

## Background

Learning and retaining a new language is significantly more difficult as an adult compared to during childhood, with research showing that children are much more likely to attain native-like fluency than adolescents or adults (Abrahamsson & Hyltenstam 2008). Possible reasons for this difficulty of language learning include exiting the sensitive period of language, as well as declines in neuroplasticity and the brain's production of brain-derived neurotrophic factor (Mundkur 2005; Hurford 1991; Bathina & Das 2015). Despite the increased difficulty, learning a second language has become increasingly important in today's global environment. There is also evidence that language acquisition can provide career opportunities in today's multilingual workforce (Damari et al. 2017), improve various aspects of cognition (Morales et al. 2013; Kharkhurin 2012; Bialystok & Craik 2010), and potentially provide neuroprotective benefits (Craik et al. 2010). Considering the increased need for a second language, more efficient and accessible methods of improving language retention are necessary. In this study, we examined the use of taVNS to improve learning and retention of novel vocabulary words in college-aged students.

## Methods

**Participants (N = 31):** college-aged students with average to above-average intelligence and no reading impairments  
**Behavior Session:** series of 12 assessments to measure intelligence and reading performance

**Training Session:** exposure and recall of 30 novel vocabulary words in Palau. Participants received sham or active stimulation at 5 or 25 Hz.

**Testing:** immediately before, after, and one week following training, participants were asked to provide the English translations for the 30 Palauan words learned

## The Details

Table 1 Participant Characteristics and Standard Assessment Scores (M ± SD) by Stimulation Group

	KBIT	SWE	PDE	WID	WA	RDN	RLN	DMC	VLC	NL	DMR	VLR
Sham	108.45 ± 12.56	109.36 ± 10.65	110.82 ± 6.32	111.27 ± 4.69	104.27 ± 5.69	11.36 ± 1.30	10.82 ± 1.75	9.09 ± 1.98	11.27 ± 2.45	12.27 ± 1.91	9.82 ± 1.95	11.18 ± 2.37
5 Hz	102.20 ± 12.70	111.50 ± 10.54	110.10 ± 3.65	107.20 ± 6.58	106.60 ± 8.80	12.00 ± 1.18	11.30 ± 1.55	8.10 ± 2.07	10.90 ± 2.30	12.00 ± 1.48	9.60 ± 2.25	10.10 ± 2.21
25 Hz	107.64 ± 9.75	109.82 ± 10.24	112.18 ± 6.75	107.00 ± 8.32	103.64 ± 7.61	11.45 ± 2.78	10.36 ± 2.81	10.45 ± 1.23	11.55 ± 1.83	11.73 ± 2.26	11.45 ± 2.35	12.09 ± 2.35
<i>p</i>	0.46	0.89	0.73	0.29	0.67	0.74	.63	<b>0.03*</b>	0.82	0.37	0.14	0.19

Table 2 Effects of Stimulation Groups on Test Outcomes

<i>P</i>	25 Hz vs Sham	25 Hz vs 5 Hz	5 Hz vs Sham
Post-test	0.11	0.22	0.59
Retention	<b>0.014*</b>	<b>0.047*</b>	0.68

Table 3 Correlations for Post Test & Retention Scores, and Stimulation Intensity

Variable	1	2	3
1. Post Test	—		
2. Retention	<b>.70*</b>	—	
3. Stimulation Intensity	-.03	-.19	—

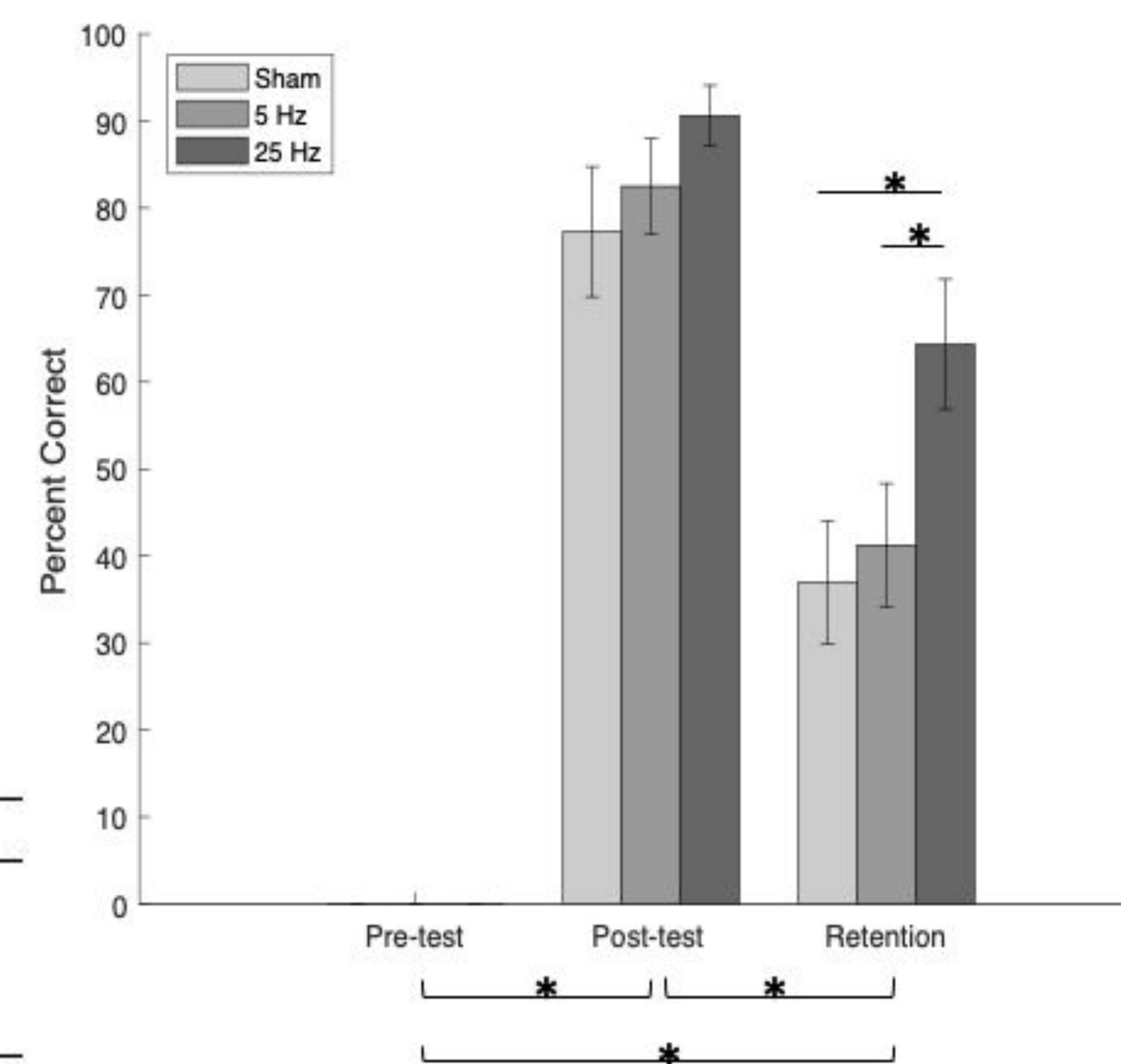


Figure 1 Means and Standard Deviations of Palauan Test Scores (% Correct) by Stimulation Group

Figure 2 Electrode Placement for taVNS Device



Figures 3-6 Examples of Stimuli



Table 4 TaVNS Thresholding Measurements

Value	Question	Intensity (mA)
1	"Tell me when you feel anything unusual in your left ear."	
2	"Tell me when the stimulation feels uncomfortable, but not painful."	
3	"Tell me when you cannot feel any stimulation in your left ear."	
4	"Tell me when the stimulation feels uncomfortable, but not painful."	
Average of Values 1-4		

## Results

### Frequency Parameter

- 25 Hz, but not 5Hz of stimulation, improved retention one week after training
- No effect of stimulation on retention immediately after training

### Intensity Parameter

- No relationship found between stimulation intensity and retention outcomes

## Future Directions

- Examine effects in excluded participant groups (e.g. dyslexia, below average intelligence, etc.)
- Examine effects medications might have on taVNS efficacy
- Determine at what point in frequency taVNS becomes effective at improving language retention
- Implement these continued findings into clinical populations

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