Early signed language exposure does not harm phonemic discrimination for individuals with cochlear implants (CIs)

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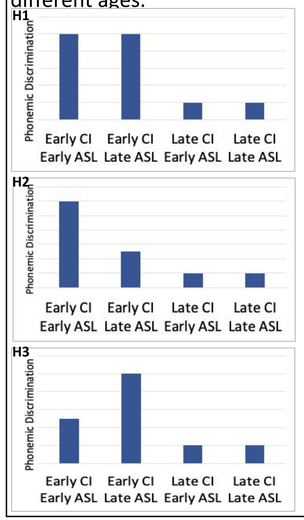
INTRODUCTION

Controversy regarding the simultaneous use of signed and spoken language with cochlear implants (CI) persists. Some claim early exposure to a signed language is detrimental to spoken language development through CI[2,6]. Others claim early signed language exposure does not harm language development, and may even offset the negative effects of language deprivation that children with CIs experience prior to implantation[1,4,7].

Specific Aim: To examine neural activation patterns underlying phonemic discrimination in individuals with CI who were both (1) exposed to signed language at different ages and (2) received their CI at different ages.

3 Hypotheses



1. Only early exposure to a spoken language (via CI) supports phonemic discrimination. Early exposure to signed language has *no impact (neither behavioral nor neural)* on spoken language phonemic discrimination.

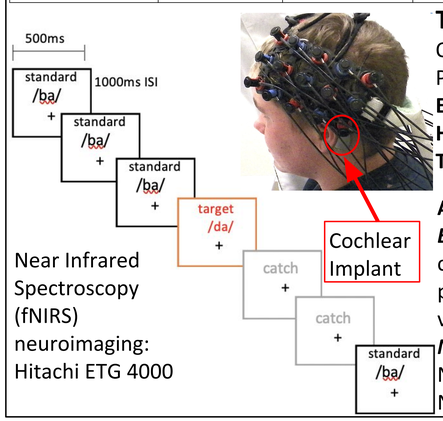
2.Early exposure to a signed and a spoken language (i.e., simultaneous bimodal bilingualism) with early CI implantation, *positively impacts* spoken language phonemic discrimination.

3. Early exposure to signed language has a *negative impact* on spoken language phonemic discrimination ability.

METHODS

Participants

Group	Language	Age of Exposure	Early exposure (Age=0-5)	Late Exposure (Age>5)
Bimodal Bilinguals N=19	English (via CI)	M=8.5, SD=6.3, range=2-21 yrs	10	9
M_{age} = 19.9; SD=1.9 range=18-24 yrs	ASL	M=8.6, SD=7.6, range=0-22 yrs	10	9



Near Infrared Spectroscopy (fNIRS) neuroimaging: Hitachi ETG 4000

Task

Oddball Paradigm

Phonemic Discrimination; PD

English (/ba/-/da/)

Hindi (/t̪a/-/ʈa/)

Tone

Analysis

Behavioral: *d'* scores were calculated using the package neuropsychology v0.3.0 [5] in R.

***Neuroimaging*:** NIRS AnalyzIR toolbox[8] NFRI functions[9]

NEUROIMAGING RESULTS

Early age of CI implantation

In participants with *early* ASL: less activation in classic left-hemisphere language areas (supramarginal gyrus part of Wernicke's area, LSTG) and right hemisphere areas (RIFG) (Table 1A)

In participants with *late* ASL: increased activation in right hemisphere language areas (supramarginal gyrus part of Wernicke's area, RMTG) (Table 1B)

Simple Effect of Age of CI in English PD

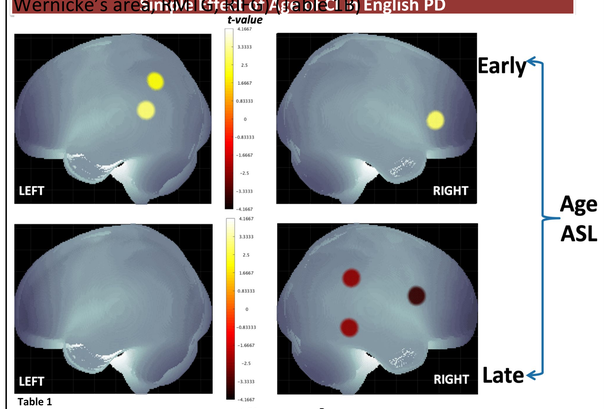


Table 1

A

Early ASL (age =1)	β (SE) for Age CI
L. Wernicke's area	1.591(0.618)*
L. STG	2.350(0.652)**
R. IFG	2.273(0.653)*

B

Late ASL (age =16.21)	β(SE) for Age CI
R. Wernicke's area	-3.472(1.186)*
R. IFG	-3.092(0.735)**
R. MTG	-1.349(.465)*

$p<.01$

Early age of ASL exposure

In participants with *early* CI: increased activation in classic left-hemisphere language areas (LMTG) but decreased activation right-hemisphere areas (RSTG) (Table 2A)

In participants with *late* CI: increased activation in right hemisphere areas (supramarginal gyrus part of Wernicke's area, RMTG) (Table 2B)

Simple Effect of Age of ASL in English PD

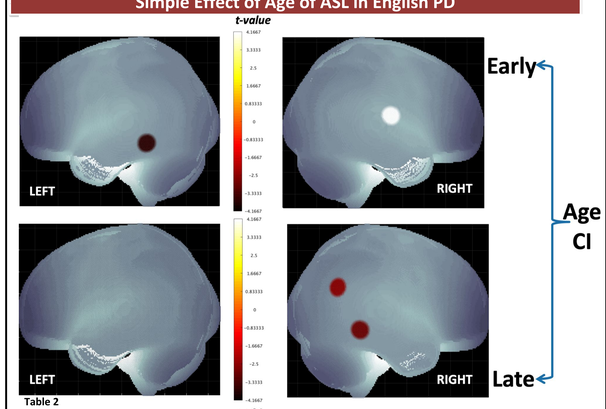


Table 2

A

Early CI (age =2.3)	β(SE) for Age ASL
L. MTG	-5.320(1.221)**
R. STG	4.472(0.661)***

B

Late CI (age =14.6)	β(SE) for Age ASL
R. Wernicke's	-1.479(0.494)*
R. MTG	-1.241(0.361)*

$p<.01$

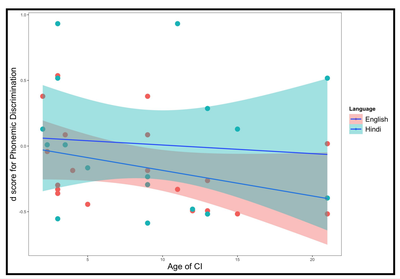
Predictor/ β(SE)	LSTG	LIFG	LMTG	L Wernicke's	RSTG	RIFG	RMTG	R Wernicke's
Age of CI	0.267(0.684)x	-0.197(0.666)x	-3.369(0.767)***	-1.168(0.863)x	1.542(0.795)*	0.814(0.637)x	-0.598(1.025)x	0.110(0.635)x
Age of ASL	1.819(0.462)**	1.887(0.465)**	1.396(0.642)*	1.441(0.475)*	2.309(0.610)**	0.697(0.463)x	0.255(0.577)x	1.263(0.463)*
Age of CI x English	0.996(0.657)x	-0.952(0.614)x	2.693(0.699)**	0.950(0.823)x	-2.135(0.744)*	-2.486(0.587)**	-2.188(0.744)*	1.811(0.592)*
Age of ASL x English	-1.967(0.461)**	0.173(0.552)x	-2.318(0.636)**	-0.678(0.939)x	-2.835(0.628)***	0.387(0.497)x	-0.953(0.667)x	-0.521(0.461)x
Age of CI x Hindi	-1.057(0.833)x	1.681(1.009)x	0.545(1.020)x	-2.103(1.154)x	3.900(1.146)*	1.403(1.716)+	-1.147(1.613)x	-0.691(0.694)x
Age of ASL x Hindi	-0.493(0.557)x	0.417(0.887)x	0.683(0.946)x	-0.770(1.124)x	-1.985(0.455)**	-0.141(0.741)x	-1.796(1.112)x	-1.541(0.515)*
Age of CI x Age of ASL in English vs Tone.	**-0.345(0.090)****	**0.004(0.105)x**	**0.482(0.114)****	**0.084(0.136)x**	**-0.423(0.094)*****	**-0.037(0.104)x**	**-0.059(0.161)x**	**-0.188(0.099)***
Age of CI x Age of ASL x Hindi	0.412(0.134)*	0.040(0.173)x	0.071(0.132)x	-0.338(0.196)*	-0.089(0.189)x	0.148(0.146)x	0.156(0.271)x	-0.139(0.115)x

BEHAVIORAL RESULTS

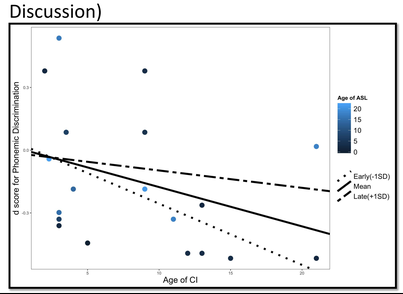
Predictor	β(SE)
Age of CI for English	-0.019(0.012)+
Age of ASL for English	0.010(0.010)x
Age of CI for Hindi	-0.006(0.020)x
Age of ASL for Hindi	0.016(0.015)x
Age of CI x Age of ASL x Language	-0.004(0.002)+

p<.0001***, p<.001**, p<.05*, p<.1+, p>.1x

Age of CI x Language: Early CI implantation was associated with higher d' scores in English, but not in Hindi



Age of CI x Age of ASL x Language: Early age of ASL had no negative impact on English PD for participants with early age of CI (see Discussion)



DISCUSSION

Behavioral

Early Age of CI was associated with better performance in the English PD task.

No negative impact of early simultaneous signed and spoken language exposure (via CI).

High degree of individual differences in PD ability; some CI users show poor PD despite early implantation.

Neuroimaging

Early language exposure (ASL and/or via CI) is associated with greater activation of LH language areas and their right hemisphere homologues. Similar to spoken languages, early exposed bimodal bilinguals recruit predominantly left-lateralized language networks. However, we also observe some reduced LH activation for early implanted users with early exposure to ASL.

Late language exposure (ASL and/or via CI) is associated with greater RH activation. Corroborates previous findings with *new* bimodal English (via CI)-ASL bilinguals: Later age of language exposure is associated with poorer language proficiency and greater RH activation[3].

Supports H1

Exposure to signed language early in life has no negative impact on spoken language phonemic discrimination ability

2 sets of sources that might explain the variability in the results:

ASL: Quality and quantity of *early ASL* input, source of language input (i.e. from a non-proficient ASL user)

CI: Status of auditory nerves before implantation, lack of language therapy, limited benefits from CI and/or irregular use

FUTURE DIRECTIONS

Why do some individuals show poor phonemic discrimination and decreased left hemisphere neural activity despite receiving their implants early?

(1) Investigate additional sources of variation in CI users' PD abilities:status of auditory nerves and quantity and quality of language input after implantation

(2) Investigate neurobiological basis of PD in young CI users during sensitive periods for language acquisition immediately post implantation and examine changes in neural pathways underlying PD over time.

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