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Background

Most research on the dynamics of Galileo Space have involved associating objects with each other. In one of the earliest such studies, Barnett, et. al, associated the concepts of convenience and conserving natural resources with Proposition A, a Michigan referendum on the proposition to charge deposits on glass bottles with the message: "Proposition A: a convenient way to conserve natural resources." In their study, this campaign resulted in the movement of Proposal A toward the position of the self-concept, resulting in a victory against overwhelming financial resources. [1] Another early political experiment associated the concepts "crime fighter" and "democratic party" with a relatively unknown candidate for a congressional seat. This resulted in the candidate moving closer to the self-point of a sample of voters, and the candidate's election over a much better funded and more well-known incumbent.[2]

Barnett sent messages to undergraduate students associating pigs, hogs, boar and swine with the terms *beneficial* and *attractive*. He found that the porcine terms approached *beneficial* and *attractive* and was able to establish the relative masses of three of the terms (pigs, hogs and swine). He found these masses correlated with the frequency of occurrence of the terms in English 1.0 [3]. In a replication and extension of this study 38 years later, McIntosh and Woelfel again found that the terms approached beneficial and attractive and were able to establish the inertial masses of the porcine terms which replicated Barnett's values and correlated with two measures of their frequency of occurrence in English better than .99. They were also able to establish the relative masses of *beneficial* and *attractive*[4].

On a much larger scale, Kincaid, et.al. showed that the galileo spaces of Korean immigrants to Hawaii converged on the resident US population of Hawaii as a function of the time they resided in the US. Many more examples can be found in the Galileo literature [6].

There are, however, no Galileo based studies in which concepts are directly differentiated. Woelfel, et. al. had 75 subjects read a message assigning random attributes (e.g., height, intelligence, political position, etc.) to six fictitious persons, then had them fill out a complete paired comparison Galileo questionnaire after a randomly selected waiting period of 0, 1 hour, 24 hours or 178 hours (one week). The results showed an increase in the separations among the names of the people that was not complete after one hour, followed by a decrease at 24 hours, and no change after one week.[7]

A second experiment was performed, this time randomly assigning 471 undergraduate students to a random waiting period starting ½ hour after receipt of the message until one week. This study showed an increase in distances among the names in the first hour as was found in the earlier study, and a large and unanticipated bump in size between 9 and 12 hours. A third experiment utilizing 550 additional subjects the following year gave similar results.

Although all of these experiments resulted in expansions rather than convergence of Galileo space, they were not the result of differentiating concepts; these concepts moved apart because they were associated with concepts that were still further apart, and the divergence resulted from the convergence of the manipulated concepts on the more divergent concepts. In the present study, a pair of concepts is both differentiated and associated in two separate treatments.

Theory

Out of these and other experiments, a general working theory has emerged. Concepts or "objects" are considered to be clusters of neurons which represent linked perceptions which are defined in terms of their relationships to other concepts or objects. These may be represented as points in a multidimensional non-Euclidean (i.e., non-linear) spatial manifold where similar concepts are "close" to each other. Statements of the form "X is Y", or "X is Y_i" where i=1…n, may be represented as multidimensional non-Euclidean vectors from the position of X to the position(s) of the Y_i. The force associated with any statement is given by the magnitude of the average of these vectors.

Since all experiments over the past 40 years have seen effects decay in reasonably short time periods, we assume the system is damped, and, since both expansion of the space followed by return toward the original positions have been observed repeatedly, we assume the system equilibrates, which suggests an equation for damped harmonic motion

(1) $$m(d^2x/dt^2)+C(dx/dt)+kx = 0$$

where m= the mass of a concept
C= the damping constant
K= the restoring force.

Concepts like "different" or "Similar", however, aren't given their meaning by a location in the space, but rather serve as operators on the space. Thus, there is no place where "different" is located, and no obvious vector associate with its use. The meaning of "different" or "similar" therefore is given by their effect on the location of its referents.

We are aware of no theory that predicts the different outcomes to be expected between differentiation and association, other than the simple expectation that associated concepts should approach each other while differentiated concepts ought to move further apart, so no specific hypotheses are presented, other than the general expectation that concepts that are said to be different ought to diverge, while those said to be similar ought to converge.

Methods

A complete paired comparison magnitude estimation Galileo questionnaire including the names of 10 cars (Chevrolet, Ford, Alfa Romeo, Maserati, VW, BMW, Lexus, Jeep, Volvo and Infiniti), four attributes (Good, Expensive, Affordable, Durable) and the self-term (Yourself) was administered to 240 undergraduate students at a the University at Buffalo, State University of New York. One third of the respondents comprised a control condition, and read these instructions:

This questionnaire will ask you about the differences among cars.

Instructions

Please estimate how different or "far apart" each of the following words or phrases is from each of the others. The more different, or further apart they seem to be, the larger the number you should write. To help you know what size number to write, remember
FORD AND CHEVROLET ARE 50 UNITS APART
If two words or phrases are not different at all, please write zero (0). If you have no idea, just leave the space blank.

Thank you very much for your help.

Another third read exactly the same instructions, but included this single line:

```
This questionnaire will ask you about the differences among cars

For example, CHEVROLET and VOLVO are VERY DIFFERENT
```

Finally, a third of the respondents read the otherwise identical questionnaire, which included the following single line:

```
This questionnaire will ask you about the differences among cars

For example, CHEVROLET and VOLVO are VERY SIMILAR
```

All respondents then filled out a complete (105) paired comparison questionnaire in 13 blocks of eight responses, one of which is reproduced here (The 14th box contained the sole remaining pair):

		FORD AND CHEVROLET ARE 50 UNITS APART			
	COL.				
0102	9–17	CHEVROLET	and	FORD	_____
0103	18–26	CHEVROLET	and	ALFA ROMEO	_____
0104	27–35	CHEVROLET	and	MASERATI	_____
0105	36–44	CHEVROLET	and	VW	_____
0106	45–53	CHEVROLET	and	BMW	_____
0107	54–62	CHEVROLET	and	LEXUS	_____
0108	63–71	CHEVROLET	and	JEEP	_____
0109	72–80	CHEVROLET	and	VOLVO	_____

Results

Data were recorded using the SPED program from the Galileo software suite, and descriptive statistics, eigenvalues and eigenvectors for all three datasets were computed using Galileo Version 5.7. The two treatment conditions were then rotated to least squares best fit on the control condition. The manipulated concepts, Chevrolet and Volvo, were left out of the least squares best fit, so that the remaining unmanipulated concepts can serve as an inertial reference frame against which the relative motions of the manipulated concepts can be gauged.

Mean values for every pair were computed; the largest standard deviation among the 105 pairs was 1026.527 for the Alfa Romeo to yourself distance, (Mean = 238.1) so, following Chauvenet's Criterion,

Maxval = 3(1026.5)+238.1 = 3317.6, rounded to 3318.

All outliers above this number were trimmed. 22 values were deleted, which represented .011% of the 21,830 total responses.

As is typical for ratio scaled complete paired comparison measures, precision was very good by social science standards, with standard errors as small as 4.3% for distances between familiar cars (e.g., Chevrolet and Ford). Appropriately, standard errors are considerably higher for exotic vehicles, and individual differences – that is, distances from the self to other objects – are higher still. Assuming that the variation around any given paired distance is the sum of the errors of the individual elements

(2) $e_i = e_j + ek$

Where e_i = the error around the i^{th} concept, and
ej and e_k = the error around the j^{th} and k^{th} concepts

yields, for the 15 concepts in this study, 105 equations in 15 unknowns. Solution of this system using the Microgal program from the Galileo suite yields the following estimates for the errors around the concepts in this study, shown in Table 1.

Table 1: Standard Errors By Concept

Standard Errors of Estimate		
1	CHEVROLET	4.8495
2	FORD	5.5767
3	ALFA ROMEO	6.9104
4	MASERATI	9.4126
5	VW	6.3019
6	BMW	5.2783
7	LEXUS	5.5182
8	JEEP	5.2283
9	VOLVO	4.4956
10	INFINITI	5.0665
11	GOOD	3.2357
12	EXPENSIVE	4.8710
13	AFFORDABLE	8.4593
14	DURABLE	3.9875
15	YOURSELF	12.2324

Table 2 shows the relationships among the eigenvectors of the three conditions after rotation to least squares best fit:

Table 2: Relations Among Control Reference Frame and Two Treatment Reference Frames

Row Vector Correlations Between Time 1 and Time 2					
Concept	T 1 Magnitude	T 2 Magnitude	Scalar Product	Correlation	Angle
1 Chevrolet	55.12	88.07	3031.45	0.624494	51.4
2 Ford	51.95	83.61	3687.60	0.848983	31.9
3 Alfa Romeo	62.89	81.05	5165.77	0.986572	9.4
4 Maserati	82.62	102.73	8639.93	0.982067	10.9
5 VW	55.98	62.08	3197.82	0.920272	23.0
6 BMW	43.90	48.53	1153.52	0.541514	57.2
7 Lexus	39.32	49.31	1755.94	0.905633	25.1
8 Jeep	45.18	63.27	2406.08	0.841672	32.7
9 Volvo	48.39	47.99	715.15	0.307959	72.1
10 Infiniti	38.83	48.37	1778.14	0.946845	18.8
11 Good	-31.14	-19.45	-811.85	0.659975	48.7
12 Expensive	69.53	91.18	5962.32	0.940543	19.9
13 Affordable	85.94	109.68	9287.82	0.985313	9.8
14 Durable	16.16	-15.90	-247.17	0.961673	15.9
15 Yourself	96.34	86.08	7772.17	0.937131	20.4
Col Vector Correlations Between Time 1 and Time 2					
-	T 1 Magnitude	T 2 Magnitude	Scalar Product	Correlation	Angle
1	151.81	204.05	29280.33	0.945195	19.1
2	116.80	114.77	12331.59	0.919878	23.1
3	82.61	114.17	8322.15	0.882416	28.1
4	67.10	74.33	3106.83	0.622972	51.5
5	51.81	59.05	2259.03	0.738341	42.4
6	49.29	58.49	2174.11	0.754115	41.1
7	44.30	60.37	1275.33	0.476848	61.5
8	34.35	51.08	1188.79	0.677514	47.4
9	31.90	57.02	710.71	0.390699	67.0
10	14.17	44.84	209.06	0.329087	70.8
11	0.00	0.43	0.00	1.000000	0.0
12	0.40	14.94	1.19	0.198928	78.5
13	12.93	25.23	80.20	0.245828	75.8
14	28.19	48.17	421.58	0.310445	71.9
15	81.98	111.06	6860.26	0.753464	41.1
Row Vector Correlations Between Time 1 and Time 3					
Concept	T 1 Magnitude	T 3 Magnitude	Scalar Product	Correlation	Angle
1 Chevrolet	55.12	61.82	1998.76	0.586600	54.1

2 Ford	51.95	74.78	3748.47	0.964911	15.2
3 Alfa Romeo	62.89	63.10	3516.27	0.886145	27.6
4 Maserati	82.62	66.47	5501.88	0.998212	3.4
5 VW	55.98	51.33	2646.75	0.921217	22.9
6 BMW	43.90	29.76	1328.43	0.983193	10.5
7 Lexus	39.32	38.99	1371.45	0.894519	26.6
8 Jeep	45.18	40.92	1546.81	0.836567	33.2
9 Volvo	48.39	49.37	1254.40	0.525141	58.3
10 Infiniti	38.83	40.83	1706.81	0.923388	22.6
11 Good	-31.14	-25.02	-804.84	0.967039	14.8
12 Expensive	69.53	69.99	4691.43	0.964158	15.4
13 Affordable	85.94	85.09	7233.78	0.989176	8.4
14 Durable	16.16	-5.81	11.22	-0.119470	96.9
15 Yourself	96.34	76.53	6929.83	0.939849	20.0
Col Vector Correlations Between Time 1 and Time 3					
-	T 1 Magnitude	T 3 Magnitude	Scalar Product	Correlation	Angle
1	151.81	150.77	21761.44	0.950726	18.1
2	116.80	99.37	10237.88	0.882072	28.1
3	82.61	86.48	6725.58	0.941426	19.7
4	67.10	57.69	2369.70	0.612146	52.3
5	51.81	52.43	2280.02	0.839416	32.9
6	49.29	50.62	2127.18	0.852445	31.5
7	44.30	38.18	1243.48	0.735100	42.7
8	34.35	37.90	954.86	0.733429	42.8
9	31.90	50.92	906.32	0.557900	56.1
10	14.17	42.66	153.69	0.254343	75.3
11	0.00	0.00	0.00	1.000000	0.0
12	0.40	6.58	0.43	0.161985	80.7
13	12.93	38.78	192.35	0.383540	67.4
14	28.19	46.05	-96.12	-0.074028	94.2
15	81.98	79.97	5982.04	0.912420	24.2

The first and third blocks of Table 2 show the respective lengths, scalar product, correlations and corresponding angles among the position vectors of the concepts in the control condition and the two treatment conditions, *different* and *similar*. The second and fourth blocks show the respective lengths, scalar product, correlations and corresponding angles among the basis vectors of the control condition and the two treatment groups. Table 2 shows considerable

stability among the unmanipulated concepts, sufficient to establish an inertial reference frame against which the motions of the manipulated concepts can be measured. Table 3 shows these relative motions. It also shows that the imaginary eigenvectors (12, 13, 14 and 15) are generally stable across the three conditions, showing that the underlying geometry of the space is non-Euclidean.

Table 3: Distance Moved by Treatment Condition

		Different	Similar
Concept 1 CHEVROLET	moved	67.476	53.169 units
Concept 2 FORD	moved	43.423	24.439 units
Concept 3 ALFA ROMEO	moved	13.145	28.293 units
Concept 4 MASERATI	moved	6.716	15.158 units
Concept 5 VW	moved	24.021	20.821 units
Concept 6 BMW	moved	44.368	9.982 units
Concept 7 LEXUS	moved	19.230	16.239 units
Concept 8 JEEP	moved	33.588	24.894 units
Concept 9 VOLVO	moved	55.722	46.338 units
Concept 10 INFINITI	moved	16.652	15.489 units
Concept 11 GOOD	moved	8.524	3.213 units
Concept 12 EXPENSIVE	moved	28.927	18.593 units
Concept 13 AFFORDABLE	moved	20.563	11.991 units
Concept 14 DURABLE	moved	9.080	4.991 units
Concept 15 YOURSELF	moved	33.107	33.700 units
Mean		28.3	21.2
SD		18.1	14.1
Mean of Unmanipulated Concepts		23.2	17.5
SD of Unmanipulated Concepts		12.7	8.9

Table 3 show that both manipulated concepts, *Chevrolet* and *Volvo*, moved significantly in both conditions. In the *different* condition, *Chevrolet* moved 67.5 units compared to a mean

motion of the unmanipulated concepts of 23.2, with a standard deviation for the unmanipulated concepts – a fair measure of error – of 12.7. In the same condition, *Volvo* moved 55.7 units. In the *similar* condition, *Chevrolet* moved 53.2 units compared to a mean motion of the unmanipulated concepts of 21.2, with a standard deviation for the unmanipulated concepts of 8.9.

These motions resulted in the distance between the manipulated concepts, *Chevrolet* and *Volvo*, increasing significantly in the *different* condition, but not changing significantly in the *similar* condition, as Table 4 shows:

Table 4: Distances Between Manipulated Concepts (Chevrolet/Volvo) by Treatment Condition

Condition	Mean Distance	Standard Deviation	Change
Control	53.36	5.394	
Different	71.623	9.614	18.263
Similar	51.686	4.409	-1.674

At first, it may seem that this indicates it is easier to move objects apart than to pull them together, but further analysis suggests otherwise. Examination of the mean distances among cars in the control condition shows that respondents already believe Chevrolet and Volvo are quite similar, so very little change is advocated. The average distance among cars in the control group is 73.5; *Chevrolet* and *Volvo* are only 52 units apart, which is a whole standard deviation closer than the average pair of cars.

Table 5: Distances Among Cars (Control Group)

	Chevy	Ford	Alfa	Maserati	VW	BMW	Lexus	jeep	Volvo
Chevy									
Ford	43.4								
Alfa	112.2	99							
Maserati	142.7	138.9	76.3						
VW	51.4	69.7	97.9	110.7					
BMW	95.6	100.4	65.4	43.4	66.1				
Lexus	77.5	100.7	76.9	47.7	61.6	34			
jeep	55.8	55.4	91.5	90	60.9	61.9	73.6		
Volvo	52	68.8	93	91.6	47.9	55.6	62.2	53.9	
Infiniti	60.3	87.7	77.2	71.8	58.4	52.1	43.2	67.6	64.2
total	3308.1	Mean	73.5133333	SD	24.453598				

It is possible, however, to assess resistance to acceleration in both directions. If we assume that the force of the message a measured by the amount of change advocated is split evenly among the two objects, the distance each moves can give an indication of their relative inertial masses.

Table 6: Ratio of Masses by Treatment Condition

Condition		Different Chevrolet/Volvo	Similar Chevrolet/Volvo
Mass Ratio	Volvo	1.21184919	1.14902808
Mass Ratio	Chevrolet	0.82518519	0.87030075

Table 6 shows no significant difference in the ratio of masses of Chevrolet/Volvo across the *different* and *similar* conditions. This indicates that, in this case, we cannot rule out the possibility that the space is isotropic.

Direction of Motion

Simple, atheoretical guess as to how the manipulated concepts ought to move when they are designated as different or similar might be that they move directly away from or toward one

another along the line segment connecting them. Since the space is non-Euclidean, we might suggest a geodesic or shortest line instead of a straight line. The observed motions, however, are not so straightforward. To find the predicted trajectory based on this guess, we simply calculate the difference between the position vector of Chevrolet in the rotated coordinate system control condition and the position vector of Volvo in the same system. This will yield one vector moving in a given direction along the geodesic connecting Chevrolet and Volvo in the space; the negative of this vector will represent the predicted motion in the opposite direction, for a total of four predicted vectors, i.e.,

(2) $\mathbf{P}v(sim) = \mathbf{V}(con) - \mathbf{C}(con)$
$\mathbf{P}v(dif) = -\mathbf{P}v(sim)$
$\mathbf{P}c(sim) = \mathbf{P}v(dif)$
$\mathbf{P}c(dif) = -\mathbf{P}c(sim)$

Where $\mathbf{V}(con)$ = the Volvo position vector in the control condition
$\mathbf{C}(con)$ = the Chevrolet position vector in the control condition
$\mathbf{P}v(sim)$ = the predicted Volvo movement vector in the similar condition
$\mathbf{P}v(dif)$ = the predicted Volvo movement vector in the different condition
$\mathbf{P}c(sim)$ = the predicted Chevrolet movement vector in the *similar* condition
$\mathbf{P}c(dif)$ = the predicted Chevrolet movement vector in the *different* condition.

We can similarly derive four observed motion vectors by subtracting the position vectors of Chevrolet and Volvo in the *control* condition from their position vectors in the *different* and *similar* conditions:

(3) $\mathbf{O}c(dif) = \mathbf{C}(con) - \mathbf{C}(dif)$
$\mathbf{O}c(sim) = \mathbf{C}(con) - \mathbf{C}(sim)$
$\mathbf{O}v(dif) = \mathbf{V}(con) - \mathbf{V}(dif)$
$\mathbf{O}v(sim) = \mathbf{V}(con) - \mathbf{V}(sim)$

Where $\mathbf{O}c(dif)$ = observed *Chevrolet* motion vector in *different* condition
$\mathbf{O}c(sim)$ = observed Chevrolet motion vector in *similar* condition
$\mathbf{O}v(dif)$ = observed Volvo motion vector in *different* condition
$\mathbf{O}v(sim)$ = observed Volvo motion vector in *similar* condition.

The degree to which the direction of the observed motion corresponds to the predicted direction can be found by taking the scalar product of the predicted and observed vectors:

(3) $\mathbf{PO}^T = |\mathbf{P}|X|\mathbf{0}|\cos\alpha_{\mathbf{PO}}$

Where $\mathbf{P}$ = the predicted motion vector
$\mathbf{O}$ = the observed motion vector
$|\mathbf{P}|$ the length of the predicted motion vector

$|\mathbf{O}|$ the length of the observed motion vector
$\alpha_{\mathbf{PO}}$ = the angle between the predicted and observed vector

Table 7 shows that Volvo moves exactly as predicted, but Chevrolet moves generally perpendicular to the predicted motion,

Table 7: Cosines (correlation) and angles between predicted and observed motion vectors

Condition	Different		Similar	
	Chevrolet	Volvo	Chevrolet	Volvo
Cosine	.0102	.9996	.1432	.9998
Angle	90	0	81.8	0

So the atheoretical guess is only half correct. Clearly, the meaning of the words “different” and “similar”, at least in terms of their effects on the cognitive structure of their hearers, is not simple. Table 8 sheds some light on the complexity.

Table8: Distance of Manipulated Concepts from Remaining Concepts by Condition

Car	Chevrolet			Volvo		
Condition	control	different	similar	control	different	similar
1 Chevy	0	0	0	53.4	71.6	51.7
2. Ford	42.1	43.9	43.6	55.4	74.8	67.6
3 Alfa	69.4	102.9	109.9	75.9	103.8	91.7
4 Maserati	111.3	215.7	138.8	115.9	107.1	90.1
5 VW	69.9	89.4	51.2	47.7	76.1	47.3
6 BMW	86.2	122.6	94	61.3	81.9	53.3
7 Lexus	93.8	113.7	76.2	76.6	83.6	61.6
8 Jeep	53.1	63.4	55.6	59.2	72.2	53
9 Volvo	53.4	71.6	51.7	0	0	0
10 Infiirti	54.6	92.3	59.6	49.7	61.9	63.7
11 Good	34.8	42.5	26.3	35.8	49.9	49
12 Expensive	61.4	75.7	40.9	43.9	55.7	66.1
13 Affordable	30.1	36.2	26.6	43.2	72	52.2
14 Durable	35.3	34.8	29.2	32.2	42.2	47.7
15 Yourself	121.3	133.8	99.8	116.3	99	112.3
Sum	916.7	1238.5	903.4	866.5	1051.8	907.3
Mean	61.1133333	82.5666667	60.2266667	57.7666667	70.12	60.4866667
SD	32.2577536	52.3451276	37.1297622	29.9671407	26.8658094	25.3701981

Table 8 seems to show that respondents who read the message that Chevrolet and Volvo are different took the message to mean they were not only different from each other, but "different". In the *different* condition, the distance between Chevrolet *and every other car and every other attribute except one* increases. The distance between Volvo and every other car except one (Maserati) increases, as does the distance from every attribute except one, *yourself*. The mean distance of Chevrolet from the rest of the objects in the neighborhood increases from 61.1 to 82.6; for Volvo, the increase is from 57.8 to 70.1. In fact, the overall size of the space itself as measured by the trace (sum of eigenvalues) increases from 37,866 to 57,509.

No corresponding decrease in any of these values occurs for the *similar* condition. Apparently, on legitimate meaning of "different" in English is "set apart from everything," while there is no equivalent meaning for the word "similar" as in "similar to everything."

References

1. J. Woelfel and E. L. Fink, *The measurement of communication processes: Galileo theory and method*. (Academic Press, New York, 1980).
2. G. A. Barnett, K. Serota and J. Taylor, Human Communication Research **2** (3), 227-244 (1976).
3. G. A. Barnett, in *Readings in the Galileo system: Theory, methods, and application* edited by G. A. Barnett and J. Woelfel (Kendall/Hunt, Dubuque, IA, 1988), pp. 243-264.
4. R. McIntosh and J. Woelfel, Communication and Science Journal (2017).
6. C. Evans, (RAH Press, Buffalo, 2012).
7. J. Woelfel, B. J. Newton, R. A. Holmes, D. L. Kincaid and J. Lee, Quality and Quantity **20**, 133-145 (1986).