

A Obtaining L2 Glosses

Using Amazon Mechanical Turk (MTurk), we asked bilingual speakers (English-Spanish or English-German) to produce a gloss for each token in English documents. Each Turker was given a sentence in English (L1) and produced a L2 gloss for each L1 token. Each sentence was annotated by three Turkers. For each L1 token, we then selected the L2 gloss that was agreed on by a majority of the Turkers. If there was no such gloss, we did not select any L2 gloss, meaning that the machine teacher was required to leave that token as L1.

B Hyperparameter Search

We tuned the model hyperparameters by hand on separate English-Spanish data, namely the second chapter of “Sense and Sensibility,” equipped with glosses. Hyperparameter tuning results are reported in this appendix. All other English-Spanish results in the paper are on the first chapter of “Sense and Sensibility,” which was held out for testing. We might have improved the results on English-German by tuning separate hyperparameters for that setting.

The tables below show the effect of different hyperparameter choices on the quality $MRR(\mathbf{F})$ of the embeddings learned by the simulated student. Recall from §3.4 that the MRR score evaluates \mathbf{F} using all glosses, not just those used in a particular macaronic document. Thus, it is comparable across the different macaronic documents produced by different machine teachers.

QueueSize (§3.5) affects only how hard the machine teacher searches for macaronic sentences that will help the simulated student. We find that larger QueueSize is in fact valuable.

The other choices (Model, n -grams, μ) affect how the simulated student actually learns. The machine teacher then searches for a document that will help that particular simulated student learn as many of the words in the reference set as possible. Thus, the MRR score is high to the extent that the simulated student “can be successfully taught.” By choosing hyperparameters that achieve a high MRR score, we are assuming that human students are adapted (or can adapt online) to be teachable.

The scale factor μ (used only for s_{GSM}) noticeably affects the macaronic document generated by the machine teacher. Setting it high ($\mu = 1.0$) has a adverse effect on the MRR score. Table 4 shows how the MRR score of the simulated student (§3.4) varies according to the student model’s μ

value. Tables 5 and 6 show the result of the same hyperparameter sweep on the number of L1 word tokens and types replaced with L2 glosses.

Note that μ only affects initialization of the \mathcal{F} parameters. Thus, with $\mu = 0$, the L2 word and subword embeddings are initialized to $\mathbf{0}$, but the simulated s_{GSM} student still has the ability to learn subword embeddings for both L1 and L2. This allows it to beat the simulated GSM student.

We see that for s_{GSM} , $\mu = 0.2$ results in replacing the most words (both types and tokens), and also has very nearly the highest MRR score. Thus, for s_{GSM} , we decided to use $\mu = 0.2$ and allow both 3-gram and 4-gram embeddings.

Model	n -grams	QueueSize	Scale Factor μ					
			1.0	0.4	0.2	0.1	0.05	0.0
s_{GSM}	2,3,4	1	0.108	0.207	0.264	0.263	0.238	0.175
s_{GSM}	3,4	1	0.113	0.199	0.258	0.274	0.277	0.189
s_{GSM}	3,4	4	-	-	0.267	0.286	-	-
s_{GSM}	3,4	8	-	-	0.288	0.292	-	-
GSM	\emptyset	1						0.159
GSM	\emptyset	4						0.171
GSM	\emptyset	8						0.172

Table 4: MRR scores obtained with different hyperparameter settings.

Model	n -grams	QueueSize	Scale Factor μ					
			1.0	0.4	0.2	0.1	0.05	0.0
s_{GSM}	2,3,4	1	149	301	327	275	201	247
s_{GSM}	3,4	1	190	340	439	399	341	341
s_{GSM}	3,4	4	-	-	462	440	-	-
s_{GSM}	3,4	8	-	-	478	450	-	-
GSM	\emptyset	1						549
GSM	\emptyset	4						557
GSM	\emptyset	8						530

Table 5: Number of L1 tokens replaced by L2 glosses under different hyperparameter settings.

Model	n -grams	QueueSize	Scale Factor μ					
			1.0	0.4	0.2	0.1	0.05	0.0
s_{GSM}	2,3,4	1	39	97	121	106	75	88
s_{GSM}	3,4	1	44	97	125	124	112	99
s_{GSM}	3,4	4	-	-	124	127	-	-
s_{GSM}	3,4	8	-	-	145	129	-	-
GSM	\emptyset	1						106
GSM	\emptyset	4						111
GSM	\emptyset	8						114

Table 6: Number of distinct L2 word types present in the macaronic document under different hyperparameter settings.

L2	τ	Model	Closed-class	Open-class
Es	0.0	rand	0.81±0.0084(54)	0.72±0.0088(17)
		GSM	0.80±0.0045(54)	0.79±0.0057(17)
		sGSM	0.86±0.0027(41)	0.84±0.0032(21)
	0.2	rand	0.81±0.0085(54)	0.72±0.0089(17)
		GSM	0.80±0.0045(54)	0.79±0.0057(17)
		sGSM	0.86±0.0027(41)	0.84±0.0033(21)
	0.4	rand	0.79±0.0101(54)	0.66±0.0117(17)
		GSM	0.76±0.0057(54)	0.75±0.0071(17)
		sGSM	0.84±0.0033(41)	0.82±0.0039(21)
	0.6	random	0.74±0.0126(54)	0.61±0.0134(17)
		GSM	0.72±0.0061(54)	0.70±0.0084(17)
		sGSM	0.82±0.0038(41)	0.80±0.0044(21)
0.8	rand	0.62±0.0143(54)	0.46±0.0124(17)	
	GSM	0.59±0.0081(54)	0.58±0.0106(17)	
	sGSM	0.71±0.0052(41)	0.67±0.0062(21)	
1.0	rand	0.62±0.0143(54)	0.45±0.0124(17)	
	GSM	0.59±0.0081(54)	0.55±0.0097(17)	
	sGSM	0.70±0.0052(41)	0.64±0.0063(21)	
De	0.0	random	0.70±0.0039(34)	0.56±0.0046(13)
		GSM	0.85±0.0023(34)	0.84±0.0039(13)
		sGSM	0.87±0.0045(33)	0.84±0.0044(14)
	0.2	random	0.69±0.0042(34)	0.56±0.0047(13)
		GSM	0.85±0.0024(34)	0.84±0.0039(13)
		sGSM	0.87±0.0046(33)	0.84±0.0044(14)
	0.4	random	0.64±0.0052(34)	0.45±0.0064(13)
		GSM	0.83±0.0029(34)	0.81±0.0045(13)
		sGSM	0.84±0.0055(33)	0.81±0.0054(14)
	0.6	random	0.59±0.0054(34)	0.38±0.0065(13)
		GSM	0.80±0.0033(34)	0.78±0.0056(13)
		sGSM	0.82±0.0063(33)	0.79±0.0062(14)
0.8	random	0.45±0.0058(34)	0.25±0.0061(13)	
	GSM	0.72±0.0037(34)	0.66±0.0081(13)	
	sGSM	0.75±0.0079(33)	0.65±0.0077(14)	
1.0	random	0.45±0.0058(34)	0.24±0.0061(13)	
	GSM	0.71±0.0040(34)	0.63±0.0082(13)	
	sGSM	0.75±0.0079(33)	0.63±0.0081(14)	

Table 7: An expanded version of Table 2 (human comprehension experiments), reporting results with various values of τ .

C Results Varying τ

A more comprehensive variant of Table 2 is given in Table 7. This table reports the same human-subjects experiments as before; it only varies the measure used to assess the quality of the humans’ guesses, by varying the threshold τ . Note that $\tau = 1$ assesses exact-match accuracy, $\tau = 0.6$ as in Table 2 corresponds roughly to synonymy (at least for content words), and $\tau = 0$ assesses average *unthresholded* cosine similarity. We find that sGSM consistently outperforms both GSM and the random baseline over the entire range of τ . As we get closer to exact match, the random baseline suffers the largest drop in performance.

L2	τ	Model	Closed-class	Open-class
Es	0.0	random	0.67±0.0037(60)	0.60±0.0027(46)
		GSM	0.67±0.0060(60)	0.62±0.0076(15)
		sGSM	0.71±0.0035(47)	0.68±0.0028(24)
	0.2	random	0.67±0.0037(60)	0.60±0.0027(46)
		GSM	0.67±0.0061(60)	0.61±0.0080(15)
		sGSM	0.71±0.0036(47)	0.67±0.0029(24)
	0.4	random	0.60±0.0051(60)	0.50±0.0037(46)
		GSM	0.60±0.0086(60)	0.51±0.0106(15)
		sGSM	0.66±0.0044(47)	0.61±0.0037(24)
	0.6	random	0.47±0.0058(60)	0.40±0.0041(46)
		GSM	0.48±0.0084(60)	0.42±0.0105(15)
		sGSM	0.52±0.0054(47)	0.50±0.0037(24)
0.8	random	0.40±0.0053(60)	0.30±0.0032(46)	
	GSM	0.41±0.0078(60)	0.37±0.0097(15)	
	sGSM	0.46±0.0055(47)	0.41±0.0041(24)	
1.0	random	0.40±0.0053(60)	0.29±0.0031(46)	
	GSM	0.40±0.0077(60)	0.36±0.0092(15)	
	sGSM	0.45±0.0053(47)	0.39±0.0042(24)	

Table 8: An expanded version of Table 3 (human retention experiments), reporting results with various values of τ .

Similarly, Table 8 shows an expanded version of the retention results in Table 3. The gap between the models is smaller on retention than it was on comprehension. However, again sGSM > GSM > random across the range of τ . We find that for function words, the random baseline performs as well as GSM as τ is increased. For content words, however, the random baseline falls faster than GSM.

We warn that the numbers are not genuinely comparable across the 3 models, because each model resulted in a different document and thus a different vocabulary quiz. Our human subjects were asked to translate just the L2 words in the document they read. In particular, sGSM taught *fewer* total types (71) than GSM (75) or the random baseline (106). All that Table 8 shows is that it taught its chosen types better (on average) than the other methods taught their chosen types.

D Macaronic Examples

Below, we display the actual macaronic documents generated by our methods. Table 9 is the opening of Jane Austin’s “Sense and Sensibility,” converted into a macaronic English-Spanish document using our sGSM-based teacher. Table 10 shows the same passage converted into macaronic form with the GSM-based teacher. Similarly, Tables 11 and 12 show macaronic English-German versions of “The Metamorphosis.”

Sense y Sensibility

La family de Dashwood **llevaba** long been settled **en** Sussex. Their estate **era** large, and their **residencia** was **en** Norland Park, in **el** centre **de** their property, where, for **muchas** generations, they **habían** lived **en** so respectable a manner as to engage **el** general good opinion of **los** surrounding acquaintance. **El** late owner **de** this **propiedad** was **un** single man, **que** lived to **una** very advanced age, **y** **que** **durante** many years of his life, had a **constante** companion and housekeeper in **su** sister. But **ella** death, **que** happened ten **años** **antes** his own, produced a great alteration in **su** home; for to supply her loss, he invited and received into his house **la** family of **su** **sobrino** señor Henry Dashwood, the legal inheritor of the Norland estate, and the person to whom he intended to bequeath it. **En** **la** society **de** **su** nephew **y** niece, **y** their children, **el** old Gentleman's days **fueron** comfortably spent. **Su** attachment **a** them all increased. The constant attention **de** Mr. **y** Mrs. Henry Dashwood to **sus** wishes, **que** proceeded **no** merely from interest, but from goodness of heart, **dio** him every degree **de** solid comfort which **su** age **podía** receive; and **la** cheerfulness of the children added a relish to his **existencia**.

By **un** former marriage, Mr. Henry Dashwood **tenía** one son : by **su** present lady, three **hijas**. **El** son, **un** steady respectable young man, was amply provided for **por** the **fortuna** **de** his mother, which **había** been large, **y** half of which devolved on him on his coming of **edad**. **Por** **su** own **matrimonio**, likewise, which happened soon **después**, he added **a** his wealth. To him therefore **la** succession **a** **la** Norland estate **era** **no** so really **importante** as to his sisters; **para** their **fortuna**, independent **de** what **podiera** arise **a** **ellas** from **su** father's inheriting that **propiedad**, could **ser** but small. **Su** mother had nothing, **y** their father only seven **mil** pounds **en** his own **disposición**; for **la** remaining moiety of his first **esposa**'s fortune was also secured to her child, and **él** **tenía** **sólo** a life-interest in it.

el anciano gentleman died : his will was read, and like almost **todo** other will, **dio** as **tanto** disappointment as pleasure. He **fue** neither so unjust, **ni** so ungrateful, as **para** leave his estate **de** his nephew; --but he left it **a** him **en** such terms as destroyed half the **valor** **de** **el** bequest. Mr. Dashwood **había** wished for it more **por** **el** sake of his **esposa** and **hijas** than for himself or **su** son; --but **a** his son, **y** **su** son's son, **un** child **de** four **años** old, it **estaba** secured, in **tal** a way, as **a** leave **a** himself no power **de** providing **por** those **que** were most dear **para** him, and who most **necesitaban** a **provisión** by any charge on **la** estate, or **por** any sale **de** its valuable woods. **El** whole **fue** tied **arriba** **para** the **beneficio** **de** this child, **quien**, in occasional visits with his **padre** and mother at Norland, had **tan** far gained on **el** affections **de** his uncle, by such attractions as are by no means unusual in children of two **o** three years old; **una** imperfect **articulación**, an earnest desire of having his own way, many cunning tricks, and a great deal of noise, as to outweigh all the value **de** all the attention which, for years, **él** **había** received from his niece and **sus** daughters. He meant **no** **a** **ser** unkind, however, **y**, **como** a mark **de** his affection for **las** three girls, he left **ellas** **un** **mil** **libras** a-piece.

Table 9: First few paragraphs of “Sense and Senibility” with the sGSM model using $\mu = 0.2$, 3- and 4-grams, priority queue size of 8, and $r_{\max}=4$.

Sense y Sensibility

La family **de** Dashwood **llevaba** long been settled **en** Sussex. **Su** estate **era** large, and **su** residence **estaba** **en** Norland Park, in **el** centre **de** their property, where, **por** many generations, they had lived in so respectable **una** manner as **a** engage **el** general good opinion **de** **los** surrounding acquaintance. **El** late owner **de** **esta** estate was **un** single man, **que** lived to **una** very advanced age, **y** who **durante** many years **de** **su** **existencia**, had **una** constant companion **y** housekeeper in his sister. But **ella** death, **que** happened ten years **antes** **su** own, produced a great alteration in **su** home; for **para** supply her loss, **él** invited and received into his house **la** family **de** **su** nephew Mr. Henry Dashwood, the legal inheritor **de** the Norland estate, and the person to whom **se** intended to bequeath it. In the society **de** **su** nephew and niece, and **sus** children, **el** old Gentleman's days **fueron** comfortably spent. **Su** attachment **a** them all increased. **La** constant attention **de** Mr. **y** Mrs. Henry Dashwood to **sus** wishes, which proceeded not merely from interest, but **de** goodness **de** heart, **dio** him every degree **de** solid comfort **que** his age could receive; **y** **la** cheerfulness of the children added **un** relish **a** **su** existence.

By **un** former marriage, Mr. Henry Dashwood **tenía** one son : by **su** present lady, three **hijas**. **El** son, **un** steady respectable **joven** man, was amply provided for **por** **la** fortune **de** **su** madre, **que** **había** been large, **y** half **de** **cuya** devolved on him on **su** coming **de** **edad**. By **su** own marriage, likewise, **que** happened soon **después**, he added **a** **su** wealth. **Para** him therefore **la** succession **a** **la** Norland estate was **no** so really **importante** as to his sisters; **para** their fortune, independent **de** what **podiera** arise **a** them from **su** father's inheriting that property, could **ser** but small. **Su** madre had nothing, **y** **su** padre only **siete** thousand pounds in **su** own disposal; for **la** remaining moiety of his first wife's fortune **era** also secured **a** **su** child, **y** **él** had only **una** life-interest in **ello**.

el old gentleman died : **su** will was read, **y** like almost every **otro** will, gave as **tanto** disappointment as pleasure. He **fue** neither so unjust, nor so ungrateful, as to leave **su** estate from his nephew; --but he left it to him **en** such terms **como** destroyed half the **valor** of the bequest. Mr. Dashwood **había** wished for it **más** for **el** sake **de** **su** wife and daughters than **para** himself or **su** hijo; --but **a** **su** hijo, **y** his son's hijo, **un** child **de** four **años** old, it **estaba** secured, **en** **tal** **un** way, as **a** leave **a** himself no power of providing for **aquellos** who were most dear **para** him, **y** who most needed **un** provision by any charge **sobre** **la** estate, or **por** any sale **de** its valuable woods. **El** whole was tied **arriba** for **el** benefit **de** this child, **quien**, in ocasionales visits with his father and mother at Norland, had **tan** far gained on the affections of his uncle, by such attractions as are **por** no means unusual in children of two or three years old; an imperfect articulation, an earnest desire of having his own way, many cunning tricks, and a **gran** deal of noise, as to outweigh **todo** the value of all the attention which, for years, he had received from his niece and her daughters. He meant **no** **a** **ser** unkind, however, **y**, **como** **una** mark **de** **su** affection **por** **las** three girls, he left them **un** **mil** pounds **a**-**pieza**.

Table 10: First few paragraphs of “Sense and Senibility” with the GSM model using priority queue size of 8 and $r_{\max}=4$.

Metamorphosis

One morning, **als** Gregor Samsa woke from troubled dreams, he **fand** himself transformed in **seinem** bed into **einem** horrible vermin. He lay on **seinem** armour-like back, **und** if **er** lifted **seinem** head a little he **konnte** see his brown belly, slightly domed **und** divided by arches into stiff sections. The bedding **war** hardly able **zu** cover it **und** seemed ready **zu** slide off any moment. His many legs, pitifully thin compared **mit** the size **von dem** rest **von** him, waved about helplessly as **er** looked.

“What’s happened to **mir**?” he thought. His room, **ein** proper human room although **ein** little too small, lay peacefully between its four familiar walls. **Eine** collection of textile samples lay spread out on the table – Samsa was **ein** travelling salesman – and above it there hung a picture **das** he had recently cut out **von einer** illustrated magazine **und** housed **in einem** nice, gilded frame. It showed **eine** lady fitted out **mit** a fur hat **und** fur boa who sat upright, raising **einen** heavy fur muff **der** covered the whole **von** her lower arm towards **dem** viewer.

Gregor then turned **zu** look out the window at the dull weather. Drops **von** rain could **sein** heard hitting the pane, **welche** made him **fühlen** quite sad. “How about if **ich** sleep **ein** little bit longer and forget all **diesen** nonsense,” he thought, **aber** that was something **er** was unable **zu** do because he **war** used **zu** sleeping **auf** his right, **und** in **seinem** present state couldn’t **bringen** into that position. However hard he threw **sich** onto **seine** right, he always rolled **zurück** to where he was. He must **haben** tried it a **hundert** times, shut **seine** eyes so **dass er** wouldn’t **haben zu** look at **die** floundering legs, and only stopped when **er** began **zu fühlen einen** mild, dull pain there **das** he **hatte** never felt before.

“Ach, God,” he thought, “what a strenuous career it is **das** I’ve chosen! Travelling day in **und** day out. Doing business like **diese** takes **viel** more effort than doing your own business at home, **und auf** top of that there’s the curse **des** travelling, worries **um** making train connections, bad **und** irregular food, contact **mit** different people all the time so that **du** can **nie** get to know anyone or become friendly **mit ihnen**. It can **alles** go **zum** Hell!” He felt a slight itch up **auf** his belly; pushed himself slowly up **auf** his back towards **dem** headboard so **dass** he **konnte** lift his head better; **fand** where **das** itch was, **und** saw that **es** was covered **mit vielen** of little **weißen** spots which he didn’t know what to make of; **und als** he **versuchte** to **fühlen** the place with one **von seinen** legs he drew it quickly back because as soon as he touched it he was overcome **von** a cold shudder.

Table 11: First few paragraphs of “The Metamorphosis” with the sGSM model using $\mu = 0.2$, 3- and 4-grams, priority queue size of 8, and $r_{\max}=4$.

Metamorphosis

One morning, **als** Gregor Samsa woke from troubled dreams, he **fand** himself transformed **in** his bed into **einem** horrible vermin. **Er** lay on **seinem** armour @-@ like back, **und** if **er** lifted his head a little **er** could see **seinem** brown belly, slightly domed **und** divided by arches into stiff **teile**. **das** bedding was hardly **fähig** to cover **es und** seemed ready **zu** slide off any moment. His many legs, pitifully thin compared **mit** the size **von dem** rest **von** him, waved about helplessly **als er** looked.

“What’s happened to **mir**?” **er** thought. His room, **ein** proper human room although **ein** little too **klein**, lay peacefully between **seinem** four familiar walls. **Eine** collection of textile samples lay spread out on the table – Samsa was **ein** travelling salesman – **und** above it there hung a picture that **er** had recently cut **aus** of **einer** illustrated magazine **und** housed in **einem** nice, gilded frame. **Es** showed a lady fitted out with a fur hat and fur boa who **saß** upright, raising a heavy fur muff **der** covered the whole of her lower arm towards **dem** viewer.

Gregor then turned **zu** look out the window at the dull weather. Drops **von** rain could **sein** heard hitting the pane, which **machte** him feel **ganz** sad. “How about if **ich** sleep **ein** little bit longer and forget all **diesen** nonsense,” he thought, but that **war** something he was unable to **tun** because **er** was used to sleeping **auf** his right, and in his present state couldn’t get into that position. However hard he **warf** himself onto **seine** right, he always rolled **zurück** to **wo** he was. **Er** must **haben** tried it **ein** hundred times, shut **seine** eyes so **dass** he wouldn’t **haben** to **sehen** at **die** floundering legs, **und** only stopped when he **begann** to feel **einen** mild, dull pain there that he **hatte nie** felt before.

“Ach, God,” he thought, “what a strenuous career it **ist** that I’ve chosen! Travelling day in **und** day **aus**. Doing business like **diese** takes much **mehr** effort than doing your own business at home, **und on oben** of that there’s **der** curse of travelling, worries **um** making train connections, bad and irregular food, contact with different people all the time so that you **kannst nie** get to know anyone or become friendly with **ihnen**. It **kann** all go to **Teufel!**” He felt **ein** slight itch up **auf seinem** belly; pushed himself slowly up **auf** his back towards **dem** headboard **so dass** he could lift his head better; **fand** where **das** itch was, and saw that it was **besetzt** with lots of little **weißen** spots which he didn’t know what to make of; and **als** he tried to feel the place with one of his legs he drew it quickly back because as soon as he touched it he was overcome by a cold shudder.

Table 12: First few paragraphs of “The Metamorphosis” with the GSM model using priority queue size of 8 and $r_{\max}=4$.