Genetics, Sweet Preference, and Short Sleep: Important Players in Food Choice?

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SWEETENER SYSTEMS CONFERENCE

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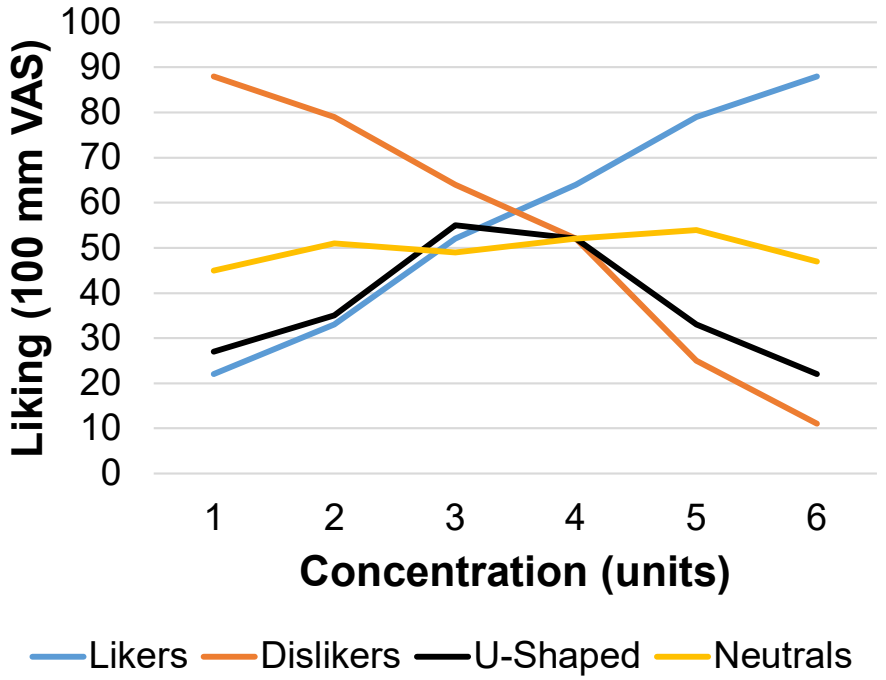
Today: Under-studied contributors to food choice

- Genetics: Sweet liking phenotype

- Sleep: Sweet preference, cravings, food reward

Sweet liking phenotypes (SLP)

- Phenotype: observable trait that results due to genetic and environmental interactions
- 3-4 “foundational” patterns of liking responses consistently reported[1]
- SLP —> intake of total sugar,[2] refined sugar,[2] and sugar sweetened beverages.[3,4]

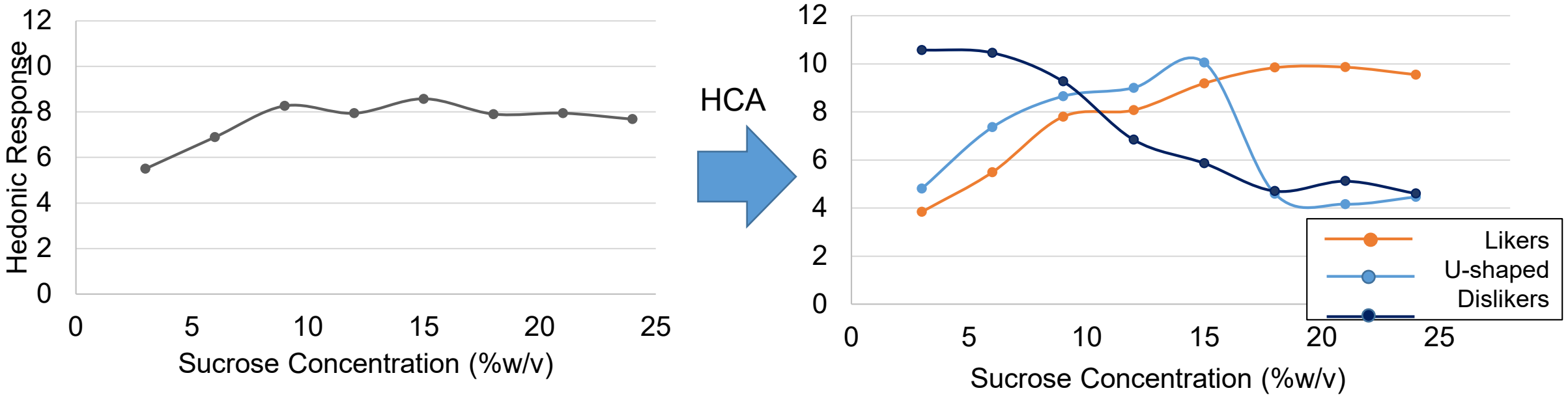


Likers consume more.

1. Iatridi, Food Qual Pref, 2018; 2. Holt, Food Qual Pref, 2000; 3. Garneau, Food Qual Pref, 2018; 4. Methven, Food Qual Pref, 2016

Sweet liking phenotypes (SLP)

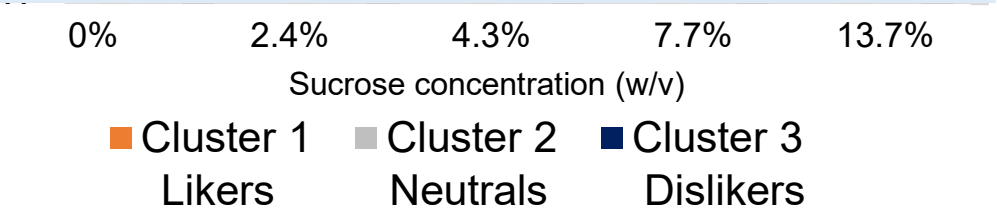
- Recent review: SLP strengthens likelihood of identifying taste-dietary intake relationships[1]
- Your interest: identifying different types of consumers



1. Tan and Tucker, Nutrients, 2019; HCA = Hierarchical Cluster Analysis

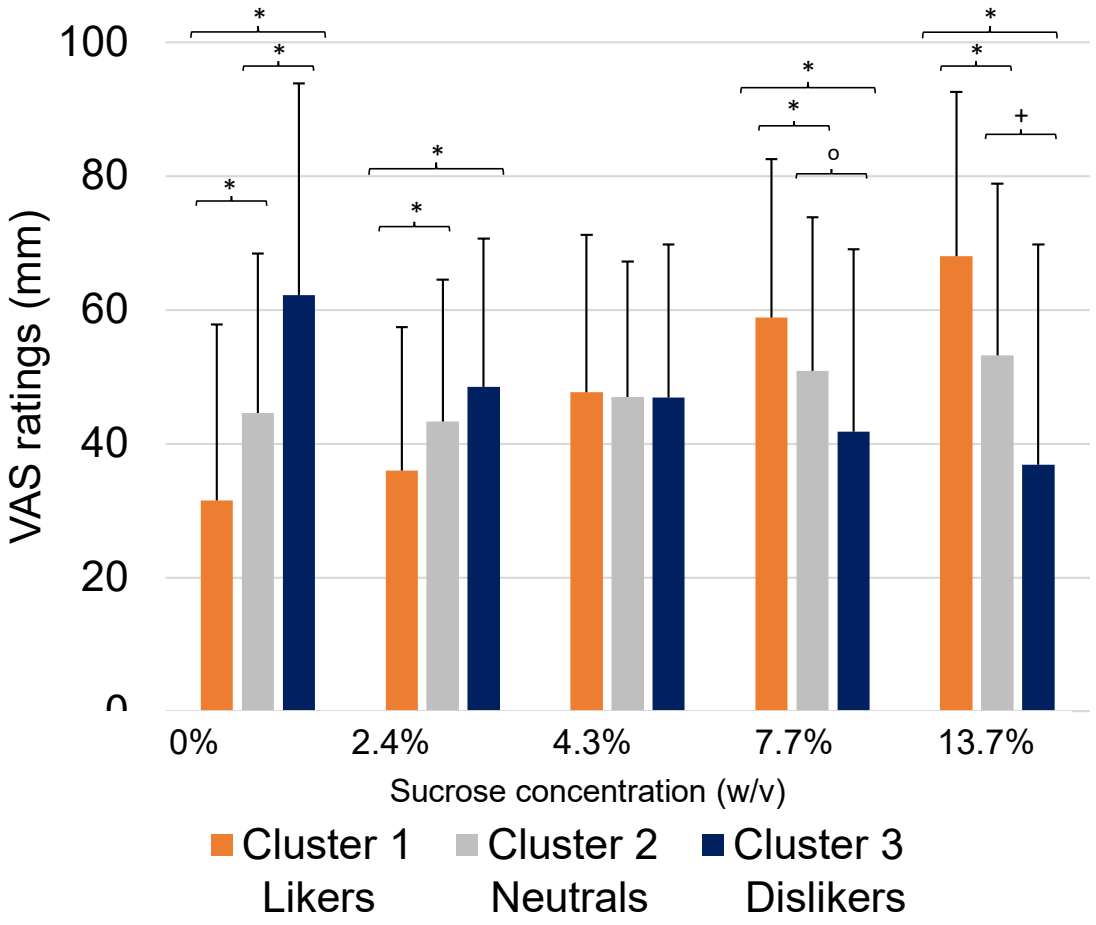
Adults – Differences in liking by concentration according to SLP

Mean overall liking of model solutions did not differ.



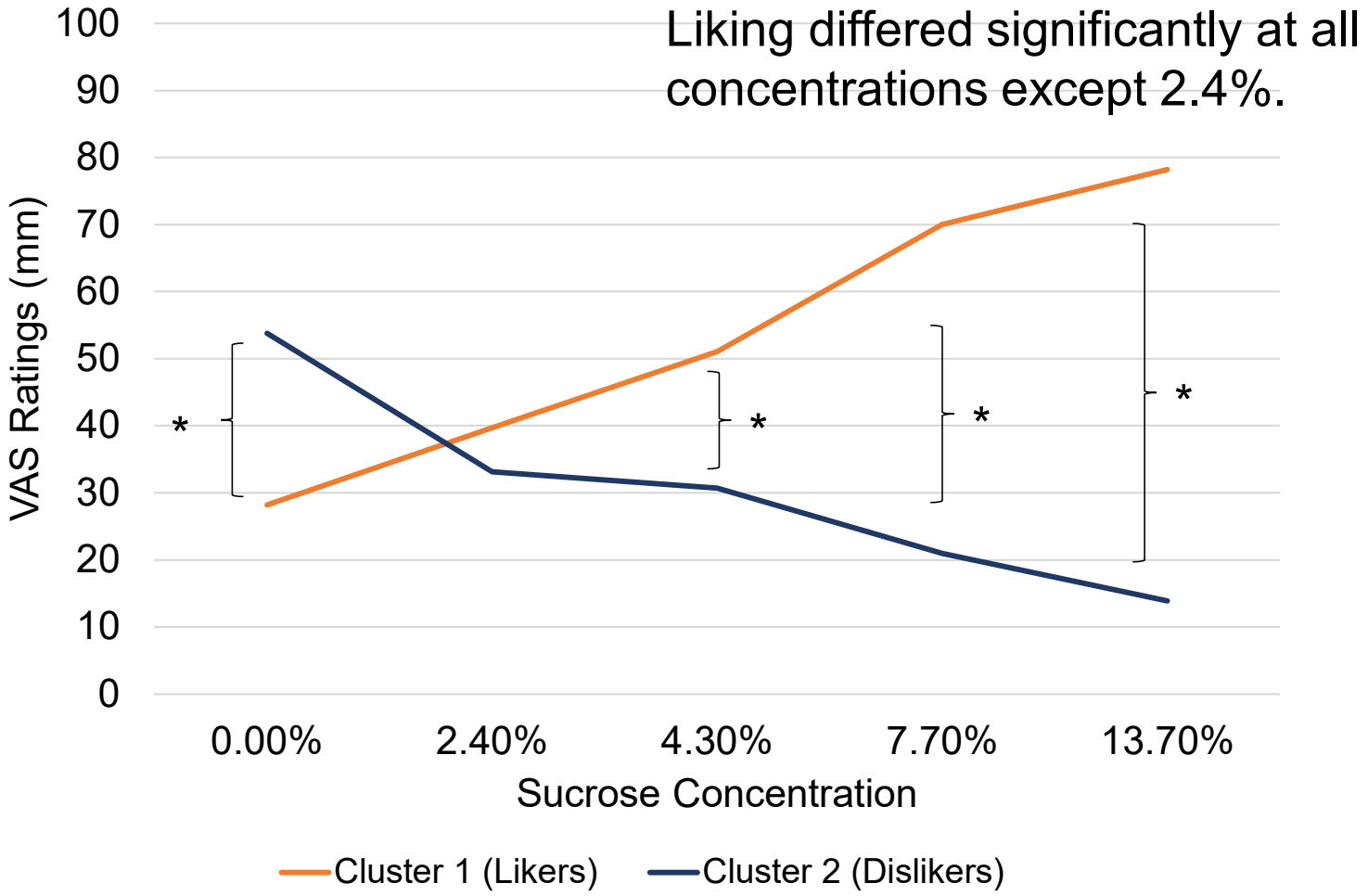
Garneau, et al., Food Qual Pref, 2018

Adults – Differences in liking by concentration according to SLP



Garneau, et al., Food Qual Pref, 2018

Children



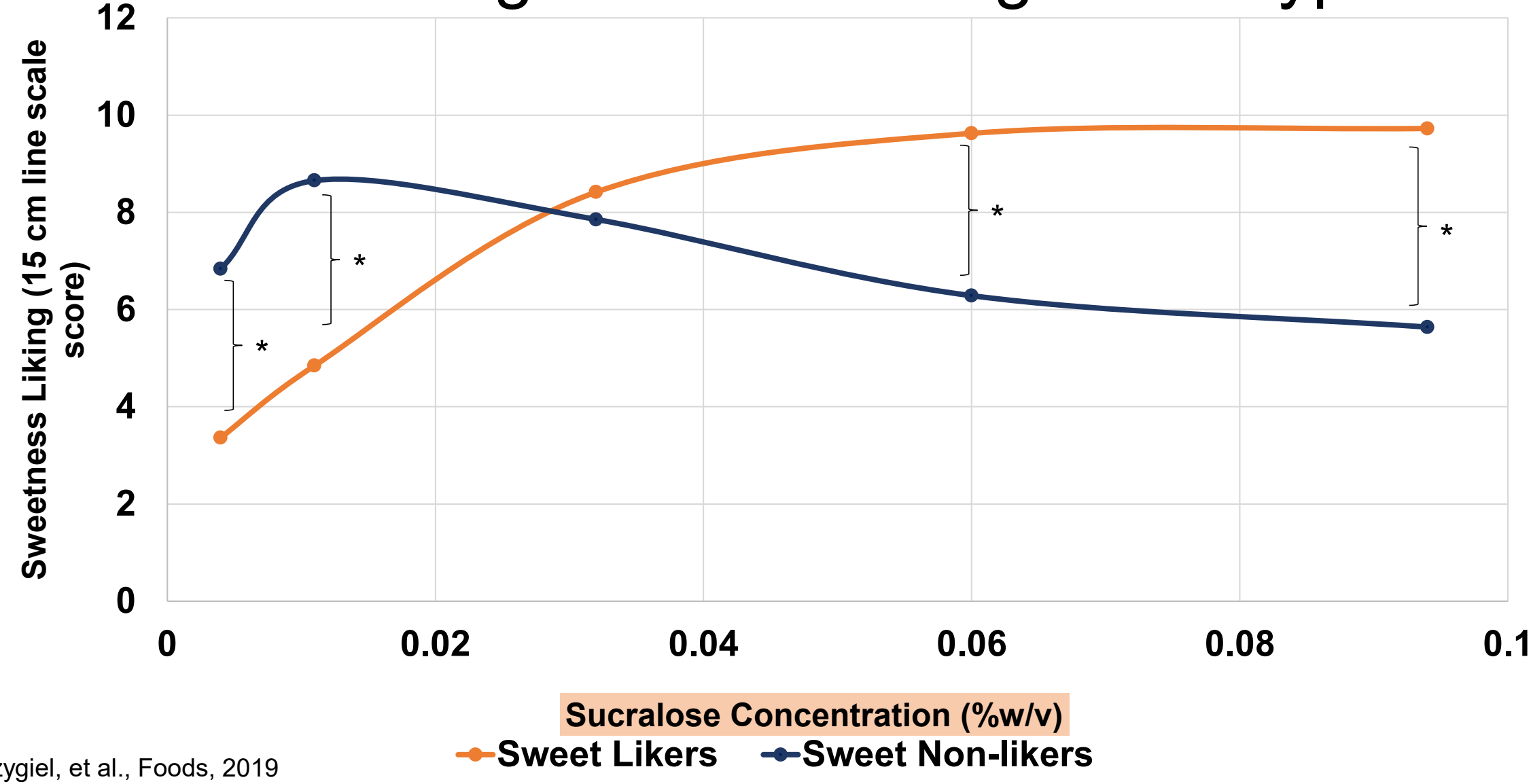
Garneau, et al., Food Qual Pref, 2018

Sweet Liking Phenotype predicts preferred sweetness concentrations for both sucrose and sucralose

Habitual Cluster		Preferred Concentration (% w/v)	
		Sucrose	Sucralose
Likers	Likers (n = 25)	14.9±4.4[a]	0.05±0.02[a]
"Non-likers"	U-shaped + Dislikers (n=15)	6.8±4.1[b]	0.02±0.02[b]

Szczygiel, et al., Nutrients, 2019

Differences in liking by concentration according to Sweet Liking Phenotype



Szczygiel, et al., Foods, 2019

Prevalence of sweet liking phenotypes: Adults and children

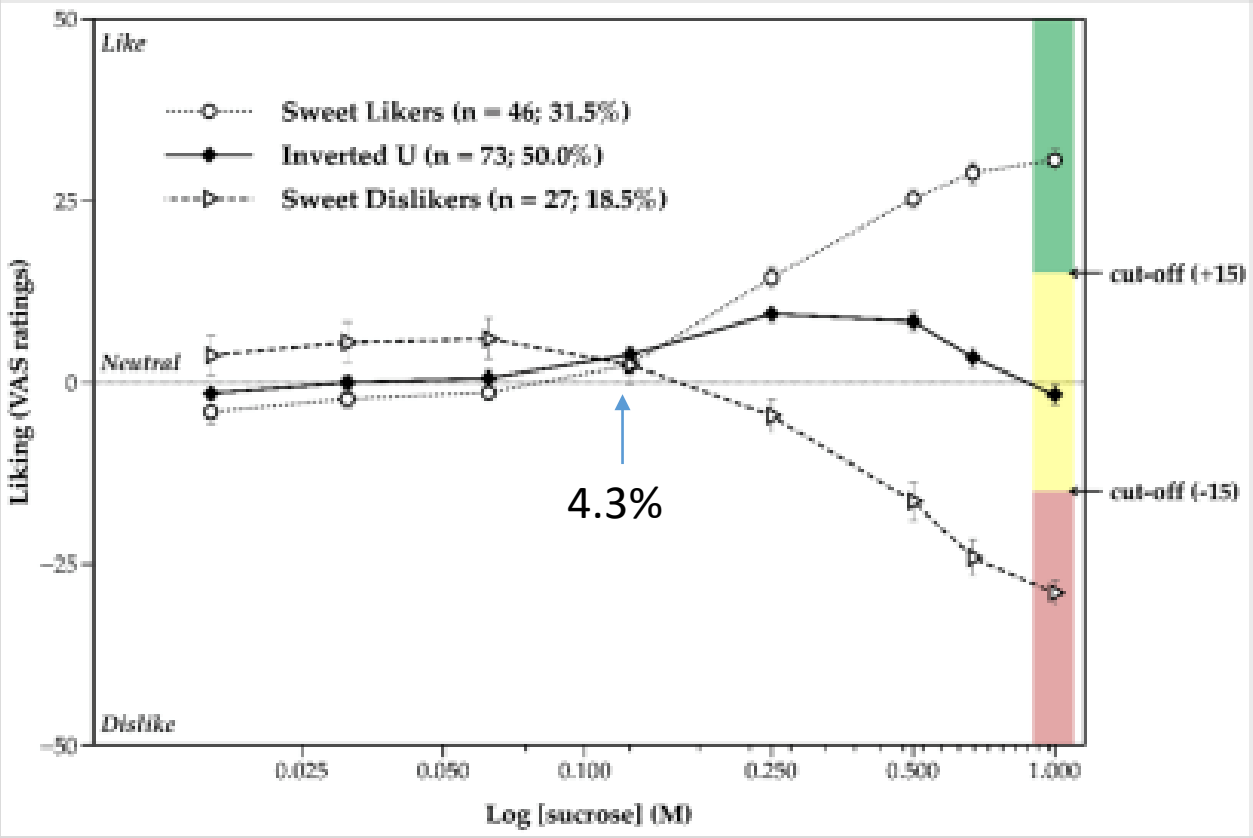
Study	Concentrations used (% w/v)	Sweet Likers (n,%)	Neutral/Inverted U-Shape (n,%)	Dislikers (n,%)
Garneau et al, Food Qual Pref, 2018				
• Adults (n=650)	0-13.7	218, 33.5%	377, 58.0% includes 115, 30.5% U-shaped	55, 8.5%
• Children (ages 8 -18), n=303	0-13.7	237, 78.2%	-	66, 21.8%

Identifying SLPs: Best practices

- Lots of different ways to determine SLPs.
  - Visual inspection of slopes, cut-offs, hierarchical cluster analysis (HCA)
- Hayes et al. has proposed the use of the following concentrations[1]:
  - 0.03125, 0.0625, 0.125, 0.25, 0.5, 0.67, and 1 M
  - Equivalent to: 1.1%, 2.1%, 4.3%, 8.6%, 17.1%, 22.9%, 34.2% w/v
  - Use Hierarchical Cluster Analysis (HCA) – least biased

1. Hayes et al., Nutrients, 2019

Identifying SLPs: Faster approach?[1]



Likers	U-shaped	Dislikers
46, 31.5%[1]	73, 50%	27, 18.5%
218, 33.5%[2]	377, 58.0%	55, 8.5%

Proposed cut-offs for 1 M (34.2% w/v)[1]:

- Likers +15 or greater
- U-shaped: <+15 - >-15
- Dislikers: > -15

1. Hayes et al., Nutrients, 2019; 2. Garneau et al, Food Qual Pref, 2018

Sweet Liking Phenotype summary

- Identifies sub-groups of the population
- Better predictor of dietary intake compared to other taste tests
- Use HCA to identify groups
- Possible to use cut-offs?

Pop quiz!

- How much sleep did you get last night?
  - A. Sleep, what's that?
  - B. A solid 4-6 hours.
  - C. 7-9 hours.
  - D. 9+ hours.

If you answered A or B, count yourself as part of the 35% of Americans who do not routinely meet sleep recommendations of 7-9 h/night.

Sleep and chemosensory function

- Increased intake of high fat, high sugar foods after insufficient sleep[1-3] —> weight gain
- Foods consumed —> typically selected based on their sensory properties (taste, smell, chemesthesis, texture, etc…)[4-6]
- Does chemosensory function/perception change after insufficient sleep?
  - Focus: sweet taste
    - Sweet tasting foods are often high in added sugars, fats, and calories

1. Nedeltcheva et al., Am J Clin Nutr, 2009; 2. Calvin et al, Chest, 2013; 3. Weiss et al., Sleep, 2010; 4. Dressler and Smith, 2013; 5. Glanz and Basil, 1998; 6. Sørensen et al., 2003

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Volume 43, Issue 4
May 2018

Characterization of the Relationships Between Sleep Duration, Quality, Architecture, and Chemosensory Function in Nonobese Females

Edward J Szczygiel, Sungeun Cho, Robin M Tucker

Chemical Senses, Volume 43, Issue 4, 23 April 2018, Pages 223–228,
https://doi.org/10.1093/chemse/bjy012
Published: 07 March 2018

ELSEVIER

Food Quality and Preference
Volume 75, July 2019, Pages 105-112

Associations between chemosensory function, sweet taste preference, and the previous night's sleep in non-obese males

Edward J. Szczygiel, Sungeun Cho, Margaret K. Snyder, Robin M. Tucker

- Research question: Are measures of sleep duration and quality associated with chemosensory function and perception?
  - Observational studies

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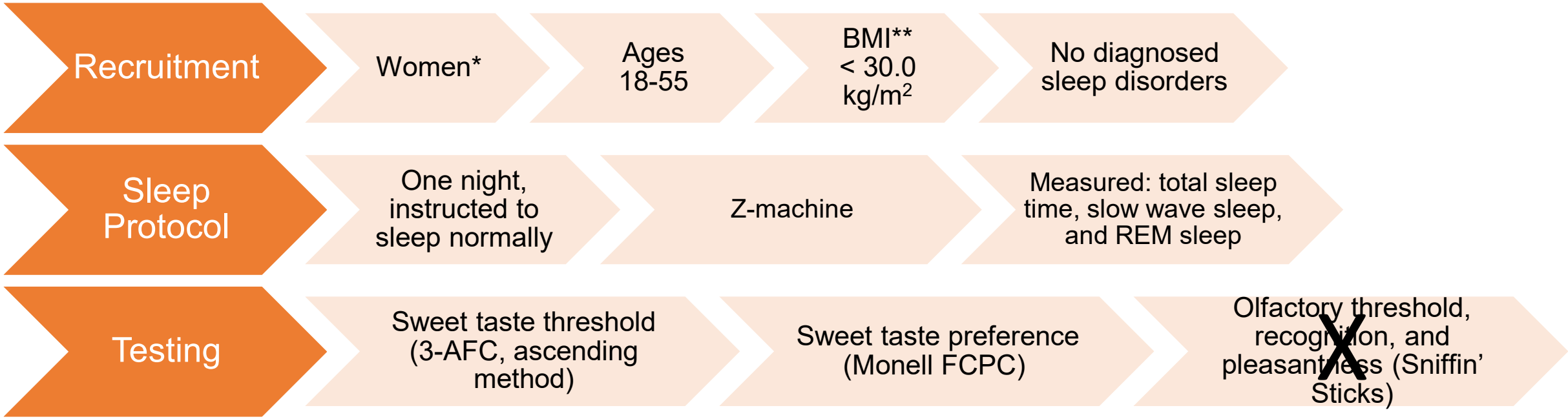
Protocol



*Higher incidence of insomnia (Zhang et al., Sleep, 2006); differences in sleep architecture (deeper sleepers) (Redline et al., JAMA Int Med, 2004)

**Deeper sleep among those with lower BMI (Redline et al., JAMA Int Med, 2004)

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Sensitivity

- No correlation between any of the sleep variables and sweet taste sensitivity for either males or females.

Relationships between sleep and preferred sucrose solution concentration

Variable	Pearson's *r*	R^2	*P*-value
Females (n=56)			
TST	−0.35	0.12	0.0074**
REM	−0.41	0.16	0.0018**
SWS (N3)	−0.31	0.09	0.0221*
SWS + REM	−0.43	0.18	0.0008***
Males (n=51)			
TST	−0.35	0.12	0.0111*
REM	−0.49	0.24	0.0010**
SWS (N3)	−0.31	0.10	0.0248*
SWS + REM	−0.47	0.22	0.0005***

Multiple regression, best models:

F (2,56) = 6.58, P = 0.0028

F(2, 51) = 15.31, P = 0.0010

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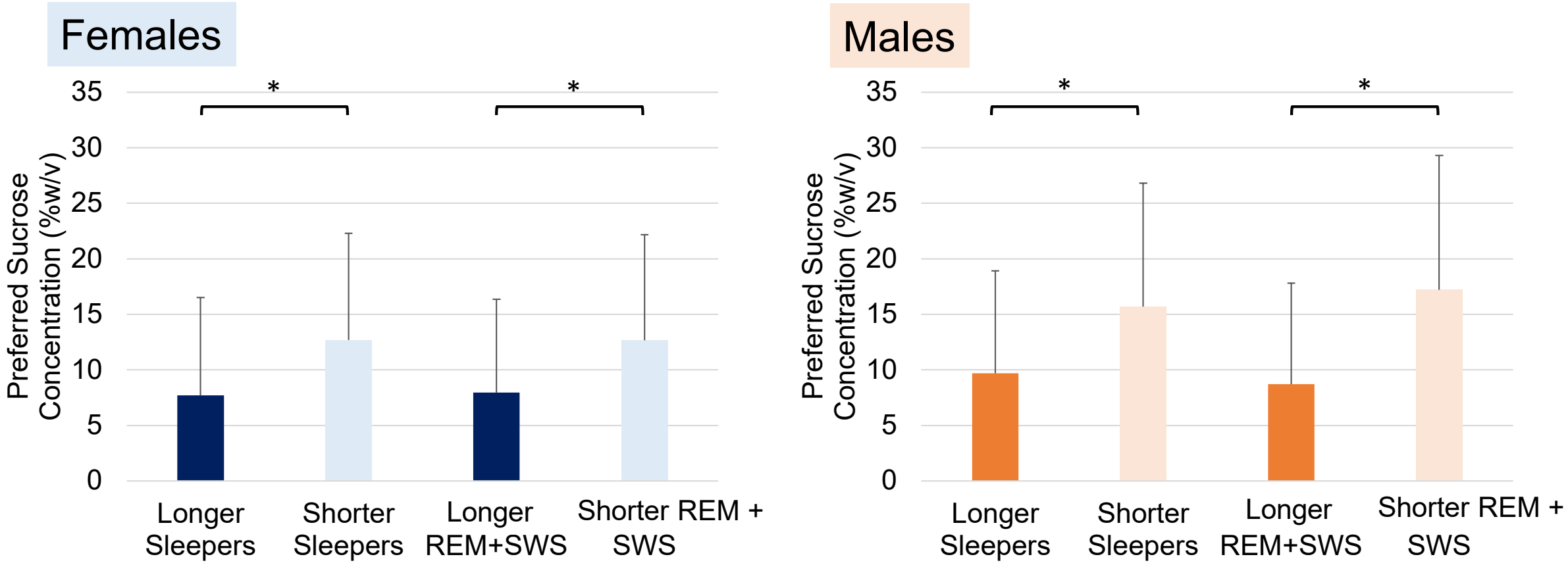
Sleep duration and architecture



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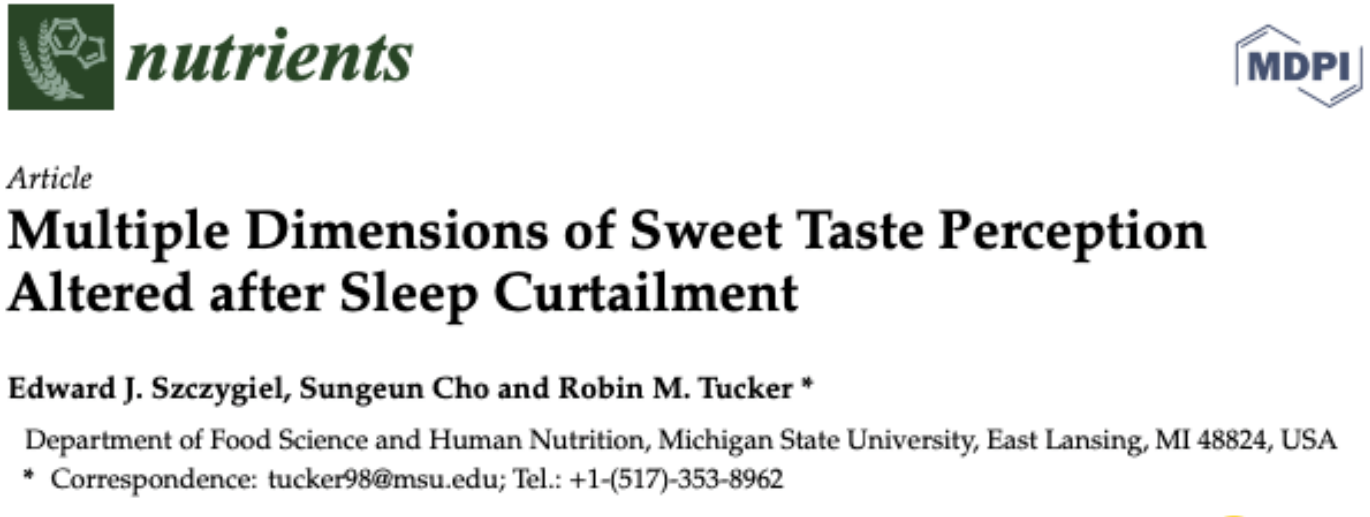
Observational studies summary: Sensitivity (function) not associated; taste hedonic effects?

Associations suggest that differences in sleep duration may contribute to differences in sweet taste liking or preference.

What happens if we intervene?

- Research question: Does sleep curtailment alter sweet taste function (intensity) or perception (hedonics: liking, preference)?



nutrients

MDPI

Article

Multiple Dimensions of Sweet Taste Perception Altered after Sleep Curtailment

Edward J. Szczygiel, Sungeun Cho and Robin M. Tucker *

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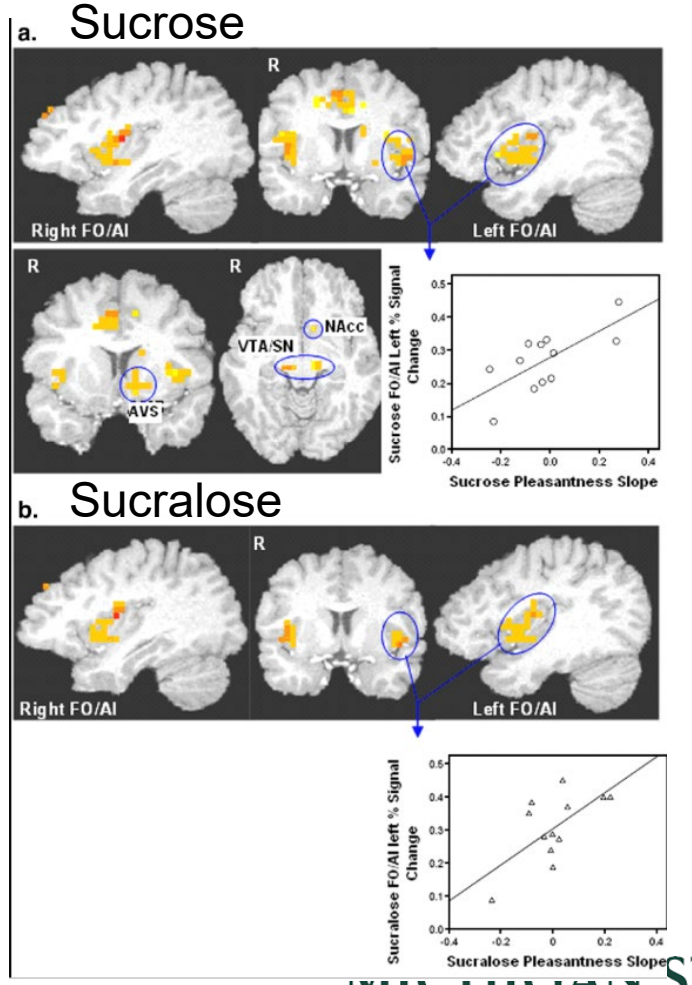
Research question: Does sleep curtailment alter sweet taste function or perception?

Secondary question: Do effects vary by sweetener?

- Sucrose vs. Sucralose (Splenda)
- Differential neural activation[1]
  - Authors concluded: “Sucrose relative to sucralose (Splenda) elicits greater absolute brain response in the taste pathway and downstream reward system….”



1. Frank et al., NeuroImage, 2008

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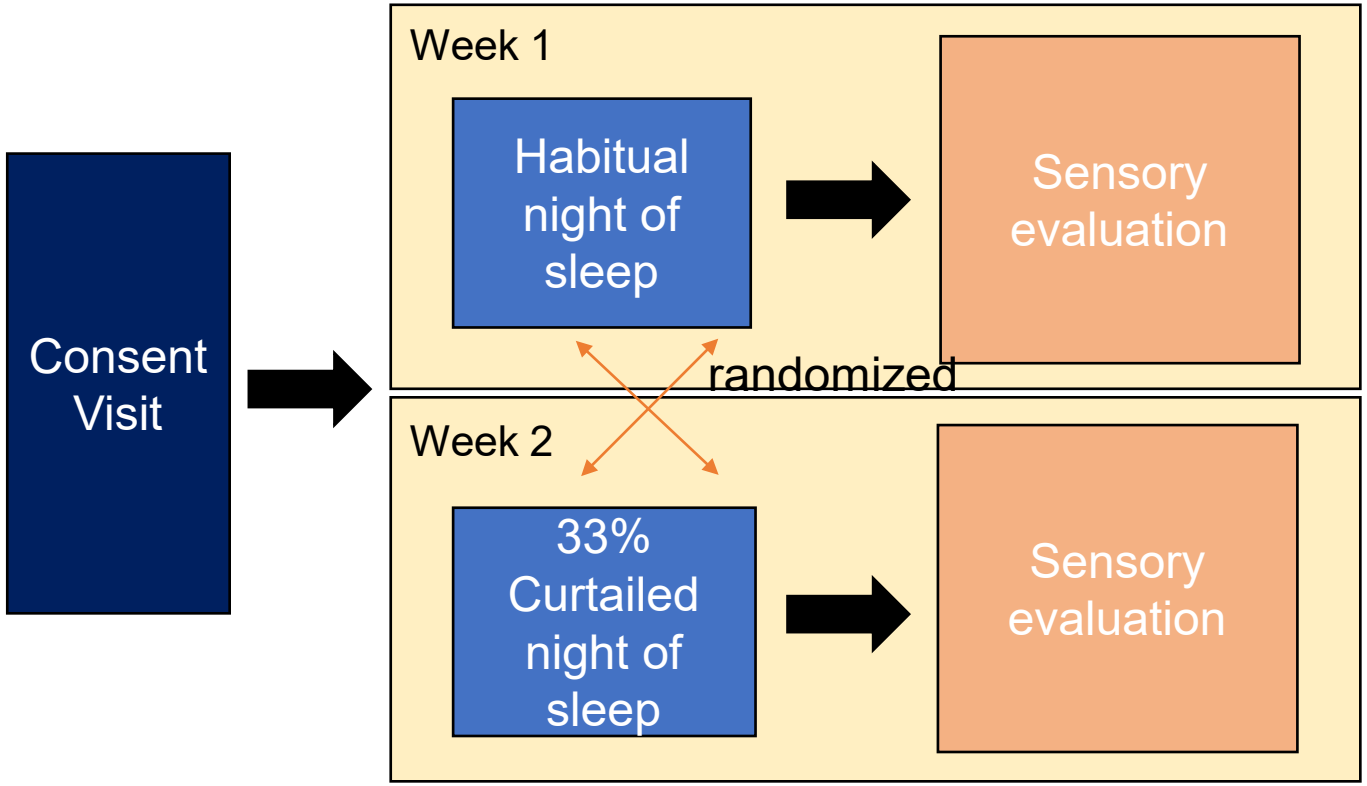
Assessed participants' response to sucrose and sucralose after a habitual and curtailed night of sleep



- Intensity
- Liking
- Preference

Szczygiel et al., Foods, 2019

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Sleep curtailment

- Curtailment: 33% reduction based on self-reported habitual sleep duration
  - Better ecological validity than total deprivation.[1]
    - Results in ~ 2-2.5 h reduction

1. Dinges, Sleep, 1987

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Healthy participants were recruited and sleep curtailment was effective

Anthropometric and Demographic Summary			
Sex		n	%
	Male	13	32%
	Female	27	67%
Race		n	%
	White	26	65%
	Asian	12	30%
	Other/More than 1	2	5%
Anthropometrics		Mean±SD	Range
	Body mass index (kg/m^2)	22.9±3.0	18.5-29.7
	Body fat (%)	22.3±7.9	9.9-35.5
	Age (y)	23.8±4.6	18-37

Summary of Objective Sleep Measures					
		Habitual	Curtailed	% Reduction	Paired t-test
Objective Sleep Measures (h)	Time in bed	8.2±0.7	5.3±0.7	35.3%	<0.0001
	Total sleep time	7.0±0.8	4.5±0.8	36.0%	<0.0001
	Light sleep	3.6±0.7	2.0±0.6	44.2%	<0.0001
	REM	1.9±0.5	1.1±0.3	40.4%	<0.0001
	Slow wave sleep	1.6±0.3	1.3±0.4	16.7%	0.0005

Szczygiel et al., Nutrients, 2019

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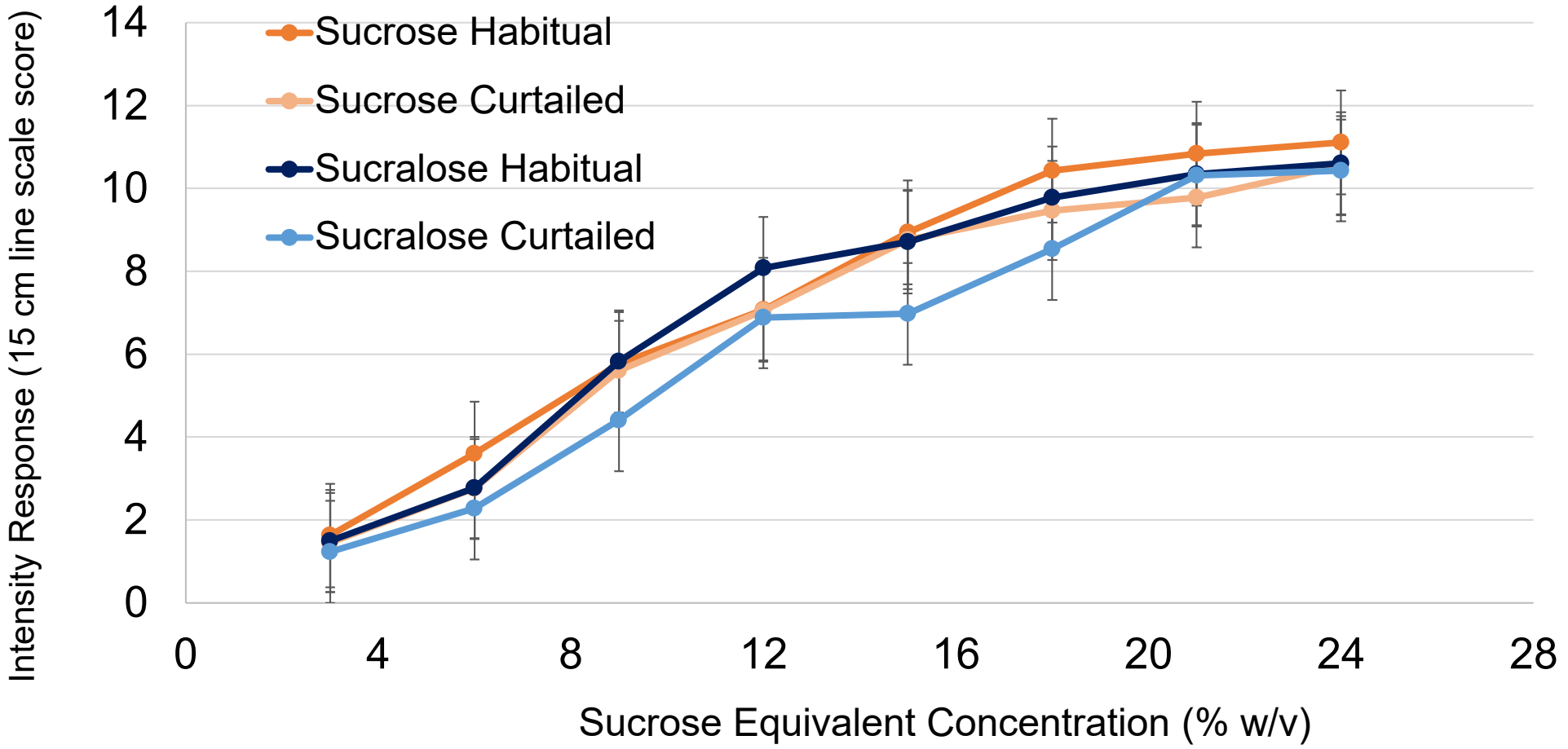
Intensity perception was not altered by sleep curtailment



Szczygiel et al., Nutrients, 2019

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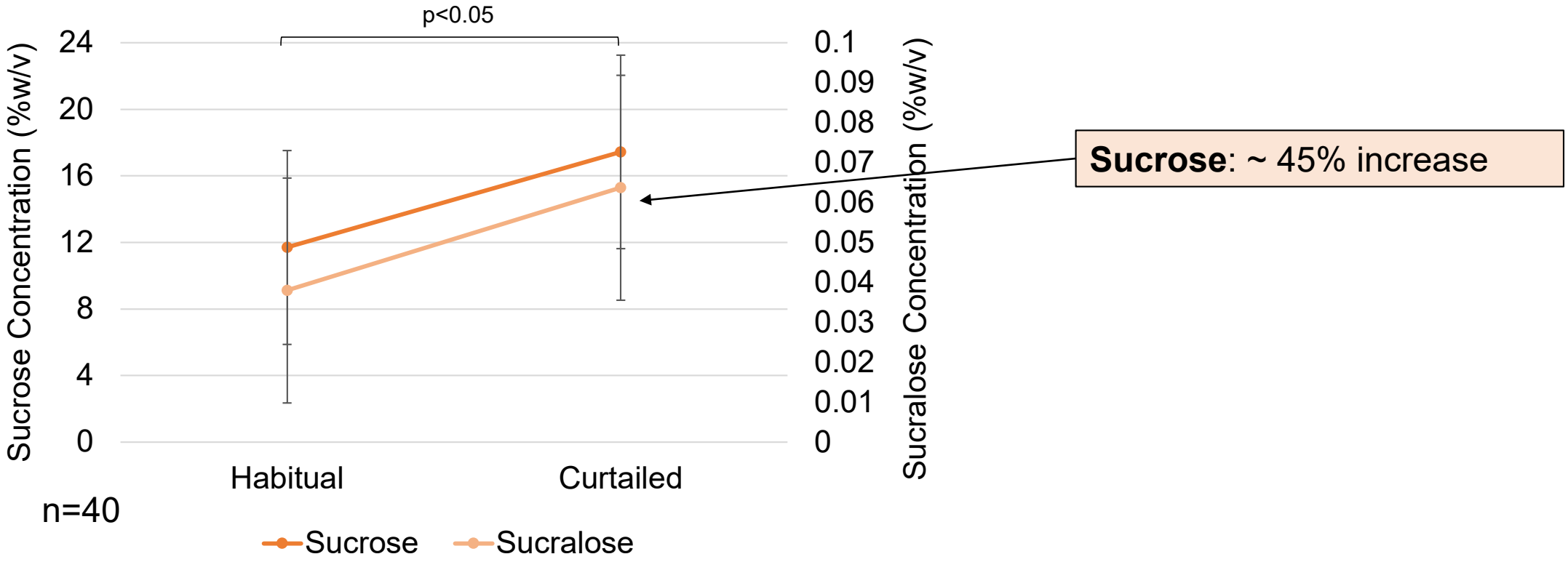
Preferred sweetness concentration increased after sleep curtailment



Szczygiel et al., Nutrients, 2019

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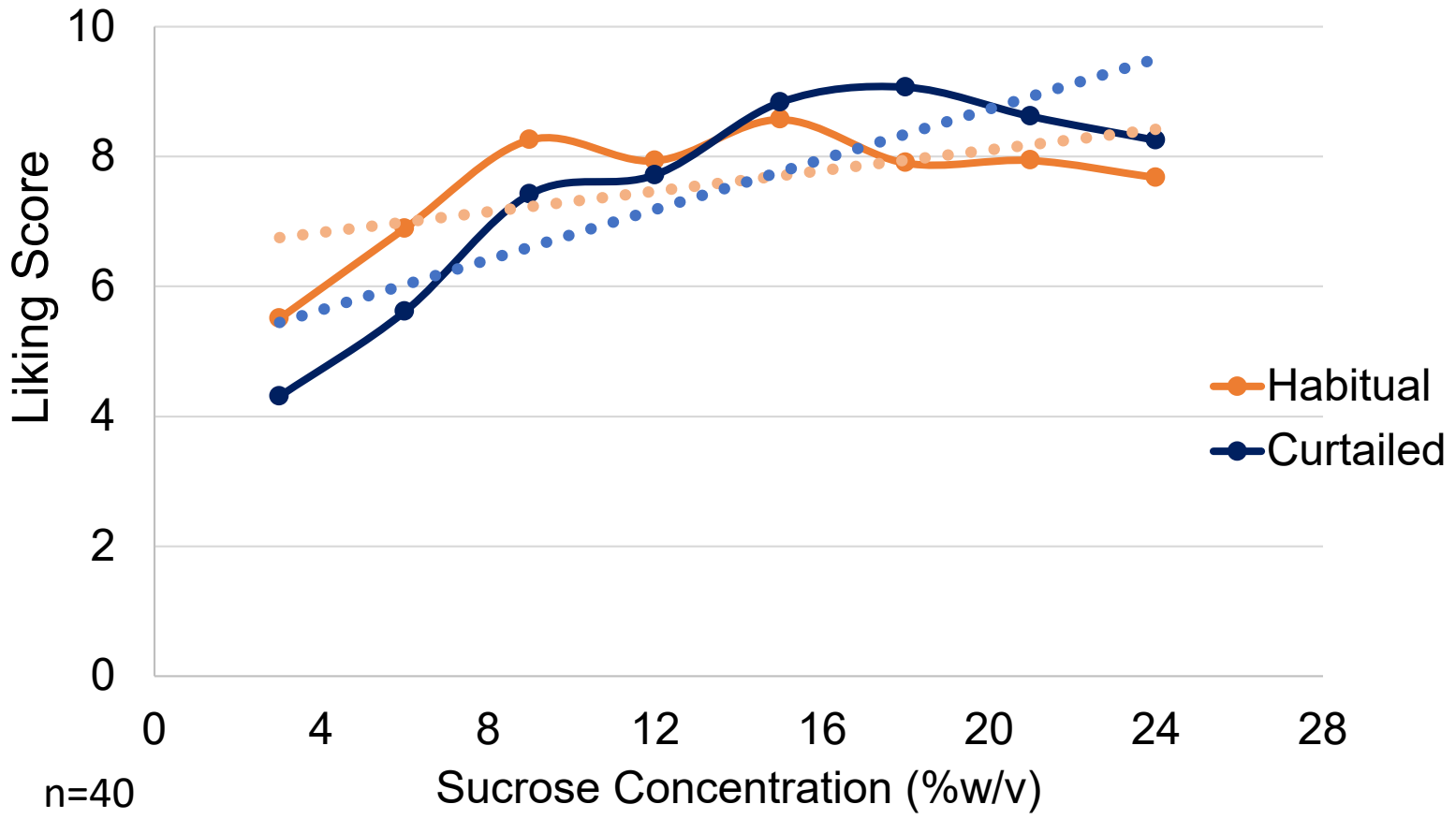
Patterns of liking of sucrose altered after sleep curtailment



No difference in liking at each concentration

Significant difference in slope steepness p=0.001

Szczygiel et al., Nutrients, 2019

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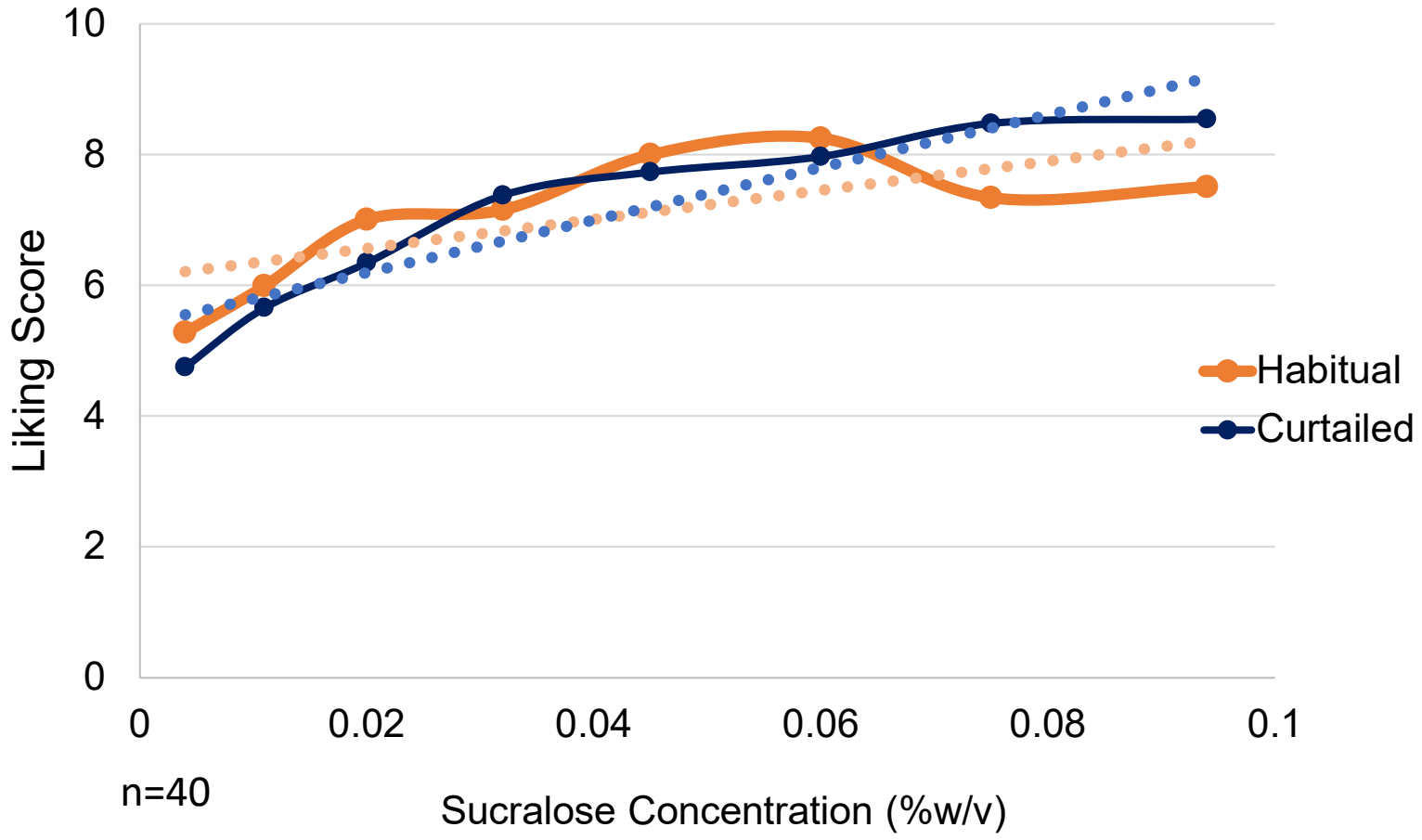
When sucralose is used, the increase in slope steepness after curtailment is smaller



No difference in liking at each concentration

Slope: reduced effect when sucralose is tasted p=0.129

Szczygiel et al., Nutrients, 2019

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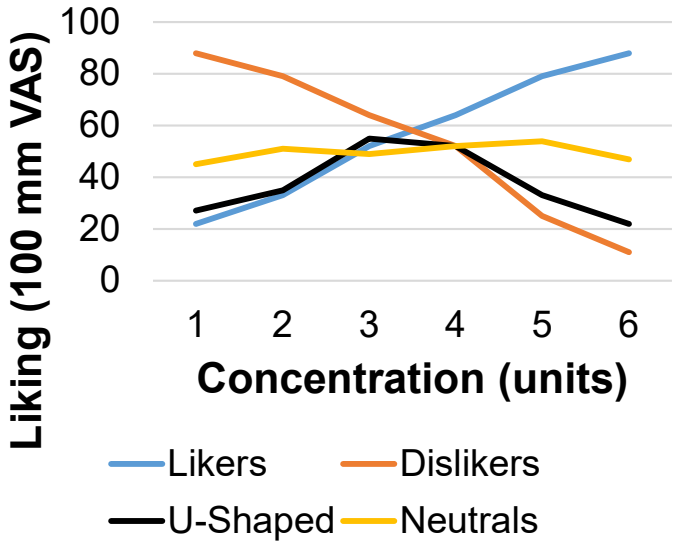
Sweet liking phenotypes → affected equally

- Insufficient sleep did not affect sweet likers and non-likers differently.
  - Everyone is susceptible to the effects of sleep curtailment.



To summarize…

Sleep curtailment resulted in…

Higher preferred sweetener concentration regardless of nutritive value

Increased liking for sweeter stimuli - sucrose (increased slope steepness)

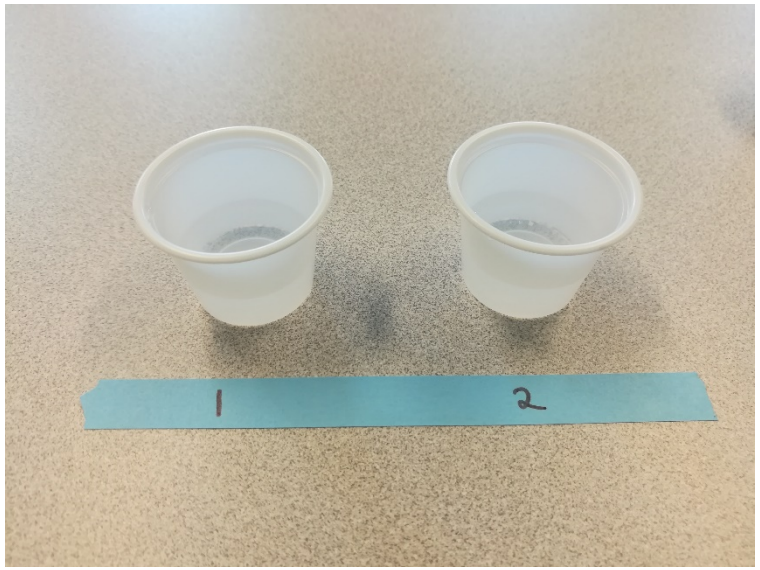
- Changes in hedonic evaluation of sucralose less susceptible to sleep curtailment?

No changes in sweet taste intensity perception

Szczygiel et al., Nutrients, 2019

How does sleep curtailment change food perception?

Model systems Vs. Complex Food



Research question: Do model system findings reflect hedonic response to complex foods? (Szczygiel, Cho, Tucker, Foods, 2019.)

Oat-based sweet food products were developed

Oat
Beverage

Oat
Crisp

Ingredients:
- Oats
- Sucralose
- Water

✓ Confirmed Delicious
(preliminary liking test n=20)

- Solids and liquids have different obesogenic capacity.[1]

1. Tucker & Mattes, 2013

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Oat-based food system

Sucralose Concentration →

Oat Crisp

Oat Beverage

Macronutrient Composition of Oat Products		
	Oat Beverage	Oat Crisp
Macronutrient	100 kcal	100 kcal
Fat	2 g	2 g
Carbohydrates	18 g	17 g
Protein	3 g	3 g
Crude Fiber	<1 g	<1 g
Moisture	189 g	1 g
Ash	<1 g	<1 g

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Why use sucralose in the oat products?

- Disadvantages
  - Observed lessened effect of sleep curtailment in previous study; bias towards type II error?

Advantages

- Controls for other sensory properties across sweetness levels
- Controls for energy across the products

Other reasons:

- Very commonly used sweetener
  - Most people exposed to sucralose daily in the developed world[1]
- Flavor is experienced through multiple modalities, so the hedonic response to taste is influenced by other sensations.

1. Binns et. al. 2003

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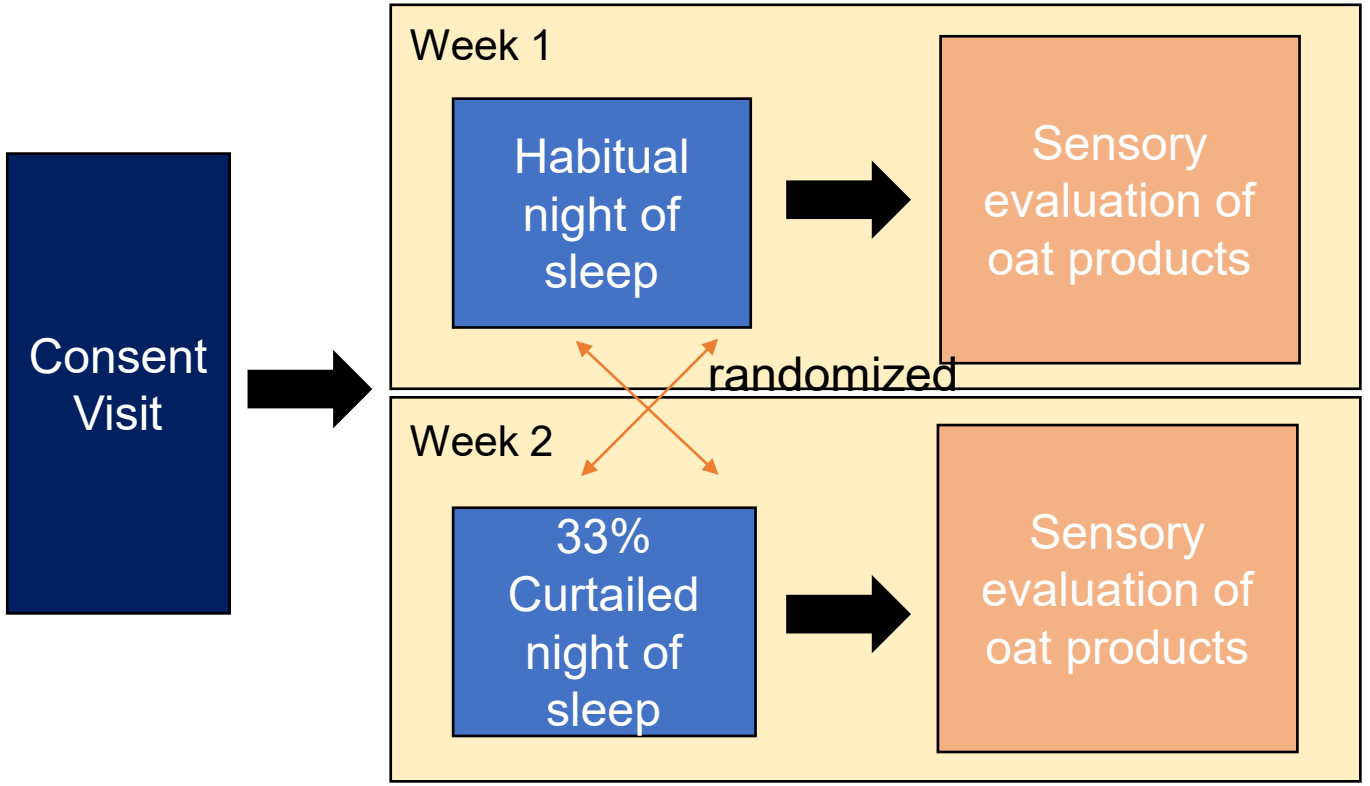
Assessed participants' response to oat products after a habitual and curtailed night of sleep



- Flavor Liking
- Overall Liking

Szczygiel et al., Foods, 2019

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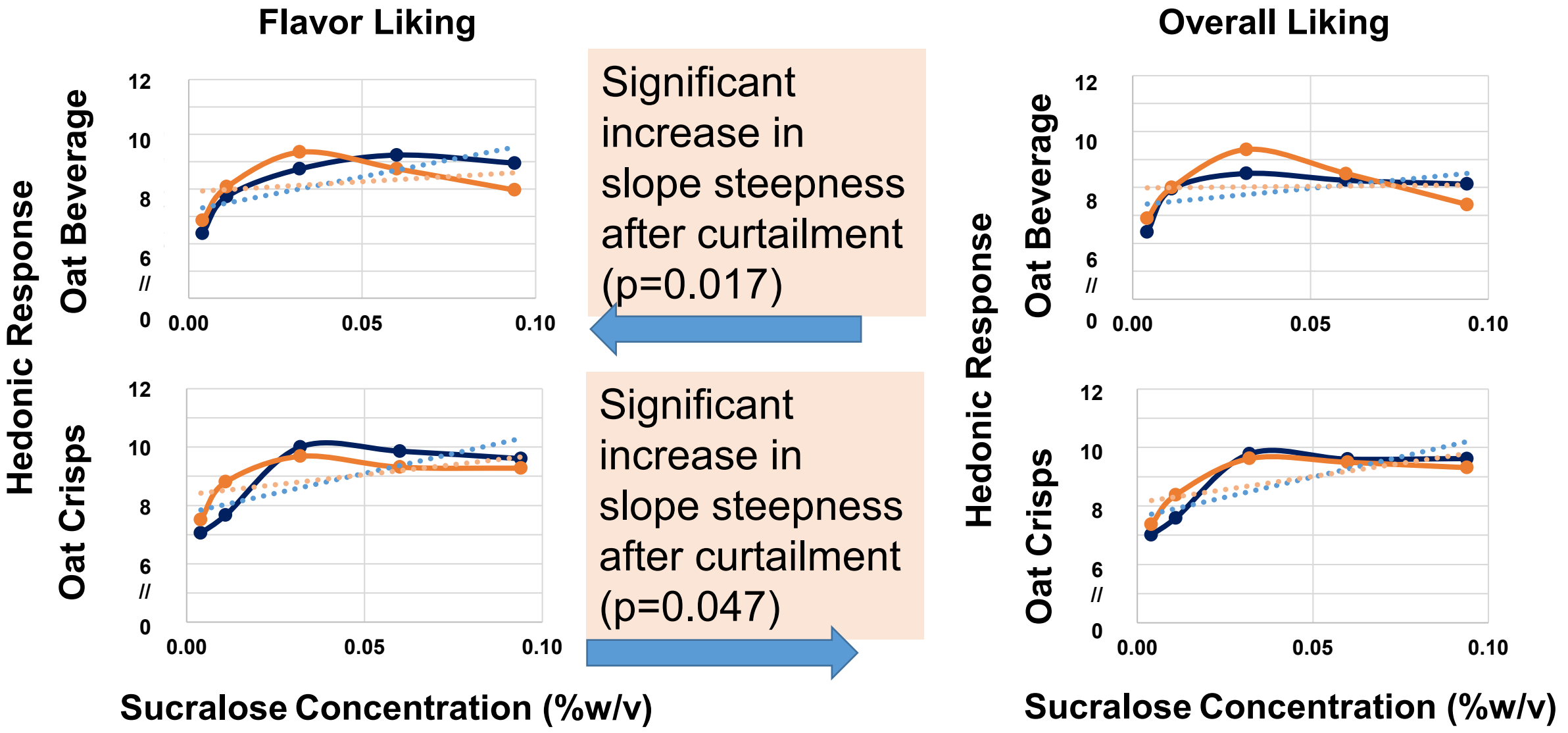
Healthy participants were recruited and sleep curtailment was effective

Anthropometric and Demographic Summary		
Sex	n	%
Male	15	37%
Female	26	63%
Race		
White	27	66%
Asian	13	32%
Other/More than 1	1	2%
Anthropometrics	Mean±SD	Range
BMI (kg/m^2)	23.1±3.0	16.4-29.2
BF (%)	24.8±11.8	9.1-35.5
Age (y)	24.1±5.0	18-41

Summary of Objective and Subjective Sleep Measures					
		Habitual	Curtailed	% Reduction	p-value
Objective Sleep Measures (h)	Time in Bed	8.3±0.7	5.4±0.7	34.90%	<0.001
	Total Sleep Time	7.2±0.7	4.5±1.0	37.50%	<0.001
	Light Sleep	3.8±0.5	2.0±0.8	47.40%	<0.001
	REM Sleep	1.9±0.5	1.2±0.4	36.90%	<0.001
	Slow Wave Sleep	1.5±0.4	1.4±0.4	6.70%	0.043[a]

Szczygiel et al., Foods, 2019



Szczygiel et al., Foods 2019

To summarize…

Sleep curtailment resulted in…

Increased **flavor** liking for sweeter versions of the two food products (increased slope steepness)

Increased **overall** liking for sweeter versions of the two food products (increased slope steepness)

Likely to see even larger changes if sucrose were used?

Sleep, hunger, & food reward

- Increased intake of high fat, high sugar foods after insufficient sleep[1-3]
- Research question: Does sleep curtailment affect appetite, food reward, and/or food cravings?

1. Nedeltcheva et al., Am J Clin Nutr, 2009; 2. Calvin et al, Chest, 2013; 3. Weiss et al., Sleep, 2010

Sleep, hunger, & food reward

- Females without obesity
- Two test visits
  - Habitual night's sleep
  - Curtailed night's sleep (33% reduction → ~ 2-2.5 h reduction)
- Same breakfast was consumed at the same time both days
- Came into the lab at the same time both days
- Appetite: rated how hungry they were – 100 mm VAS
- Cravings: General Food Cravings Questionnaire – State version
- Food reward: progressive ratio task where they could work for chocolate candy

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Demographics

- N = 24

Variable	Mean ± SD
Age (year)	24.4 ± 7.2
BMI (kg/m^2)	22.1 ± 2.6
Body fat (%)	25.8 ± 6.7
PSQI*	3.1 ± 1.1
	%
Race (%)	
White	75.0
Asian	25.0
Ethnicity (%)	
Non-Hispanic	95.8
Prefer not to answer	4.2

*PSQI, Pittsburgh Sleep Quality Index.

Yang et al., Nutrients, 2019

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Results: Sleep and Hunger

Sleep parameters from Z-machine

Sleep parameter (h)	Habitual sleep	Curtailed sleep	p-value
Time in bed	8.19 ± 0.66	5.45 ± 0.56	<0.001*
Total sleep time	7.03 ± 0.96	4.60 ± 0.72	<0.001*
Slow wave/N3 sleep	1.49 ± 0.41	1.15 ± 0.41	<0.001*
REM sleep	2.03 ± 0.74	1.30 ± 0.48	<0.001*

34.3% reduction

Effects of curtailed sleep on self-reported sleepiness, tiredness, quality of sleep, and hunger

	Habitual sleep	Curtailed sleep	p-value
Sleepiness	2.8 ± 1.3	4.9 ± 1.9	<0.001*
Tiredness	24.8 ± 16.2	58.5 ± 15.3	<0.001*
Quality of sleep	55.2 ± 17.2	43.0 ± 17.0	0.030*
Hunger	53.7 ± 16.9	60.8 ± 15.7	0.013*

Data expressed as: Mean ± SD.

Yang et al., Nutrients, 2019

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Results: Cravings

Differences in G-FCQ-S after normal and curtailed sleep night

Factor *(max score for each factor = 15)*	**Normal sleep**	**Curtailed sleep**	**p-value**
An intense desire to eat	9.5 ± 2.3	11.0 ± 1.9	0.009*
• *I'm craving tasty food.*			
Anticipation of relief from negative states and feelings as a result of eating	9.7 ± 2.3	11.1 ± 2.1	0.008*
• *If I ate something, I wouldn't feel so sluggish and lethargic.*			
Craving as a physiological state	9.9 ± 1.5	11.2 ± 1.8	0.009*
• *If I ate right now, my stomach wouldn't feel as empty.*			
Obsessive preoccupation with food or lack of control over eating	6.3 ± 2.4	7.7 ± 2.5	0.022*
• *My desire to eat something tasty feels overpowering.*			
Anticipation of positive reinforcement that may result from eating	10.0 ± 2.2	10.6 ± 1.9	0.236
• *Eating something tasty would make things just perfect.*			
Total score	45.5 ± 8.4	51.5 ± 7.4	0.002*

Data expressed as: Mean ± SD.
G-FCQ-S, General Food Cravings Questionnaire-State.

Food Reward: *Number of chocolate candies consumed increased (2.6 ± 0.9 vs. 3.3 ± 1.5, p = 0.004) under the curtailed sleep condition.

Yang et al., Nutrients, 2019

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Conclusions

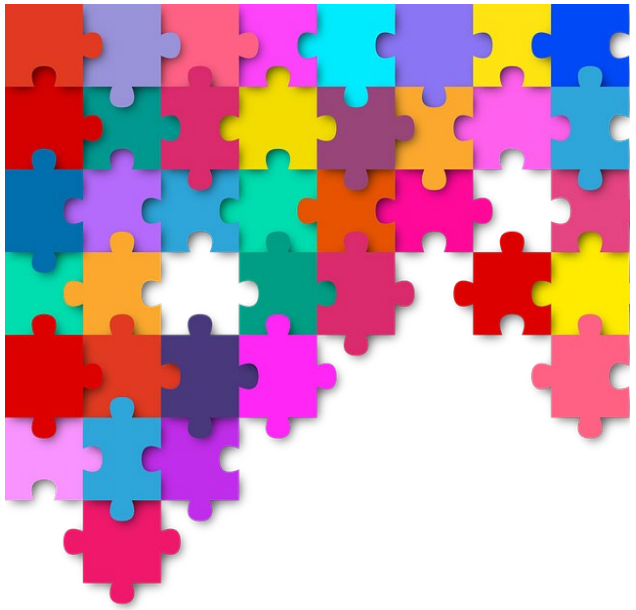
- Increased hunger, cravings, and food reward (willingness to work for palatable food) after **one** night of moderate sleep curtailment.
- All of these can contribute to increased intake.

Future directions

- Are the relationships observed present among people with obesity?
  - Individuals with obesity frequently sleep less and report lower sleep quality.
- Chronically short sleepers?
- Other taste qualities: salty
  - Does preferred salt concentration increase?

Summary

- 3-4 patterns of sweet liking.
  - Sweet likers tend to consume more sugar and sugar sweetened beverages.
  - Useful to separate consumers?
- Strong epidemiological and experimental evidence to suggest insufficient sleep increases the risk of weight gain and higher BMI.
  - Numerous mechanisms – including changes in hedonic processing, appetite, food reward, and food cravings.
- These changes in perception are likely part of the puzzle that explains relationships between insufficient sleep and alterations in food choice.



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