Changes in cerebral hemodynamics and oxygenation induced by different speech tasks – an assessment by combining functional near-infrared spectroscopy and capnography

Felix Scholkmann[1,2], Sabine D. Klein[1], Ursina Gerber[1], Ursula Wolf[1]

1 Institute of Complementary Medicine IKOM, University of Bern
2 Biomedical Optics Research Laboratory, University Hospital Zurich
Contact: felix.scholkmann@usz.ch; sabine.klein@ikom.unibe.ch

Introduction

In several studies, we found that during guided rhythmic speech exercises, a decrease in cerebral hemodynamics and oxygenation occurred as the result of a decrease in the partial pressure of carbon dioxide in the arterial blood ($PaCO_2$). To further explore the effect of $PaCO_2$ variations and different speech tasks on cerebral hemodynamics and oxygenation, the aim of the present study was to investigate the impact of spoken, inner and heard speech tasks on these parameters.

Material and methods

Speech tasks included recitation or inner recitation or listening to hexameter, alliteration, prose, or performing an arithmetic task. The following physiological parameters were measured: tissue oxygen saturation (StO_2), absolute concentrations of oxyhemoglobin, deoxyhemoglobin, total hemoglobin (over the left and right anterior prefrontal cortex, using an ISS OxiplexTS frequency domain near-infrared spectrometer) and end-tidal CO_2 ($P_{ET}CO_2$; using Nellcor N1000 and Datex NORMOCAP capnographs).

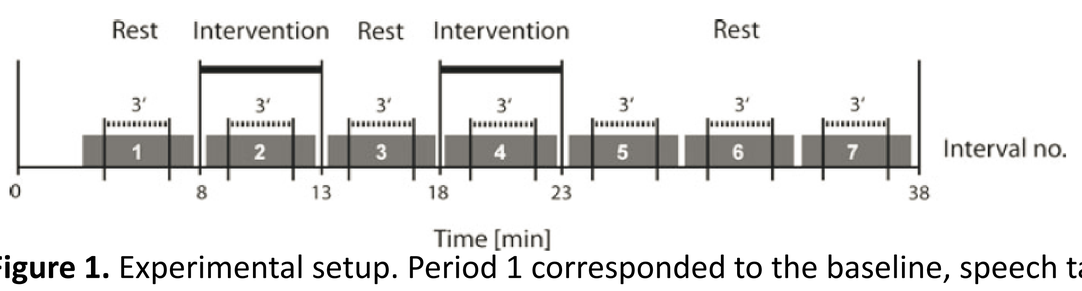

Figure 1. Experimental setup. Period 1 corresponded to the baseline, speech tasks were performed during periods 2 and 4.

Statistical analysis was applied to the differences between baseline, 2 tasks, and 3 post-baseline periods (see experimental setup, Figure 1). Data of 3 studies with 24, 7 and 29 healthy subjects, respectively, were combined, and linear regression analyses were calculated.

Results

Linear regression analyses revealed significant relations between changes in oxyhemoglobin, deoxyhemoglobin, total hemoglobin or StO_2 and the participants' age, the baseline $P_{ET}CO_2$ or certain speech tasks (Table 1). While hexameter verses affected changes during the tasks, alliteration verses affected changes during the recovery phase.

Discussion and conclusion

The observed effects in hemodynamics, oxygenation and $PaCO_2$ indicate a combination of neurovascular coupling (increased neuronal activity leading to an increase in the cerebral metabolic rate of oxygen resulting in an increase in cerebral flood flow/volume) and CO_2 reactivity (increased breathing during speech tasks causing a decrease in $PaCO_2$ leading to vasoconstriction and decrease in cerebral blood flow). The neurovascular coupling characteristics are task-dependent.

Table 1. Linear regression analyses to test for significant relations between changes in cerebral hemodynamics and oxygenation and the different speech tasks.

Model no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Dependent variable	ΔStO_2	ΔStO_2	$\Delta[O_2Hb]$	$\Delta[O_2Hb]$	Δ[HHb]	Δ[HHb]	Δ[tHb]	Δ[tHb]
Time interval[b]	4	7	4	7	4	7	4	7
Independent variables[c]								
Age	.022*	.037*	.024***	.032***		-.009*	.024***	
Gender[d]						.275**		.528*
Body mass index							-.052*	
Baseline $P_{ET}CO_2$			.033**	.038*	-.014**			
Side[e]					-.125*			
Inner speech of hexameter					.224*			
Listening to person reciting hexameter	.905*		.578**				.627**	
Listening to record of hexameter					.364*	.627**		
Mental arithmetic	1.189*		.888***		-.297**			
Inner speech of alliteration								.897*
Listening to record of alliteration								1.624**
Adjusted R^2	.024	.009	.099	.045	.048	.037	.074	.037

a Non-standardized B coefficients are shown. Significant coefficients are marked as follows: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Recitation of prose was considered the basic task.
b Interval 1 represents the baseline value. During interval 4, the task is performed for the second time, and intervals 5 to 7 (or 8, depending from which of the 3 studies the data are from) represent recovery time.
c Only those variables are listed that were included in at least one of the models.
d male = 0, female = 1
e right PFC = 0, left PFC = 1

References

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Scholkmann F, Wolf M, Wolf U. The effect of inner speech on arterial CO_2, cerebral hemodynamics and oxygenation – A functional NIRS study. Adv Exp Med Biol 2013;789:81-87.