



Multi-Attribute Time Intensity (MATI) Texture Breakdown Path Study of Fruit Chews

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RESEARCH & DEVELOPMENT



Background Challenge *Functional Fruit Chews*

Both flavor and texture are concerns, however, primary focus in this study is on texture during chew down of the fruit chews.

- Chews
  - a healthy snack
- Functional Ingredients
  - Organically grown superfruits
  - Taste challenge – *sour and bitter*
  - Texture challenge – *chalky, fibrous, gritty particulates*

MATI offers advantages for studying the Texture Breakdown Path.

Traditional Time-Intensity

- Single attribute at a time
- Continuous measurement
- One sequence/run

- Advantages
  - Thorough evaluation for a single attribute
  - Consistent attention by panelist to one attribute
- Disadvantages
  - Time-intensive
  - Other options

Multi-Attribute Time Intensity

- Multiple attributes
- Intermittent measurement
- Repeated cycles through attributes—at paced rate

- Advantages
  - Rapid collection - multiple attributes
  - Controlled prompting for attributes
  - Ability to capture events over time

- Disadvantages
  - Limited data and 'missed' moments
  - Experience required

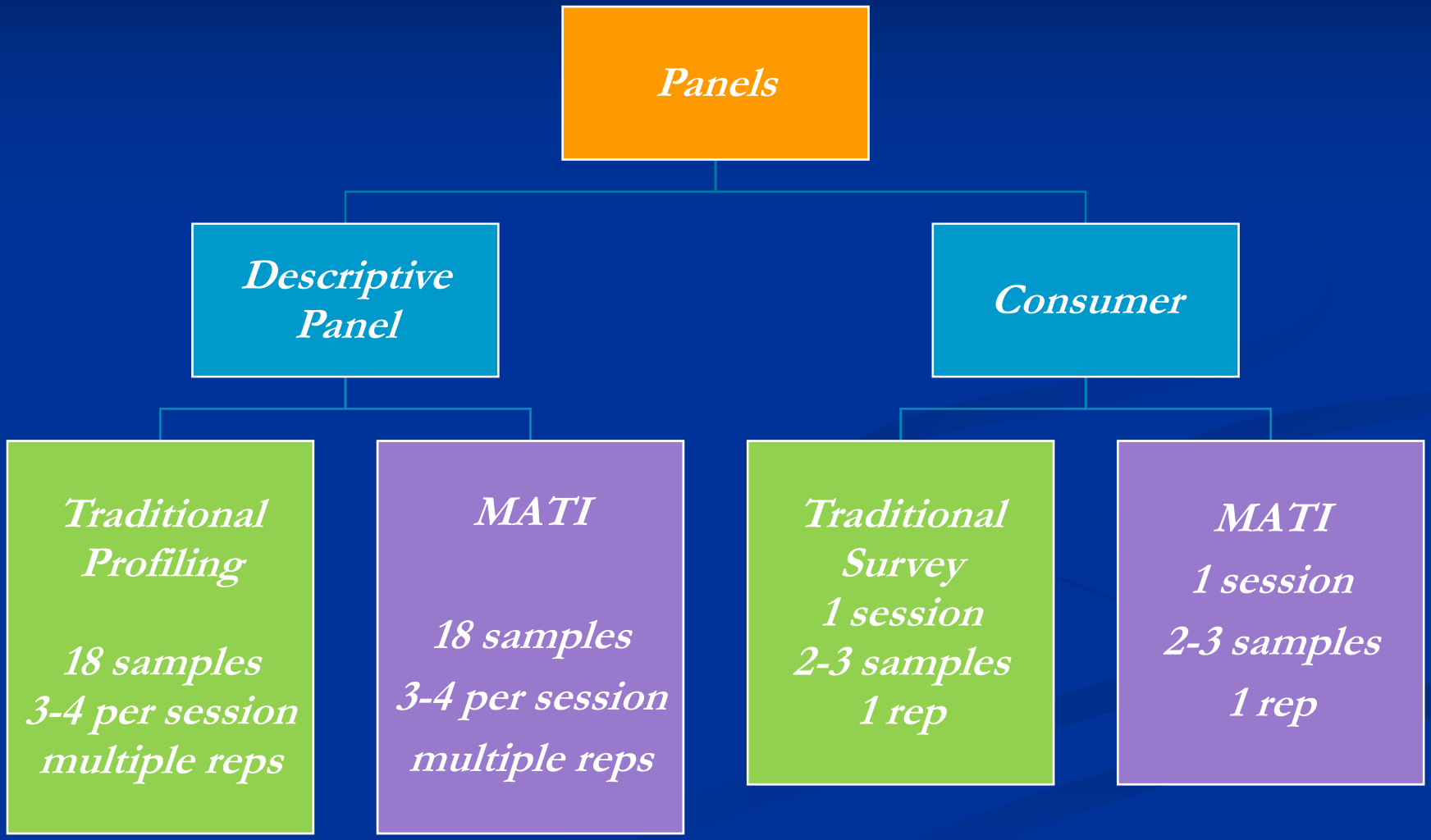
Hutchings and Lillford (1988) in their Discussion Paper on
THE PERCEPTION OF FOOD TEXTURE-THE PHILOSOPHY OF THE BREAKDOWN PATH
emphasizes that ***texture perception is a dynamic sensory monitor of changes made to a food***

and postulates a general three dimensional model using "Degree of Structure", "Degree of Lubrication" and "Time"

Objectives MATI

- Method Objectives
  - Explore capture of responses using a computerized Access Visual Basic program that 'paces' respondents through multiple attributes and cycles throughout the Texture Breakdown Path
    - Continuous line scale attributes
    - Dynamic Temporal CATA
  - Assess enhanced MATI approach with Temporal CATA
  - Compare and contrast
    - Trained descriptive panelists (MATI vs. traditional profiling)
    - Adult consumers (MATI vs. traditional survey)
  - Expand analytics applied to MATI data
- Product Objectives
  - Relate descriptive and consumer results to understand consumer liking as a function of descriptive attributes throughout consumption experience
  - Guide flavor and texture optimization for functional fruit chews

Methodology Panels *MATI*



Methodology Samples *MATI*

Number	Code	Flavor	Example
1	125	chocolate	
2	194	cherry	
3	305	multi-fruit	
4	311	multi-fruit	**P1**
5	319	cherry	
6	425	berry	
7	491	chocolate	
8	498	cherry	**C1**
9	550	multi-fruit	**P2**
10	582	cherry	
11	608	cherry	
12	672	multi-fruit	
13	691	berry	
14	726	chocolate	**C2**
15	773	multi-fruit	
16	892	cherry	
17	924	multi-fruit	
18	938	berry	

For this study presentation, focus will be on 4 samples:

#C1 -- Cherry Chew Candy
#C2 -- Chocolate Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

Methodology Descriptive Panel Scorecard *Traditional Profiling*

Flavor Attributes	Descriptors Recorded			
Aroma and Flavor				
Overall Aroma Intensity	✓	None	⟷	Strong
Overall Flavor Intensity	✓	None	⟷	Strong
Identifying Flavor Intensity	✓	None	⟷	Strong
Overall Fruit	✓	None	⟷	Strong
Sweet Aromatics	✓	None	⟷	Strong
Balance/Blend		Unblended	⟷	Blended
Sweet		None	⟷	Strong
Sour		None	⟷	Strong
Salty		None	⟷	Strong
Bitter		None	⟷	Strong
Overall Off-notes	✓	None	⟷	Strong
Aftertaste				
15 Sec Aftertaste	✓	None	⟷	Strong

Scale

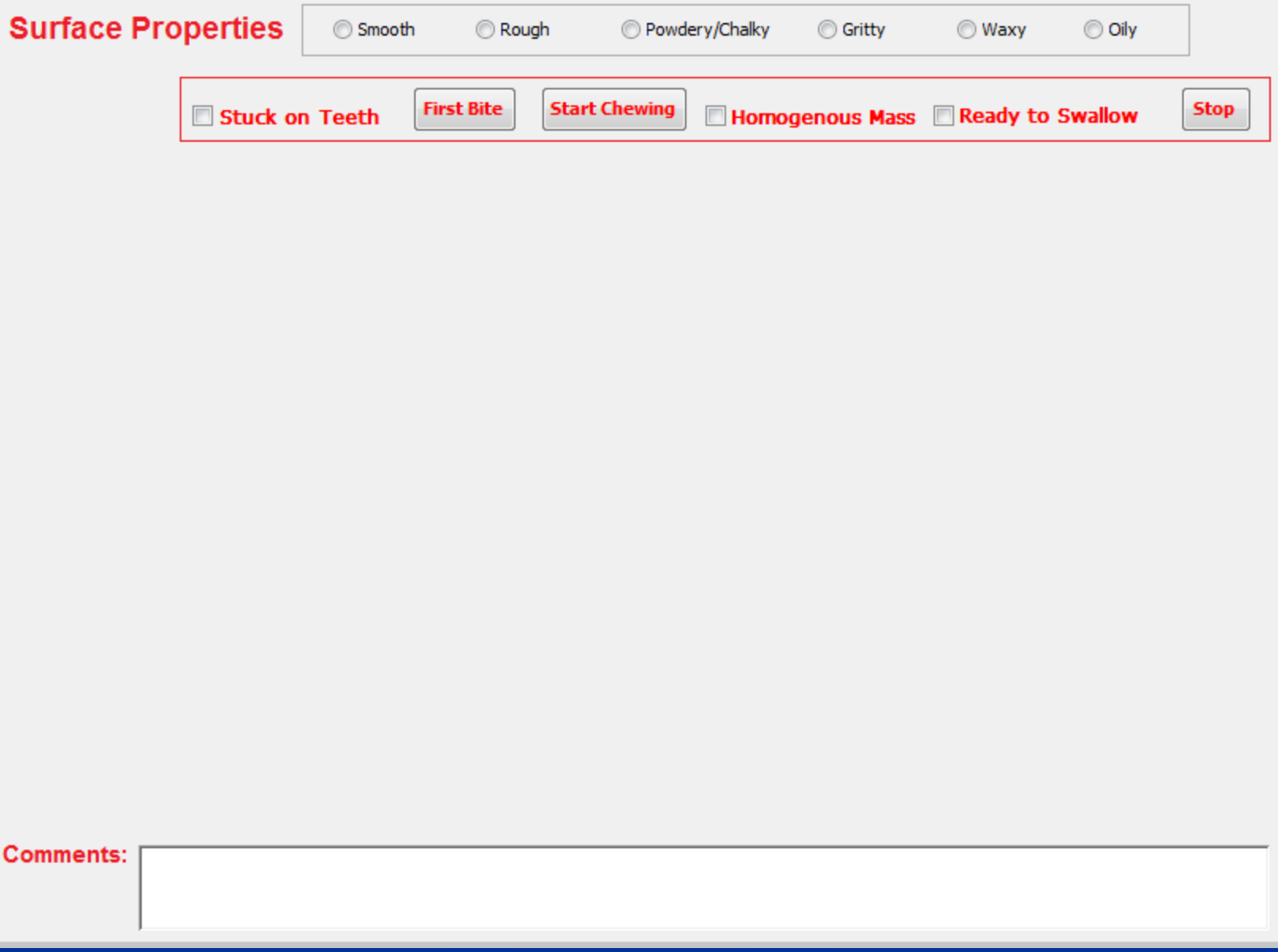
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Texture Attributes			
Surface Properties			
Roughness	Less	⟷	More
First Bite			
Hardness	Less	⟷	More
Adhesiveness	Less	⟷	More
Cohesiveness	Less	⟷	More
Fracturability	Less	⟷	More
Chew Down			
Dissolvability	Less	⟷	More
Adhesiveness	Less	⟷	More
Cohesiveness of Mass	Less	⟷	More
Moistness of Mass	Less	⟷	More
Roughness of Mass	Less	⟷	More
Particle Size	Smaller	⟷	Bigger
Amount of grit	Less	⟷	More
Residual			
Toothpack/Toothstick	Less	⟷	More
Loose Particles	Less	⟷	More
Chalky Mouthcoat	Less	⟷	More
Oily Mouthcoat	Less	⟷	More

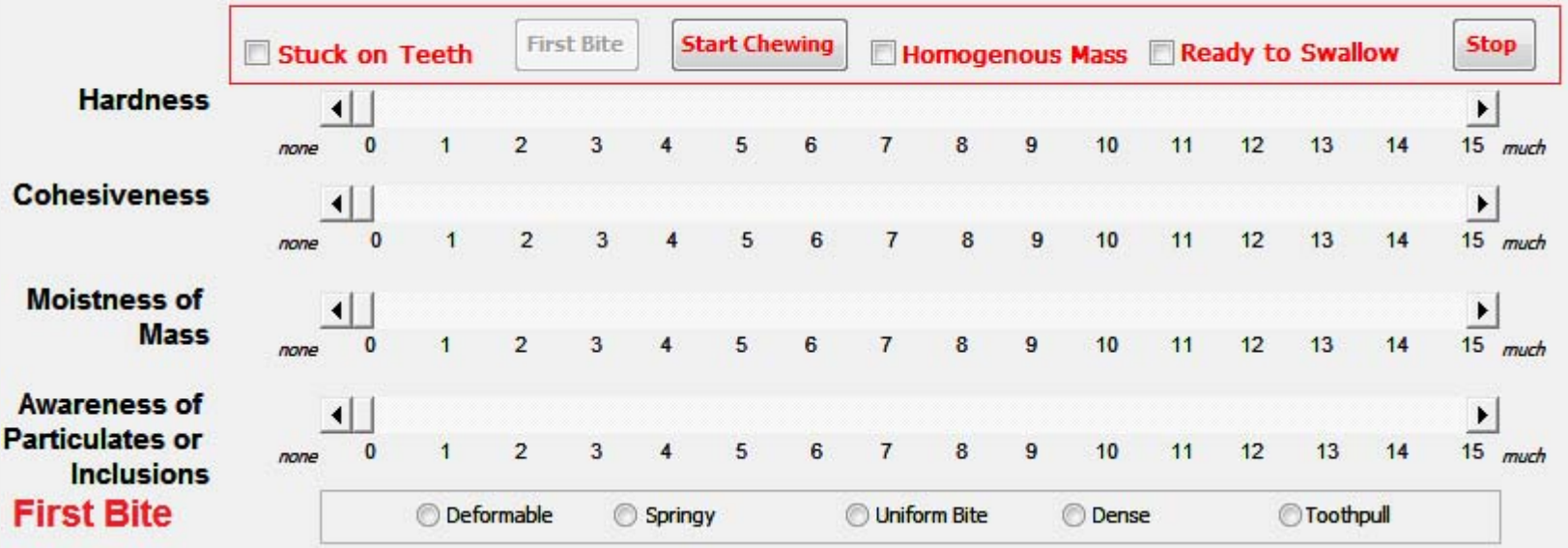
Methodology Descriptive Panel Scorecard *MATI*

Stage	Line Scale 0-150 point	CATA						Timer
Surface Properties		Smooth	Rough	Powdery/Chalky	Gritty	Waxy	Oily	
First Bite	Hardness	Deformable	Springy	Uniform Bite	Dense	Toothpull		**FREE**
	Cohesiveness							
	Moistness of Mass							
	Awareness of Particulates							
Chew Down		Fruit	Sweet	Sour	Bitter	Off-Notes		**START**
Break Down		Fruit	Sweet	Sour	Bitter	Off-Notes		
								END
Swallow	Moistness of Mass	Smooth	Rough	Thin	Thick	Throat Irritation		**START**
	Loose Particles							
Residual (60 seconds)		Astringent	Powdery/Chalky	Gritty	Waxy	Oily		
								END

Methodology Descriptive Panel Data Collection *MATI Demo*



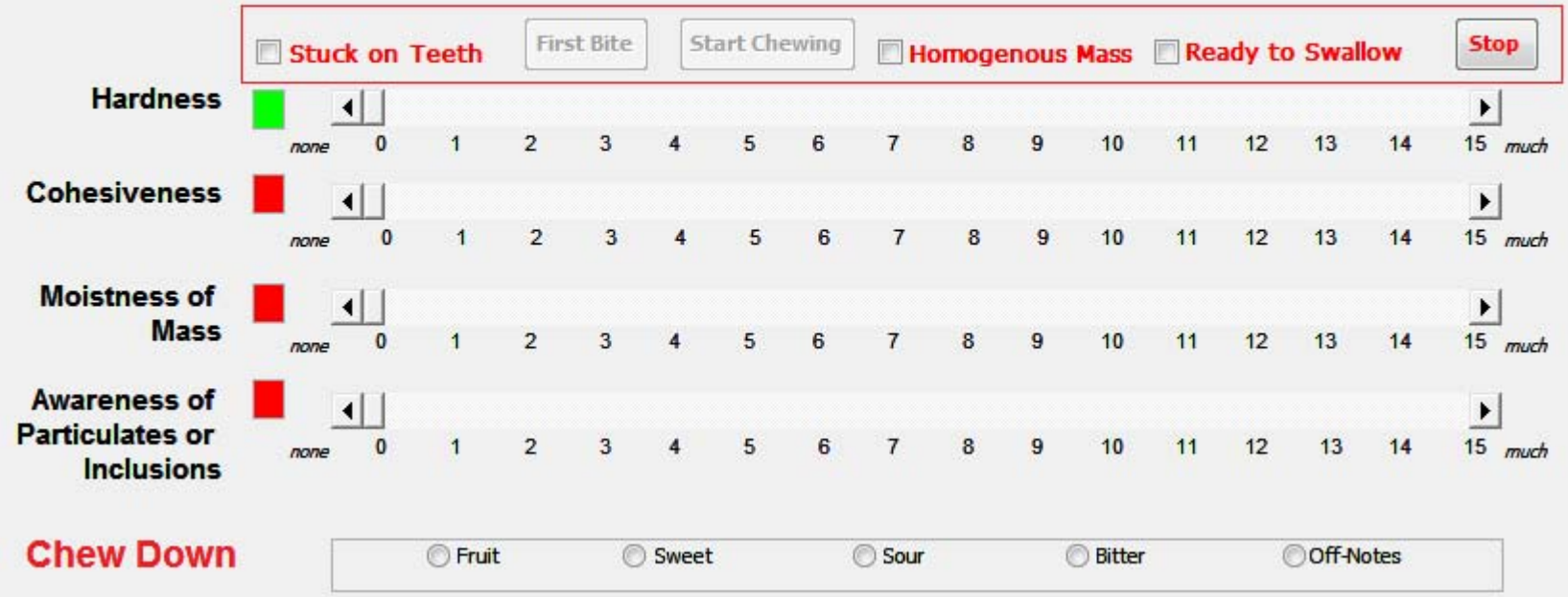
Methodology Descriptive Panel Data Collection *MATI Demo*



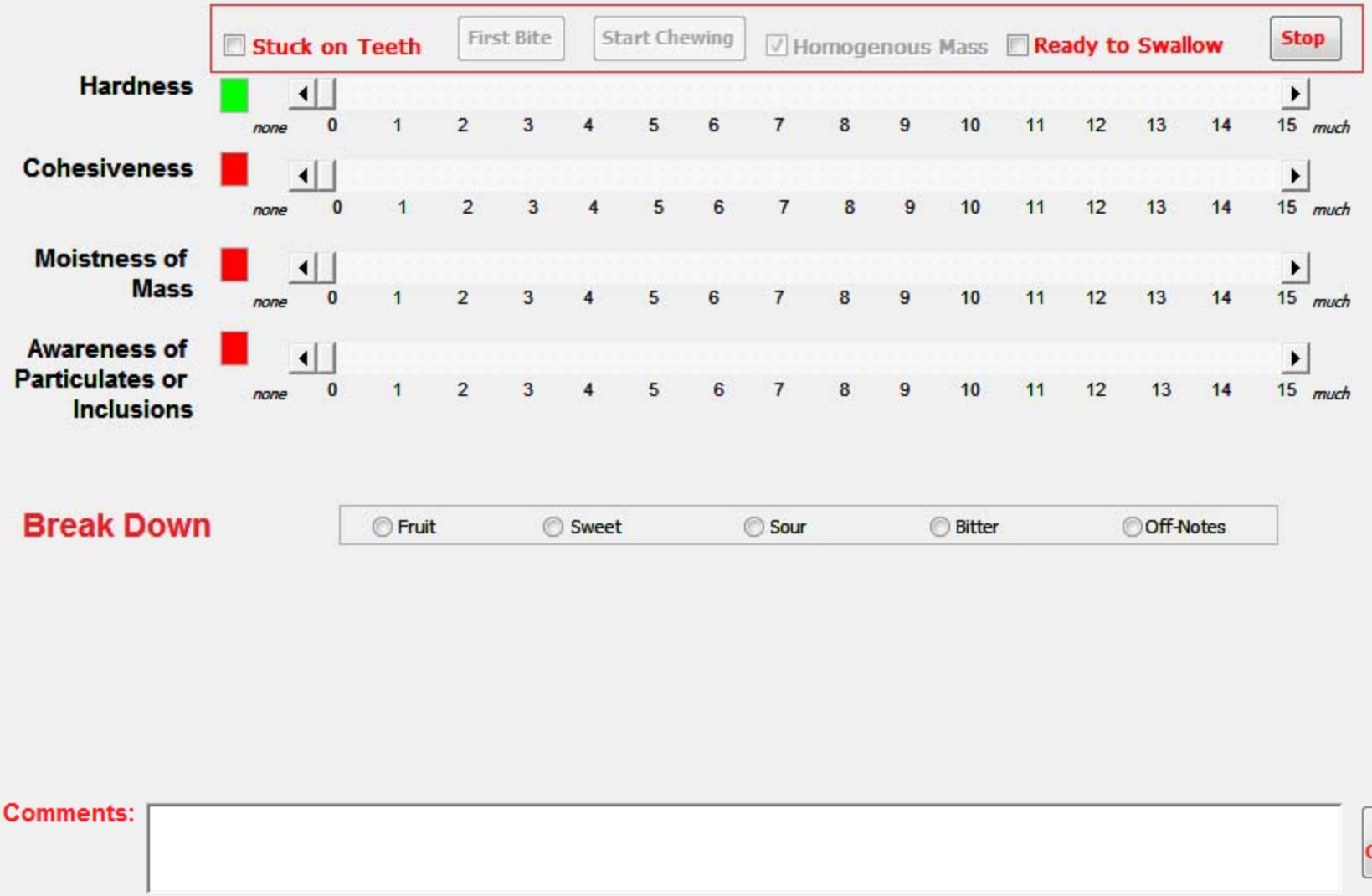
Comments:

Enter Comments

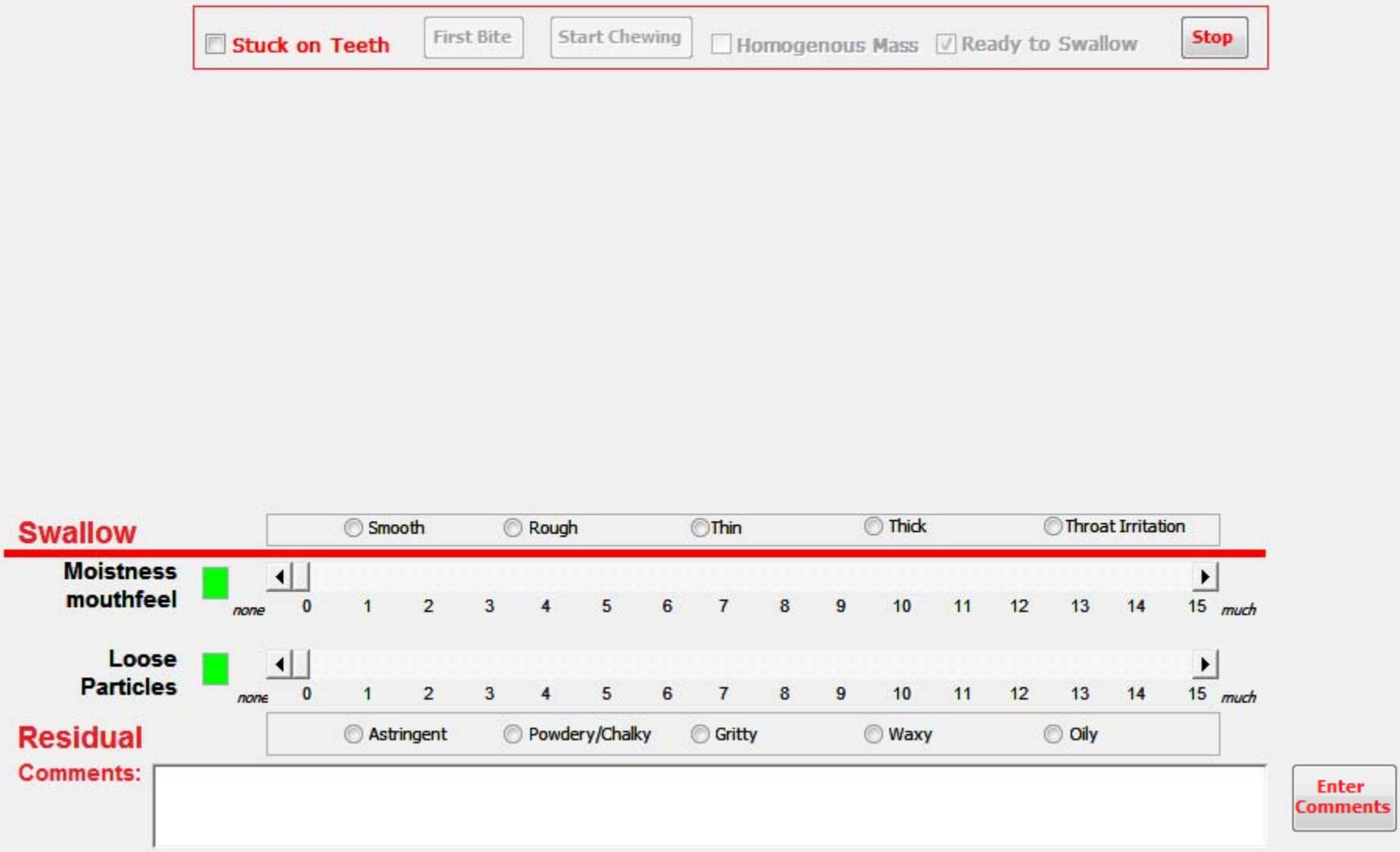
Methodology Descriptive Panel Data Collection *MATI Demo*



Methodology Descriptive Panel Data Collection *MATI Demo*



Methodology Descriptive Panel Data Collection *MATI Demo*



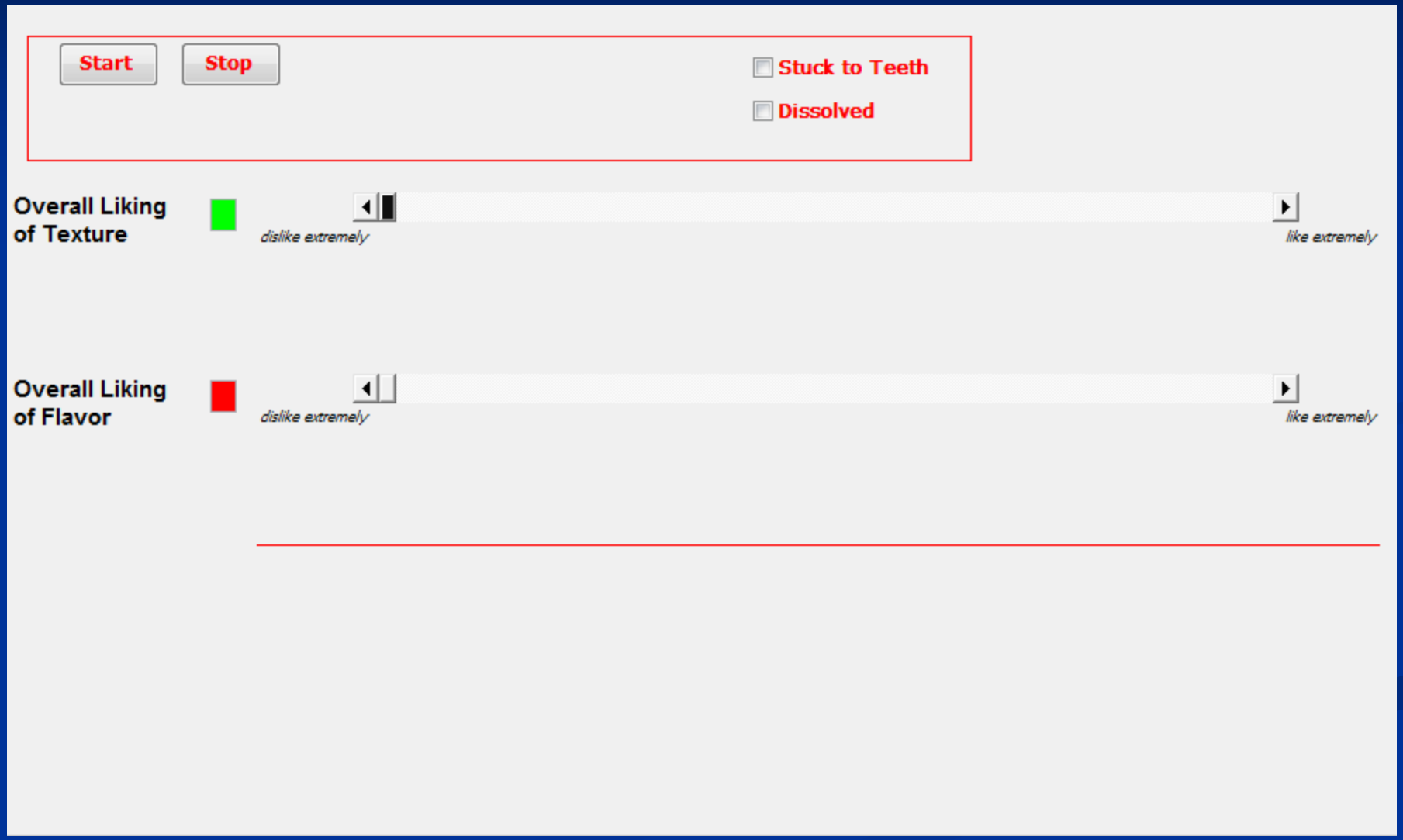
Methodology Consumer Questionnaire *Survey*

LIKES/DISLIKES	JAR	TASTE AFTER SWALLOWING
9-point HEDONIC	APPEARANCE	Pleasantness of taste
Overall Appearance	Color of the Chew	
Overall Liking		
	FLAVOR	APPROPRIATE FRUIT FLAVOR
OPEN-ENDS	Overall Fruit Flavor	
What did you **LIKE** about this sample?	Sweet	EXPECTATIONS
What did you **DISLIKE** about this sample?	Sour	
9-point HEDONIC	TEXTURE	AGREE/DISAGREE
Overall Flavor	Chewiness	This chew looks natural.
Overall Texture	Rate sample dissolves	This chew tastes great.
	Amount of fruit particles	This chew tastes natural.
	Smoothness	This chew tastes delicious.
		This chew tastes fresh.
	AFTER SWALLOWING	
	Flavor Intensity	

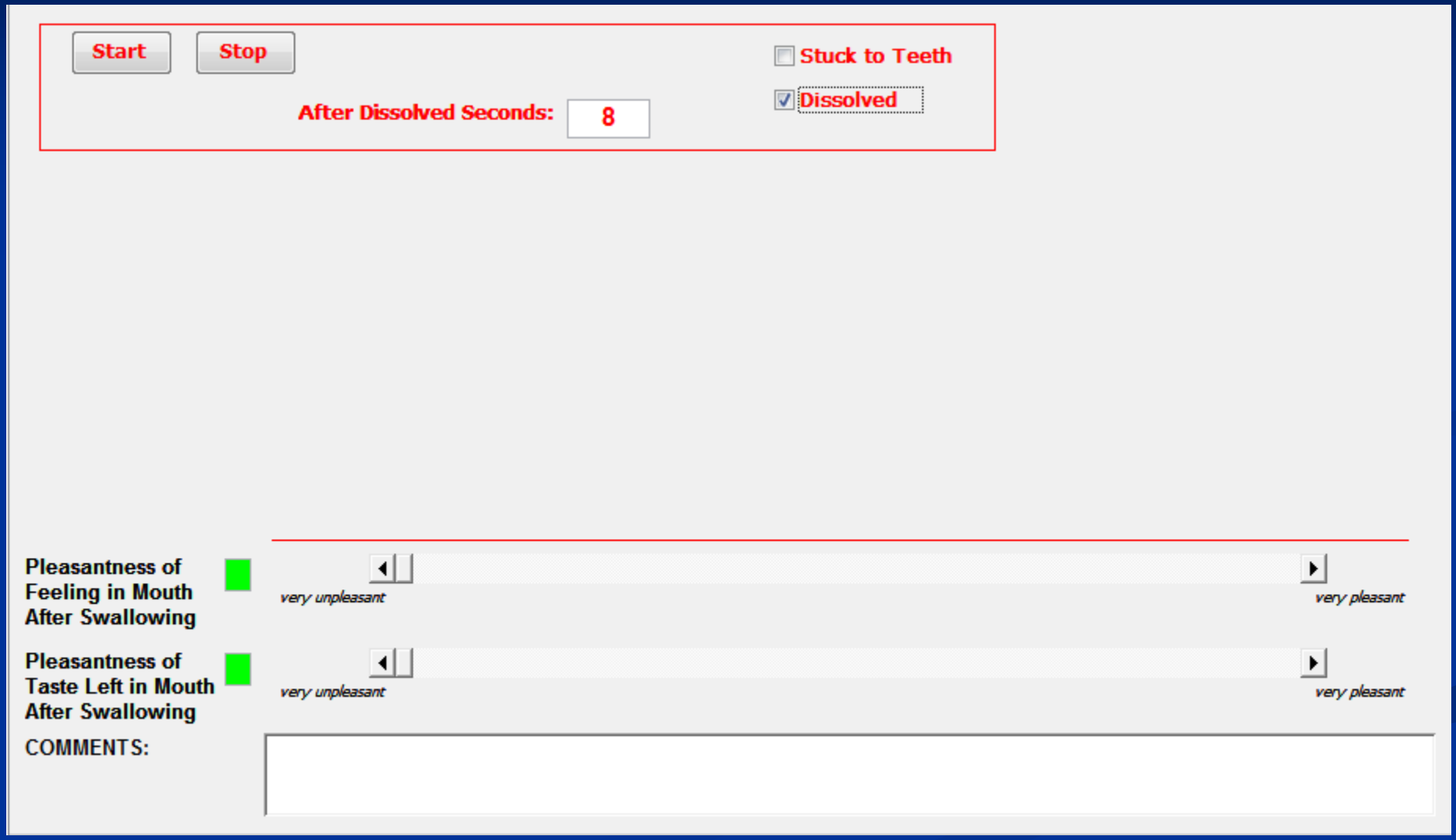
Methodology Consumer Questionnaire *MATI*

Consumer	During Chewing Line Scale 0-100 point	After Dissolved Line Scale 0-100 point
Adult N=20 10 male/10 female	Overall Liking of Texture	Pleasantness of Feeling in Mouth After Swallowing
	Overall Liking of Flavor	Pleasantness of Taste in Mouth After Swallowing

Methodology Consumer Panel Data Collection *MATI Demo*



Methodology Consumer Panel Data Collection *MATI Demo*



Methodology Consumer Orientation *MATI*

Consumer panel orientation to MATI is key.

- Suggest….
  - Explaining the data collection technique
  - Providing an understanding of the interest in collecting their responses over time
  - Offer practice with a warm-up sample
- Else…you get
  - Lack of attention over time
  - Flat-liners
  - Late/tardy/procastinating responders



Methodology Statistical Analysis *MATI*

Functional Data Analysis (FDA) a relatively new branch of advanced statistics is highlighted as a technique applicable for MATI data.

- Curves were analyzed using **Functional Data Analysis (FDA)**:
  - **Spline functions** were used to smooth the MATI curves
  - **CATA observed proportions** were used to produce a functional curve at each time point
  - **First and second derivatives** of the curves were produced using 'fda'. The derivatives represent respectively velocity and acceleration of curves.
  - **Functional Analysis of Variance (fANOVA) and permutation F-tests were used** to compare mean curves
  - **Functional PCA (FPCA)** used to summarize curves into "principal curves"
  - **MANOVA based on FPC scores** can also be used for testing sample effects
  - **K-means Cluster Analysis** of FPC scores was used to show cluster results

Methodology Statistical Analysis *MATI* *(continued)*

Other advanced statistics are also shown for MATI data analysis.

- Other statistics applied include:
  - TI curve parameters were estimated using the **Bootstrap method** and 'integrate' program (for estimating area) in S-Plus. The parameters include:
    - Average dissolution time (seconds)
    - Imax – maximum intensity
    - Tmax - Time (seconds) to reach maximum intensity
    - AUC – area under the curve
    - Area before and after Imax
- Parameters were evaluated using **ANOVA**
- Groups of curves were evaluated using **HANOVA** (adaptive ANOVA for high-dimensional data curves)
- **Cochran's Q test** to compare sample CATA maximum response probabilities
- **ICC – intra-class correlation coefficient**
  - Index and framework to evaluate panel and panelist performance for consistency, sensitivity (reliability and validity measures)
  - ICC can be calculated from the Imax data or the first FPC scores.
- **MICC – multivariate intra-class correlation coefficient**
  - Used to assess inter-relationships among the different attributes

NOTE: References for statistical methods applied to descriptive MATI and traditional profiling data are provided at the end.

Methodology Statistical Analysis *Consumer* Traditional Survey

The traditional consumer survey data was analyzed as follows:

- **ANOVA** and multiple comparisons for liking data
- **Adaptive penalty analysis** for JAR data
- Relative importance of JAR attributes
- **Proportional odds model (POM)** for ordinal categorical data (e.g., purchase intent, expectation, aftertaste, etc)

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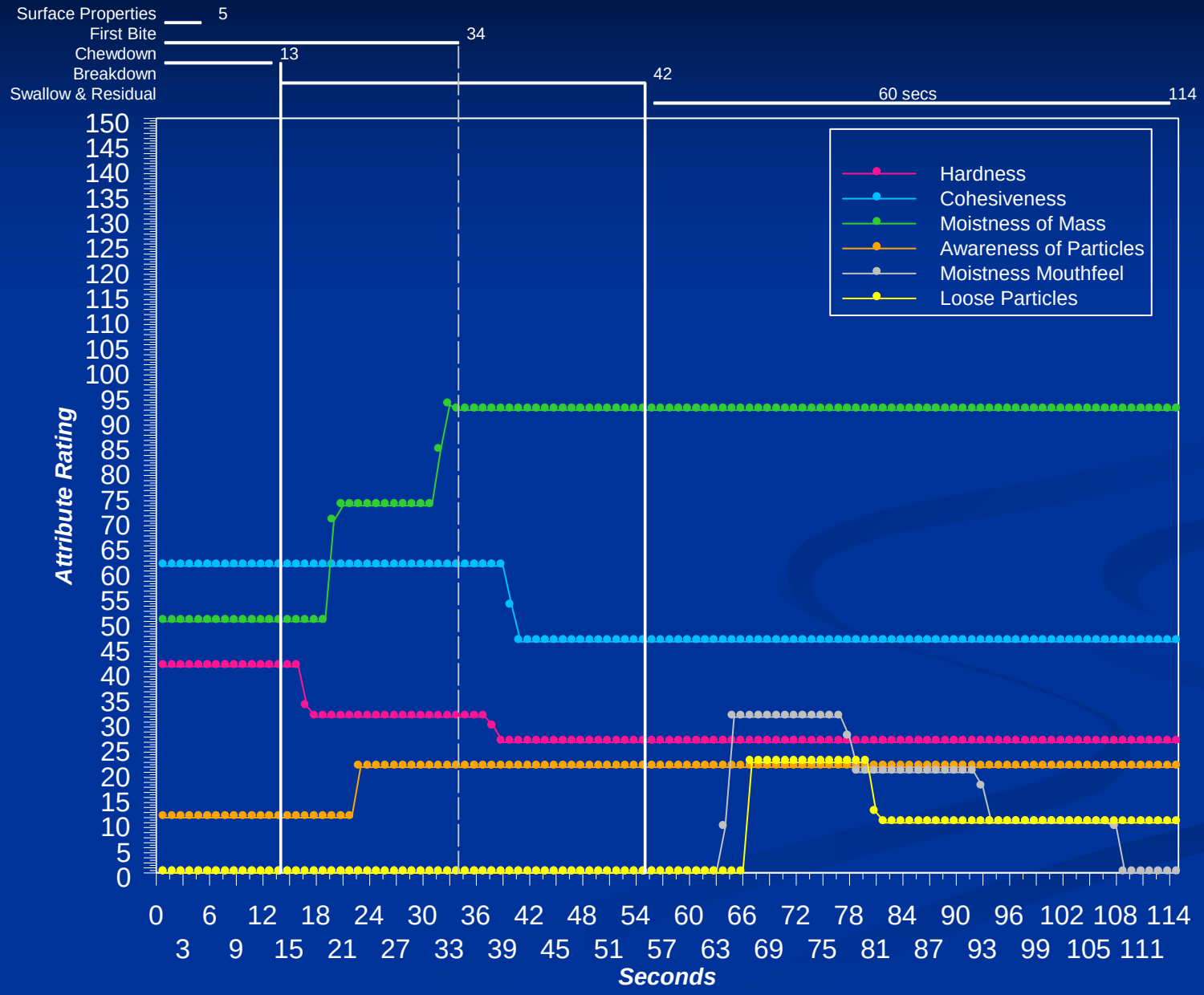
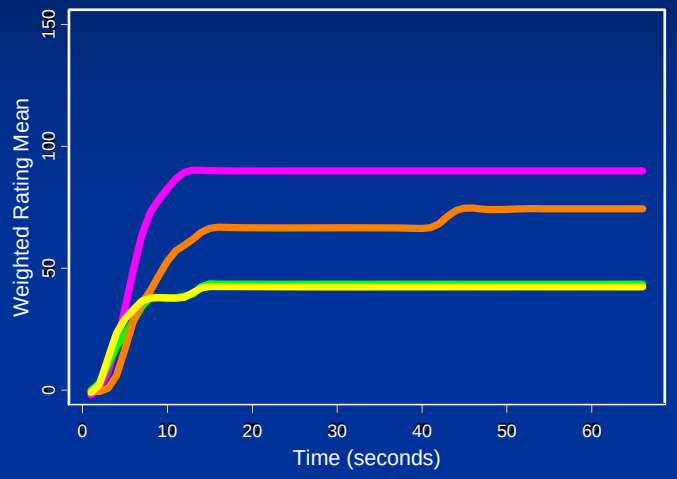
Detailed Findings Descriptive Panel *Continuous Attribute Data*



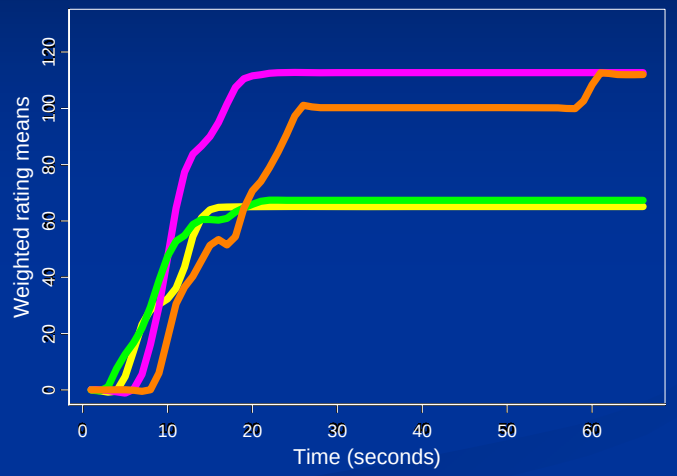
Detailed Findings Panel *Descriptive* First-Bite

#C1 -- Cherry Chew Candy
#C2 -- Chocolate Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

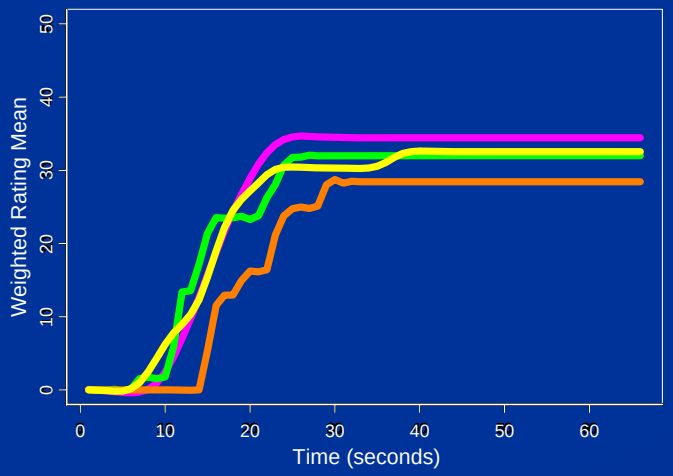
Hardness



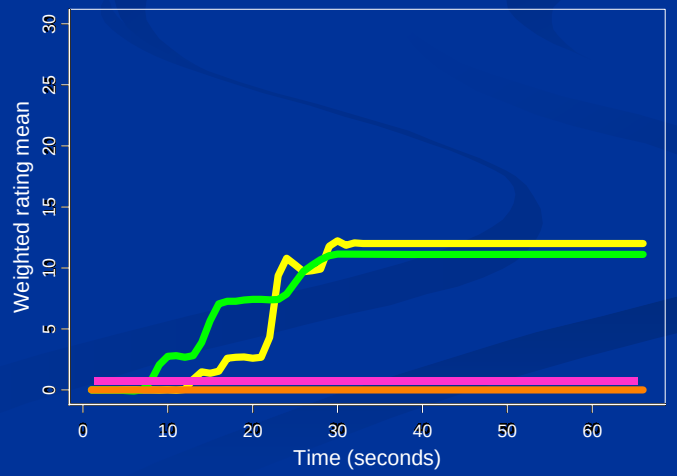
Cohesiveness



Moistness of Mass



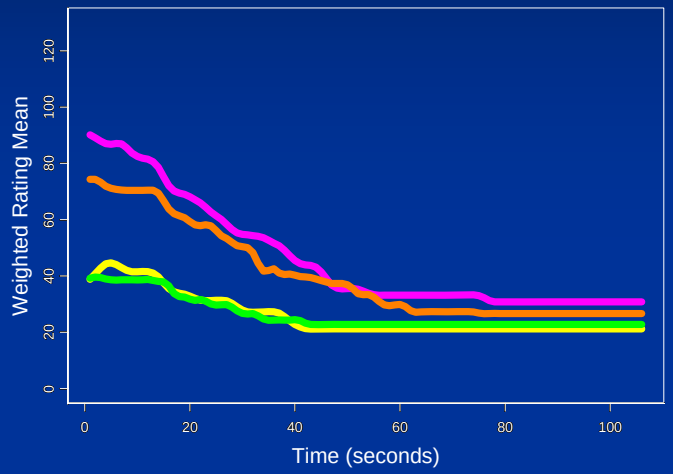
Awareness of Particles



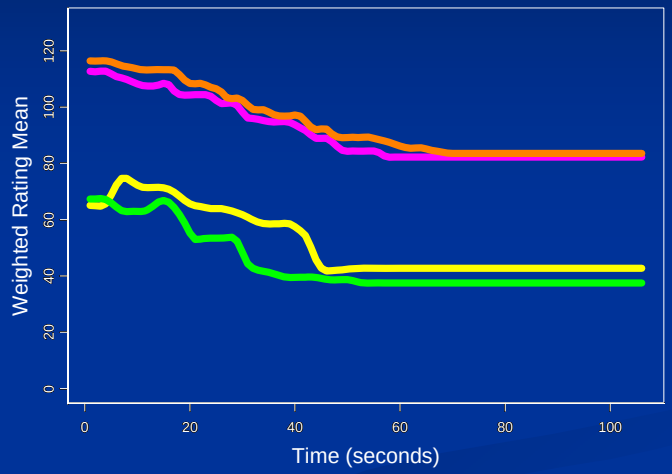
Detailed Findings Panel *Descriptive* Line-Chew Down & Break Down

#C1 -- Cherry Chew Candy
#C2 -- Chocolate Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

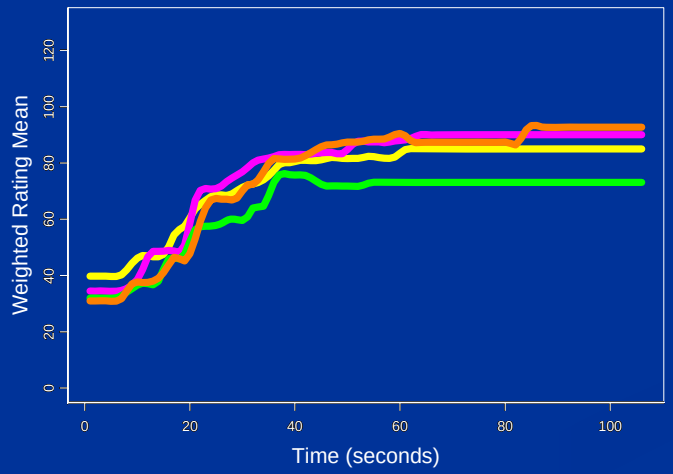
Hardness



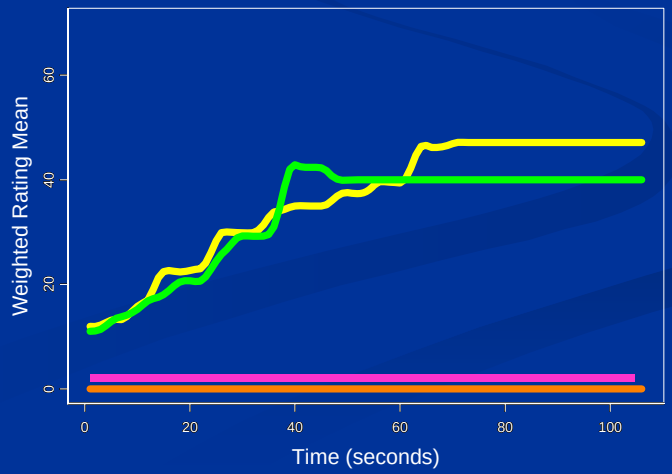
Cohesiveness



Moistness of Mass



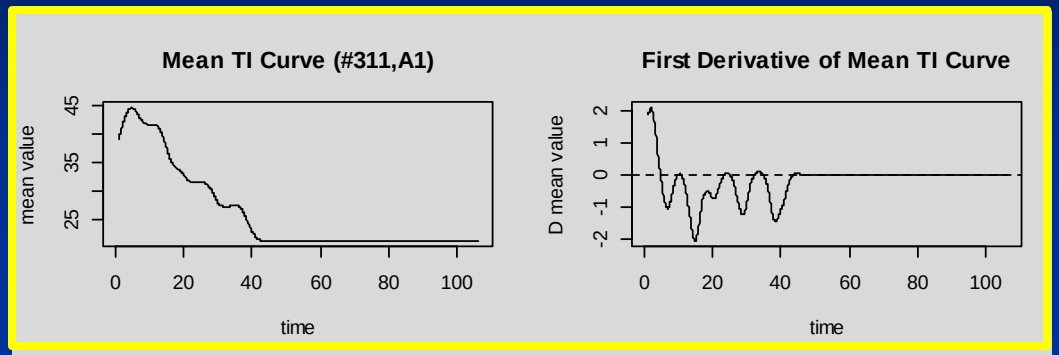
Awareness of Particles

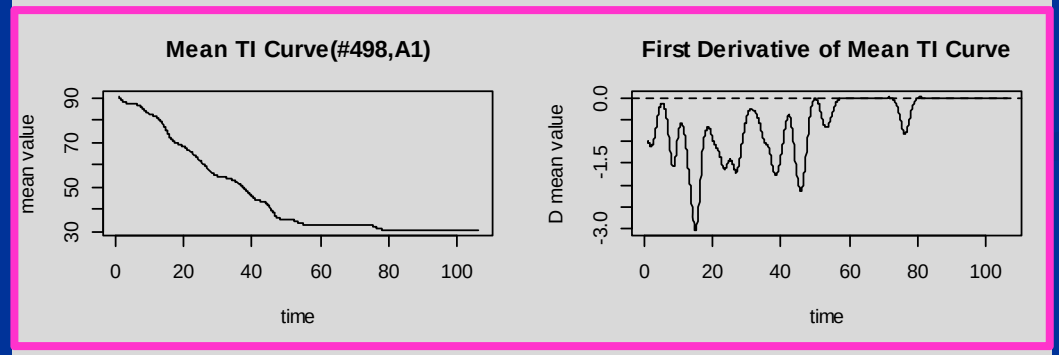


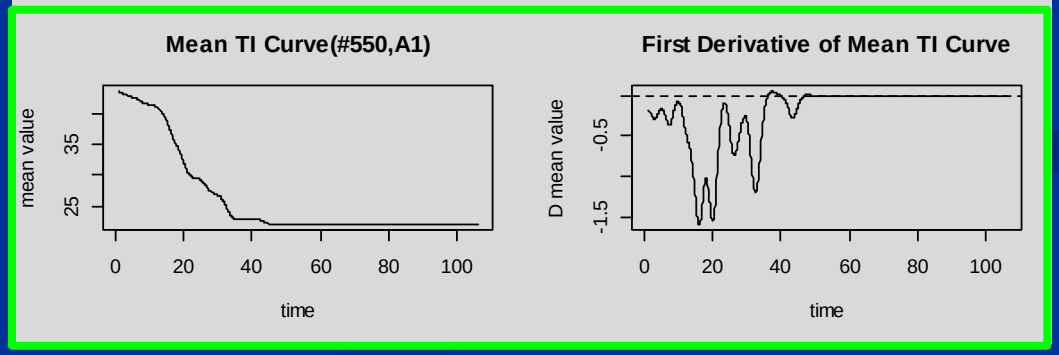
Detailed Findings Panel *Descriptive* Hardness

#P1 -- Prototype 1
#C1 -- Cherry Chew Candy
#P2 -- Prototype 2

- 1. All the derivative curves are below zero except the beginning of **#311 (P1)**. It means that the whole trend of intensity is decreasing though the rates of decrease are varying.
- 2. We can see that the time ranges of the changes are different for the samples. Sample **#498 (C1)** has a wider time range of changes (0 to 80+) than the other samples.
- 3. We can also that the ranges of intensity changes are different for the samples. Sample **#498 (C1)** has a larger range of intensity change (90 to 30) and the range of rate of change (0 to –3) compared to **P1** and **P2.**



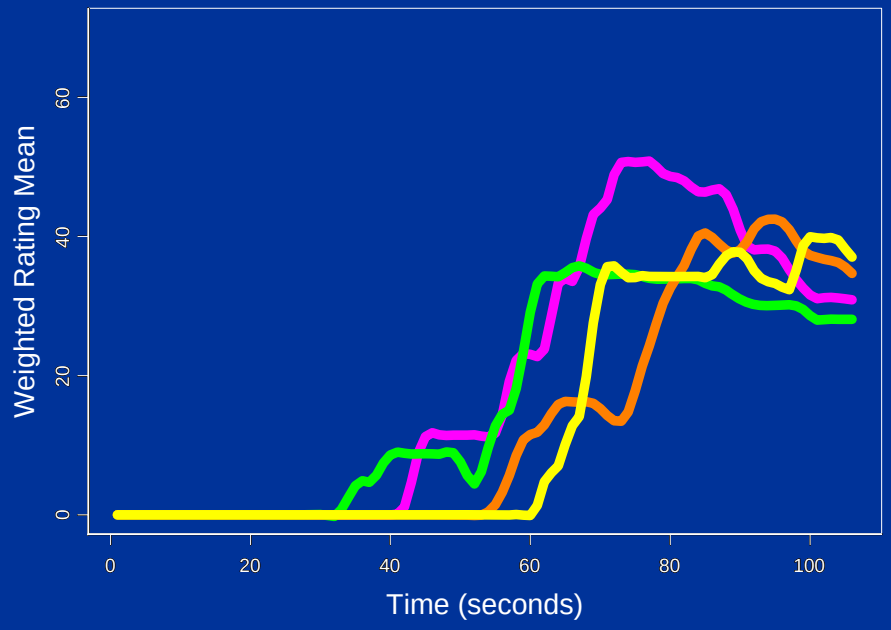




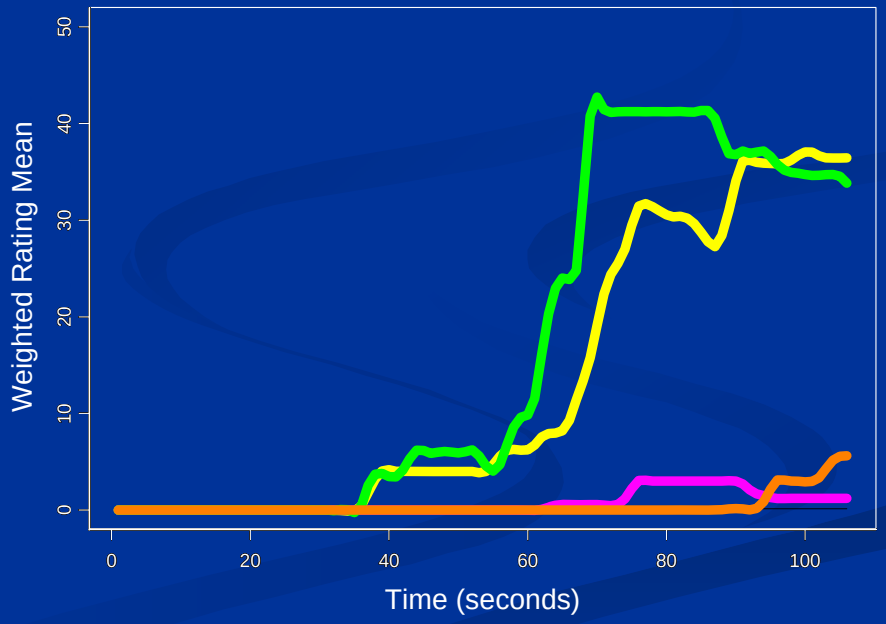
Detailed Findings Panel *Descriptive* Lines-Residual

#C1 -- Cherry Chew Candy
#C2 -- Chocolate Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

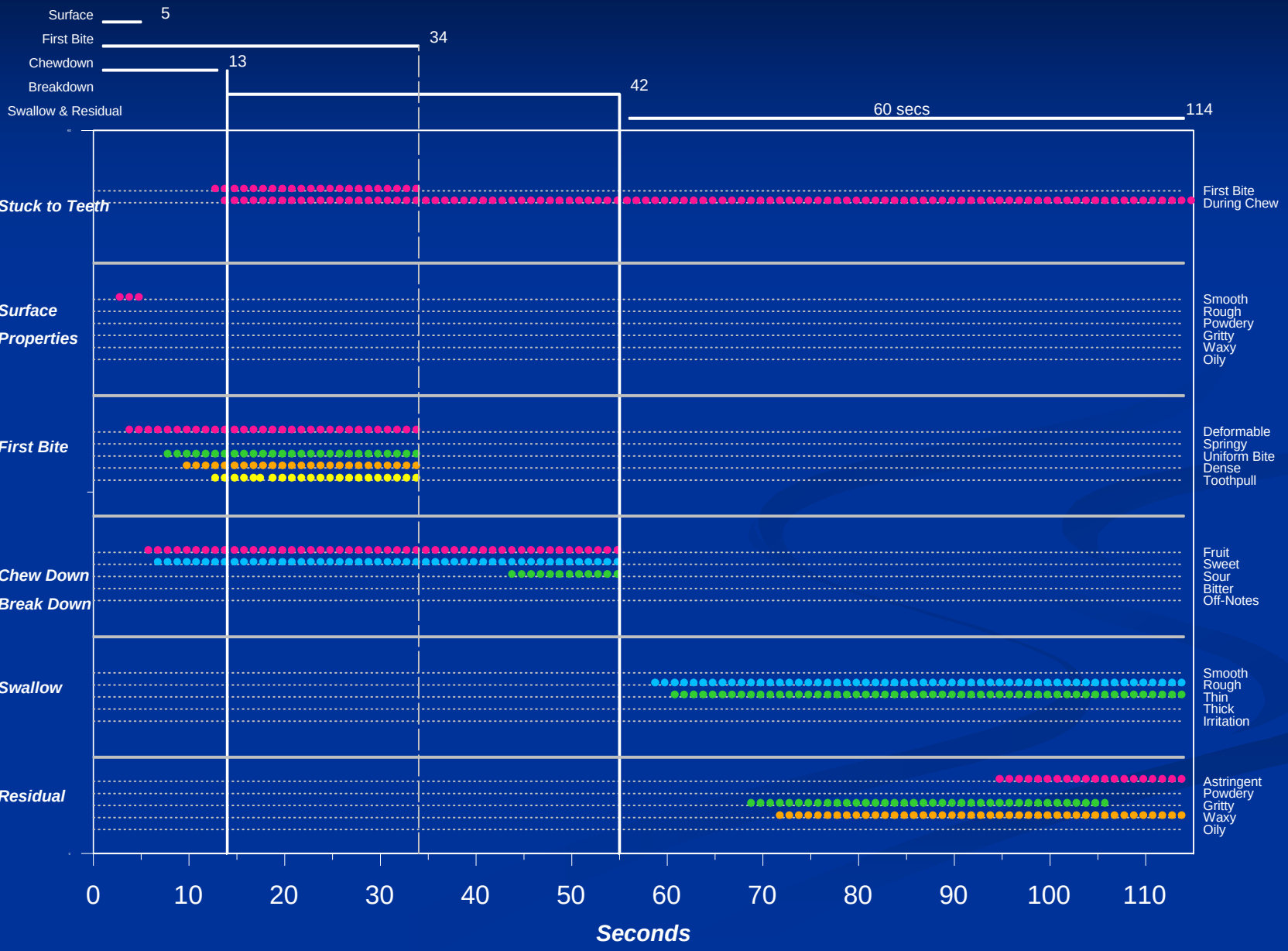
Moistness Mouthfeel



Loose Particles



Detailed Findings Descriptive Panel *CATA Data*

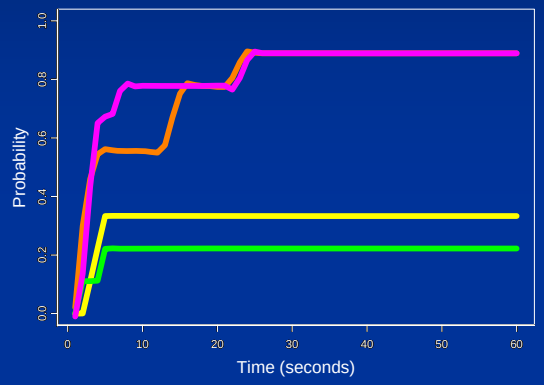


Detailed Findings Panel *Descriptive* CATA-Surface Properties

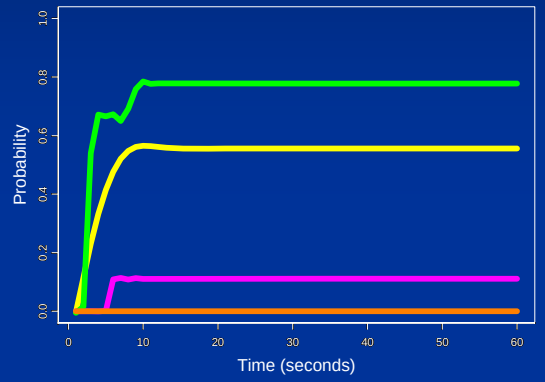
#C1 -- Cherry Chew Candy
#C2 -- Chocolate Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

Powdery/Chalky—NA

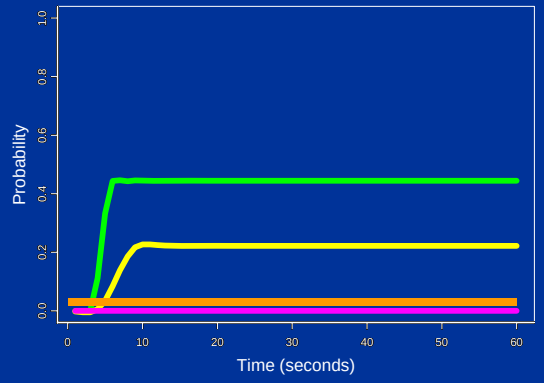
Smooth



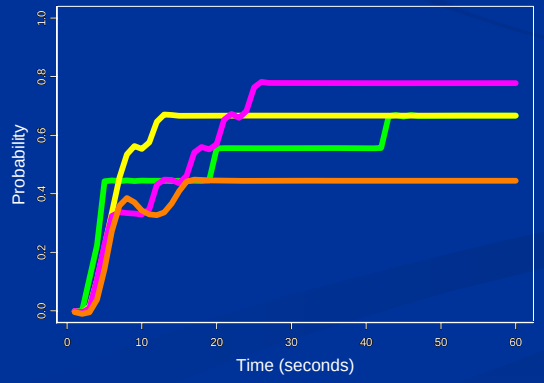
Rough



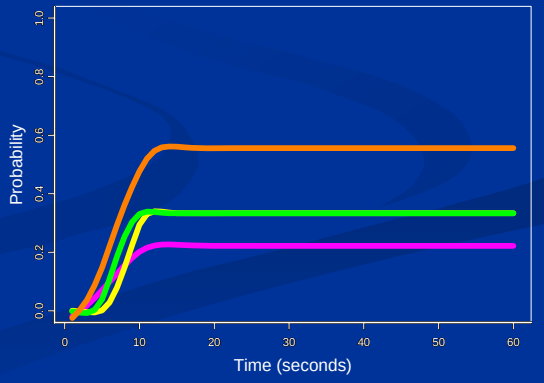
Gritty



Waxy



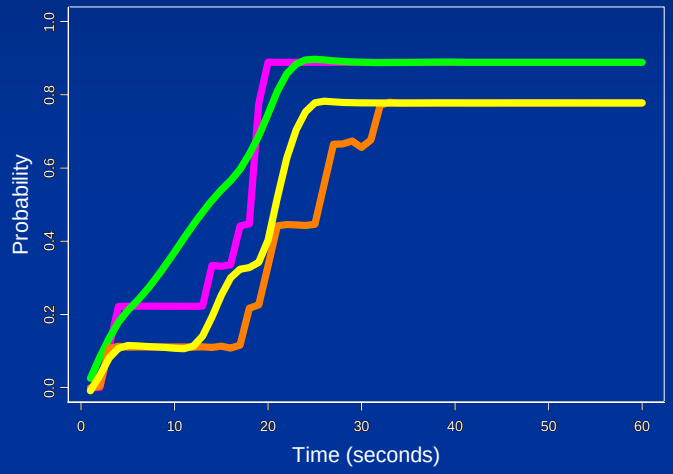
Oily



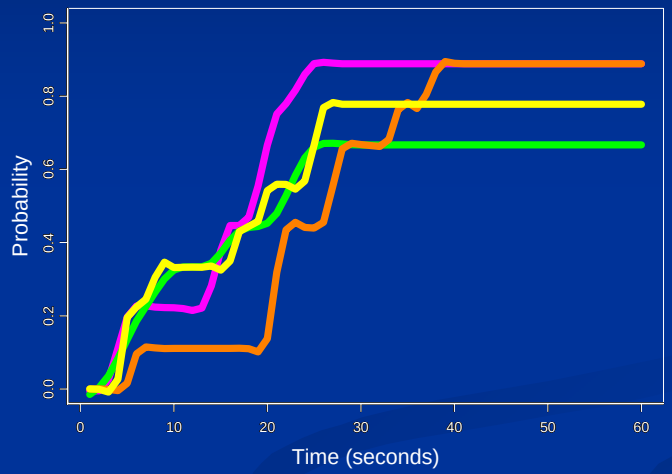
Detailed Findings Panel *Descriptive* CATA-First Bite

#C1 -- Cherry Chew Candy
#C2 -- Chocolate Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

Deformable

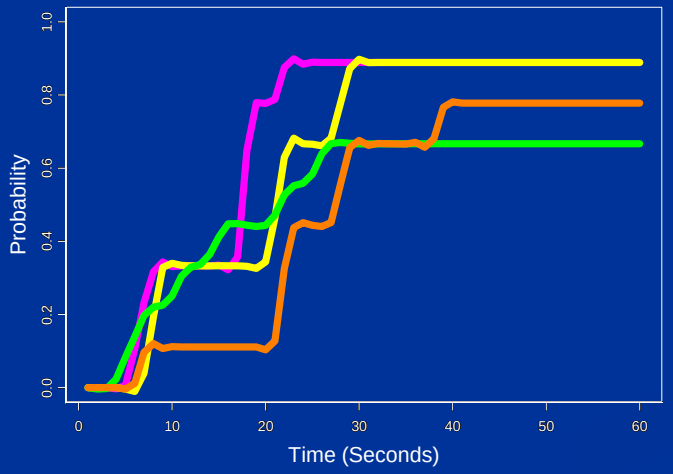


Uniform Bite

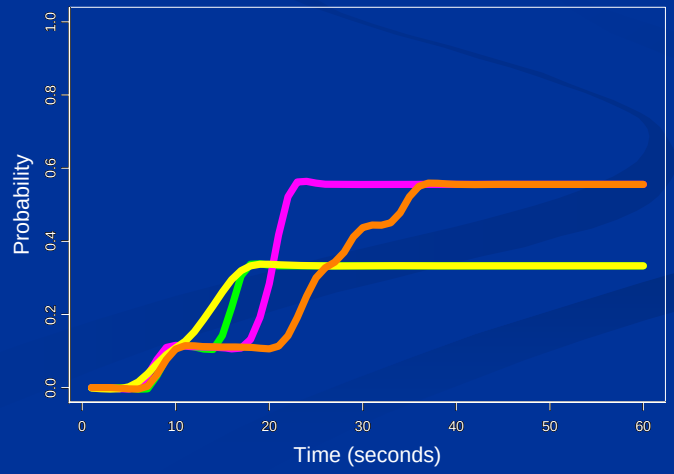


Springy—
NA

Dense



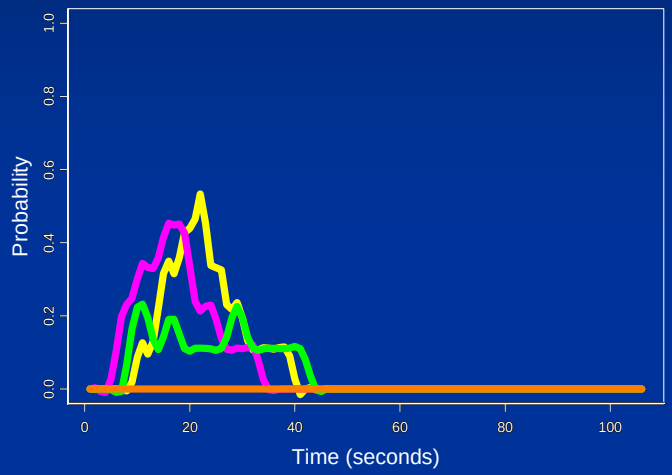
Toothpull



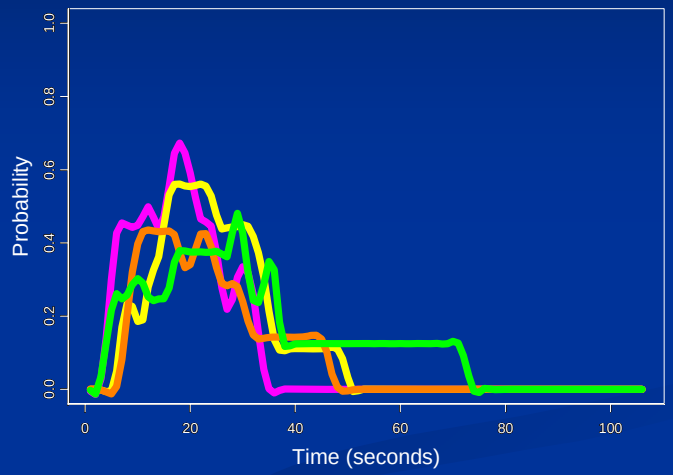
Detailed Findings Panel *Descriptive* CATA-Chew Down

#C1 -- Cherry Chew Candy
#C2 -- Chocolate Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

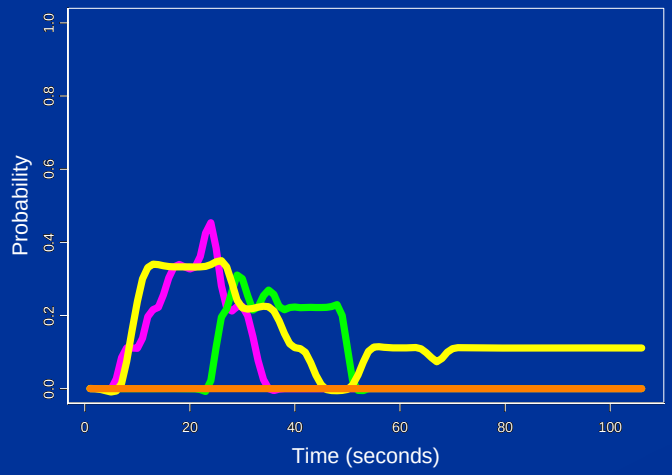
Fruit



Sweet



Sour



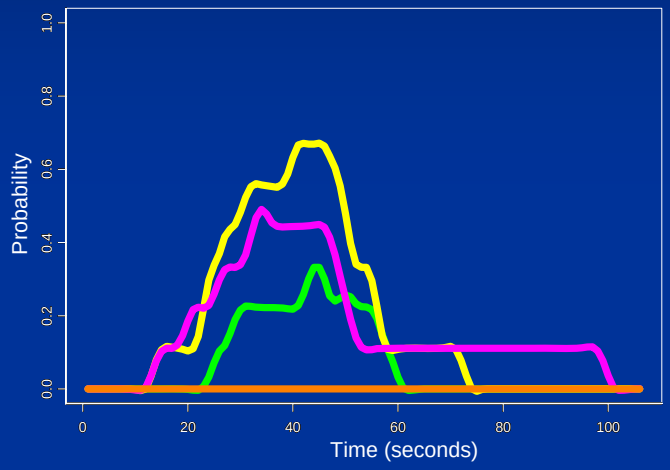
Bitter—
NA

Off-Notes—
NA

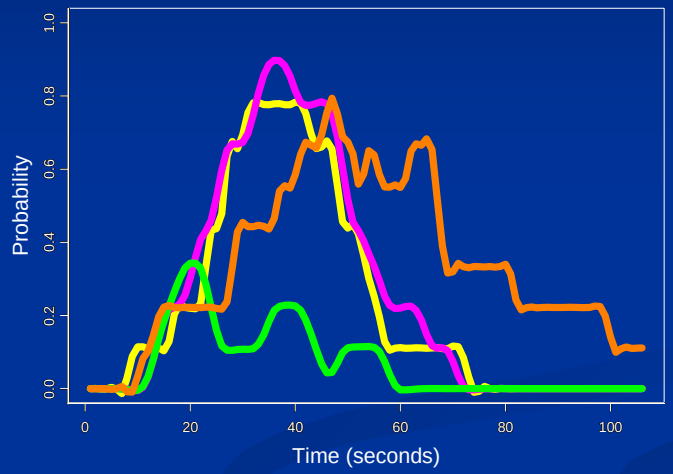
Detailed Findings Panel *Descriptive* CATA-Break Down

#C1 -- Cherry Chew Candy
#C2 -- Chocolate Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

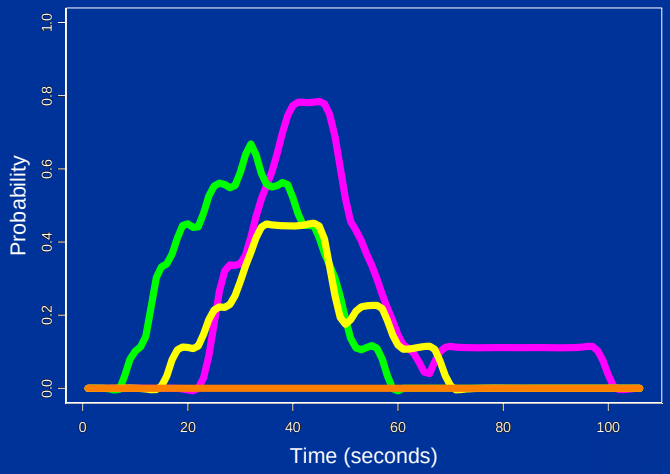
Fruit



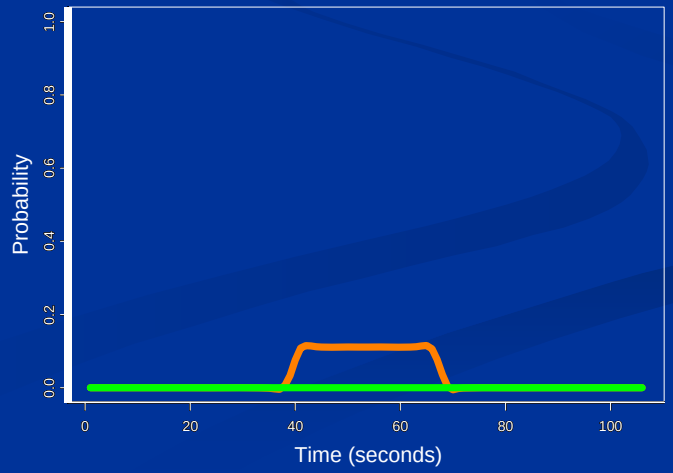
Sweet



Sour



Bitter

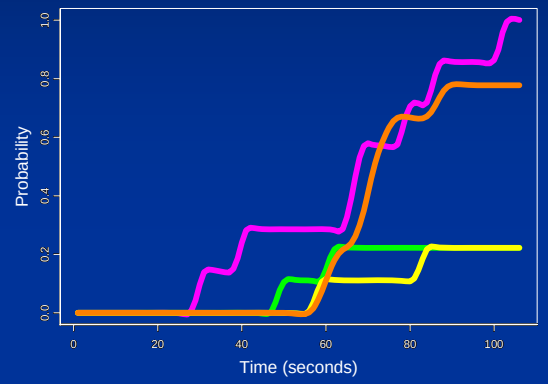


Off-Notes—NA

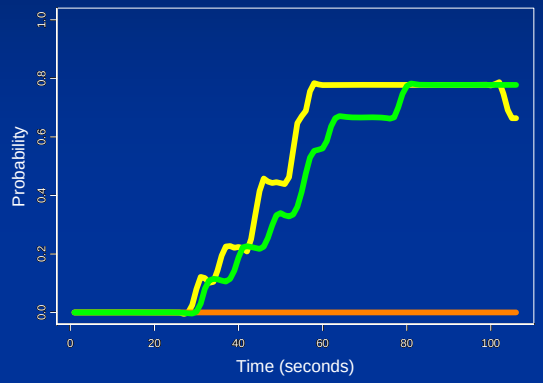
Detailed Findings Panel *Descriptive* CATA-Swallow

#C1 -- Cherry Chew Candy
#C2 -- Chocolate Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

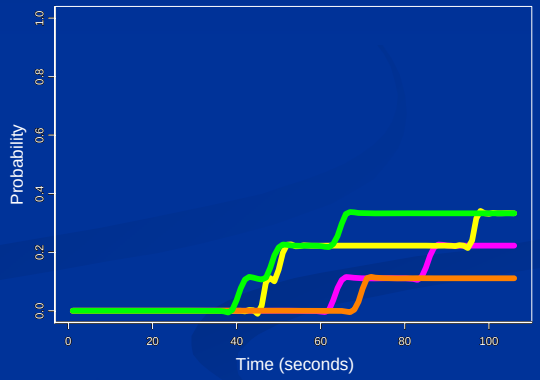
Smooth



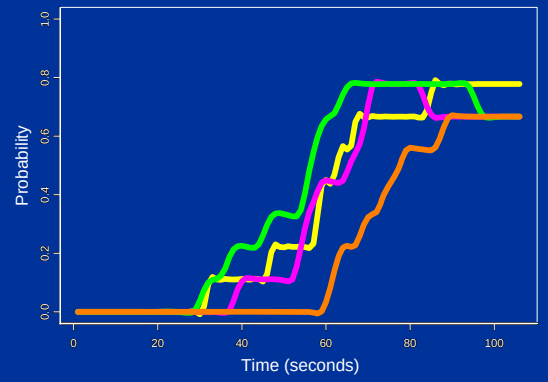
Rough



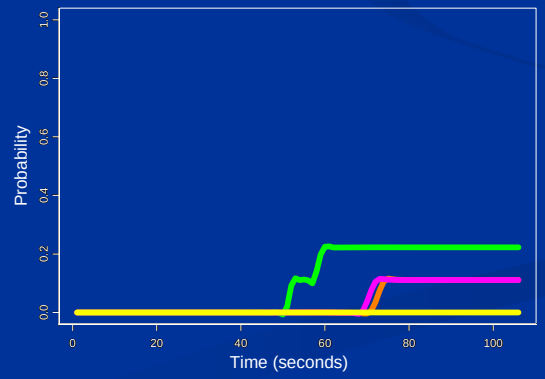
Irritation



Thin



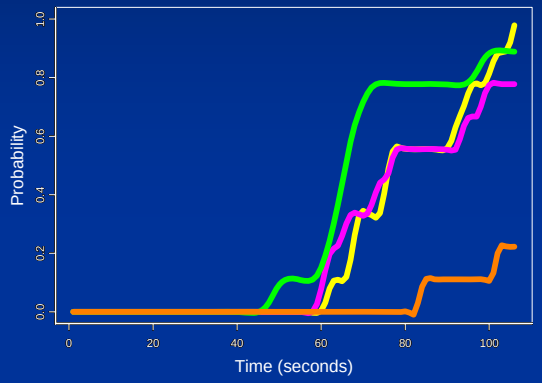
Thick



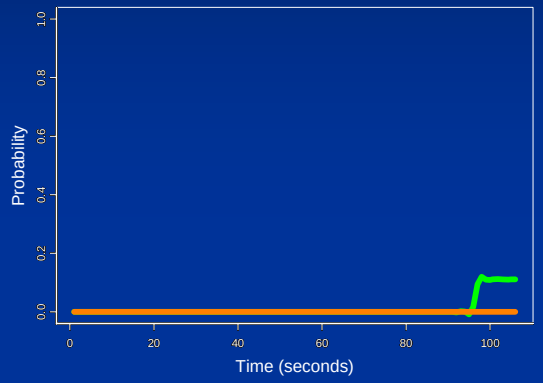
Detailed Findings Panel *Descriptive* CATA-Residual

#C1 -- Cherry Chew Candy
#C2 -- Chocolate Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

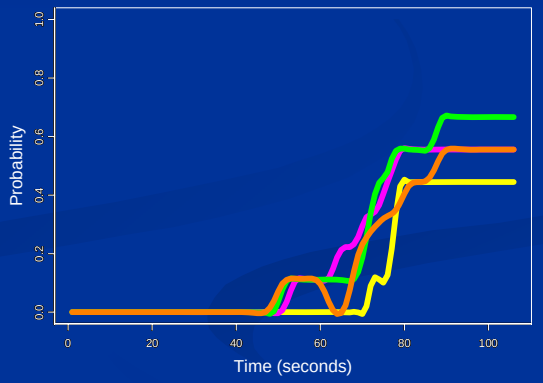
Astringent



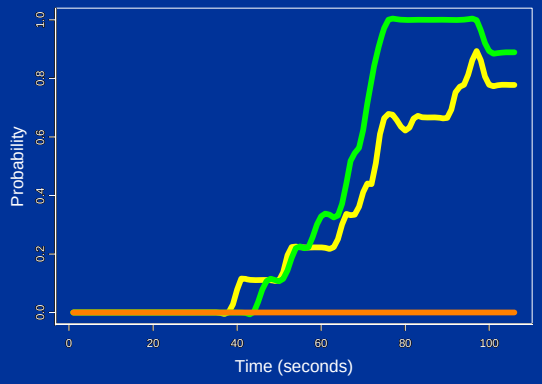
Powdery



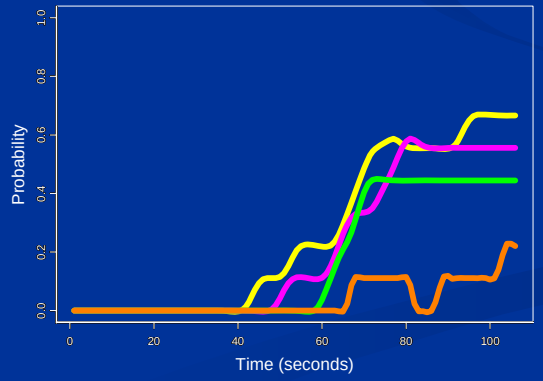
Oily



Gritty

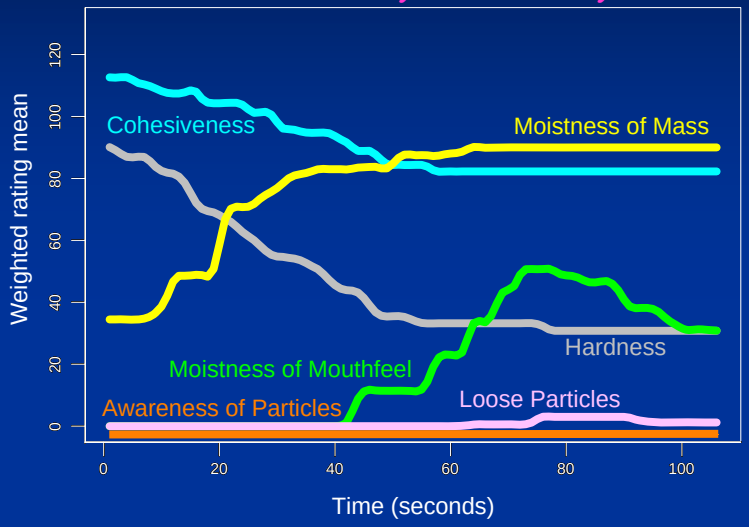


Waxy

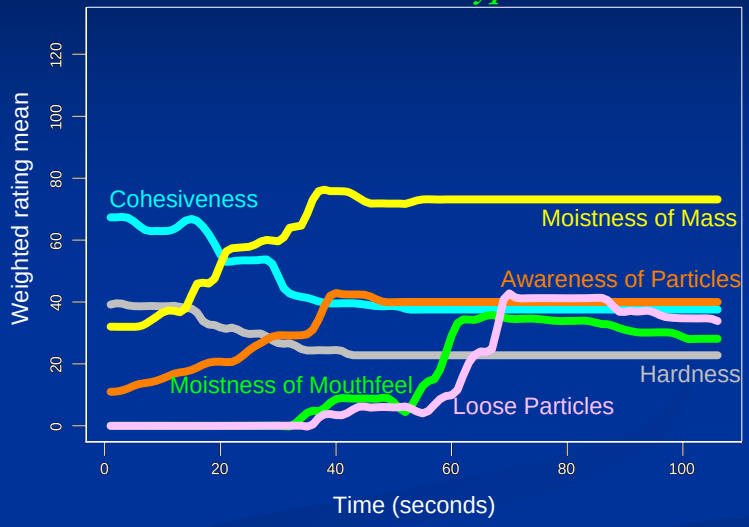


Detailed Findings Panel *Descriptive* Lines and CATA - C1 vs. P2

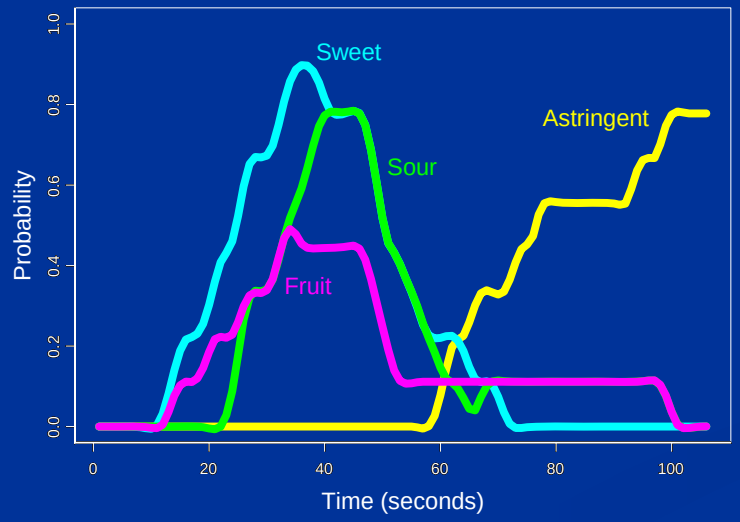
#C1 -- Cherry Chew Candy



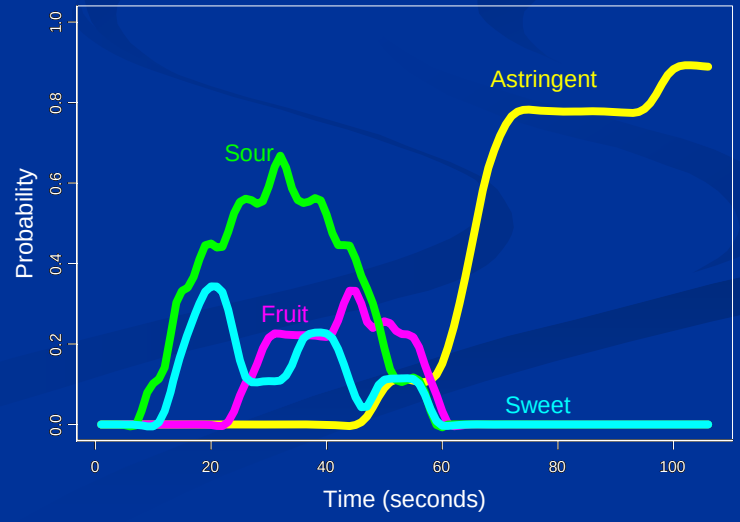
#P2 -- Prototype 2



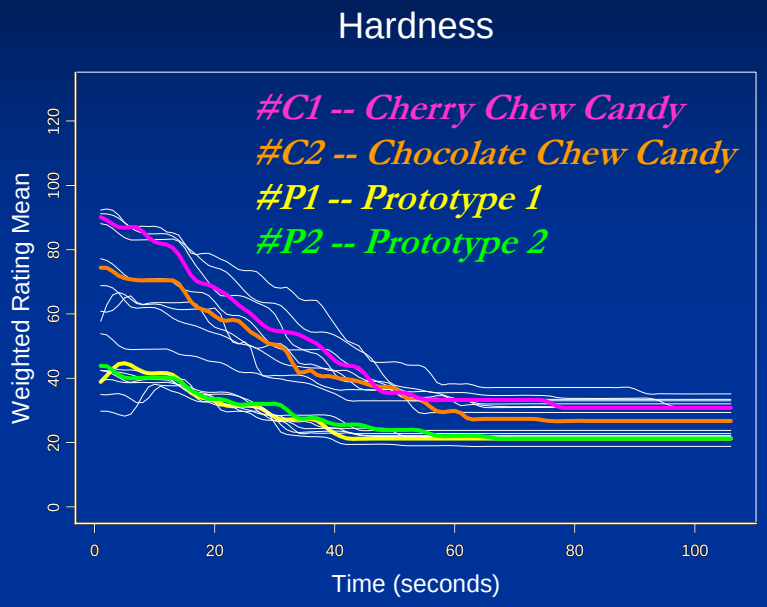
#C1 -- Cherry Chew Candy



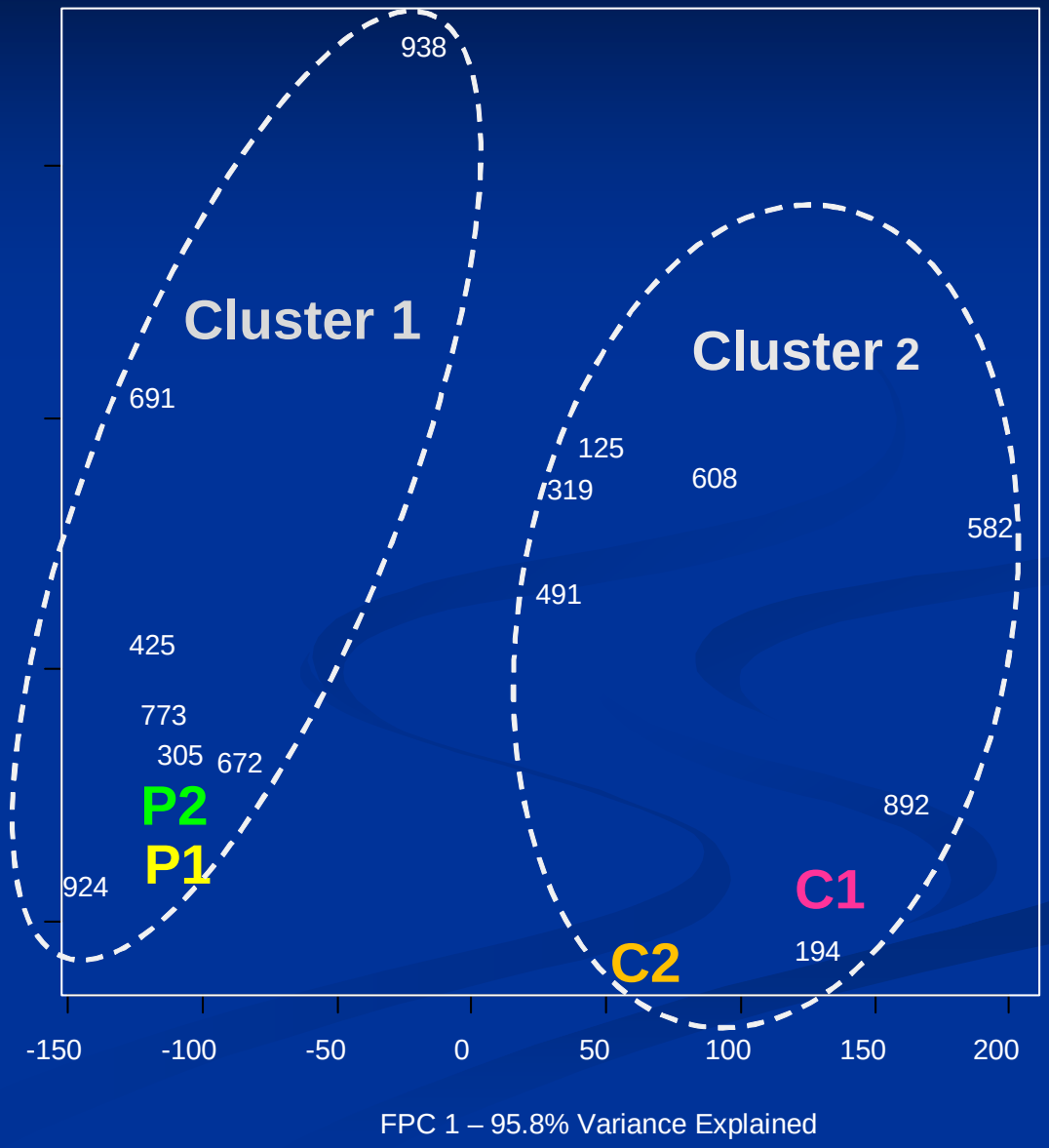
#P2 -- Prototype 2



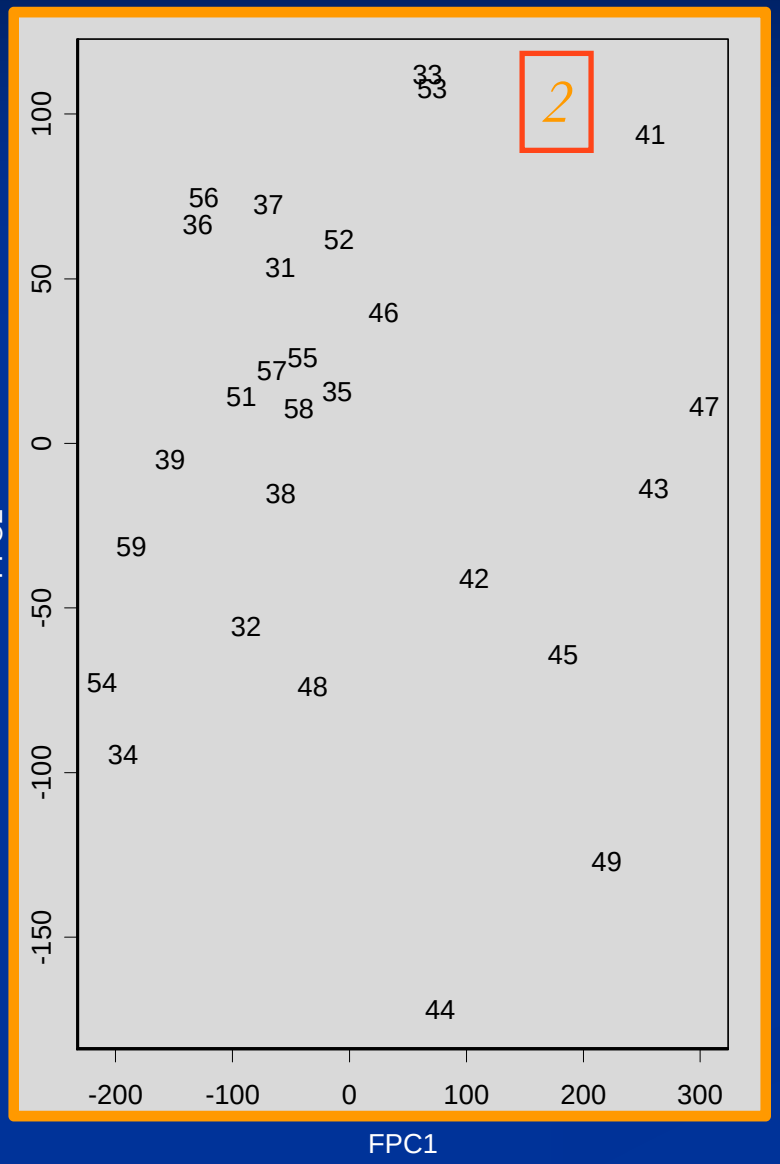
Detailed Findings Panel *Descriptive* FPCA and K-means Cluster Analysis

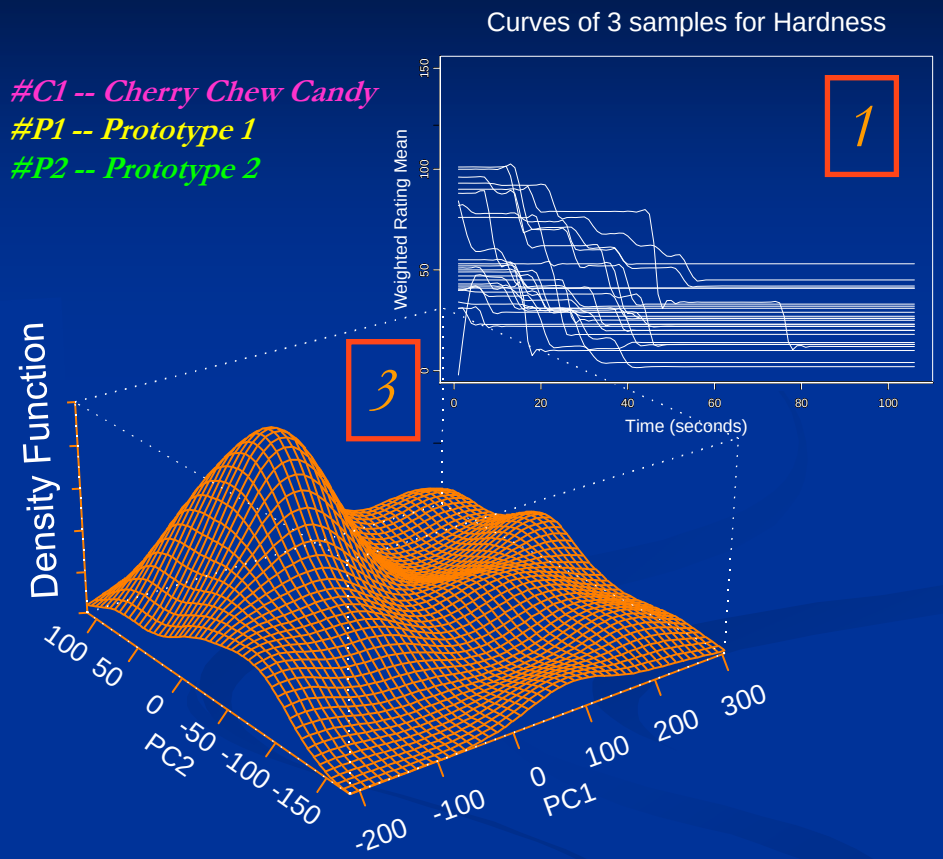


- Functional PCA (FPCA)
- An eigenfunction associated with each eigenvalue
- FPCA provides PC scores for each curve
- Converted to 2-3 dimensions
- Curves presented as points
- Cluster analysis on FPC scores



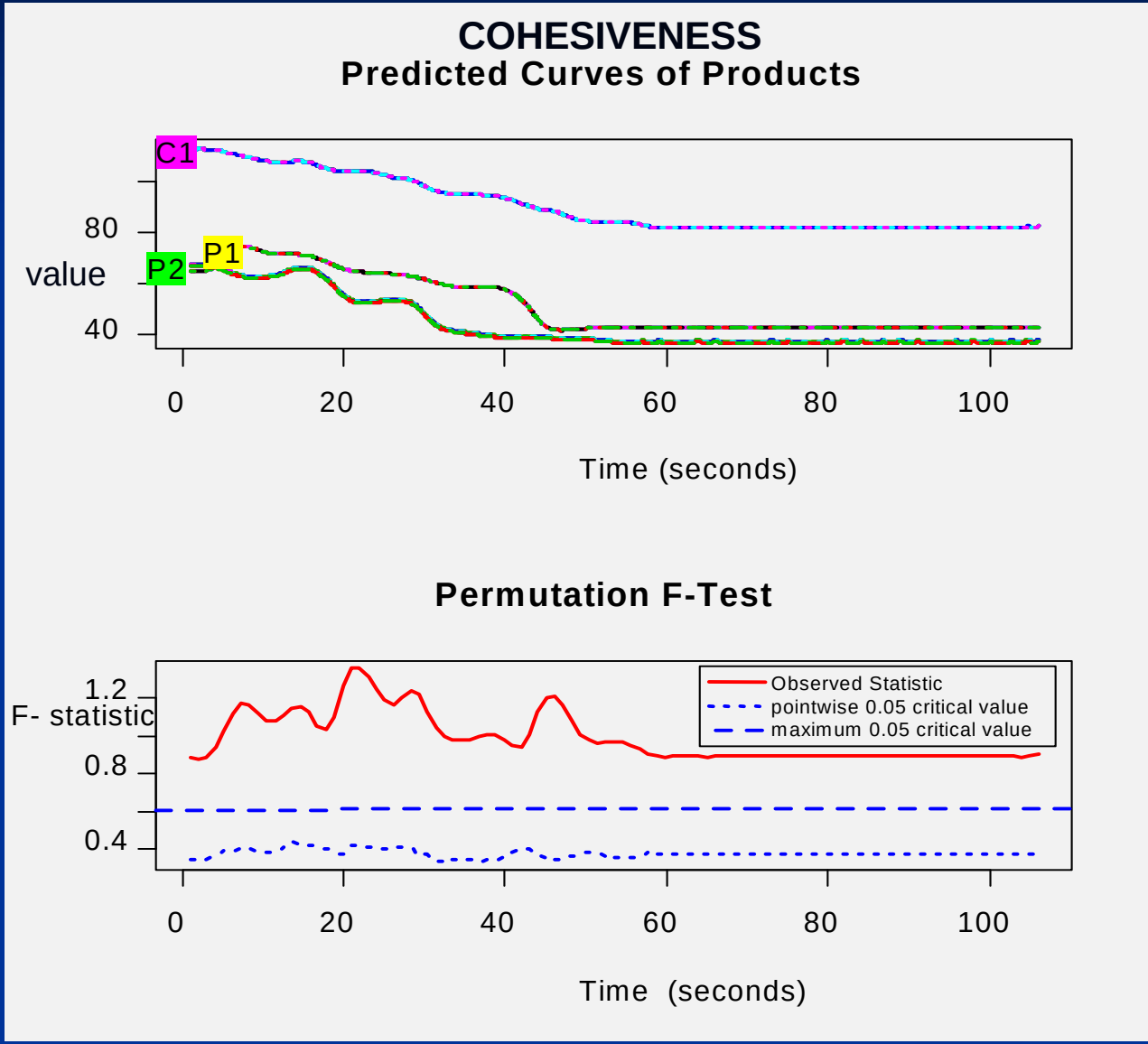
Detailed Findings Panel *Descriptive* Functional Curves and FPC Space





- Original curves (top right)
- Positions of curves in the first 2 FPC space (left)
- Density of points in the FPC space using S-Plus 'sm' (bottom right)

Detailed Findings Panel *Descriptive* FANOVA-Test for Predicted Curves



#C1 -- Cherry Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

- Functional Analysis of Variance (FANOVA) is used to compare the mean curves
- Significant differences are shown here for 'Cohesiveness'

Detailed Findings Panel *Descriptive* CATA Maximum Selection Probabilities

Cochran's Q test applied to the CATA attributes involves comparison of correlated proportions.

#C1 -- Cherry Chew Candy
#P1 -- Prototype 1
#P2 -- Prototype 2

Categories of CATA Attributes in Different Stages and Their Predicted Maximum Estimated Selection Probabilities (#P2)

Stage	1	2	3	4	5
ChewQown	Fruit	Sweet	Sour	Bitter	Off-Notes
	(0.22 at 11 sec.)	(0.28 at 12 sec.)	(0.21 at 41 sec.)	(0 at all time)	(0 at all time)
BreakDown	Fruit	Sweet	Sour	Bitter	Off-Notes
	(0.32 at 44 sec.)	(0.34 at 21 sec.)	(0.65 at 32 sec.)	(0 at all time)	(0 at all time)
Residual	Astringent	Powdery	Gritty	Waxy	Oily
	(0.89 at 100 sec.)	(0.11 at 100 sec.)	(1.00 at 77 sec.)	(0.45 at 73 sec.)	(0.67 at 91 sec.)
Swallow	Smooth	Rough	Thin	Thick	Irritation
	(0.23 at 64 sec.)	(0.78 at 100 sec.)	(0.78 at 92 sec.)	(0.23 at 62 sec.)	(0.34 at 100 sec.)

P-values of Cochran's Q tests for the CATA Attributes Among the Observed Values for Three Samples*

Stage	1	2	3	4	5
ChewQown	Fruit	Sweet	Sour	Bitter	Off-Notes
	p-v=0.311	p-v=0.368	p-v=0.472		
BreakDown	Fruit	Sweet	Sour	Bitter	Off-Notes
	p-v=0.174	p-v=0.015*	p-v=0.174		
Residual	Astringent	Powdery	Gritty	Waxy	Oily
	p-v=0.223	p-v=0.368	p-v=0.00*	p-v=0.565	p-v=0.223
Swallow	Smooth	Rough	Thin	Thick	Irritation
	p-v=0.001*	p-v=0.001*	p-v=1.00	p-v=0.223	p-v=0.779

**Significant at alpha=0.05.*

ICC can measure both consistency among panelists and sensitivity of panel or panelists--hence ICC can handle the problems of both reliability and validity.

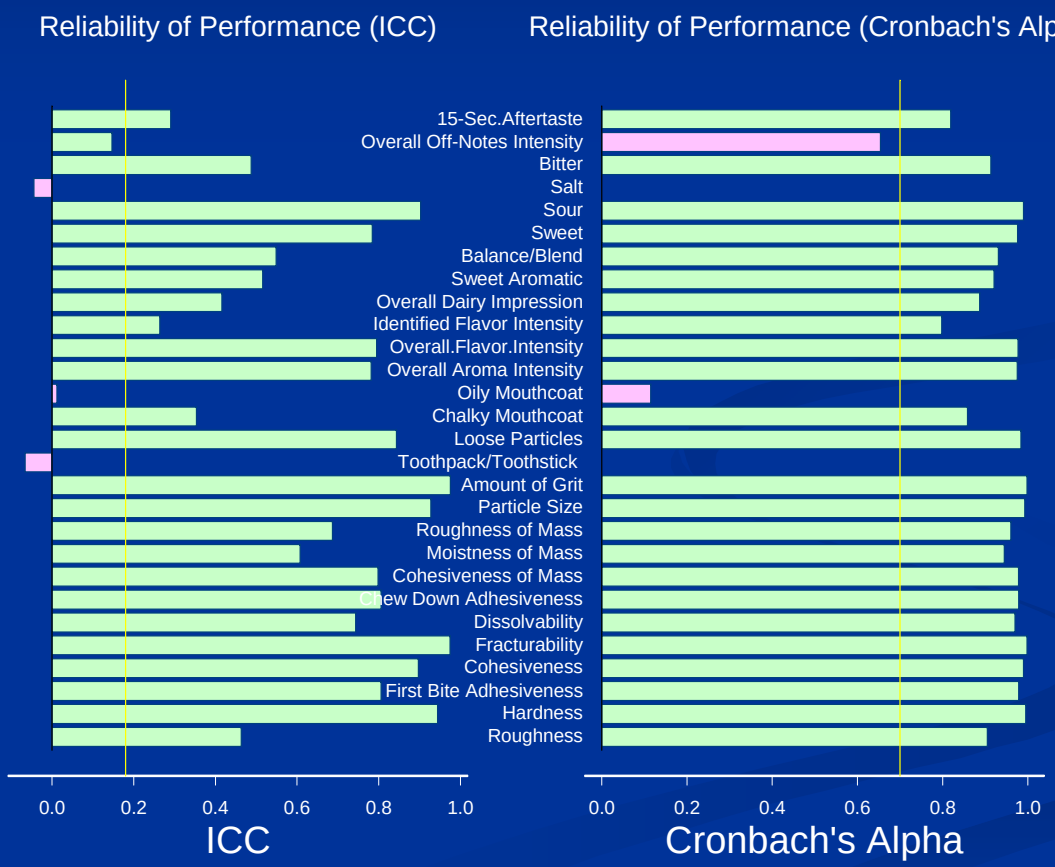
- ICC is defined as a ratio of variance of effects to total variance in a random effects model or a variance components model
- MICC is multivariate generalization of the univariate ICC. The usefulness of the MICC is that the interrelationships among the different attributes of interest can be assessed.
- Cronbach's coefficient alpha is, in fact, a version of ICC. They are one-to-one correspondence.

$$\rho = \frac{\sigma^2_A}{\sigma^2_A + \sigma^2_e}$$

Detailed Findings Panel *Descriptive ICC and Cronbach's Coefficient Alpha*

ICC and Cronbach's coefficient alpha can be used to measure performance of traditional profiling sensory data. Out of 28, 24 attributes are satisfied.

#C1 -- Cherry Chew Candy ***#P1 -- Prototype 1*** ***#P2 -- Prototype 2***

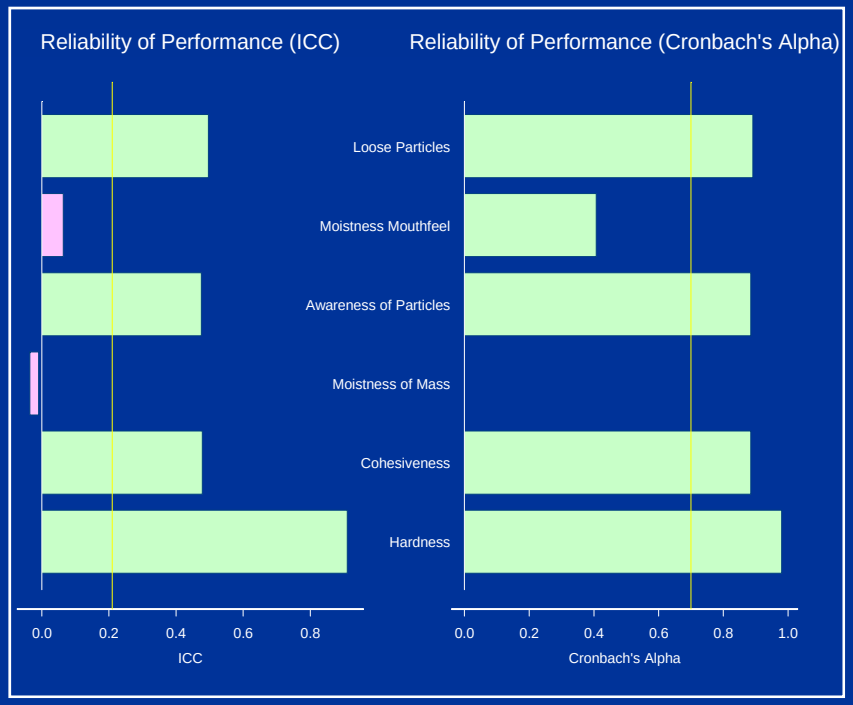


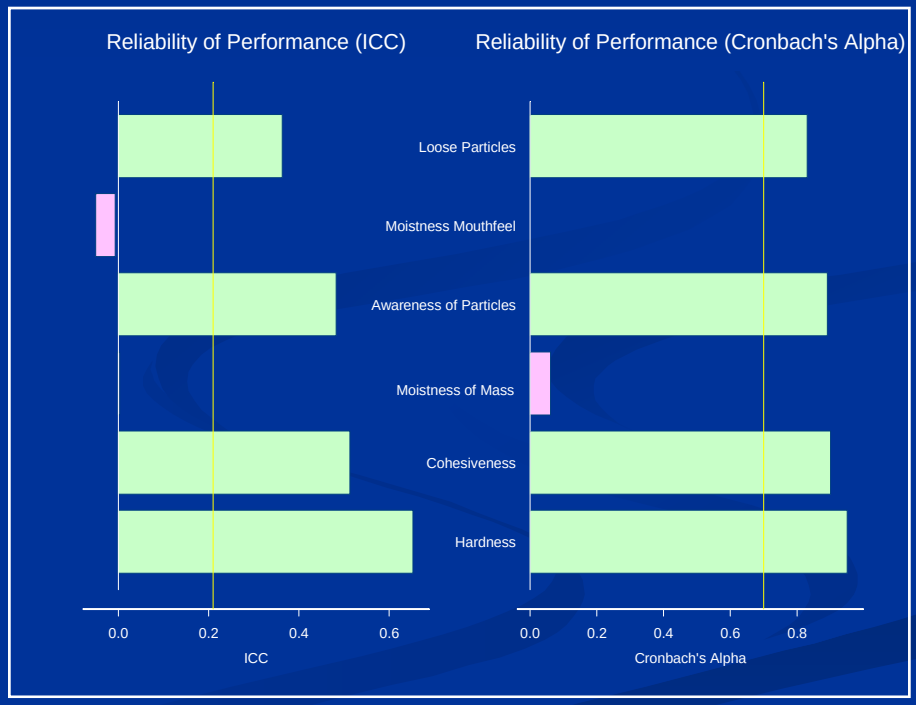
Nunnally's Rule of Thumb: Cronbach's coefficient alpha > 0.7, the reliability will suffice.

Detailed Findings Panel *Descriptive ICC and Cronbach's Coefficient Alpha*

ICC and Cronbach's coefficient alpha can be used to measure performance of MATI sensory descriptive data. Reliability for 4 of the 6 attributes suffice.

#C1 -- Cherry Chew Candy ***#P1 -- Prototype 1*** ***#P2 -- Prototype 2***





Nunnally's Rule of Thumb: Cronbach's coefficient alpha > 0.7, the reliability will suffice.

Detailed Findings Panel *Descriptive ICC and Cronbach's Coefficient Alpha*

Sample effect p-values for different approaches may be compared. Also, it is possible to compare ICC and Cronbach's coefficient alpha values for Imax data, FPC1 scores and the traditional panel data.

#C1 -- Cherry Chew Candy ***#P1 -- Prototype 1*** ***#P2 -- Prototype 2***

P-values for test sample effect based on different approaches and data

	ANOVA for Imax in curves	MANOVA for 2 FPC scores	HANOVA for discrete time points	FNOVA for curves based on permutation	ANOVA for traditional panel data
Hardness	<0.001	0.001	<0.001	<0.001	<0.001
Cohesiveness	<0.001	0.004	<0.001	<0.001	<0.001
Moistness of Mass	0.27	0.107	0.322	0.007	<0.001
Awareness of Particles	<0.001	0.004	--*	0.005	<0.001
Moistness Mouthfeel	0.013	0.082	0.68	0.845	
Loose Particles	<0.001	0.004	<0.001	0.1	

*Note:*HANOVA failed to test groups of curves with one group of zero curves.*

ICC and Cronbach's coefficient alpha

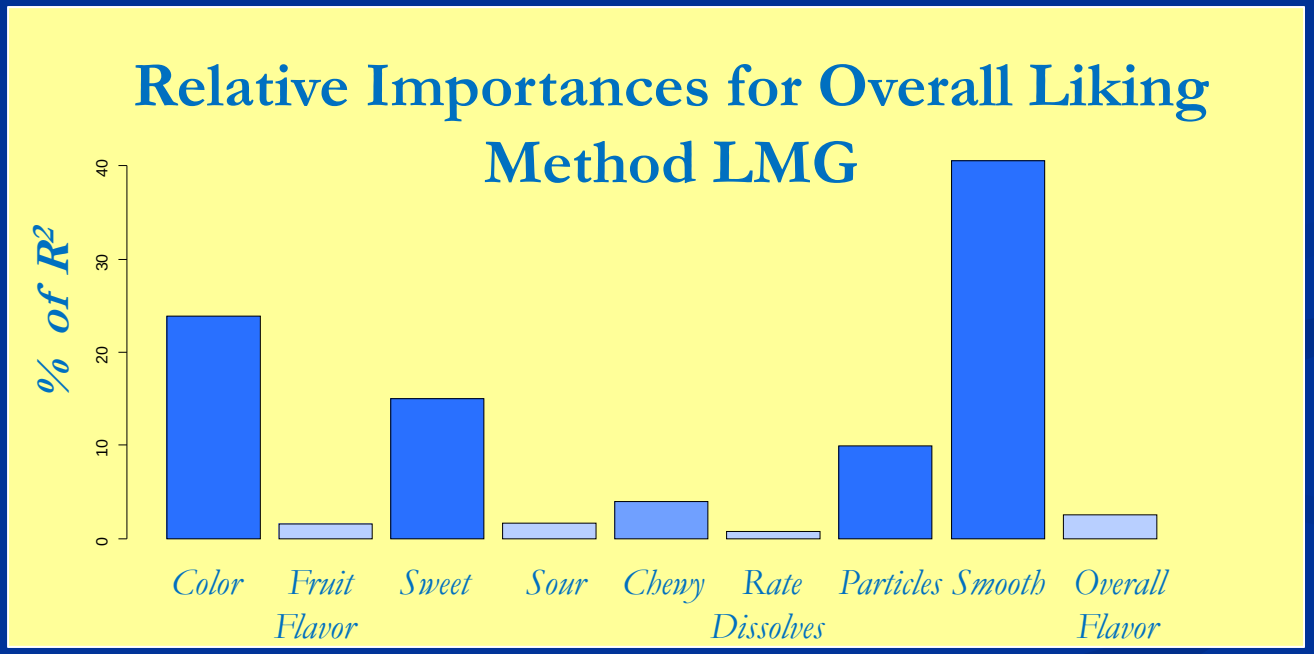
	Imax data		FPC1 scores		Traditional panel data	
	ICC	Cronbach'	ICC	Cronbach'	ICC	Cronbach'
Hardness	0.92	0.99	0.66	0.96	0.95	0.99
Cohesiveness	0.49	0.9	0.52	0.91	0.9	0.99
Moistness of Mass	-0.04	0	0.01	0.07	0.61	0.95
Awareness of Particles	0.49	0.9	0.49	0.9	0.93	0.99
Moistness Mouthfeel	0.07	0.42	-0.05	0		
Loose Particles	0.51	0.9	0.37	0.84	0.84	0.98

Note: ICC= 0.21 and 0.18 correspond to Cronbach's coefficient alpha=0.7 for n= 9 and 11, (panelists) respectively.

Detailed Findings Panel *Consumer* Relative Importance of JAR Attributes

Consumers want a smoother, brighter colored, sweeter, more chewy product.

#C1 -- Cherry Chew Candy ***#P1 -- Prototype 1*** ***#P2 -- Prototype 2***



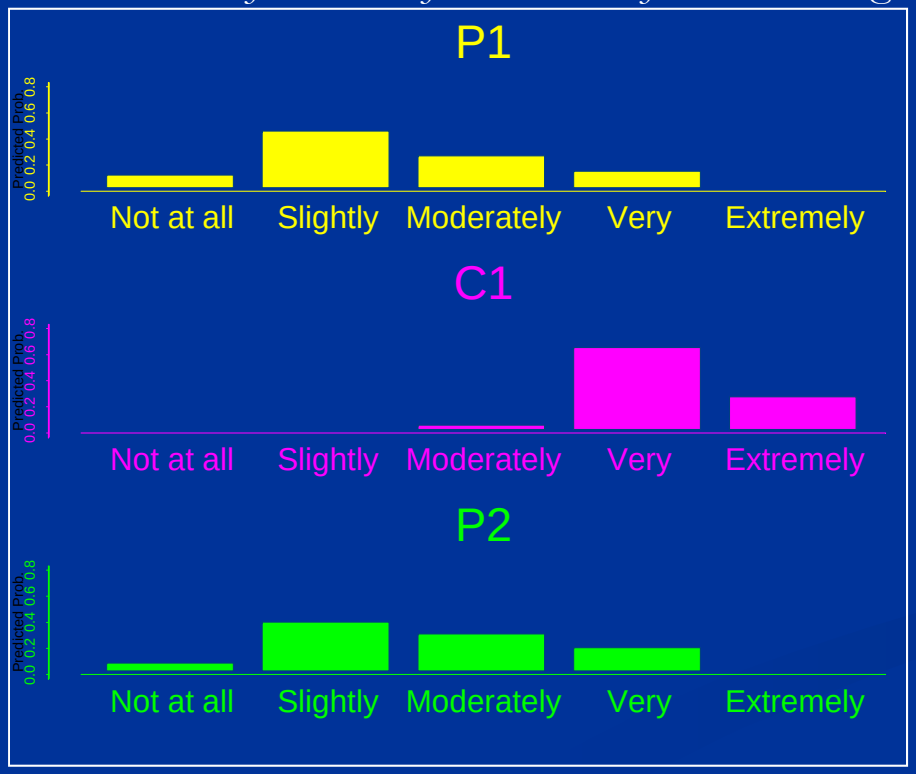
The relative importance analysis is based on the pooled data of all the 3 samples. Smooth, Color, Sweet and Particles are relatively of more importance to overall liking based on the data.

Detailed Findings Panel *Consumer* Proportional Odds Model (POM)

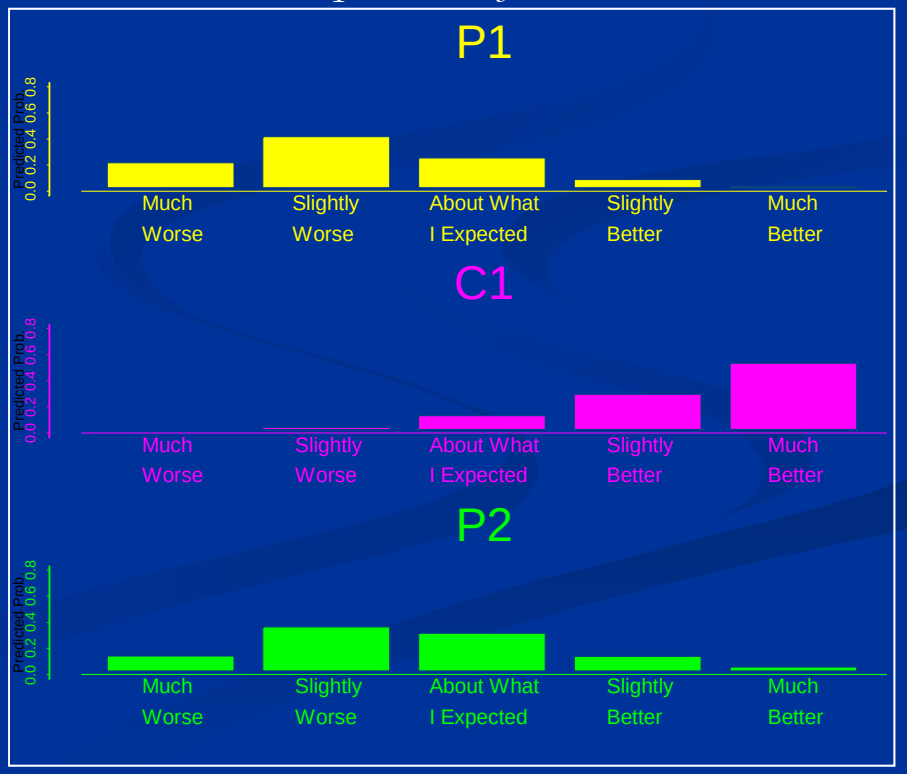
The proportional odds model (POM) applied to both ordinal measures of 'Pleasantness of Aftertaste' and 'Expectations' for the chews show the predicted probabilities of response for both prototypes vs. C1.

#P1 -- Prototype 1 ***#C1 -- Cherry Chew Candy*** ***#P2 -- Prototype 2***

Pleasantness of Taste Left in Mouth after Swallowing



Expectations for a Chew



Conclusions Method *MATI* ***Texture Breakdown Path***

- Conclusions regarding MATI are as follows:
  - MATI is a natural extension of traditional TI with one attribute
  - Rapid 'real-time' assessment tool for product screening and optimization
  - Can be applied successfully for gathering information throughout the *Texture Breakdown Path*
  - Consumption events can be logged
  - Aids and enhances panel training experiences
  - Viable with trained and consumer panels
  - Allows for relating sensory and consumer data on a time-dependent basis
  - Offers new statistical analyses of TI data

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  - Troy Nietling, Technician (Product Development)
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  - Laura Malnor, Associate Research Scientist (Sensory)
  - Descriptive and consumer panelists
- Sensometrics Research and Services
  - Jian Bi, President

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