What is a sandwich? A data analysis

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Abstract

In this paper we set out to examine the sandwich views of students and teachers at William Lyon Mackenzie C.I.

Our study consisted of a survey conducted in person with — participants. We asked participants basic demographic information about where they fit into the William Lyon Mackenzie Collegiate Institute community, and examined correlations between sandwich views and demographics.

We propose the creation of a two-dimensional sandwich alignment chart, inspired by two-dimensional political axes. The sandwich alignment chart has a dimension for "sandwich purity", and "sandwich orthodoxy".

We hypothesize that:

- Sandwich purity and sandwich orthodoxy will be positively correlated.
- Students in the MaCS or Gifted program are more likely to have a low orthodoxy score.

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Part I Introduction

Chapter 1

Terminology and notation

As this paper is dealing with sandwich mathematics, which is a developing field, we will define the terms we have coined in this chapter.

Food question A food question is any question asked about sandwiches or their ingredients. We asked 43 food questions as a part of this study. Participants answered each question on a 0 to 10 scale. We purposely started the scale at 0 so as to make 5 exactly in the middle of the range of possible responses.

Demographic question A demographic question is any of the non-food questions asked in our survey. These questions asked about participants demographics, in order to examine any correlations between demographics and sandwich views.

Chapter 2

Metrics

2.1 Axes metrics

We have two metrics used in our calculations: purity and orthodoxy.

Purity is how pure a respondent's definition of a sandwich is. The less things a respondent considers a sandwich, the greater their purity score will be. Similarly, the more things a respondent considers a sandwich, the lower their purity score will be.

Orthodoxy is a measure of how much a respondent differs from the mean set of responses. The less a respondent's answers differ from the mean set of answers, the greater their orthodoxy score will be. Similarly, the more a respondent's answers differ from the mean set of answers, the lower their orthodoxy score will be.

Both purity and orthodoxy are bound in the range [-1, 1].

We describe the general scoring system in subsection 2.1.1. This scoring system is used to calculate the purity metric described in subsection 2.1.2 and the orthodoxy metric described in subsection 2.1.3.

2.1.1 Scoring

While participants answered each food question on a 0 to 10 scale, it is more convenient to perform calculations using a -5 to 5 scale. We converted responses from the 0 to 10 scale to the -5 to 5 scale by subtracting each response from 5.

Formally, for each response to a food question, we calculate the score for the response by the passing the response through the sandwich spectrum function, defined in definition 1.

Definition 1 (Sandwich spectrum function). The sandwich spectrum function is defined as:

$$s: \{x \in \mathbb{R} \mid 0 \le x \le 10\} \to \{x \in \mathbb{R} \mid -5 \le x \le 5\} \text{ by } s(x) = 5 - x \quad (2.1)$$

Due to the format of our survey, all responses are integers, and are mapped to another integer by the sandwich spectrum function. Although, in principle, the sandwich spectrum function works for real numbers as well.

We can create a table for s:

One will note that this gives responses that were originally high a lower score. This is intentional. Subsection 2.1.2 will show it to be useful for calculating the purity metric, and subsection 2.1.3 will show it to be irrelevant for calculating the orthodoxy metric.

2.1.2 Purity

The purity score for a respondent is defined as the sum of a respondent's scores divided by the maximum possible score.

The maximum score for a question is 5, and there are 43 food questions. This means that the maximum possible score is $43 \times 5 = 215$.

Definition 2 (Sadwich purity function). For a given response with a set of 43 food answers, A, we define the sandwich purity function as:

$$p: \mathbb{R}^{43} \to \mathbb{R} \text{ by } p(A) = \frac{\sum_{i=1}^{43} A_i}{215}$$
 (2.2)

This definition illustrates why we subtract each response from 5 to get the score. The sandwich spectrum function will assign higher purity values for lower responses. Since a lower response to a question implies a more pure definition of a sandwich, definition 1 is a valid metric.

2.1.3 Orthodoxy

To calculate orthodoxy for each respondent, we take the score for each question as a dimension of a vector, which creates a vector in 43-dimensional Euclidean space.

We also calculate the mean response for each question, and create an additional \mathbb{R}^{43} vector from that. This vector is referred to as the mean vector, and denoted as \overrightarrow{m} .

The orthodoxy score for a respondent is defined as the cosine similarity between the respondent's \mathbb{R}^{43} vector and \overrightarrow{m} .

Definition 3 (Mean vector). To calculate the value of the mean vector, \vec{m} :

Let $A \in \mathbb{R}^{43}$ be the set of response vectors. Then, n(A) is the cardinality of the set A.

Then:

$$\vec{m} = \frac{\sum_{i=1}^{n(A)} A_i}{n(A)} \tag{2.3}$$

Definition 4 (Sandwich orthodoxy function). To calculate the orthodoxy score for a respondent:

Let \overrightarrow{r} be a vector in \mathbb{R}^{43} defined as having its each of its components equal to the score for each food question.

$$o: \mathbb{R}^{43} \to \mathbb{R} \text{ by } o(\overrightarrow{r}) = \frac{\overrightarrow{r} \cdot \overrightarrow{m}}{\|\overrightarrow{r}\| \|\overrightarrow{m}\|}$$
 (2.4)

Since we are calculating orthodoxy as the cosine of the angle between two vectors, it is useful to have some vector components be negative, as that allows respondents to have a negative orthodoxy score if they answer opposite to the mean response. It does not matter what direction the vectors are in, as we are only looking at the angle between them. This means that the

sandwich spectrum function could have been defined as subtracting 5 instead of subtracting from 5 for the purposes of the orthodoxy function. Since both definitions would have worked for orthodoxy, we stick with definition 1 for the sake of consistency with the purity metric.

Part II

Survey

Chapter 3

Results

Part III

Analysis

Chapter 4

Analysis

Analysis here.

Part IV

Questions

Appendix A

Questions

A.1 Sandwich Survey

What defines a sandwich?

A.2 Demographic Information

We need to study correlations and demographics.

A.2.1 What grade are you in?

Respondents were asked to select only one option. \bigcirc Grade 9 \bigcirc Grade 10 \bigcirc Grade 11 \bigcirc Grade 12 \bigcirc Teacher

A.2.2 What is/are your favourite subjects?

Resn			ject at Mackenzie.	
_	ondents were asked to Arts	check all that apply. □ Business	□ Computer Science	
	Co-op and Leadership	□ English	□ Languages	
	Library	□ Math	□ Physical Education	n
	Science	□ Social Sciences	□ Special Education	
	Other:			
		uestions		
A .:	3 Student Q	ucsulolis		
Ques $being$	tions in this section in grade 9, 10, 11, or teacher.	were asked only of response 12. It was not asked of a	respondents who identifie	

A.4 Teacher Questions

Questions in this section were asked only of respondents who identified as being a teacher. It was not asked of respondents who identified as being in grade 9, 10, 11, or 12.

A.4.1 What departments do you work in at Mackenzie?

Answer based on what dep	partment teaches the subj	ect at Mackenzie.
Respondents were asked to	check all that apply.	
\Box Arts	□ Business	☐ Computer Science and Technology
□ Co-op and Leadership	□ English	□ Languages
□ Library	\square Math	□ Physical Education
\Box Science	\square Social Sciences	$\hfill\Box$ Special Education
□ Student Services	□ Other:	

A.5 Sandwich Questions

For each of the following, answer on a scale from 0 to 10, where 0 is not at all a sandwich, and 10 is definitely a sandwich.

A.5.1 Ham between two slices of bread

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [13].

A.5.2 Bacon, lettuce, and tomato between two slices of bread

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [32].

A.5.3 Grilled cheese

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

 \bigcirc \bigcirc

Image from [4].

A.5.4 Panini

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [37].

A.5.5 Sub

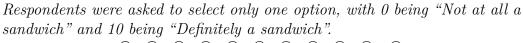


Image cropped from [9].

A.5.6 Hamburger

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [6].

A.5.7 Hotdog

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

 \circ \bigcirc 0 0 \circ 0 0 \circ \circ 2 3 5 7 0 6 8 9 10

Image from [34].

A.5.8 Ice cream between two cookies

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [8].

A.5.9 Burrito

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

 \circ \bigcirc 0 0 \bigcirc \bigcirc \bigcirc \bigcirc \bigcirc 2 3 4 5 6 7 8 10

Image from [39].

A.5.10 Taco

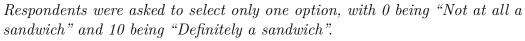


Image from [7].

A.5.11 Calzone

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [20].

A.5.12 Quesadilla

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [16].

A.5.13 Open-faced sandwich

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [30].

A.5.14 Pizza

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [31].

A.5.15 Two slices of pizza, face down, on top of each other

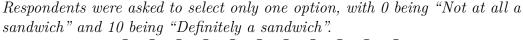


Image from [40].

A.5.16 Slice of bread between two more slices of bread

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [27].

A.5.17 Oreo cookie

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [12].

A.5.18 Ritz cracker

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [22].

A.5.19 Sushi burrito

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [15].

A.5.20 Nigiri sushi

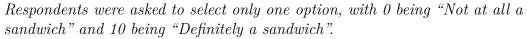


Image from [41].

A.5.21 Slice of cheese

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image cropped from [25].

A.5.22 Salad with croutons

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image from [14].

A.5.23 Brick between two slices of bread

Respondents were asked to select only one option, with 0 being "Not at all a sandwich" and 10 being "Definitely a sandwich".

Image created in GIMP using [42] and [23].

A.6 Ingredient Questions

For each of the following, answer on a scale from 0 to 10, where 0 is not at all a sandwich ingredient, and 10 is definitely a sandwich ingredient.

A.6.1 Cold cuts

Respondents were asked to select only one option, with 0 being "Not at all a sandwich ingredient" and 10 being "Definitely a sandwich ingredient".

Image from [33].

A.6.2 Tomato

Respondents were asked to select only one option, with 0 being "Not at all a sandwich ingredient" and 10 being "Definitely a sandwich ingredient".

Image from [1].

A.6.3 Cheese

Respondents were asked to select only one option, with 0 being "Not at all a sandwich ingredient" and 10 being "Definitely a sandwich ingredient".

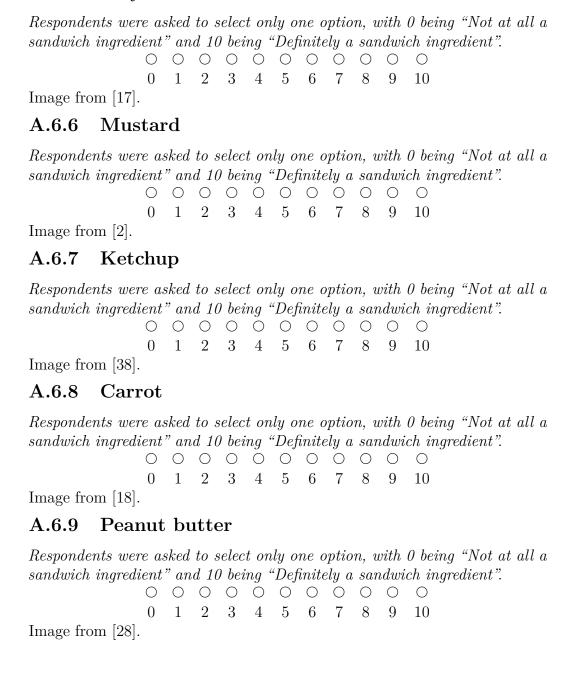
Image cropped from [25].

A.6.4 Lettuce

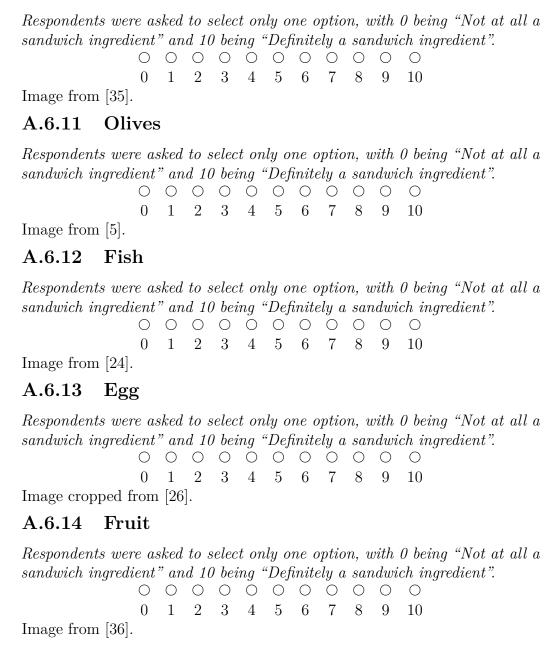
Respondents were asked to select only one option, with 0 being "Not at all a sandwich ingredient" and 10 being "Definitely a sandwich ingredient".

Image from [43].

A.6.5 Mayonnaise



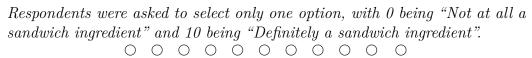
A.6.10 Jelly



A.6.15 Chicken foot

Respondents sandwich ing								_			_		t all a
	0	0		0	_	\circ				0	0		
	0	1	2	3	4	5	6	7	8	9	10		
Image from [21].												
A.6.16 I	Rice												
Respondents													t all a
sandwich ing	redient							_		_	$\stackrel{\textstyle ch\ ingre}{\scriptstyle \frown}$	dient".	
	0	0	\bigcirc 2	\bigcirc		O 5	$\begin{array}{c} \bigcirc \\ 6 \end{array}$	7	0	9	10		
Image from [_	1	2	3	4	5	U	1	0	9	10		
A.6.17 I	Potato	O											
Respondents sandwich ing	redient	an	d 10		ng	Defi	\bigcap		san	dwi	$ch\ ingre$		t all a
Image from [0 10].	1	2	3	4	5	6	7	8	9	10		
A.6.18 S	Soup												
Respondents sandwich ing													t all a
	0	1		3		5		7		9	10		
Image from [_	1	_	0	1	0	O	•	0	J	10		
A.6.19 I	Pasta												
Respondents sandwich ing					ng '		\bigcap	_	san		_		t all a
Image from [_	1	4	J	4	J	J	'	O	J	10		

A.6.20 Grass



0 1 2 3 4 5 6 7 8 9 10

Image from [19].

Appendix B

Source Code

B.1 Functions.R.

```
# Calculate the cosine similarity between two vectors.
cosineSimilarity <- function(a, b) {
    return (sum(a * b) / (sqrt(sum(a^2)) * sqrt(sum(b^2))
    ))
4 }</pre>
```

B.2 Calculate.R

```
# This is a program to calculate the orthodoxy and purity scores on the sandwich spectrum for all respondents.

source("Functions.R")

# Define the constants for what columns data is in inside the CSV file.

GRADE_COLUMN <- 1 # What column the grade data is in.

SUBJECTS_COLUMN <- 2 # What column the favourite subjects data is in.

BACKGROUND_COLUMN <- 3 # What column the ethnic background data is in.

STREAM_COLUMN <- 4 # What column the stream data is in.
```

```
10 QUESTIONS_START <- 6 # What column the food questions start
11 QUESTIONS_END <- 48 # What column the food questions end at.
12 lockBinding("GRADE_COLUMN", globalenv())
13 lockBinding("SUBJECTS_COLUMN", globalenv())
14 lockBinding("BACKGROUND_COLUMN", globalenv())
15 lockBinding("STREAM_COLUMN", globalenv())
16 lockBinding("QUESTIONS_START", globalenv())
17 lockBinding("QUESTIONS_END", globalenv())
18
19 respondents <- read.csv("Responses.csv") # Read in the CSV.
20 NUM RESPONDENTS <- nrow(respondents)
21 lockBinding("NUM_RESPONDENTS", globalenv())
23 foodResponses <- as.matrix(respondents)[,QUESTIONS_START:
      QUESTIONS_END] # Convert responses to a matrix.
24| foodResponses <- apply(foodResponses, 1, as.numeric) # \mathit{Make}
      the matrix numeric.
25 foodResponses <- 5 - foodResponses
27|\,	ext{NUM\_QUESTIONS} <- <code>nrow(foodResponses)</code> # The number of <code>sandwich</code>
       questions.
28 lockBinding("NUM_QUESTIONS", globalenv())
30 totalResponse <- numeric(NUM_QUESTIONS)
31 averageResponse <- numeric(NUM_QUESTIONS)
32
33 # Sum up the total score for each question by respondent.
34 for (i in 1 : NUM RESPONDENTS) {
35
           totalResponse <- totalResponse + (foodResponses[,i])</pre>
36|}
37 averageResponse <- totalResponse / NUM_RESPONDENTS # Divide
      by the number of respondents to find the mean.
38
39 orthodoxyScores <- numeric(NUM_RESPONDENTS)
40 purityScores <- numeric(NUM_RESPONDENTS)
41
42 for (i in 1 : NUM_RESPONDENTS) {
43
           orthodoxyScores[i] <- cosineSimilarity(foodResponses</pre>
      [,i], averageResponse)
44
           purityScores[i] <- sum(foodResponses[,i])</pre>
45|}
46 purityScores <- purityScores / (5 * NUM_QUESTIONS)
47
48 # Put data into frame.
```

```
49 data <- data.frame(purity = purityScores, orthodoxy =
    orthodoxyScores, grade = respondents[,GRADE_COLUMN],
    subjects = respondents[,SUBJECTS_COLUMN], background =
    respondents[,BACKGROUND_COLUMN], stream = respondents[,
    STREAM_COLUMN])</pre>
```

B.3 BoxPlots.R.

```
# This program creates box plots of the respondents broken
      down by their categorical data.
  library(ggplot2)
  source("Calculate.R")
6 makeBoxPlot <- function(categoryData, categoryName,
      categoryTitle) {
           boxPlotData <- data[categoryData %in% names(table(</pre>
7
      categoryData))[table(categoryData) > 1],] # Remove all
      categorical data points only occurring once, as these data
       are not helpful for a box plot.
9
           # Create the purity plot.
10
           dataPlot <- ggplot(boxPlotData, aes_string(</pre>
      categoryName, "purity", fill=categoryName), ) \# Setup the
           dataPlot <- dataPlot + geom_boxplot() # Add the data</pre>
11
      points.
           dataPlot <- dataPlot + labs(x = categoryTitle, y = "</pre>
12
      Purity") # Give axes and legend proper labels.
13
           dataPlot <- dataPlot + theme(legend.position = "none"
           ggsave(paste(categoryTitle, "Purity.pdf"), plot=
14
      dataPlot, width=9, height=8)
15
16
           # Create the orthodoxy plot.
17
           dataPlot <- ggplot(boxPlotData, aes_string(</pre>
      categoryName, "orthodoxy", fill=categoryName), ) # Setup
      the plot.
           dataPlot <- dataPlot + geom_boxplot() # Add the data</pre>
18
      points.
19
           dataPlot <- dataPlot + labs(x = categoryTitle, y = "</pre>
      Orthodoxy") # Give axes and legend proper labels.
```

```
dataPlot <- dataPlot + theme(legend.position = "none"
)

ggsave(paste(categoryTitle, "Orthodoxy.pdf"), plot=
    dataPlot, width=9, height=8)

and makeBoxPlot(data$grade, "grade", "Grade")

makeBoxPlot(data$background, "background", "Ethnic Background")

makeBoxPlot(data$stream, "stream", "Stream")</pre>
```

B.4 PurityOrthodoxyPlot.R

```
1 \mid # This is a program to plot orthodoxy vs purity on the
      sandwich spectrum for all respondents.
  library(ggplot2)
  source("Calculate.R")
  makeScatterPlot <- function(categoryName, categoryTitle) {</pre>
7
           # Create the plot.
8
           dataPlot <- ggplot(data, aes(purity, orthodoxy)) #</pre>
      Setup the plot.
9
           \#dataPlot \leftarrow dataPlot + coord\_cartesian(xlim = c(-1,
      1), ylim = c(-1, 1)) # Set the graph limits.
10
           dataPlot <- dataPlot + geom_point(aes_string(colour =</pre>
       categoryName)) # Add the data points.
11
           dataPlot <- dataPlot + geom_smooth(method = loess,</pre>
      level = 0.95, colour = "black", size = 0.5) # Add the
      confidence curve.
12
           dataPlot <- dataPlot + geom_smooth(method = lm, se =
      FALSE, colour = "black", size = 0.5, linetype="dashed") #
      Add the line of best fit.
           dataPlot <- dataPlot + labs(x = "Purity", y = "</pre>
13
      Orthodoxy", colour = categoryTitle) # Give axes and legend
      proper labels.
           ggsave(paste(categoryTitle, "PurityVsOrthodoxy.pdf"),
14
       plot=dataPlot, width=9, height=8)
15|}
16
17| makeScatterPlot("stream", "Stream")
18 makeScatterPlot("grade", "Grade")
```

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