



Second Language Acquisition Modeling

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Duolingo

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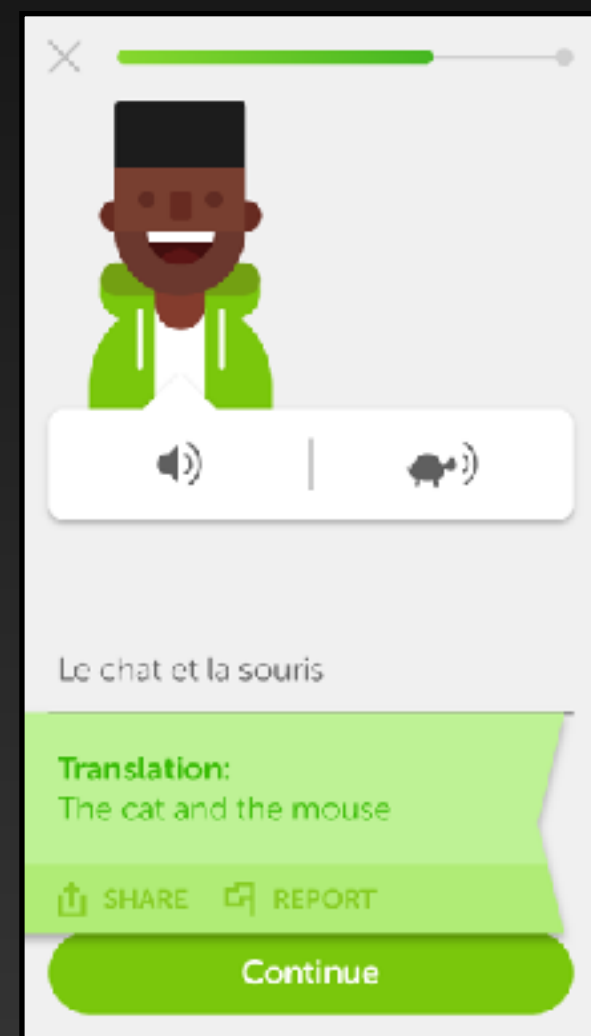
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Oct. 3-4, 2018 @ ETCPS 2018

accurately model **what**
language-learners know and
how well they know it
in a **personalized** way

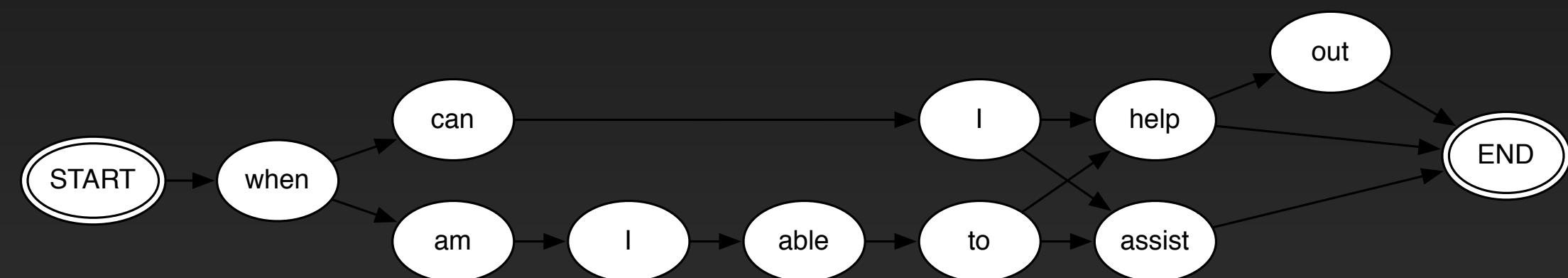
étant/être<vb><gerund>
un/un<det><ind><m><sg>
enfant/enfant<n><mf><sg>
il/il<prn><p3><m><sg>
est/être<vb><pri><p3><sg>
petit/petit<adj><m><sg>





prompt: cuándo puedo ayudar

when (can i|am i able to) (help (out|)|assist)



student: wen can help

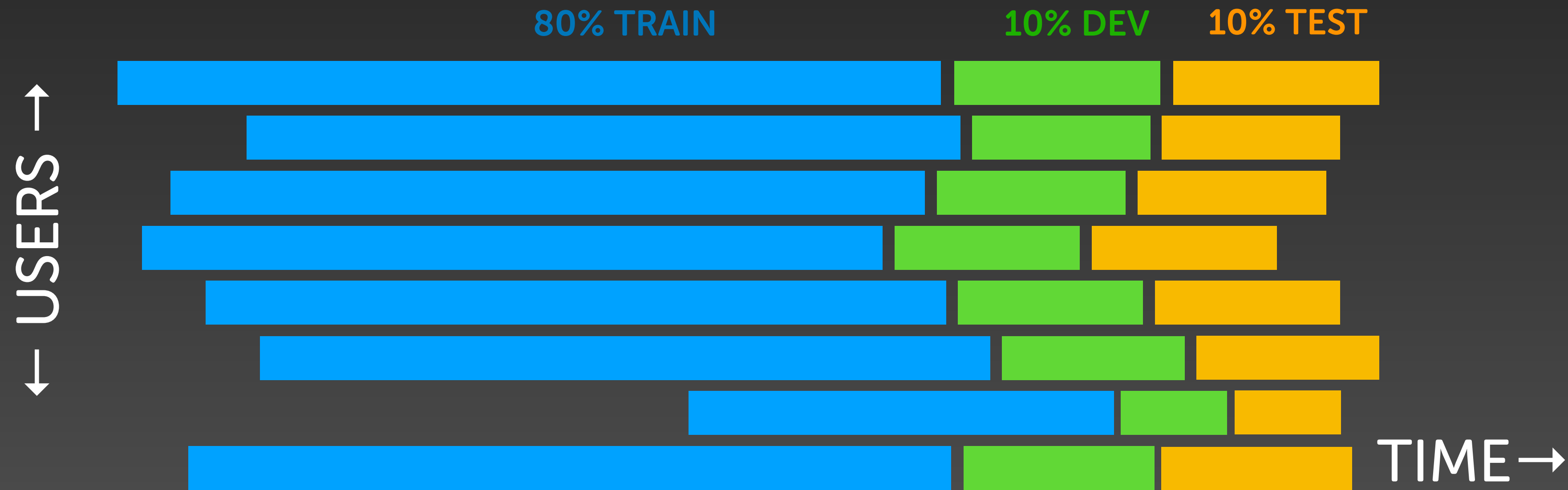
reference: when can I help

label: 1 0 1 0

user + session-level metadata

# user:XEinXf5+ countries:C0 days:2.678 client:web session:practice format:reverse_translate time:6								
oMGsnnH/0101 oMGsnnH/0102 oMGsnnH/0103 oMGsnnH/0104	When can I help	ADV	PronType=Int fPOS=ADV++WRB			advmod	4	1
		AUX	VerbForm=Fin fPOS=AUX++MD			aux	4	0
		PRON	Case=Nom Number=Sing Person=1 PronType=Prs fPOS=PRON++PRP			nsubj	4	1
		VERB	VerbForm=Inf fPOS=VERB++VB			ROOT	0	0

IDs	reference answer tokens			morpho-syntactic features				labels		
# user:XEinXf5+ countries:C0 days:5.707 client:android session:practice format:reverse_translate time:22										
W+QU2fm70301	He	PRON	Case=Nom Gender=Masc Number=Sing Person=3 PronType=Prs fPOS=PRON++PRP				nsubj	3	0	
W+QU2fm70302	's	AUX	Mood=Ind Number=Sing Person=3 Tense=Pres VerbForm=Fin fPOS=AUX++VBZ				aux	3	1	
W+QU2fm70303	wearing	VERB	Tense=Pres VerbForm=Part fPOS=VERB++VBG				ROOT	0	0	
W+QU2fm70304	two	NUM	NumType=Card fPOS=NUM++CD				nummod	5	0	
W+QU2fm70305	shirts	NOUN	Number=Plur fPOS=NOUN++NNS				dobj	3	0	
# user:XEinXf5+ countries:C0 days:10.302 client:web session:lesson format:reverse_translate time:28										
v0eGrMgP0101	We	PRON	Case=Nom Number=Plur Person=1 PronType=Prs fPOS=PRON++PRP				nsubj	2	0	
v0eGrMgP0102	eat	VERB	Mood=Ind Tense=Pres VerbForm=Fin fPOS=VERB++VBP				ROOT	0	1	
v0eGrMgP0103	cheese	NOUN	Degree=Pos fPOS=ADJ++JJ				dobj	2	1	
v0eGrMgP0104	and	CONJ	fPOS=CONJ++CC				cc	2	0	
v0eGrMgP0105	they	PRON	Case=Nom Number=Plur Person=3 PronType=Prs fPOS=PRON++PRP				nsubj	6	0	
v0eGrMgP0106	eat	VERB	Mood=Ind Tense=Pres VerbForm=Fin fPOS=VERB++VBP				conj	2	1	
v0eGrMgP0107	fish	NOUN	fPOS=X++FW				dobj	6	0	

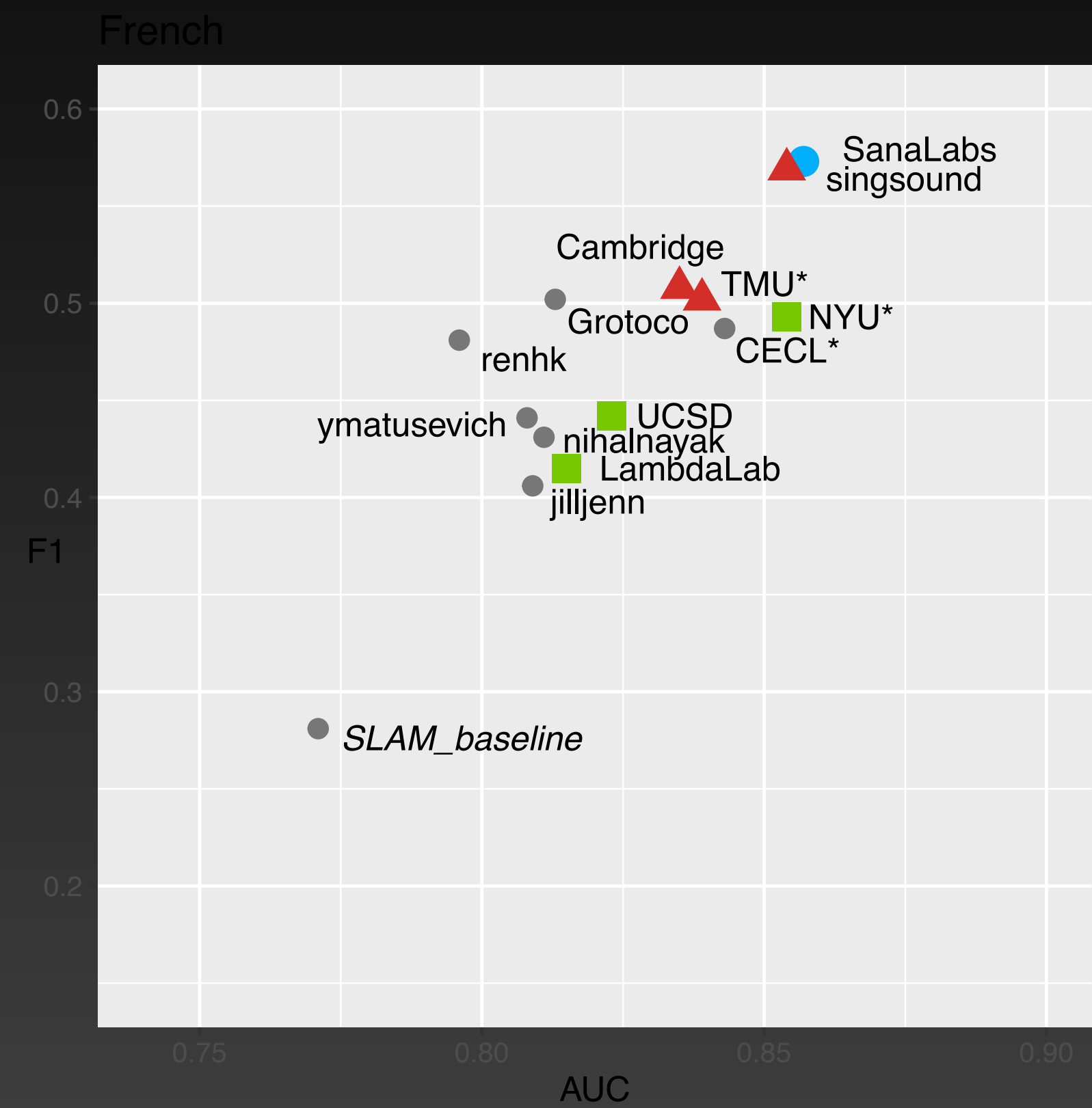
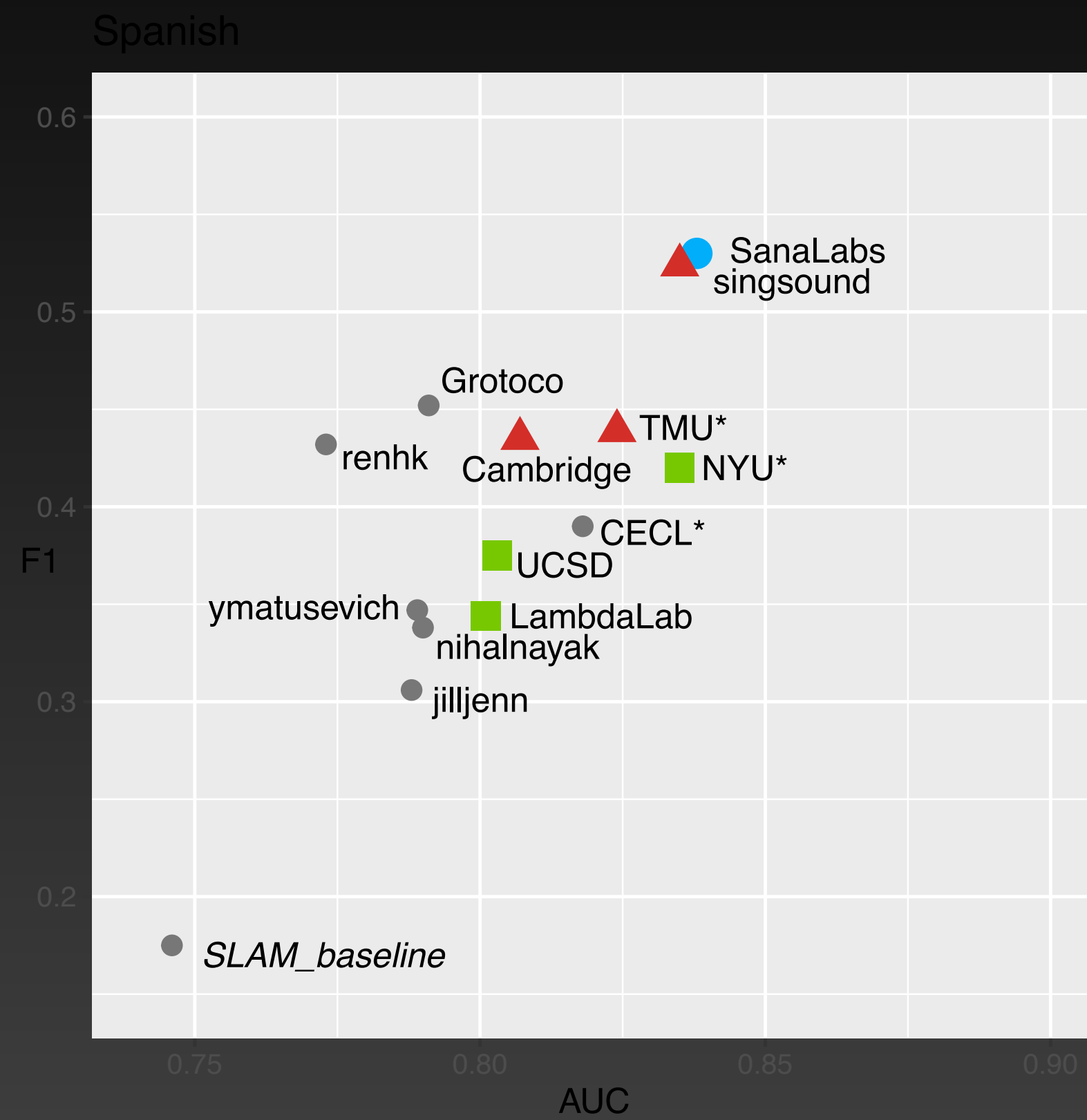
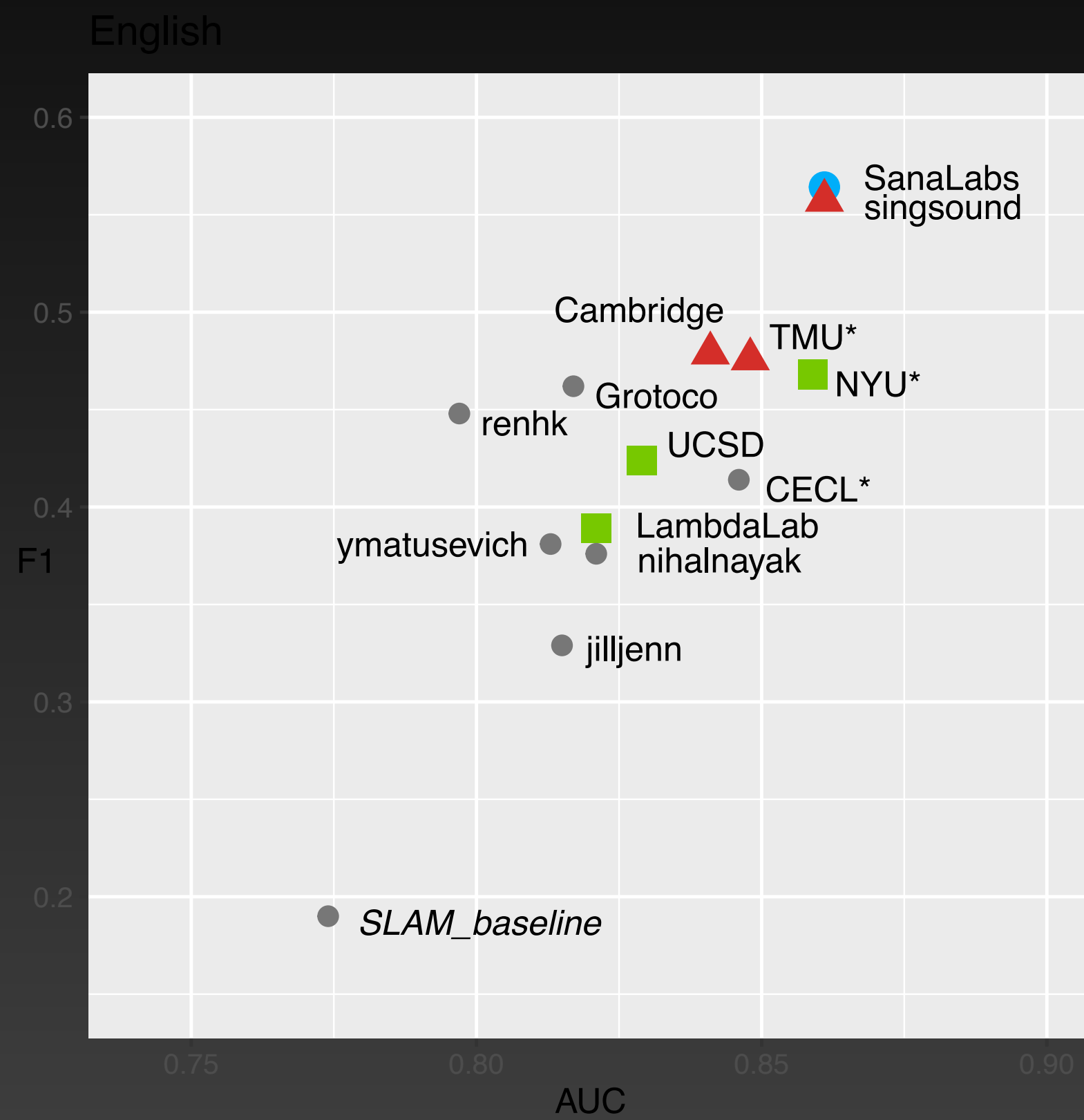




	English (EN ← ES)	Spanish (ES ← EN)	French (FR ← EN)	TOTAL (All 3 Tracks)
USERS	2,593	2,643	1,213	6,449
TRAIN (tokens)	2,622,958	1,973,558	926,657	5,523,173
DEV (tokens)	387,374	288,864	137,571	813,809
TEST (tokens)	386,604	282,181	135,525	804,310
TOTAL (tokens)	3,396,936	2,544,603	1,199,753	7,141,292

Duolingo's three **largest courses** (~40% of users)

Official Results



● Linear models

■ Tree Ensembles (GBDT, RF)

▲ RNN (across exercises)

● Hybrid (RNN+GBDT)

Algorithms

Fixed effects (algorithm choices)	Effect	p-value	
<i>Intercept</i>	.786	<.001	***
Recurrent neural network	+.028	.012	*
Decision tree ensemble	+.018	.055	.
Linear model (e.g., IRT)	−.006	.541	
Multitask model	+.023	.017	*
Random effects	St. Dev.		
User ID	±.086		
Team ID	±.013		
Track ID	±.011		

Features

Features used	Popularity	Effect
Word (surface form)	■■■■■■■■■■	+.005
User ID	■■■■■■■■■■	+.014
Part of speech	■■■■■■■■■■	−.008
Dependency labels	■■■■■■■■	−.011
Morphology features	■■■■■■■■	−.021
Response time	■■■■■■■■	+.028 *
Days in course	■■■■■■■	+.023 .
Client	■■■■■■■	+.005
Countries	■■■■■■	+.012
Dependency edges	■■■■	−.000
Session	■■■	+.014