ASR

Mboshi to French, N = 4 hours

	BLEU
baseline	3.5
+French ASR: all	5.9
+English ASR: encoder	5.3
+English ASR: encoder +French ASR: remaining	7.1

Mboshi

Encoder ← From English ASR

Attention

Decoder ⌐ From French ASR

French text
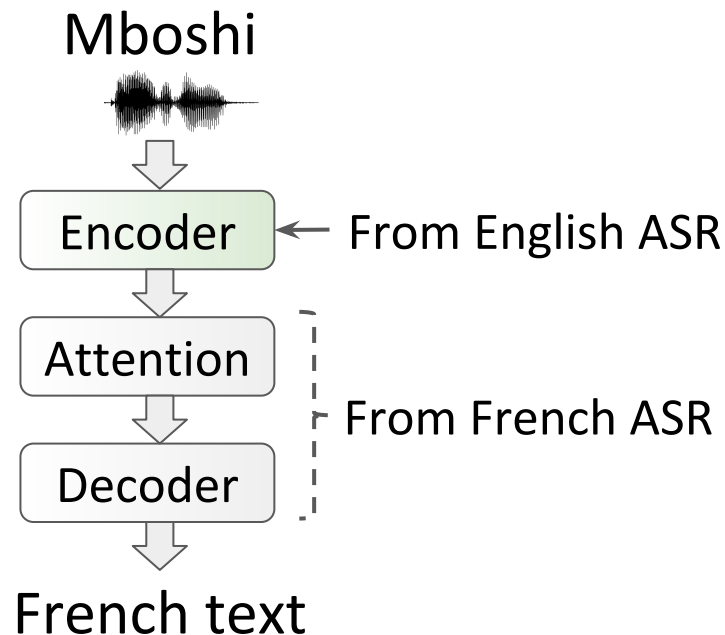
BLEU score is still low … but above naive baseline

Conclusions

- Pretraining on high-resource ASR improves low-resource ST
- Potentially useful for endangered and/or unwritten languages
- Bootstrap ST in time-critical scenarios
- Future work: experiments on more languages, multilingual training with joint vocabulary

Thanks

- Anonymous reviewers, Edinburgh NLP members
- Source code available at: https://github.com/0xSameer/ast

I am looking for full-time positions starting November 2019!

- <u>4th June, 3:30-5 pm</u> - "Fluent Translations from Disfluent Speech in End-to-End Speech Translation", Salesky et al.
- <u>5th June, 10:30-10:48 am</u> - "Neural Machine Translation of Text from Non-Native Speakers", Anastasopoulos et al.

Backup

Mboshi-French naive baseline

model	pretrain	BLEU	Pr.	Rec.
fr-top-8w	–	0	23.5	22.2
fr-top-10w	–	0	20.6	24.5
en-300h	–	0	0.2	5.7
fr-20h	–	0	4.1	3.2
	–	3.5	18.6	19.4
	fr-20h	5.9	23.6	20.9
mb-fr-4h	en-300h	5.3	23.5	22.6
	en + fr	**7.1**	**26.7**	**23.1**

Why does pretraining help?

- Speaker invariance
  - ASR data contains audio from 100s of speakers
- Learning to factor out background noise (?)

BLEU	Baseline	+English ASR
50 speakers	7.2	17.5 (+143 %)
136 speakers	10.8 (+ 50%)	19.9 (+14%)

Spanish-English ST

N hrs	2.5h	5h	10h	20h	50h	160h Weiss
baseline	2.1	1.8	2.1	10.8	22.7	47.3
+ASR	5.7	9.1	14.5	20.2	28.3	---
	+3.6	+7.3	+12.4	+9.4	+5.5	

results on Fisher test set ...

Spanish-English ST

Spanish to English, *N* = 20 hours

	BLEU
baseline	10.8
+En ASR: 300h	16.6
+Fr ASR:20h	**12.5**
+En ASR: 20h	**13.2**
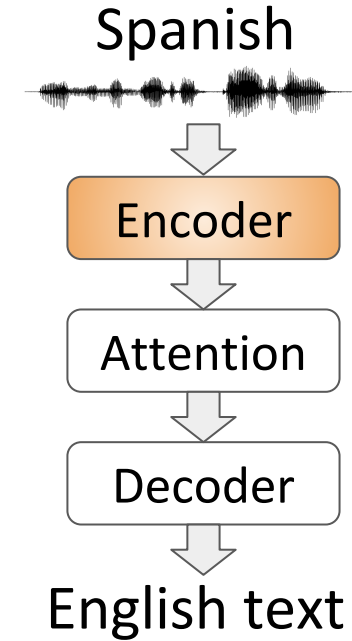
… French ASR helps improve Spanish-English ST

Spanish

Encoder

Attention

Decoder

English text

Spanish-English ST
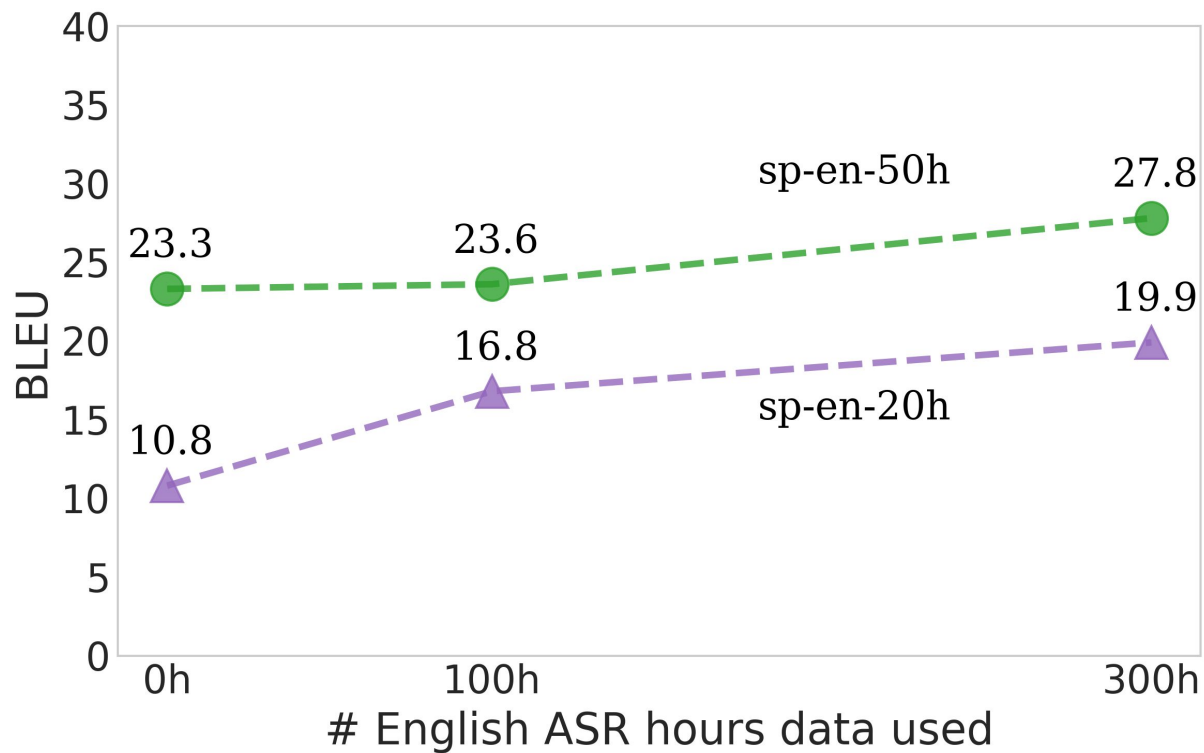
Neural model
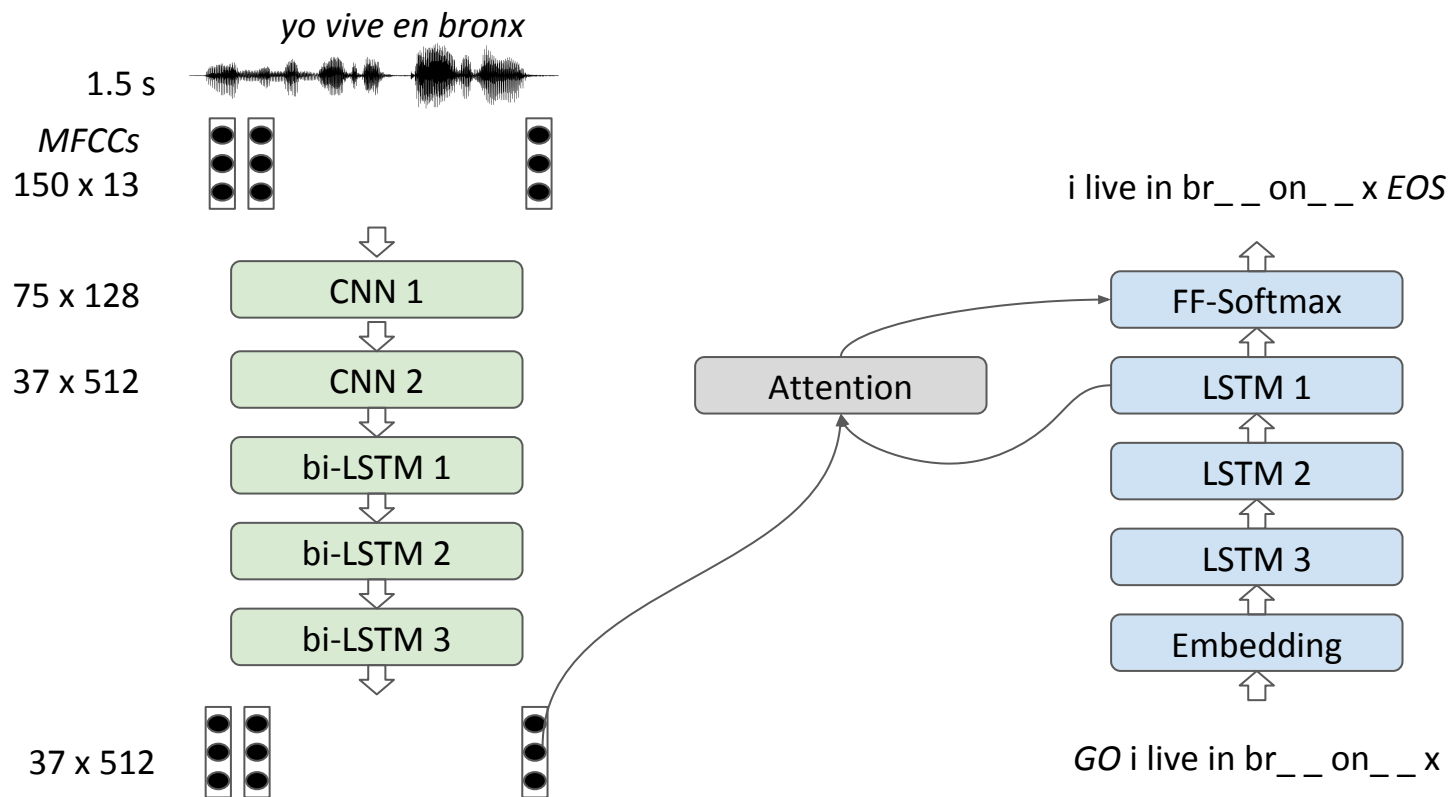
Neural model
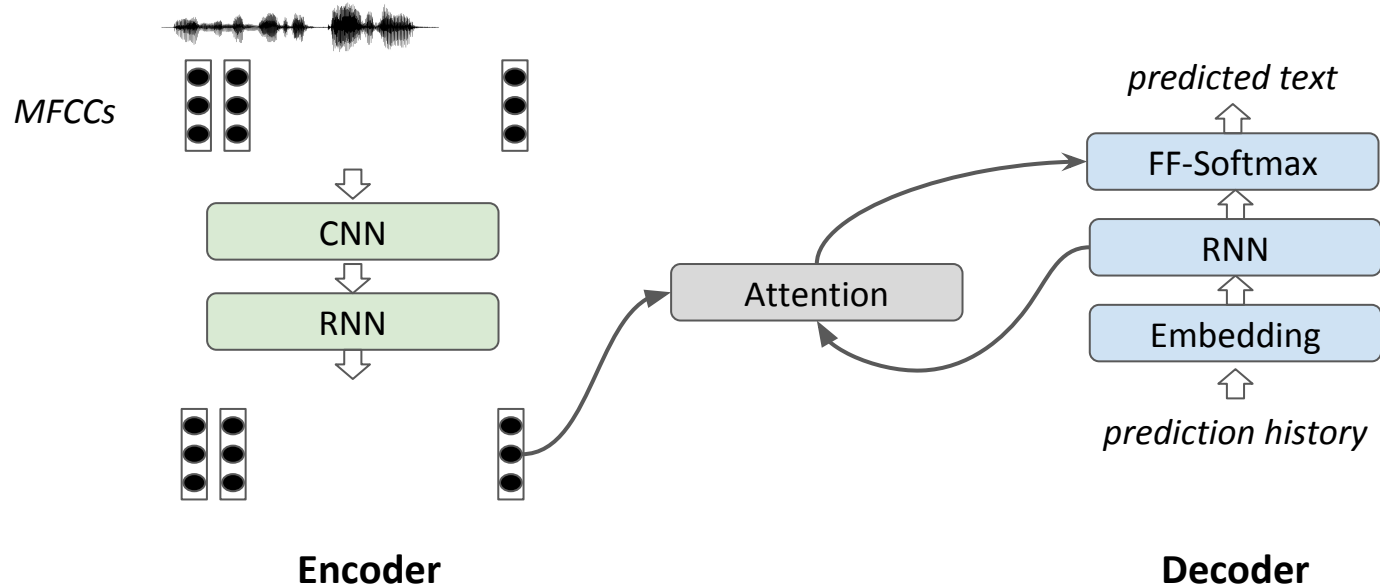
MFCCs

CNN

RNN

Encoder

Attention

predicted text

FF-Softmax

RNN

Embedding

prediction history

Decoder

100s of hours of **monolingual** speech paired with text available

… typically used to train ASR systems

Gülçehre et al., 2015
Toshniwal et al., 2018   **English** text

Spanish Audio → Sequence-to-Sequence → **English** text

~20 hours of Spanish-English