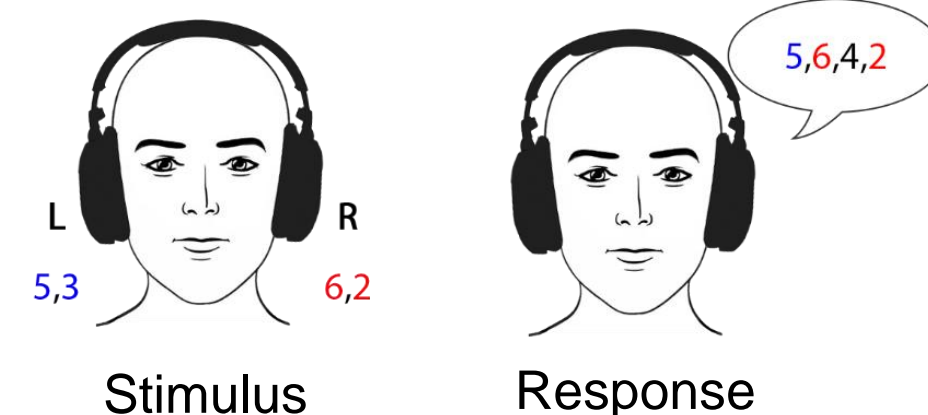
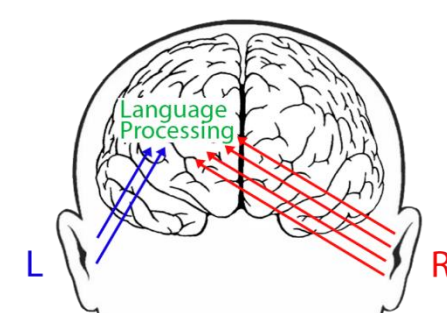


## INTRODUCTION

- For normal hearing listeners, a subtle right ear advantage (EA) is typically observed in a dichotic digits (DD) task (see Fig 1).
- The right EA may have an anatomical explanation (see Fig 2), but variations in EA can occur with shifts of attention, which means that:
  1. the DD task may not be sensitive enough to measure a stable EA; or
  2. variable EA performance may suggest that the right EA is not due to anatomical asymmetry [1].
- Although EAs may be too subtle to be detected with percent correct scores on the DD task consistently, it might be revealed in terms of an asymmetry in listening effort.
- Pupil dilation can show changes in listening effort, and is consistent even in the presence of shifts in attention [3,4,5].



**Figure 1.** In a dichotic digits task, listeners are presented with a pair of digits in both ears, simultaneously. They respond by recalling all digits they hear in any order.



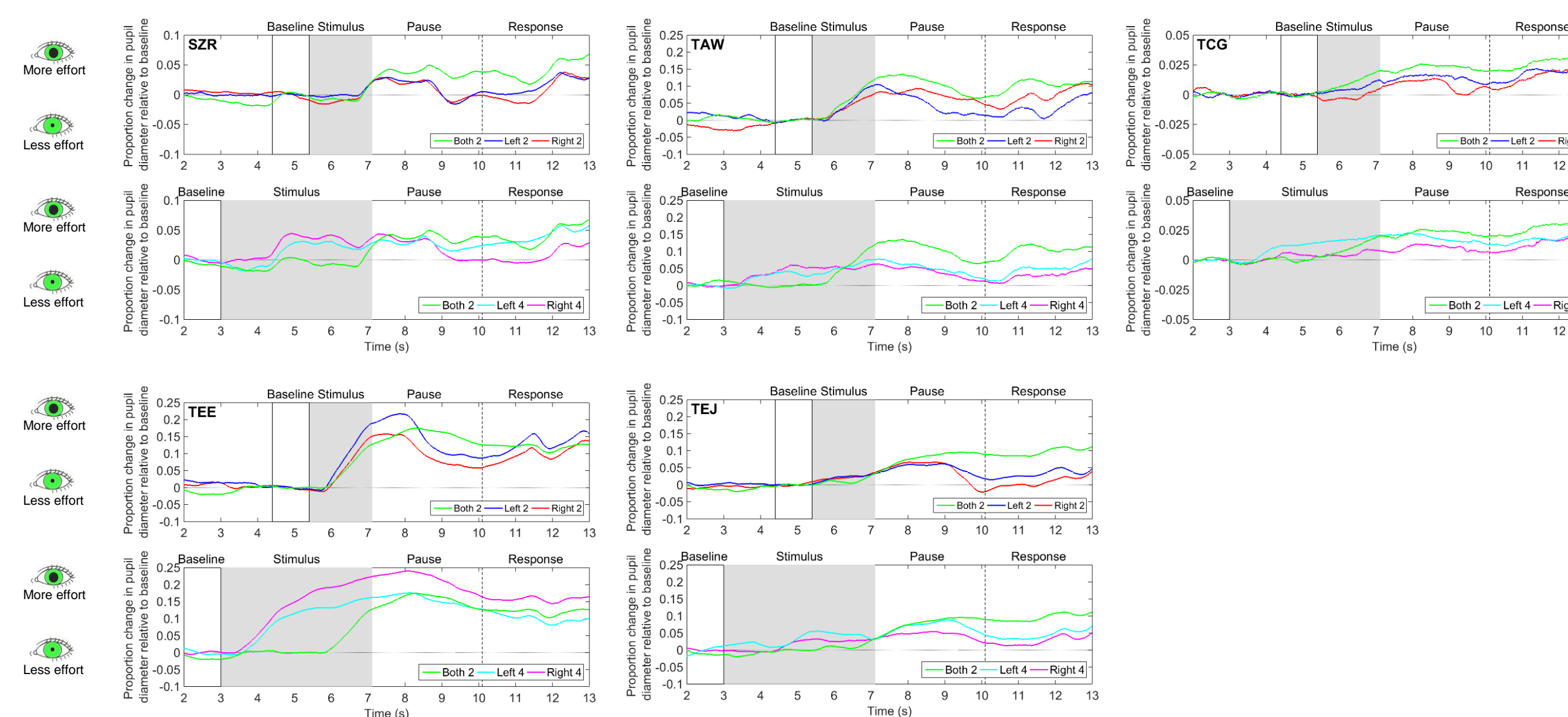
**Figure 2.** One hypothesis for a right ear advantage is that the right ear may have stronger neural connections to the language processing centers located in the left cerebral hemisphere, than the left ear [1,2].

## RESULTS

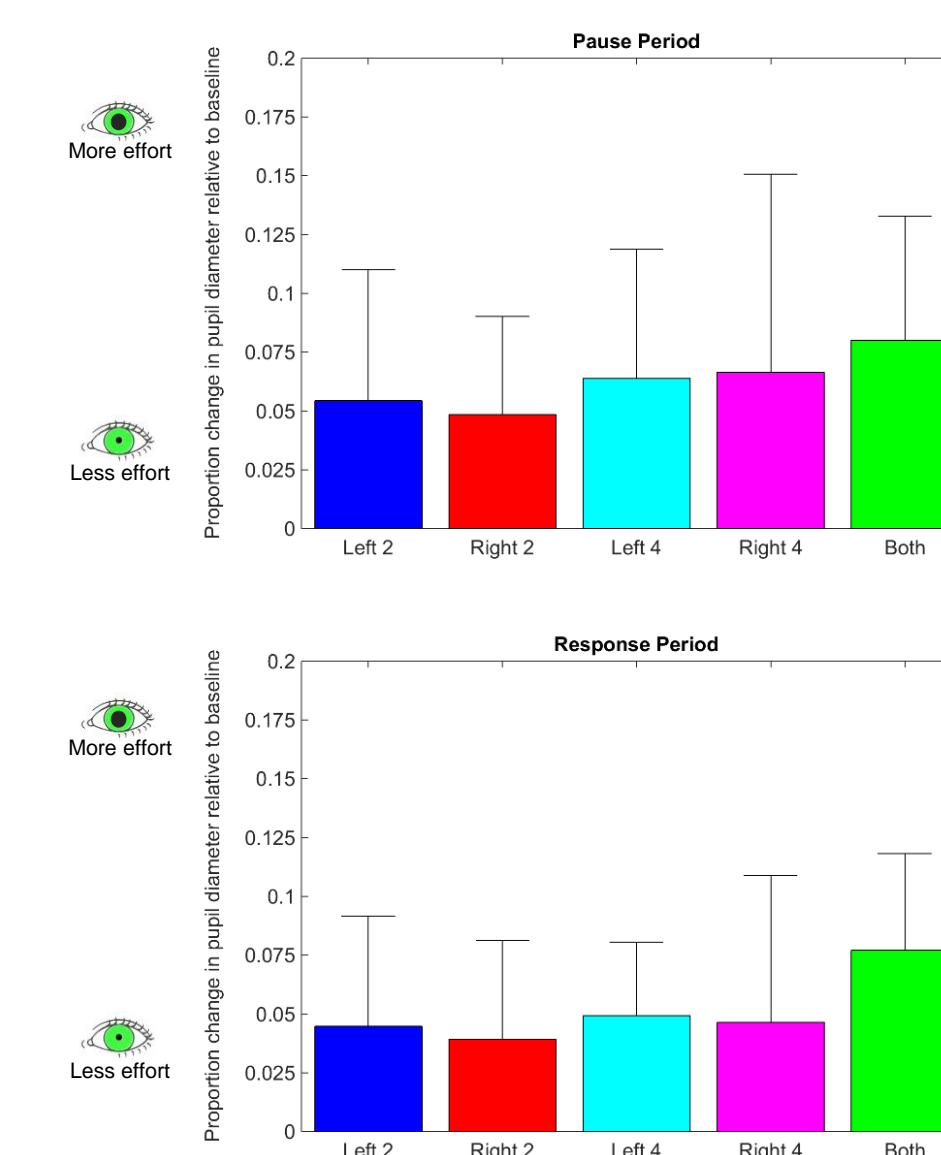
- In the dichotic digits task, subjects who showed an asymmetry in percent correct responses showed higher scores in the right ear (Table 1). In the selective attention tasks, percent correct was more variable, though most subjects showed only a small difference between ears.
- Pupil dilation response was different for each condition during the time between the end of stimulus presentation and the response period (Fig. 5).
- For all subjects, largest amount of pupil dilation (more effort) is seen when recalling digits from both ears (green). For most subjects, more pupil dilation is observed when attending to the left ear vs the right ear, for the two digit task (Fig. 5 and Fig. 6).

**Table 1.** Percent correct responses

ID	Selective Attention				Dichotic Digits	
	Left 2	Right 2	Left 4	Right 4	Both L	Both R
SZR	100%	95%	96%	94%	98%	100%
TAW	98%	100%	98%	98%	100%	100%
TCG	100%	100%	96%	99%	100%	100%
TEE	98%	98%	94%	94%	100%	100%
TEJ	98%	100%	100%	100%	95%	100%



**Figure 5.** Task-evoked pupil dilation for each individual subject. In the dichotic digits task (green), subjects repeated all four presented digits. In selective attention tasks, subjects either repeated two digits (top panel) or four digits (bottom panel), presented to their left (blue) or right (red) ear, while ignoring simultaneously presented digits in the other ear. The result for the dichotic digit task (green) is repeated in the bottom panel as a reference.



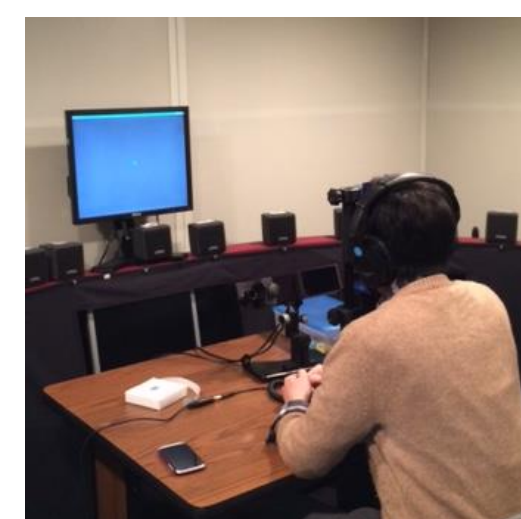
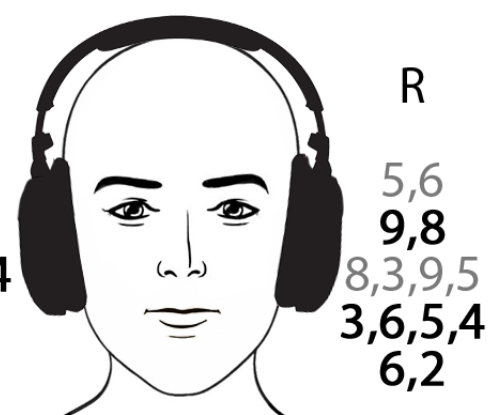
**Figure 6.** Mean pupil dilation during pause and response periods for five subjects.

The aim of this study is to determine whether pupillary response will provide a more sensitive method for establishing the presence of an ear advantage.

## METHODS

- Normal hearing subjects were screened based on pure-tone averages (PTAs) computed from the participants hearing thresholds at 500, 1000 and 2000 Hz in each ear. All subjects had less than 7.5 dB difference in PTAs across the ears, and were right-handed.
- Subjects participated in a dichotic digits task for the conditions shown in Fig 3.
- Pupil dilation data was recorded in each trial (see Fig 4) and averaged for each condition.

Condition:	Description:	L	R
Left 2	Recall left 2 digits	8,1	5,6
Right 2	Recall right 2 digits	3,6	9,8
Left 4	Recall left 4 digits	<b>2,6,1,4</b>	8,3,9,5
Right 4	Recall right 4 digits	2,9,8,1	<b>3,6,5,4</b>
Both	Recall all digits	5,3	6,2



**Figure 4.** Subjects listened with headphones (Sennheiser HD-280) to dichotic digits presented at 57 dB SPL to their left and right ears, simultaneously. During the task, an eye tracker (SR Research Eyelink 1000 Plus) was used to measure changes in pupil diameter.

**Figure 3.** The different listening conditions are shown. Subjects were instructed to verbally repeat either just the left ear digits, right ear digits, or all presented digits (shown in bold type). Sequence of digits were generated randomly for each trial, and each condition was tested 20 times.

## CONCLUSIONS

- Subjects generally showed reduced effort (smaller pupil dilation) when listening with the right ear.
- Effort is greatest when attending to both ears.
- Pupillometry may be more robust than percent correct scores for measuring an ear advantage.

## REFERENCES

1. Hiscock, M., Kinsbourne, M., "Attention and the right-ear advantage: What is the connection?", Brain Cognition, 76, 2011, p263-275
2. Kimura, D., "Functional Asymmetry of the Brain in Dichotic Listening", Cortex, 3(2), 1967, p163-178
3. Beatty, J., "Task-Evoked Pupillary Responses, Processing Load, and the Structure of Processing Resources", Psychol Bull., 91(2), 1982, p276-292
4. Zekveld, A., Kramer, S., Festen, J., "Pupil response as an indication of effortful listening: the influence of sentence intelligibility", Ear. Hear., 31(4), 2010, p480-490
5. Winn, M., Edwards, J., Litovsky, R., "The impact of auditory spectral resolution on listening effort revealed by pupil dilation", Ear. Hear., in press, 2015

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