

# 1 Real-time Sign Language Letter and Word Recognition from Depth Data - Supplemental Material

In the following, we present the ASL finger alphabet and word lexicon that have been used in the paper. Furthermore, we provide the images of Figures 4, 5, 6, and 7 in high resolution.

## 1.1 ASL Finger Alphabet Letters

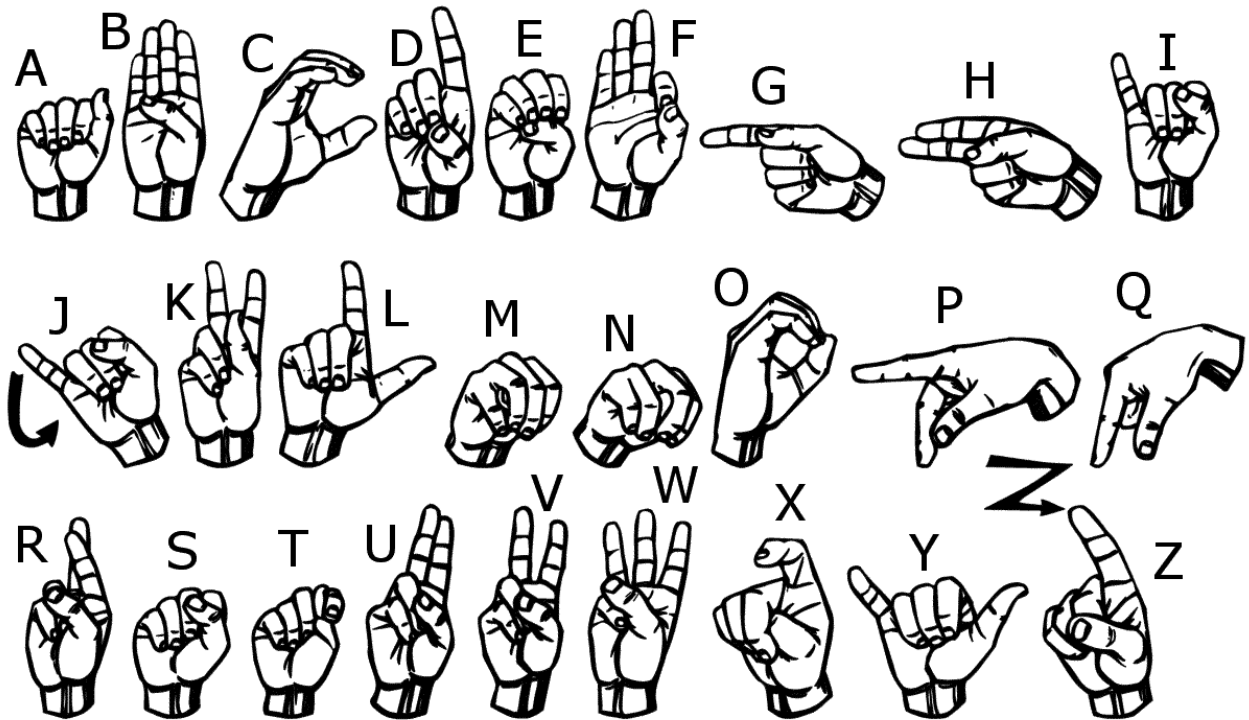


Figure 1: Symbols of the ASL finger alphabet.

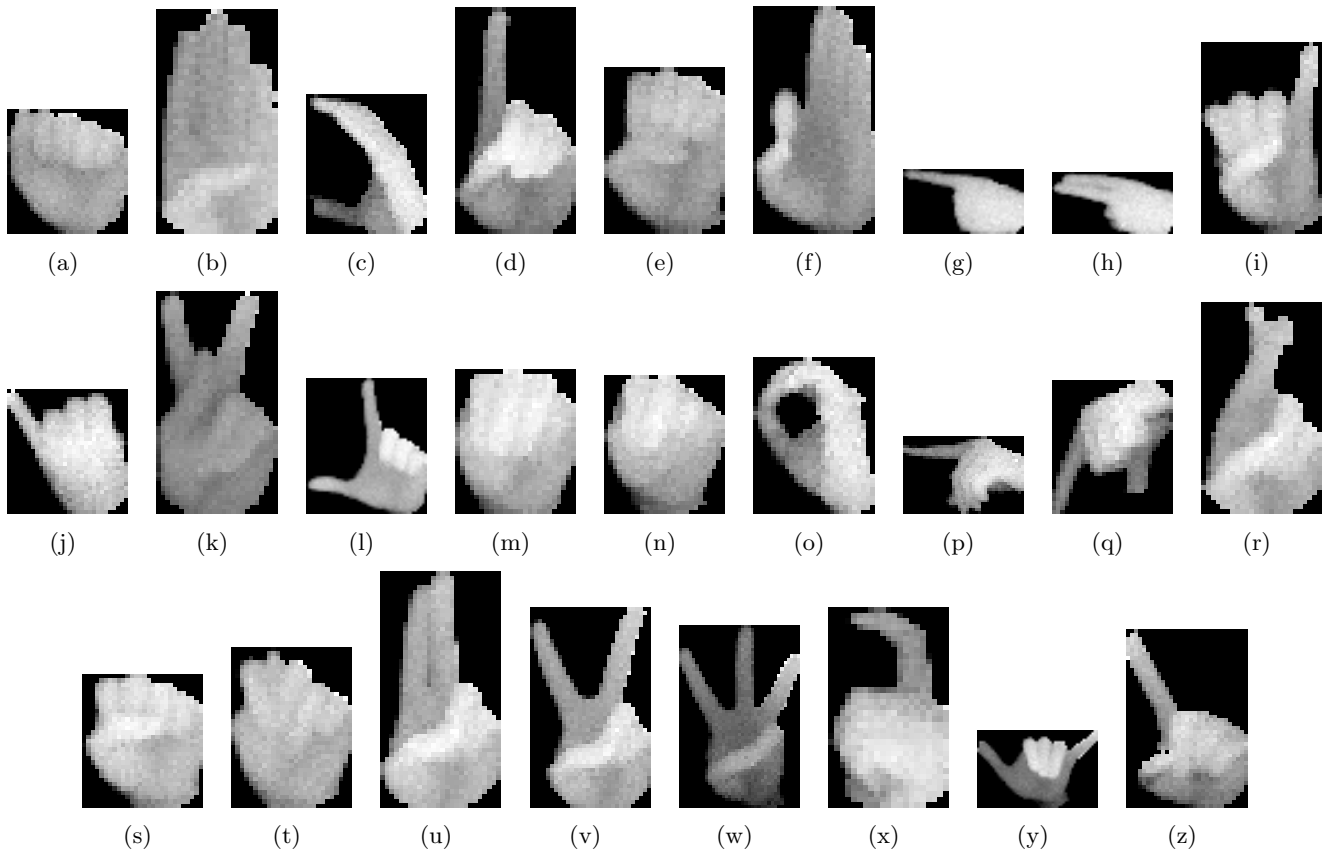


Figure 2: Depth images of the of the ASL finger alphabet gestures. The dynamic gestures “J” and “Z” are represented by static equivalents. It is the end pose for “J” and the start pose for “Z” of the respective dynamic gesture. The images are presented as seen by a person performing the gestures in front of a mirror. Note that many gestures look very similar due to the low resolution of the depth sensor.

## 1.2 Tested Words and Lexicon of Known Words

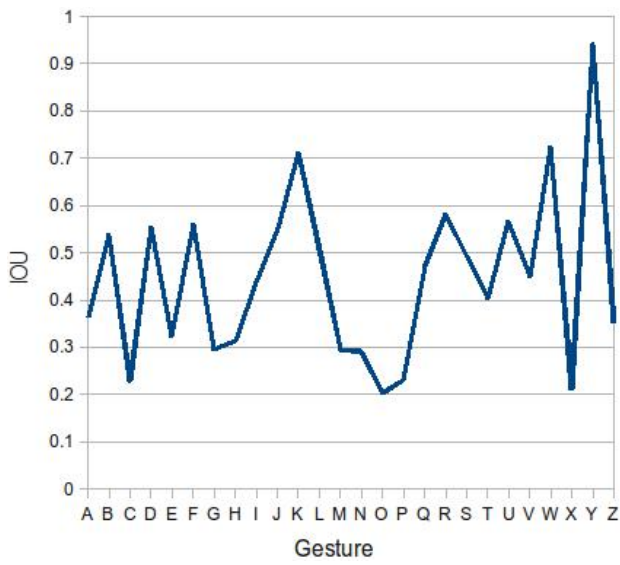
all	are	back	behaviour
blue	bravo	but	chalk
clothes	complex	crack	day
digestion	drain	eight	expansion
feeling	floor	frequent	gold
hanging	help	humour	invention
knee	let	living	market
mind	muscle	nine	offer
out	pencil	point	prison
put	read	respect	rough
screw	seven	sign	smile
soup	station	straight	swim
the	thunder	trade	us
waste	wheel	wire	yes

Table 1: Set of 56 words used to test the word recognition system. They have been selected randomly from the lexicon of 900 words known to the system.

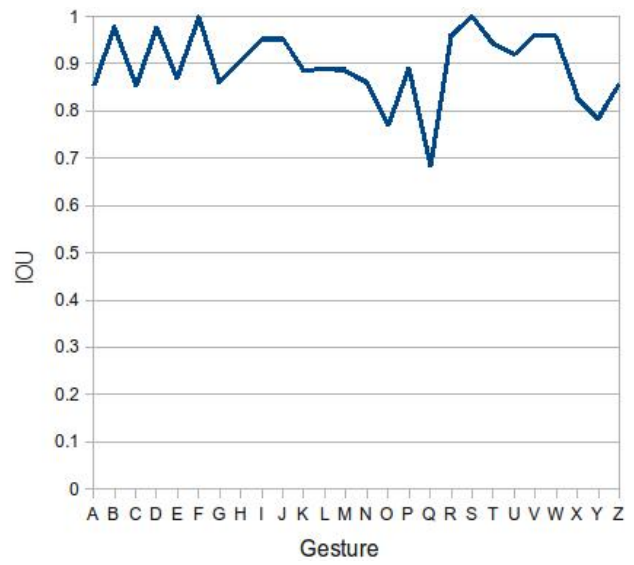
about	able	accept	account	acid	across	act	addition	advertisement	after
again	against	agreement	air	alcohol	all	almost	among	amount	amusement
and	angle	angry	animal	answer	ant	any	apparatus	apple	approval
arch	are	argument	arm	army	art	as	at	attack	attempt
attention	attraction	authority	automatic	awake	awesome	baby	back	bad	bag
balance	ball	band	base	basin	basket	bath	be	beautiful	because
bed	bee	before	behaviour	belief	bell	bent	berry	between	bird
birth	birthday	bit	bite	bitter	black	blade	blood	blow	blue
board	boat	body	boiling	bone	book	boot	bottle	bottom	box
boy	brain	brake	branch	brass	bravo	bread	breath	brick	bridge
bright	broken	brother	brown	brush	bucket	building	bulb	burn	burst
business	but	butter	button	by	cake	camera	can	canvas	card
care	carriage	cart	cat	cause	certain	chain	chalk	champion	chance
change	cheap	cheese	chemical	chest	chief	chin	church	circle	clean
clear	clock	clothes	cloud	cloud	coal	coat	cold	collar	colour
comb	come	comfort	committee	common	company	comparison	competition	complete	complex
condition	confidence	connection	conscious	control	cook	copper	copy	cord	corn
cotton	cough	country	cover	cow	crack	crazy	credit	crime	cruel
crush	cup	current	curtain	curve	curtain	curtain	damage	danger	dark
daughter	day	dead	dear	death	debt	decision	deep	degree	delicate
dependent	design	desire	destruction	detail	development	different	digestion	direction	dirty
discovery	discussion	disease	disgust	distance	distribution	division	dog	doing	doing
door	doubt	down	drain	drawer	dress	drink	driving	drop	dry
dust	ear	early	earth	east	edge	education	effect	egg	eight
elastic	electric	end	engine	enough	entertainment	equal	error	even	event
ever	every	example	exchange	existence	expansion	experience	expert	eye	face
fact	fall	false	family	farm	far	fat	father	fear	feather
feeble	feeling	female	fertile	fiction	field	fight	finger	fire	first
fish	five	fixed	flag	flame	flat	flight	floor	flower	fly
fold	food	foolish	foot	for	force	fork	form	forward	four
fowl	frame	free	frequent	friend	from	front	fruit	full	future
garden	general	get	girl	give	glass	glove	go	goat	gold
good	government	grain	grass	great	green	grey	grip	group	growth
guide	gun	hair	hammer	hand	hanging	happy	harbour	hard	harmony
hat	hate	have	he	head	healthy	hear	hearing	heart	heat
hello	help	high	highlight	higher	history	hold	hole	hollow	hook
hope	horn	horse	hospital	hour	house	how	humour	I	ice
idea	if	ill	important	impulse	in	increase	industry	ink	insect
instrument	insurance	interest	invention	iron	island	jelly	iron	join	journey
joy	judge	jump	keep	kettle	key	kick	kind	kiss	knee
knife	knot	knowledge	land	language	last	late	laugh	law	lead
leaf	learning	leather	left	leg	let	letter	level	lexicographic	library
lift	light	like	limit	line	linen	lip	liquid	list	little
live	living	lock	long	look	loose	loss	loud	love	low
machine	make	male	man	manager	map	mark	market	married	mass
match	material	may	meal	measure	meat	medical	meeting	memory	metal
middle	military	milk	mind	mine	minute	mist	mixed	money	monkey
month	moon	morning	mother	motion	mountain	mouth	move	much	muscle
music	nail	name	narrow	nation	natural	near	necessary	neck	need
needle	nerve	net	new	news	nine	night	no	noise	normal
north	nose	not	note	now	number	nut	observation	objectively	of
off	offer	office	oil	old	on	one	only	open	operation
opinion	or	opposite	orange	order	ornament	other	out	oven	over
owner	page	pain	paint	paper	parallel	parcel	part	past	paste
payment	peace	pen	pencil	person	physical	picture	pig	pin	pipe
place	plane	plant	plate	play	please	pleasure	plough	pocket	point
poison	polish	political	poor	porter	position	possible	pot	potato	powder
power	preach	present	price	print	prison	private	probable	process	produce
production	profit	property	prose	protest	public	pull	pump	punishment	purpose
push	put	quality	quest	question	quick	quiet	quite	quiz	rail
rain	range	rat	rate	ray	reach	reaction	read	reading	ready
reason	receipt	recognition	record	red	regret	regular	reject	relation	religion
replacement	representative	request	respect	response	responsible	rest	reward	rhythm	rice
right	ring	river	road	rod	roll	roof	room	root	rough
round	rub	rule	run	sad	safe	sail	salt	same	sand
say	scale	school	science	scissors	screw	sea	seat	second	secret
secretary	see	seed	seem	selection	self	send	sense	separate	serious
servant	seven	sex	shade	shake	shame	sharp	sheep	shelf	ship
shirt	shock	shoe	short	should	shut	side	sign	silk	silver
simple	sister	six	skin	skirt	sky	sleep	slip	slope	slow
small	smash	smell	smile	smoke	smooth	snake	snow	so	soap
society	sock	soft	solid	some	son	song	sort	sound	soup
south	space	spade	speaking	special	sponge	spoon	sport	spring	square
stage	stamp	star	start	statement	station	steam	steel	stem	step
stick	sticky	stiff	still	stitch	stocking	stomach	stone	stop	store
story	straight	strange	street	stretch	strong	structure	substance	such	sudden
sugar	suggestion	summer	sun	support	surprise	sweet	swim	system	table
tail	take	talk	tall	taste	tax	teaching	ten	tendency	test
than	thanks	that	the	then	theory	there	they	thick	thin
thing	this	thought	thread	three	throat	through	through	thumb	thunder
ticket	tight	till	time	tin	tired	to	toe	together	tomorrow
tongue	tooth	top	touch	town	trade	train	transport	tray	tree
trick	trouble	trousers	true	turn	twist	two	umbrella	under	unit
up	us	use	value	verse	very	vessel	view	violent	voice
wait	waiting	walk	wall	war	warm	wash	waste	watch	water
wave	wavy	wax	way	weather	we	week	weight	well	were
west	wet	wether	wheel	when	where	while	whip	whistle	white
who	why	wide	will	wind	window	wine	wing	winter	wire
wise	with	woman	wood	wool	word	work	world	worm	wound
write	writing	wrong	year	yellow	yes	yesterday	you	young	zoo

Table 2: Lexicon of the 900 words available to the word recognition system.

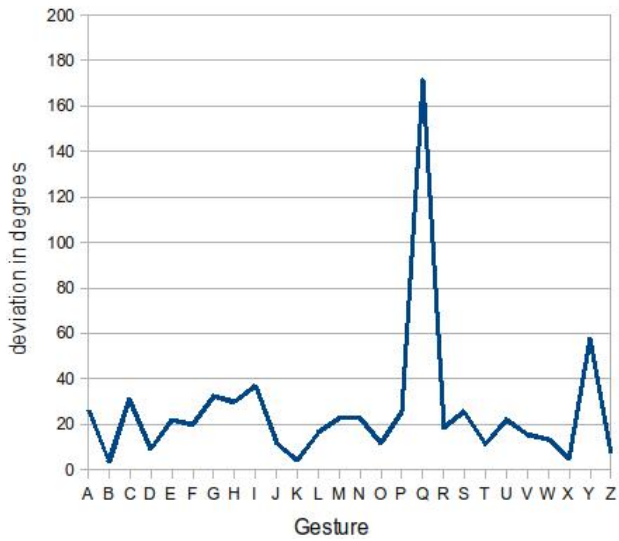
### 1.3 Figures of Section 4 (Experiments)



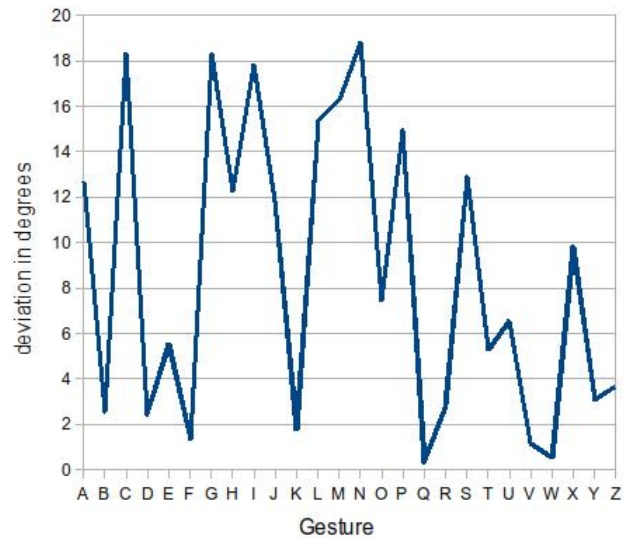
(a)



(b)



(c)



(d)

Figure 3: (a) Segmentation accuracy (IOU) after 10 iterations. (b) Segmentation accuracy (IOU) after 50 iterations. (c) Hand orientation error after 10 iterations. (d) Hand orientation after 50 iterations.

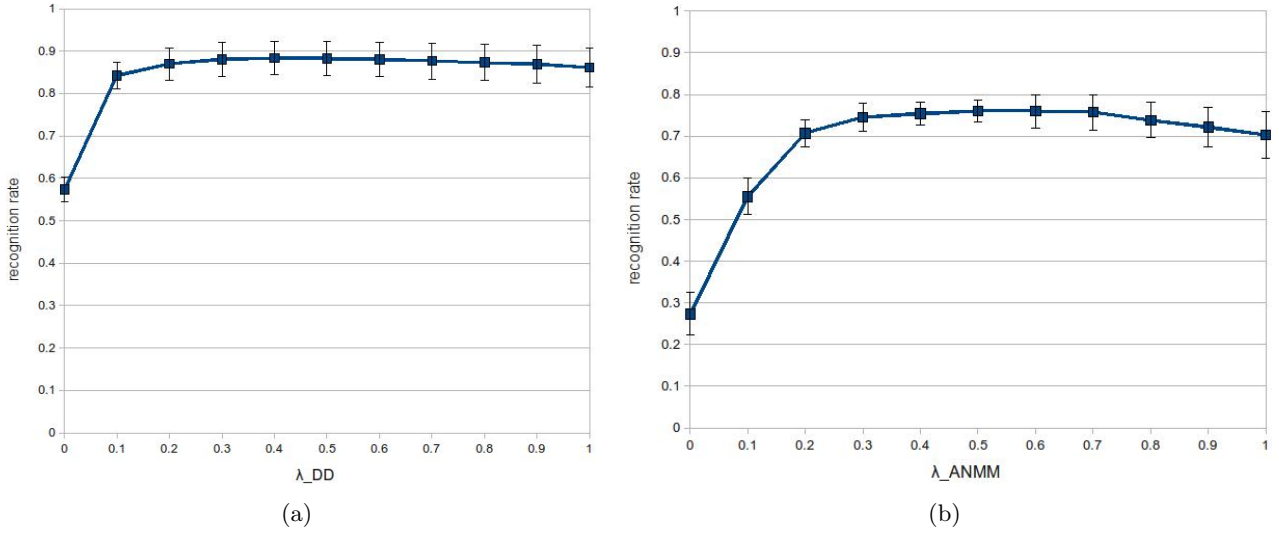


Figure 4: (a) Single-user: Average gesture recognition rates for different combinations of the DD and ROT classifiers, achieved by varying  $\lambda_{DD}$  and  $\lambda_{ROT} = 1 - \lambda_{DD}$ . (b) Multi-user: Average gesture recognition rates for different combinations of the ANMM and ROT classifiers.

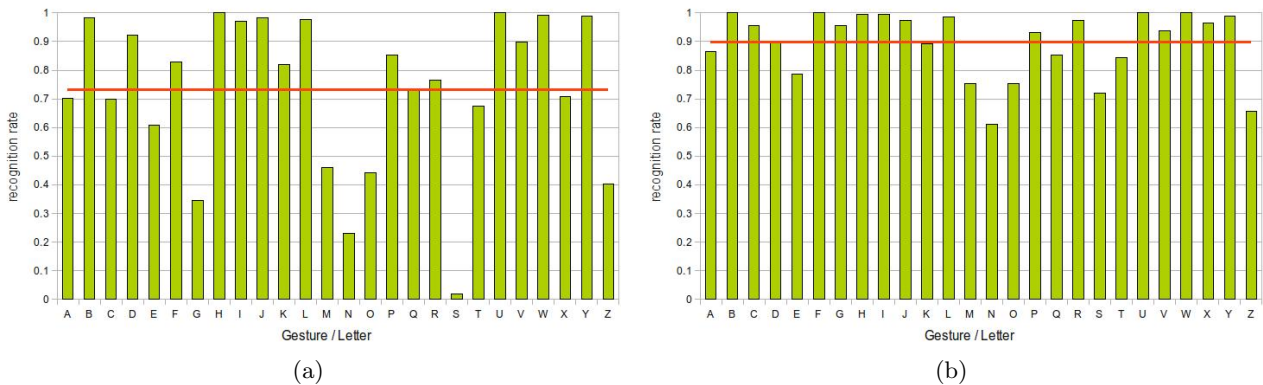


Figure 5: Letter recognition rates showing differences between the individual letters ( $\lambda_{ANMM} = \lambda_{ROT} = \lambda_{DD} = 0.33$ ). (a) In the multi-user setup, some letters like 'S' are often not correctly recognized. (b) In the mixed setup, the recognition rates of the letters that were difficult to classify in the multi-user setup are significantly improved.

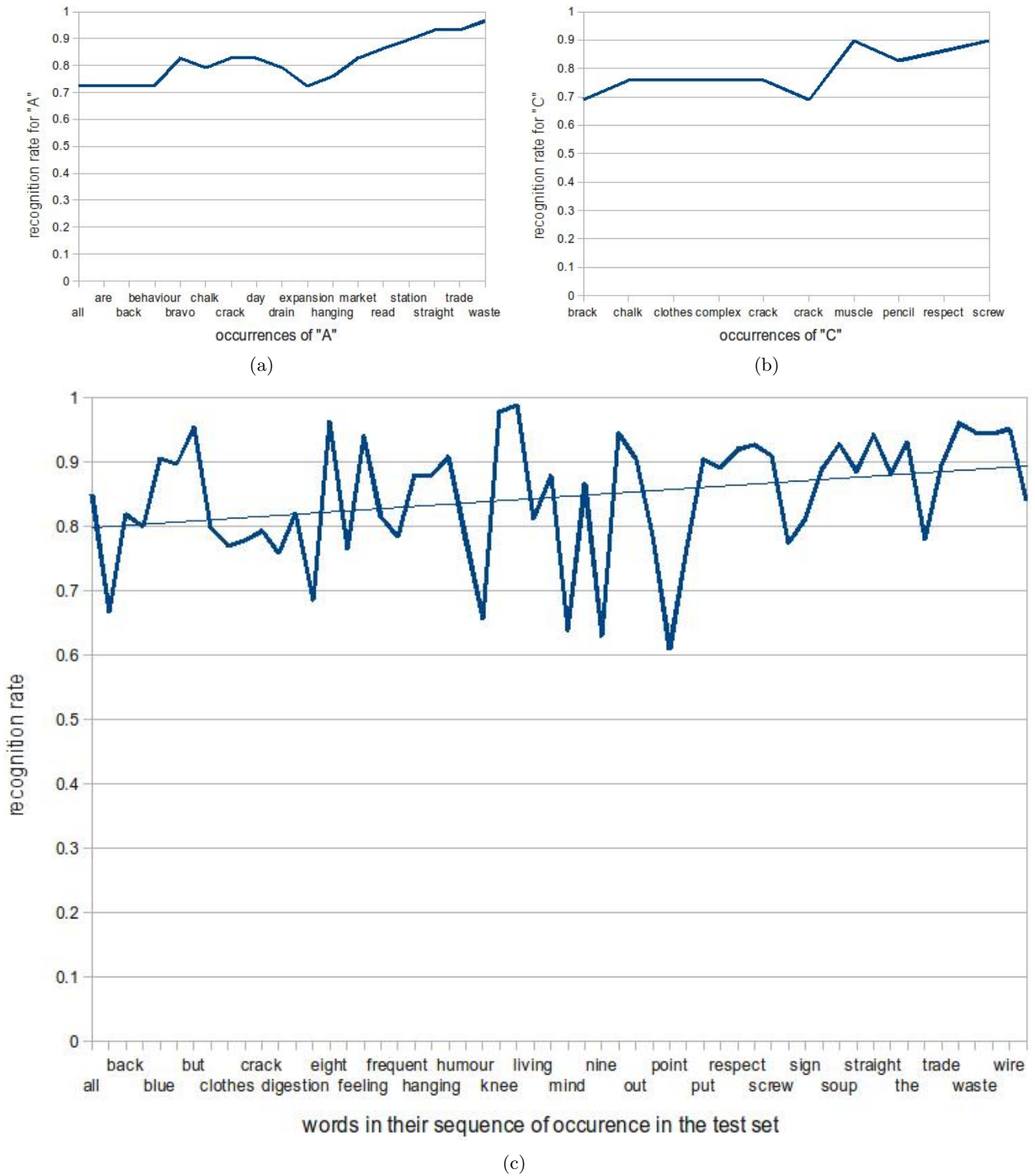


Figure 6: Due to the codebook updates, the letter and the word recognition improves over time. (a) Recognition rates for letter 'A'. (b) Recognition rates for letter 'C'. (c) Average letter recognition rates per word. The linear trend line increases over time.