Brain Activity in Farmworkers Occupationally Exposed to Pesticides in Costa Rica

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Pesticides and human health

REVIEW
OCCUPATIONAL EXPOSURE

Occupational exposure to pesticides and respiratory health

Ali Mamane[1,2], Isabelle Baldi[1,2,3], Jean-François Tessier[2], Chantal Raherison[1,2,4] and Ghislaine Bouvier[1,2]

Regulatory Toxicology and Pharmacology 96 (2018) 57–63

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Regulatory Toxicology and Pharmacology

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ELSEVIER

Pesticide exposure and risk of Parkinson's disease: Dose-response meta-analysis of observational studies

Check for updates

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International Journal of Hygiene and Environmental Health

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ELSEVIER

Exposure to non-persistent pesticides and thyroid function: A systematic review of epidemiological evidence

CrossMark

Élida Campos[a], Carmen Freire[a,b,*]

Review

A Section 508–conformant HTML version of this article is available at https://doi.org/10.1289/EHP527.

Association between Exposure to p,p'-DDT and Its Metabolite p,p'-DDE with Obesity: Integrated Systematic Review and Meta-Analysis

German Cano-Sancho,[1] Andrew G. Salmon,[2] and Michele A. La Merrill[1]

Pesticides and neurotoxicity

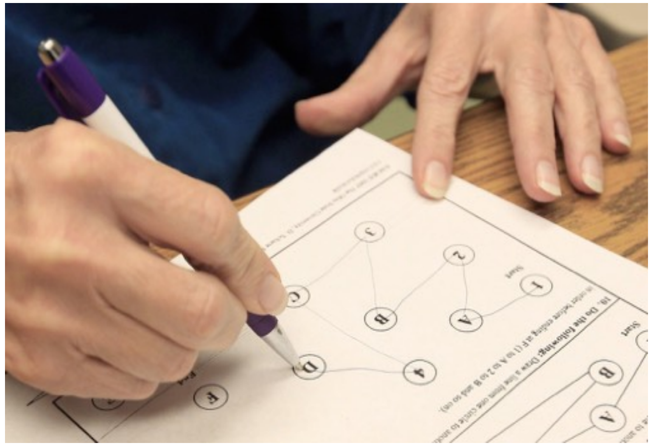
Pesticide type/class	Effects
Organophosphates (OPs) and carbamates	Behavioral problems, and poorer working memory, executive function, and motor skills
Ethylene bisdithiocarbamates	Poorer verbal learning skills and cognitive function, attention problems, behavioral disinhibition, impaired motor function
Pyrethroids	Poorer perceptual reasoning, attention deficit hyperactivity disorder (ADHD), slower processing speed
Glyphosate	Decreased locomotor activity, impaired recognition memory, and depressive-like behavior (animal studies)

Gallegos et al. 2018; Cattani et al. 2017; Muñoz-Quezada et al. 2016; Campos et al. 2016; Motsoeneng et al. 2015; Oulhote et al. 2013; Rodriguez et al. 2012

Pesticides and neurotoxicity

Epidemiological evidence comes from studies that have used neuropsychological testing

Lack of information on the brain structures or neural functions targeted by pesticides



Pesticides and structural neuroimaging

- Brain volume measured using magnetic resonance imaging (MRI)
- Farmworkers with high (n=10) and low/no (n=10) pesticide exposure, South Africa
    - Farmworkers exposed to herbicides had smaller white matter volumes
- Latino tobacco farmworkers (n=48) vs. non-farmworkers (n=26), North Carolina
    - Farmworkers had greater gray matter signal in putamen and cerebellum, and lower gray matter signal in frontal and temporal lobes

Laurienti et al. 2016; Holtman et al. in prep.

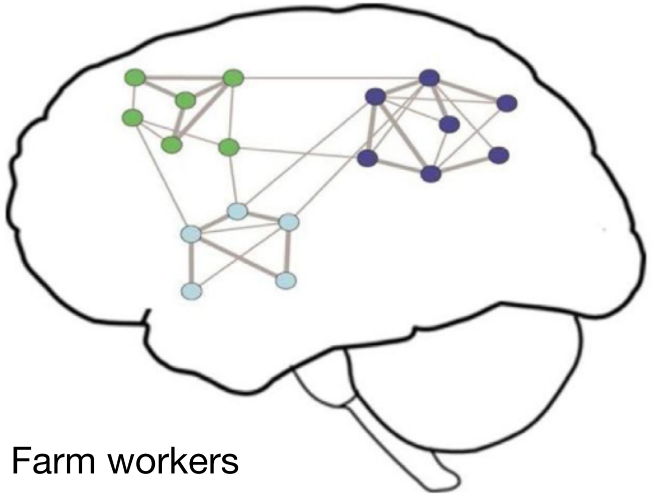
Pesticides and functional neuroimaging

- Latino tobacco farmworkers (n=48) vs. non-farmworkers (n=26), North Carolina
- Brain network connectivity patterns
    - Functional interactions among brain areas
    - Measured using resting-state functional magnetic resonance imaging (rs-fMRI)

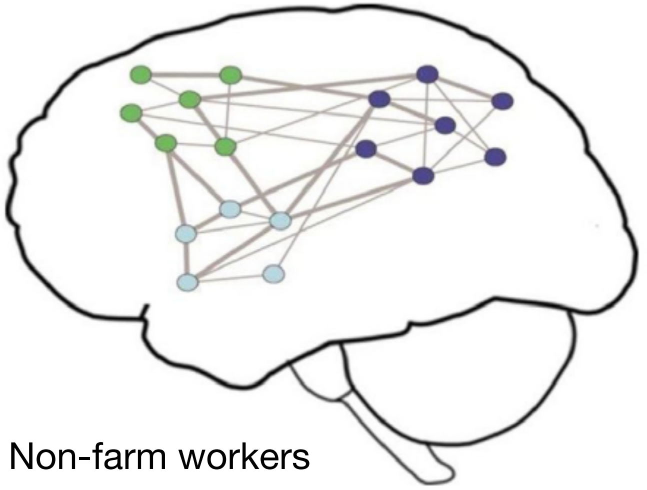
Bahrami et al. 2017

Pesticides and functional neuroimaging

- Latino tobacco farmworkers (n=48) vs. non-farmworkers (n=26), North Carolina
- Brain network connectivity patterns
  - Functional interactions among brain areas
  - Measured using resting-state functional magnetic resonance imaging (rs-fMRI)
- Brain networks in farmworkers had more clustered and modular structures
  - More segregated neural processing and less sharing of information between brain regions



Farm workers



Non-farm workers

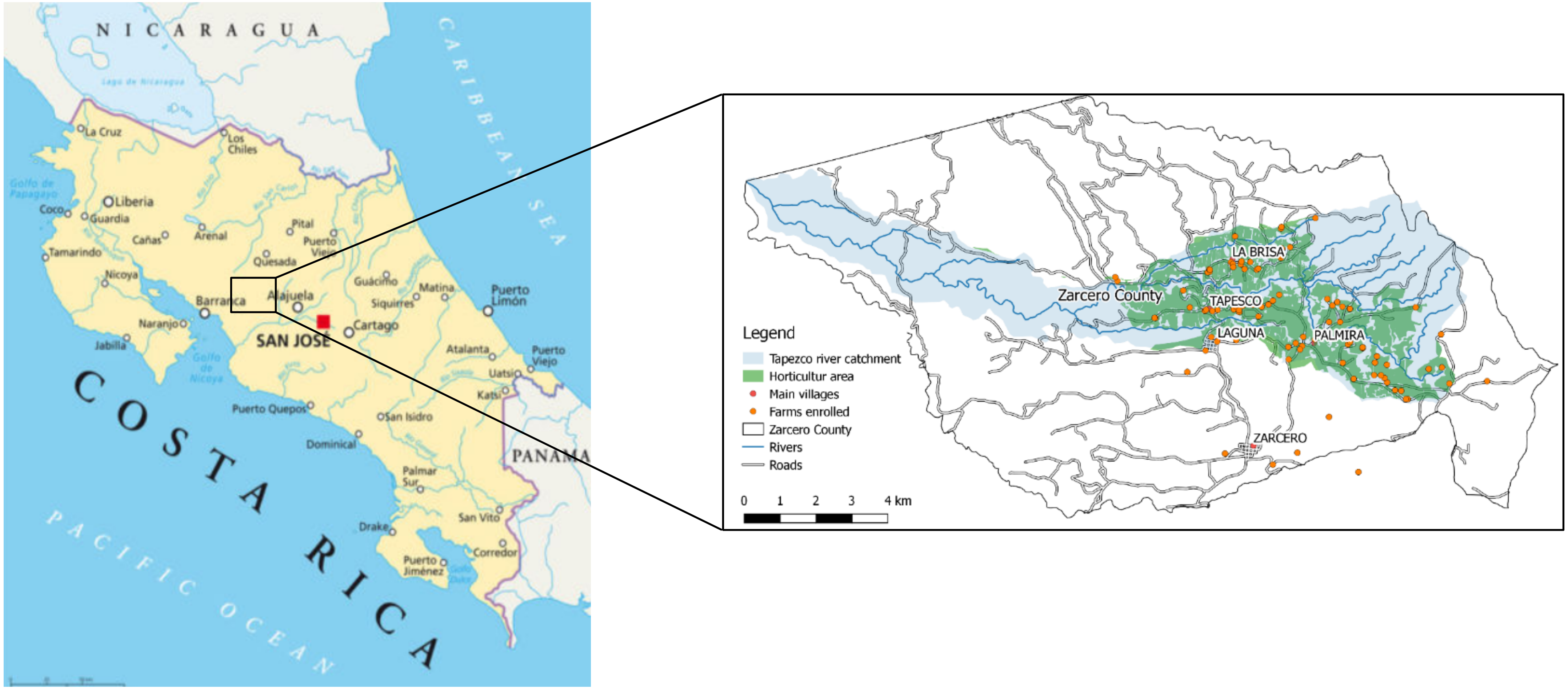
Bahrami et al. 2017

Pesticides and functional neuroimaging

No published studies of pesticide exposure have used functional neuroimaging while administering cognitive tasks

Need to elucidate how pesticides affect neural dynamics underlying cognitive function and localize pesticide-related effects on the brain

Pesticides and cortical brain activity



Fuhrimann et al. submitted

Pesticides and cortical brain activity

- Cross-sectional pilot study in Zarcero County, Costa Rica (July-August 2016)
- Convenience sample from PESTROP study (n=48)
  - 23 workers from conventional farms and 25 from organic farms
- Eligibility criteria
  - ≥18 years old
  - No psychiatric disorder or medications

Fuhrimann et al. submitted

Pesticides and cortical brain activity: data collection

- Interview
- Functional near-infrared spectroscopy (fNIRS)
- Urinary pesticide metabolites
  - Mancozeb (ETU)
  - Chlorpyrifos (TCPy)
  - Pyrethroids (3-PBA, DCCA, CFCA)
  - Tebuconazole (TEB-OH)
  - Glyphosate (GLY, AMPA)

Fuhrimann et al. submitted

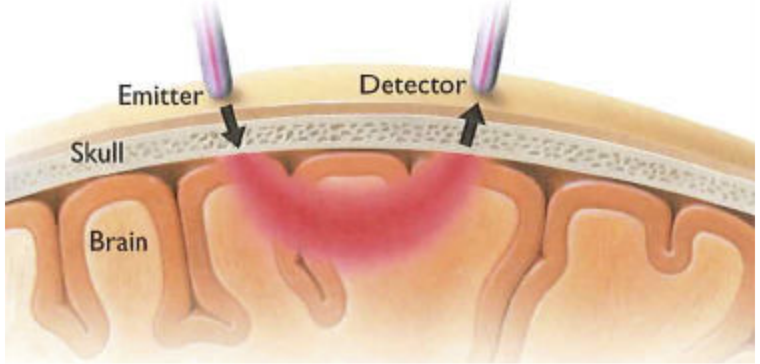
Pesticides and cortical brain activity: fNIRS

- Noninvasive optical brain imaging technology
- Measures localized changes in blood flow related to brain activity during a task
- Benefits over fMRI for population-based studies
  - Low cost
  - Portable
  - Greater tolerance to movement artifacts
- Correlates highly with fMRI across a variety of cognitive tasks

Baker et al. 2017; Cui et al. 2011

Pesticides and cortical brain activity: fNIRS

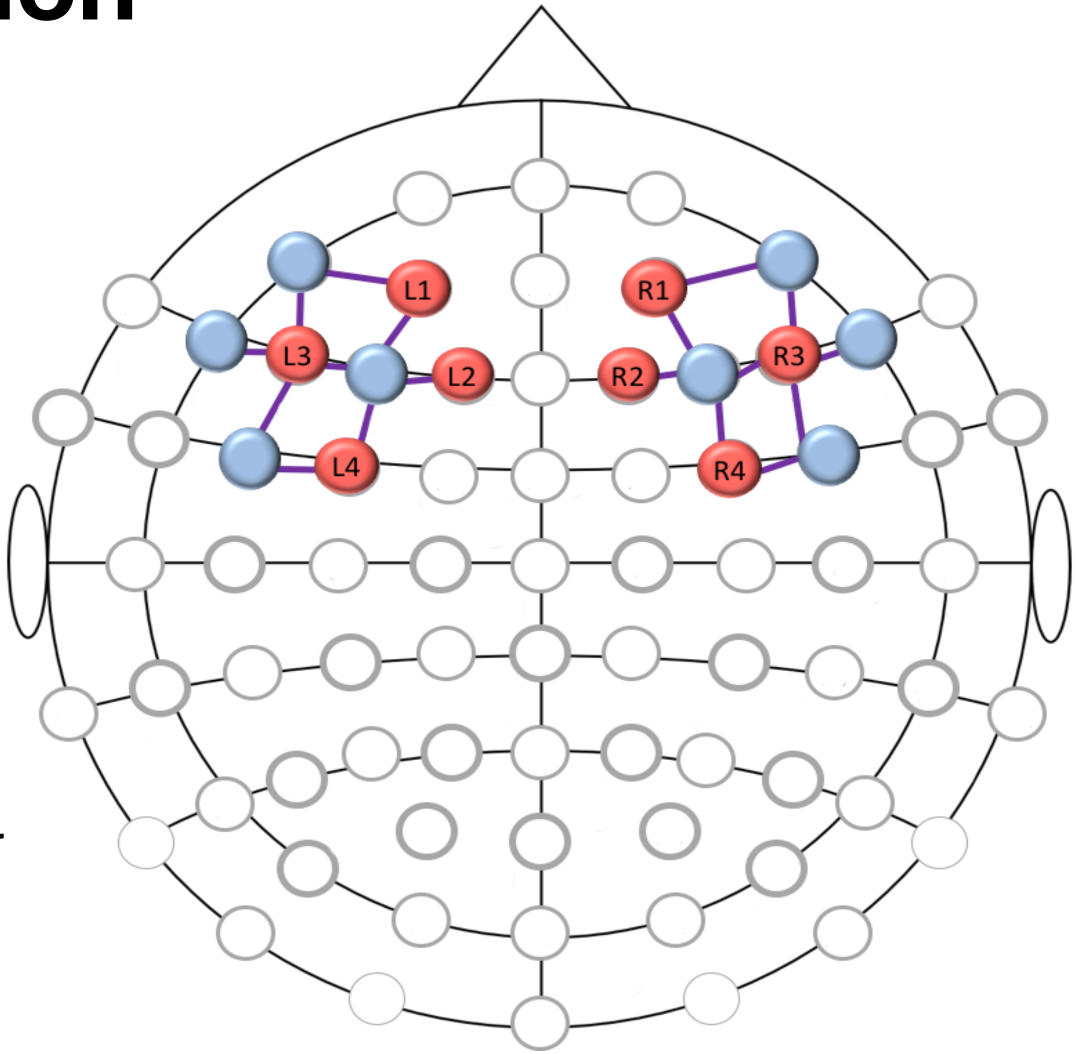
- Source and detector optodes are held in contact with a participant’s scalp by a headpiece
- Source optodes emit near-infrared light that penetrates the skull and outer 3-4 cm of the underlying cortex
- Detector optodes arranged near a source optode quantify unabsorbed light



Baker et al. 2017

Pesticides and cortical brain activity: fNIRS optode configuration

- Optodes configured over the dorsolateral prefront
- 18 channels
- 8 regions of interest



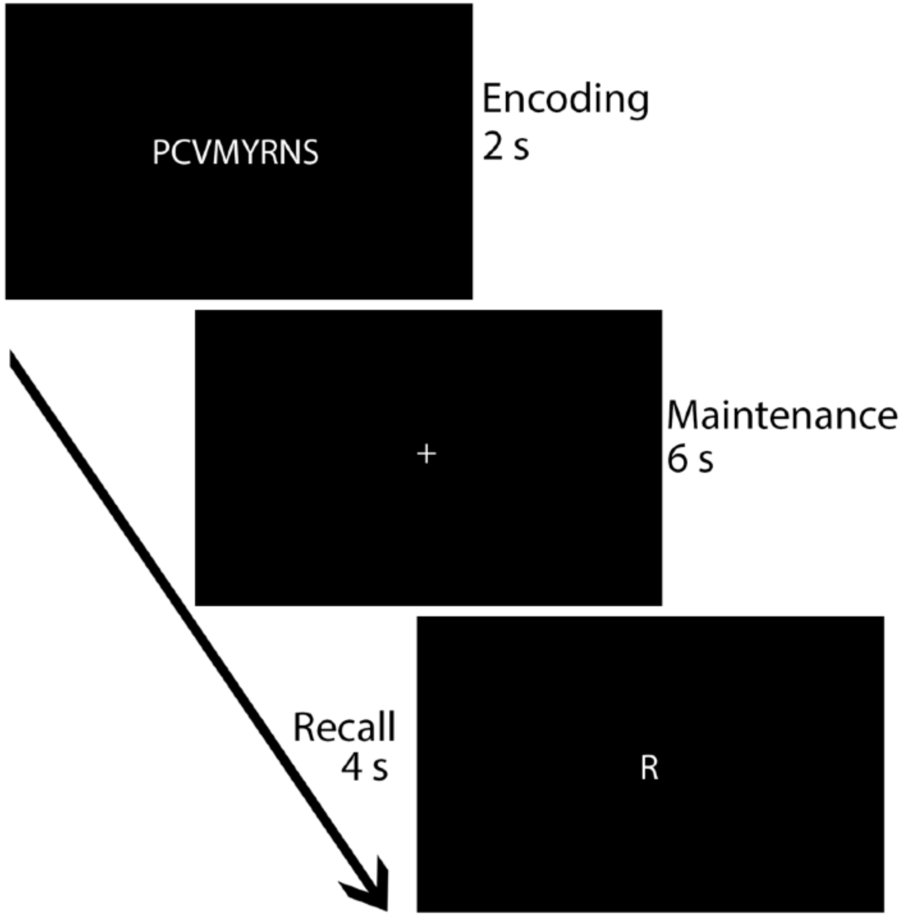
= source

= detector

= channel

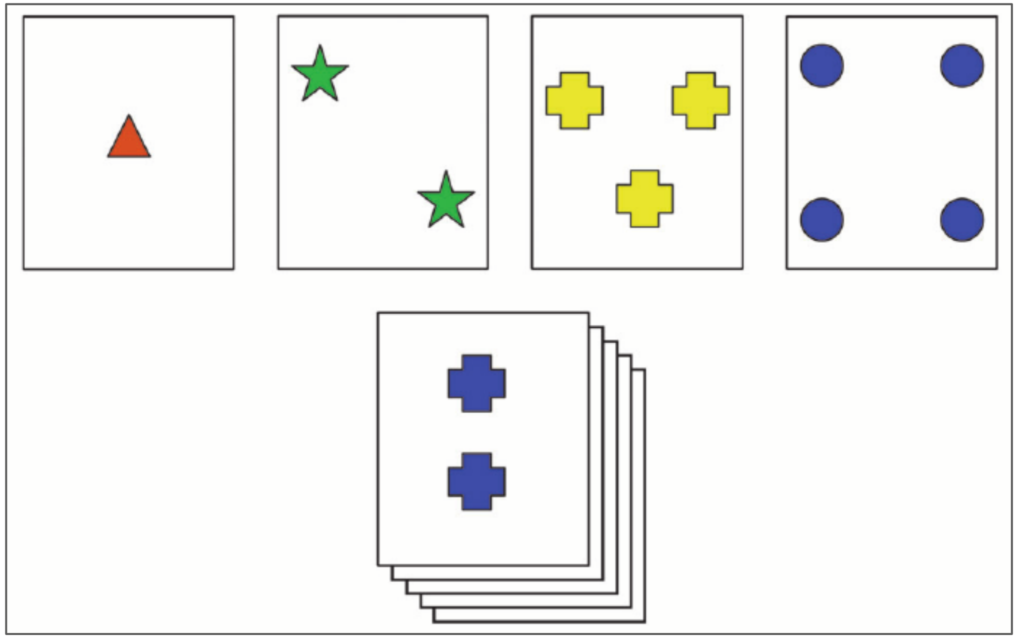
Baker et al. 2017

Pesticides and cortical brain activity: neuropsychological tasks



Baker et al. 2017

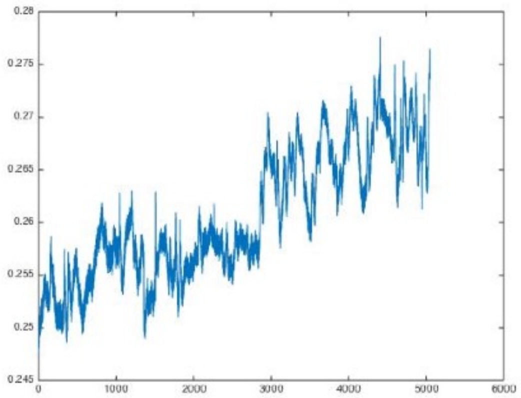
Pesticides and cortical brain activity: neuropsychological tasks

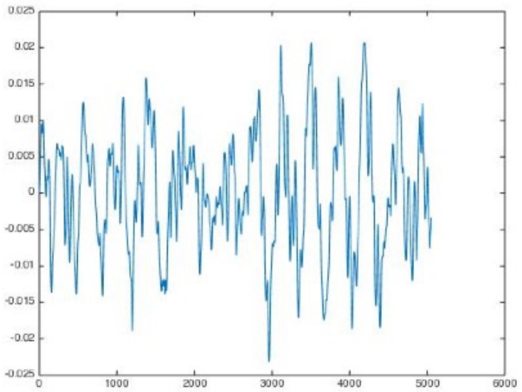


Baker et al. 2017; Jonides & Evan Nee 2005

Pesticides and cortical brain activity: fNIRS data preprocessing

- Cleaning and conversion of optical density data into time series of oxygenated (HbO) and deoxygenated (HbR) hemoglobin concentrations
- Generalized linear modeling (GLM) used to estimated a metric (beta coefficient) that describes the change in HbO and HbR concentrations during each component of the task





Schroeter et al. 2004; Hosseini et al. 2017; Brigadoi et al. 2014; Cui et al. 2010; Huppert et al. 2009

Pesticides and cortical brain activity: fNIRS data preprocessing

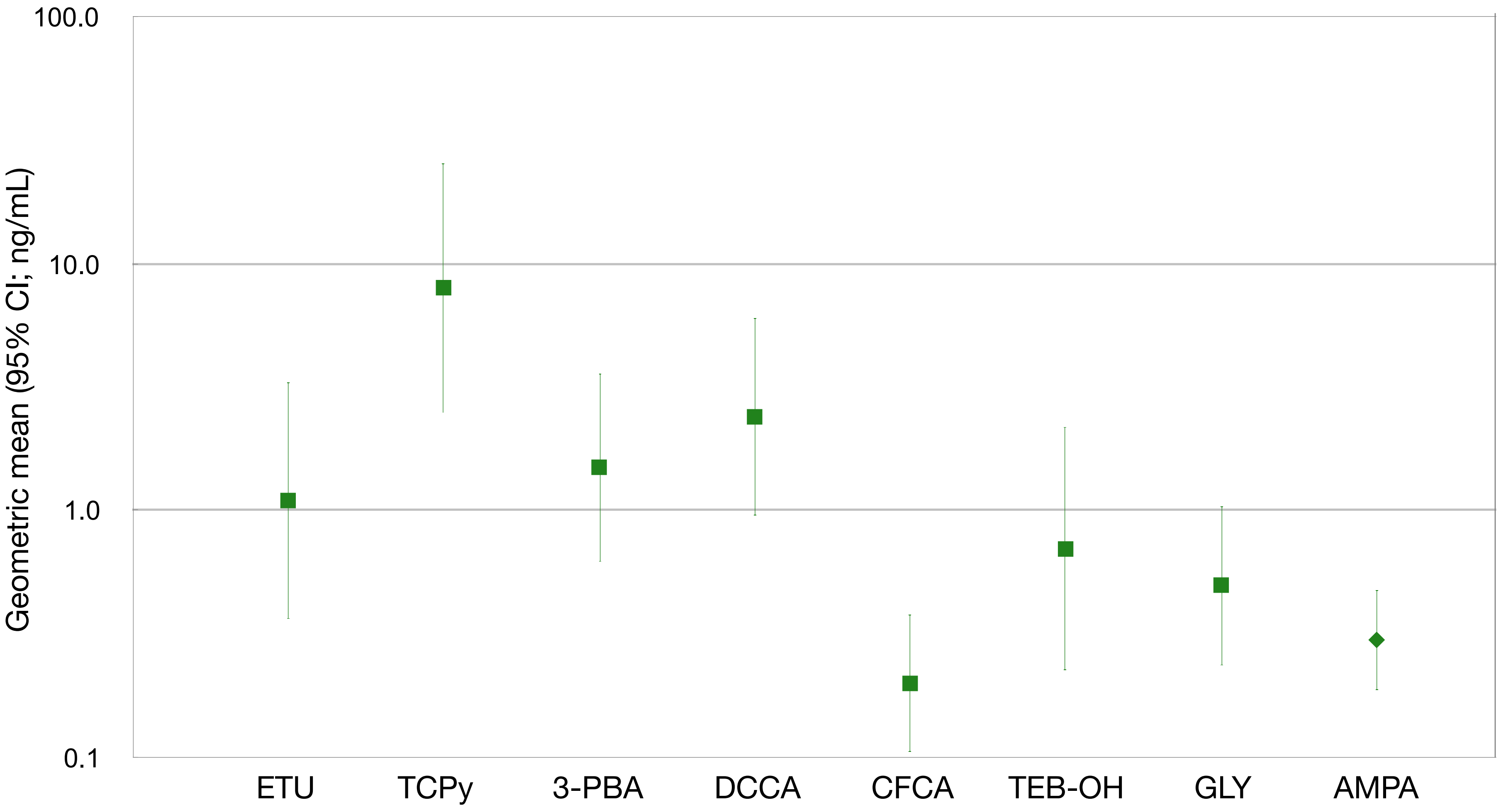
- Contrast between each β coefficient and its corresponding control for each task
    - Encoding vs. Recall
    - Matching vs. Control
    - Go vs. No-Go
- Identification of the single channel within each region of interest that showed the greatest response for each contrast

Schroeter et al. 2004; Hosseini et al. 2017; Brigadoi et al. 2014; Cui et al. 2010; Huppert et al. 2009

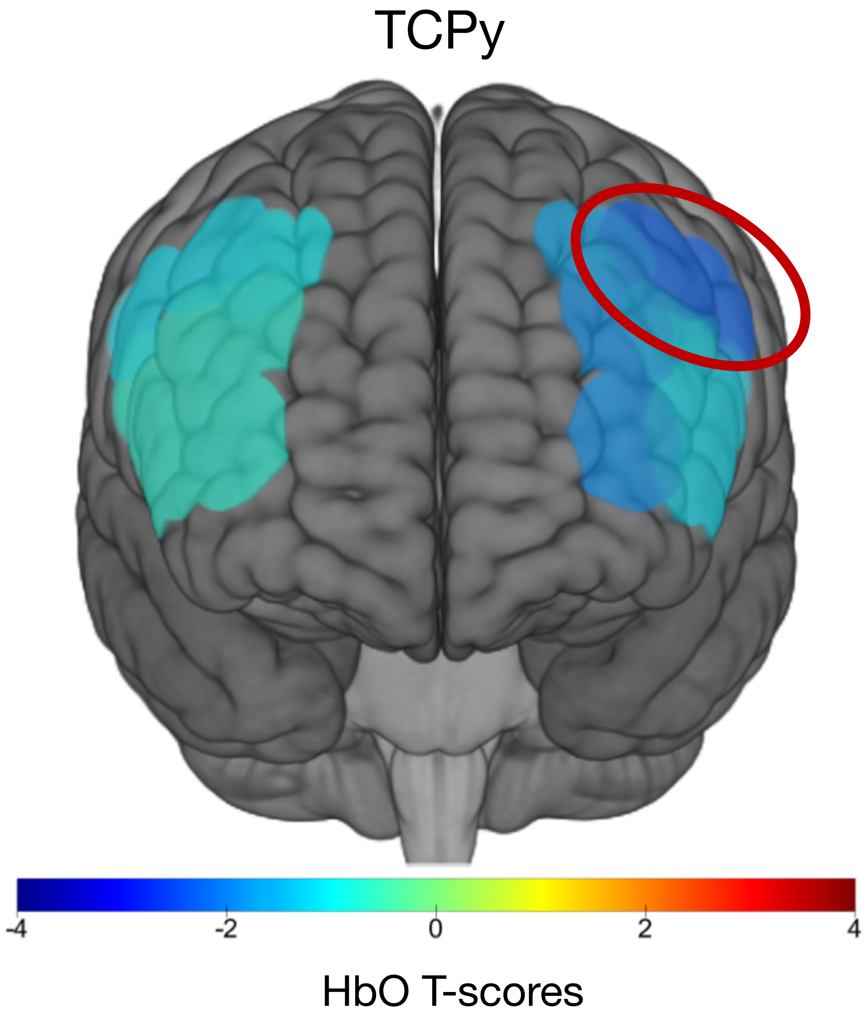
Characteristics of farmworkers

31.0	years old (median)
96%	male
71%	born in Costa Rica
65%	≤ 6th grade
73%	living above poverty level
19.0	years worked in agriculture (median)

Distribution of urinary metabolite (specific gravity-adjusted) concentrations



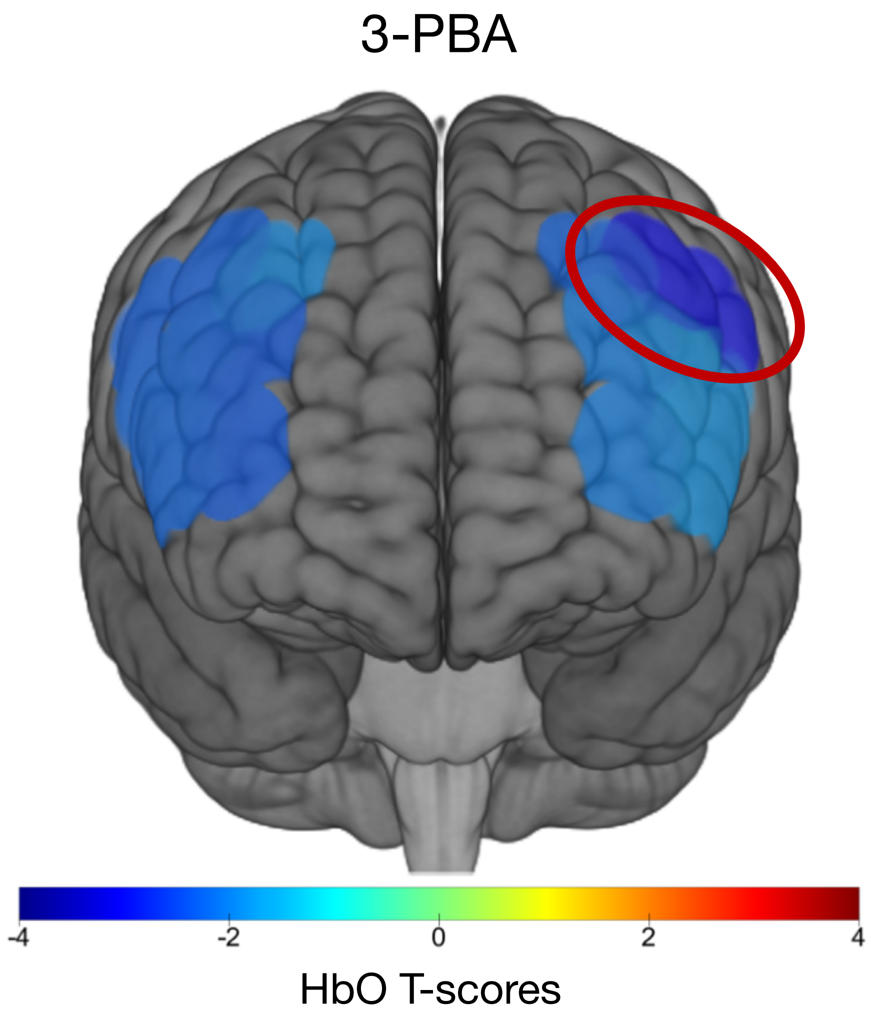
Preliminary results: pesticide exposure and working memory-related brain activity

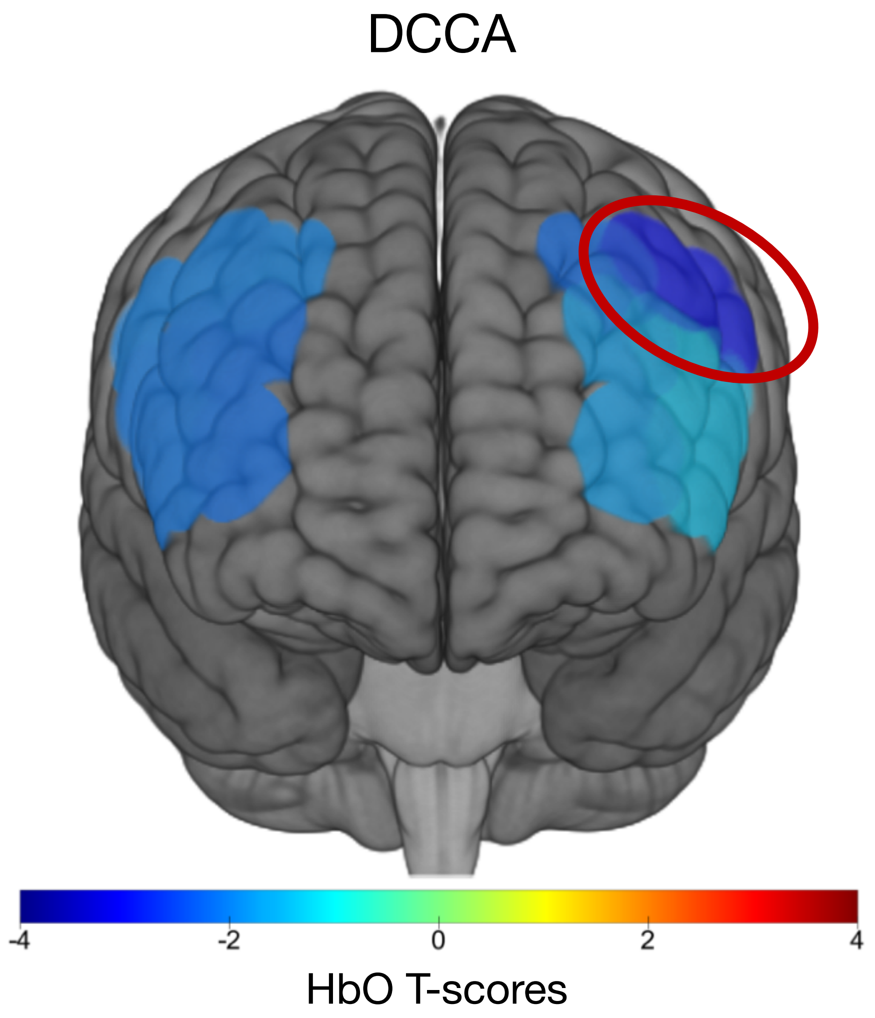


- Decreased activation in the prefrontal cortex of the left hemisphere
- Exposure has altered the overall neural response, including the ability of a region or network to marshal a typical response to a task
- Models adjusted for age and educational level

Mora et al. in prep.

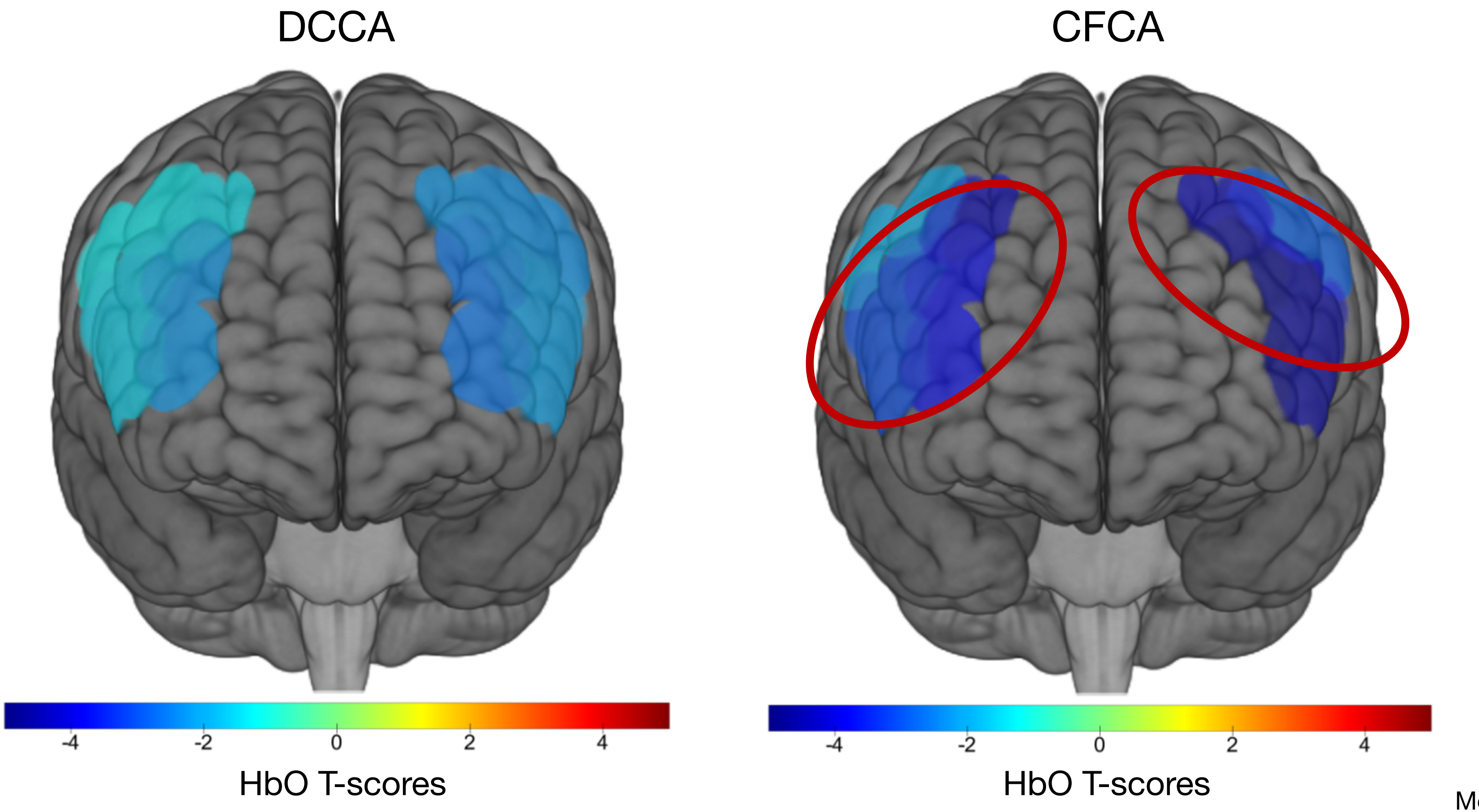
Preliminary results: pesticide exposure and working memory-related brain activity





Mora et al. in prep.

Preliminary results: pesticide exposure and executive function-related brain activity



Mora et al. in prep.

Preliminary results: pesticide exposure and brain activity

- Null associations with task of attention and response inhibition (Go/No-Go)
- Null associations with ETU, PTU, TEB-OH, and glyphosate

Mora et al. in prep.

Future steps

- Examine associations of pesticide exposure with HbR and functional connectivity
- Examine exposure-task performance and task performance-brain activation associations
- Investigate impacts of pesticide exposure during critical windows of brain development on cortical brain activity and functional connectivity
    - 600 Mexican American young adults from the CHAMACOS study

CHAMACOS

Collaborators

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eawag
aquatic research

UNA
UNIVERSIDAD NACIONAL
COSTA RICA

swiss network for international studies

Questions welcome

Additional slides

Pesticides and agriculture

Costa Rica (2005-2009):

25 million lbs of pesticide active ingredients per year

1.2 million harvested acres

United States (2012):

800 million lbs of pesticide active ingredients

315 million harvested acres

Distribution of urinary metabolite specific gravity-adjusted concentrations (ng/mL)

Urinary metabolites	LOD	% >LOD		Average of two measurements			
		1st sample	2nd sample	GM (GSD)	P25	P50	P75
ETU	0.08	98.0	95.7	1.1 (3.0)	0.5	1.1	1.9
TCP	0.05	100.0	100.0	8.0 (3.2)	2.9	7.6	16.0
3-PBA	0.03	100.0	100.0	1.5 (2.4)	0.8	1.4	2.1
DCCA	0.04	100.0	100.0	2.4 (2.5)	1.3	2.1	3.2
CFCA	0.10	61.2	63.0	0.2 (1.9)	0.1	0.2	0.3
TEB-OH	0.10	83.7	91.3	0.7 (3.1)	0.3	0.6	1.1
GLY	0.20	69.4	69.6	0.5 (2.1)	0.3	0.4	0.7
AMPA	0.20	55.1	73.9	0.3 (1.6)	0.2	0.3	0.5

Differences in metabolite concentrations specific gravity-adjusted by farm type