VALIDATING A GRAPH THEORETIC APPROACH TO SENSORY SCIENCE PROBLEMS

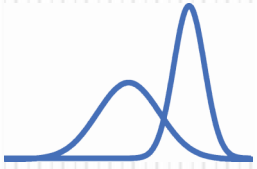
Michael A. Nestrud (1)
John M. Ennis (2)
Charles M. Fayle (2)
Danny M. Ennis (2)
Harry T. Lawless (1)

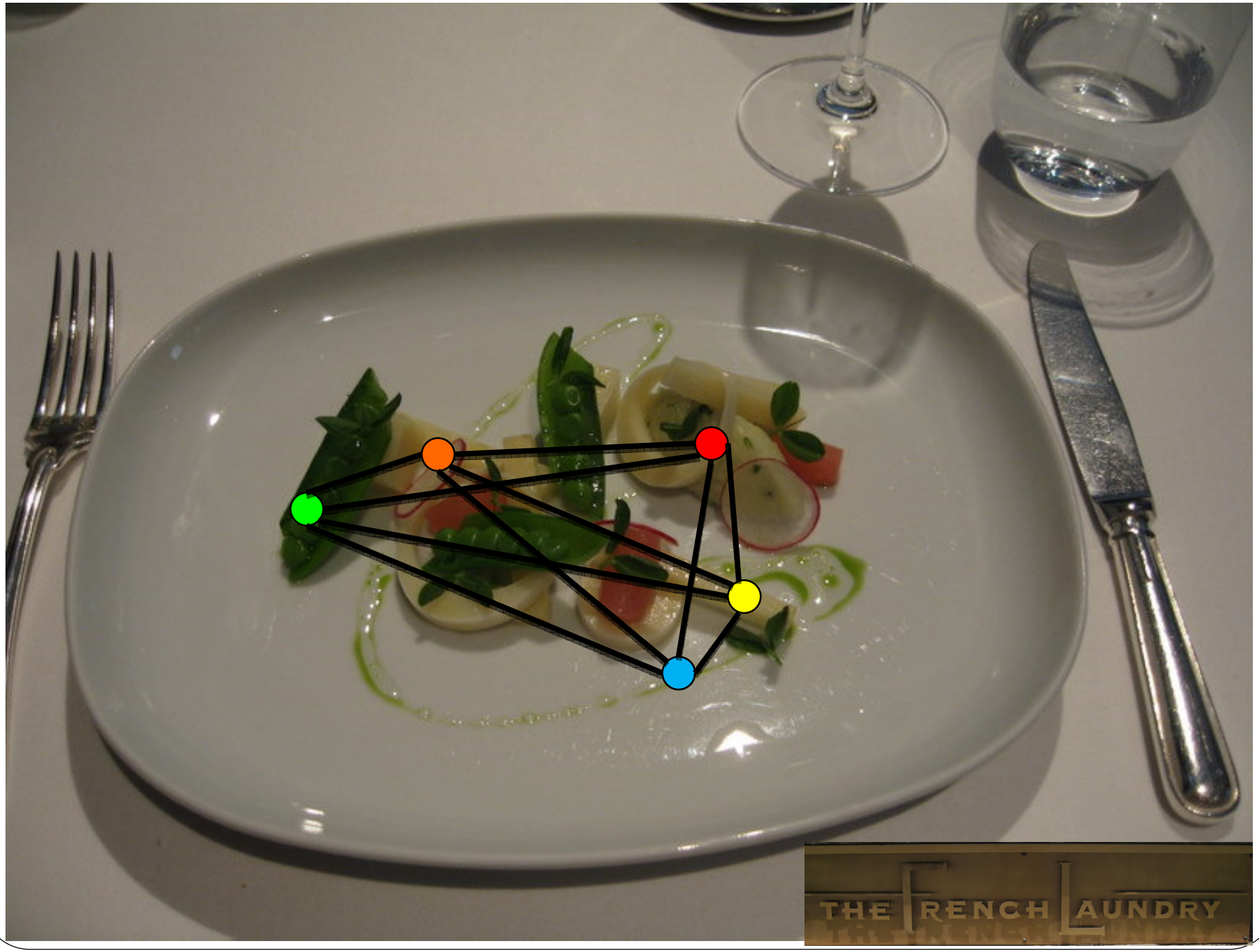
(1) Cornell University Department of Food Science

The Institute for Perception



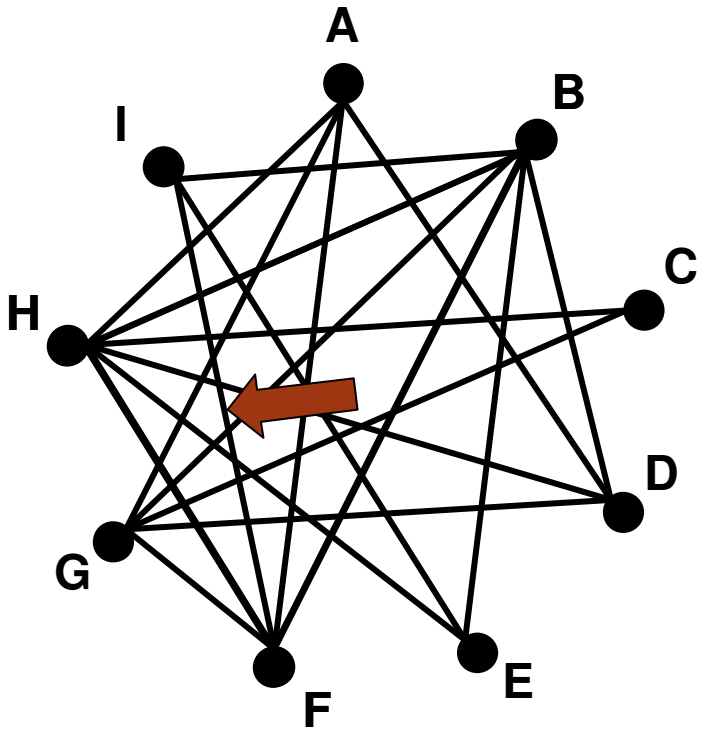
Cornell University
Department of Food Science




THE FRENCH LAUNDRY

Compatibility and Graph Theory

	Item A	Item B	Item C	Item D	Item E	Item F	Item G	Item H	Item I
Item A									
Item B	0								
Item C	0	0							
Item D	1	1	1						
Item E	0	1	0	0					
Item F	1	1	0	0	0				
Item G	1	1	1	1	0	1			
Item H	1	1	1	1	1	1	0		
Item I	0	1	0	1	1	1	0	0	



Supercombinatorality of Individual responses



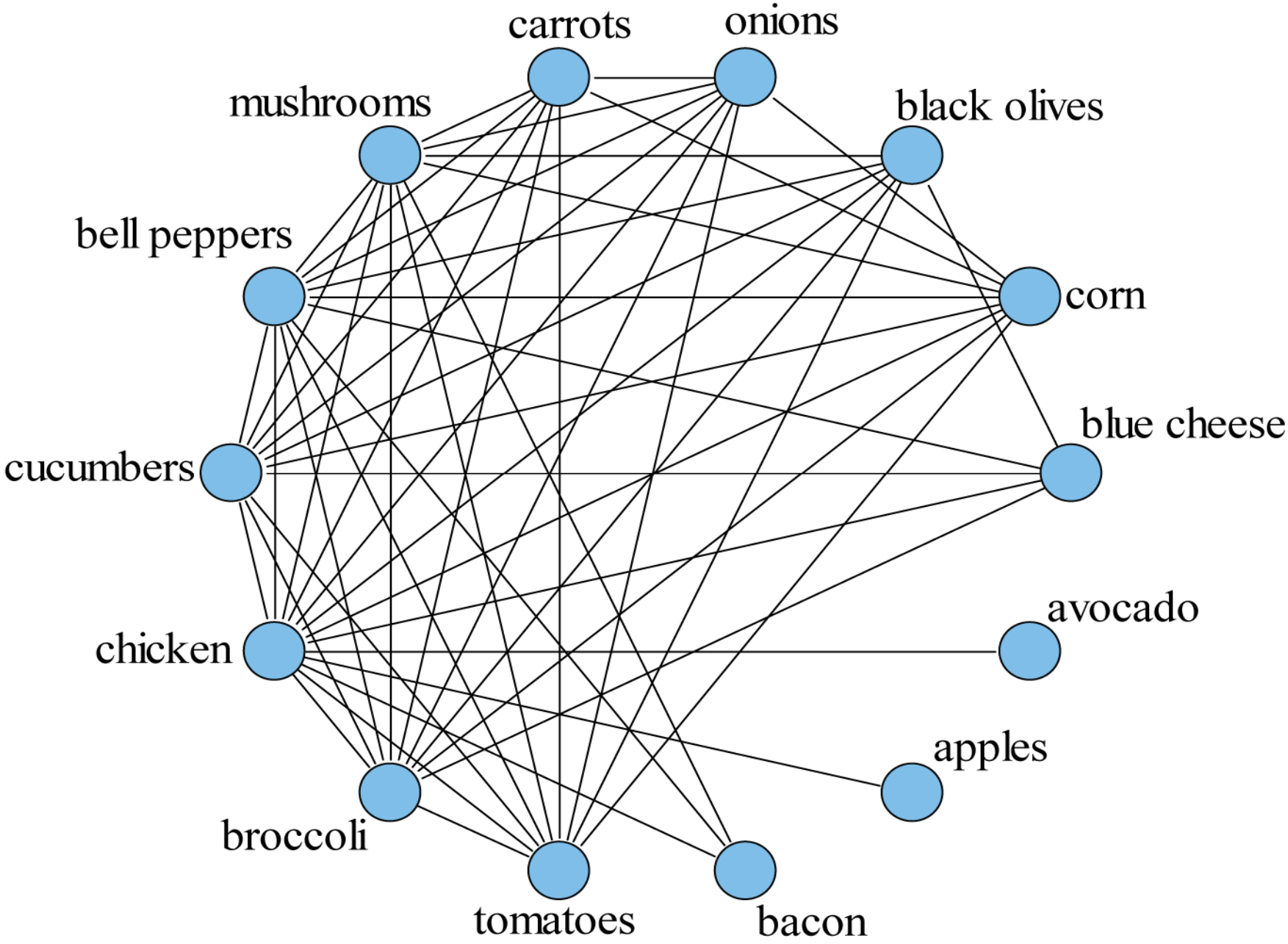
Salad Questionnaire

- 1) Gather list of “top 25” salad ingredients from consumers
- 2) Ask subjects whether they would like each ingredient from the top 25 list on a salad.
- 3) Using results from (2), ask subjects about all possible pairs.
- 4) Predict combinations of 3-8 ingredients (cliques), and ask subjects whether they would like these salads.
- 5) Compare (4) to random non-cliques of equivalent sizes.

Example: Subject 1

- Chose 15 ingredients as suitable for a salad under any circumstance
- Next part of task was to respond re: compatibility of all 105 combination pairs (15 * 14)/2

Corn & Chicken	TRUE
Carrots and Cucumbers	TRUE
Corn and Cucumbers	TRUE
Cucumbers and Avocado	FALSE
Broccoli and Carrots	TRUE
Apples and Blue Cheese	FALSE
Apples and Black Olives	FALSE
Chicken and Mushrooms	TRUE


carrots
onions
mushrooms
black olives
bell peppers
corn
blue cheese
cucumbers
avocado
chicken
apples
broccoli
tomatoes
bacon

SIZE	CLIQUE	ITEMS	RESPONSE
8	TRUE	Corn, tomato, broccoli, chicken, bell peppers, mushrooms, carrots, onions	TRUE
8	FALSE	Blue cheese, bacon, tomatoes, carrots, apples, mushrooms, broccoli, sunflower seeds	FALSE
4	TRUE	Chicken, bacon, mushrooms, bell peppers	TRUE
4	FALSE	Cucumbers, onions, corn, black olives	FALSE

Analysis

- Wilcoxon Matched Pairs Signed Rank Test on counts of compatible cliques vs. non cliques per clique size and total.
- Non-parametric equivalent of a paired t-test
- Ho: ∑(positive differences) = ∑(negative differences)
- Ha: ∑(positive differences) ≠ ∑(negative differences)

```
> sumsummary[sumsummary$size==3,c(1,2,7,10)]
    panelist size cncliq TCLIQ
31         6    3      0     0
61        11    3      0     0
73        13    3      1     3
85        15    3      1     2
97        17    3      1     0
```

Results

Clique Size	p value	Direction +=clique
3	0.025	+
4	0.023	+
5	0.016	+
6	< 0.001	+
7	0.006	+
8	< 0.001	+
ALL	< 0.001	+

- For all clique sizes, predicted combinations fared better than random combinations.
- Remember, all ingredients tested were well liked in salads!
- Supercombinatorality is a real effect.

How big is the improvement?

- Wilcox test again, Clique Size 8
- On **proportions** instead of counts
- $p < 0.0001$
- Median = 0.420
- 95% CI: [0.35, 0.50]

Thus, on average, predicted combinations have a **42% greater chance** of being accepted than random combinations.

(Absolute P for predicted in this case, about 80%)

Related research

Supercombinatorality of Group Responses

- Combine individual responses together
- Develop “group” triangular matrix
- Predict combinations, validate

Army Ration Menu Optimization



Photo by Ashley Gilbertson / VII Network

Summary

- For 25 ingredients, there are 1,807,755 potential combinations of 2-8 ingredients.
- Combinatorial approach could provide a reasonable shortcut for screening all possible combinations
- Consumer data oriented
- **Individual supercombinatorality assumption holds up under scrutiny**

Contacts

Michael A. Nestrud
Cornell University
Department of Food Science
mike@ataraxis.org
Phone: 209-736-7679

Dr. John M. Ennis
The Institute for Perception
john.m.ennis@ifpress.com
Phone: 804-675-2980



