Statistical Breakthrough or Numerical Nonsense?
The logic and utility behind a Vessel Volume Index in studying Dollarware

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Abstract: The research concerns the utility of a Vessel Volume Index in studying Dollarware. Displacement volume (Vd) and Content Volume (Vc) are measured over 289 discount vessels to form an index value in the form of Vd/Vc=VVI. A z-test shows that Dollarware VVI differs from non-Dollarware. This is attributed to multiple possibilities including sample bias or stylistic preference. Groups within Dollarware are then isolated based on physical traits. Regression analysis shows that VVI correlates weakly with these traits, though a single factor ANOVA test shows that VVI is still significant within most groups. Finally, suggestions for future research are considered.

Introduction

Since most of archaeology is limited to the surviving material record – and since much of that record exists in fragments and broken remains - it is not surprising that researchers have tried to apply a wide range of statistical methods to reveal potential patterns about cultural remains. Having gained prominence from the processualist movement of the 1960s and 70s, statistics in archaeology are necessary for artefact studies, mainly because they aid in inferring broad-scale patterns from what are usually small or incomplete samples.

The nature of the present research is unusual in that the material record is drawn from the present. As a subject, Dollarware may not seem particularly interesting, but it is allowing archaeologists to perform a series of studies with less concerns regarding broken artefacts or incomplete assemblages. Our own research has focused on the issue of a statistical index in Dollarware; specifically, we have addressed the question as to whether a relationship exists between a drinking vessel's displacement volume and its volume contained. We also have sought to discover whether this index distinguishes a) Dollarware from other collections of drinking vessels, and b) subgroups identified within Dollarware. Ultimately, the goal of this research was to evaluate whether such an index is useful for explaining elements of material culture.

Previous archaeological studies on drinking vessels have neglected to examine this proposed index, nor its equivalent. Instead, most have been limited to attempts at inferring vessel volume or recreating their shape based on fragmentary evidence (Ericson and de Atley, 1976; Senoir and Birnie, 1995; Whalen, 1998; Zapassky et.al., 2006).

The present research report serves to outline the basic methodology, results, and interpretations regarding the Vessel Volume Index as it relates to Dollarware. The decision to examine an index that potentially reveals characteristics invisible to simple observation is risky, in that we may very well fail at learning anything exciting about Dollarware and drinking vessels in general. We have chosen to take this risk, since true understanding is equally about what we know *is*, and *is not*.

Methods

The Dollarware collection was gathered by a number of undergraduate archaeology students at McGill University across a range of dollar and discount/thrift stores in the Montreal region. Where possible, roughly 20 drinking vessels were collected per site to form a total of 289 vessels classified into 14 assemblages (13 dollar stores ranging from Assemblage A through M, and one second-hand store as the control/comparison Assemblage N).

It is necessary to begin our report with a discussion of what exactly VVI represents. We were both interested in the physical relationships between and within Dollarware, particularly with respect to differences in volume. This led us to develop the Vessel Volume Index, a ratio which considers a vessel's contents volume as well as its displacement volume. It can be calculated using the following formula:

$$VVI = \frac{Vd}{Vc}$$

where Vd = liquid volume displaced by a vessel and Vc = liquid volume contained by a vessel. Discussing vessels based on this ratio allows us to factor in variability, but not isolate it, in shape, thickness, height and even handle size when noting how much liquid any given vessel contains. For example, a mug that contains x amount of liquid and that has thicker than average rims may actually have a relatively equal VVI to another mug that contains x-y liquid but that has thinner than average rims. VVI indicates whether vessels are efficient in their volume capacity relative to the amount of space that they occupy. Since we expect that most mugs contain more liquid than they displace, we expect that $0 < VVI < 1$. However, this does not discount the theoretical possibility of exceptions, those being vessels that displace more space than they contain. Such exceptions will only be discussed if they are encountered.

The data collection was centered on both measurements of volume. In order to measure volume contained, each vessel was weighed with and without water. The difference in mass was then converted using the fact that 1 g=1 ml. Displacement volume was measured by individually immersing the vessels into a beaker containing a set amount of water (usually 2,500 ml). Using a smaller beaker and pipette, the displaced water was transferred into a graduated cylinder and measured (Vd). The large beaker was reset to 2,500 ml, and the process was repeated for each vessel.

The data for both Vc and Vd was entered into Microsoft Excel alongside the metric data taken by other students. VVI was then calculated by dividing each vessel's Vd by its Vc. The results were separated into two main groups, those being Dollarware (samples A – M) and the comparative Value Village Collection (sample N), both of which were fitted with linear regression lines and respective Pearson's R coefficients. It was then possible to calculate descriptive and inferential statistics on the samples. T-tests were used to compare the Dollarware collection to the comparative collection in order to determine if the sample means differed significantly.

We then attempted to isolate subgroups within Dollarware in order to examine whether VVI correlated with our particular group selection. It was hypothesized from **Figure 2** that the clustered vessels at either ends of the scatter-plot shared particular attributes and forms. This led Gravel to divide the entire Dollarware collection into 7 sub-categories based on a combination of metrical analysis and visual inspection. What began as a somewhat arbitrary process was refined until significant results were determined. First, Gravel examined the measurements for height, external diameter and top-base ratio of each vessel and verified that each measurement matched with its mug. It was decided that no vessel should be categorized into more than one group. The sample size of assemblage N was insufficient for us to complete a similar categorization for comparison. We isolated the following six categories using the selection criteria below, while **Figure 1** displays the sample form per category ('Other' category excluded):

Tall cups:
- Height > 120mm
- Form unimportant

Conical Curved
- In nearly all cases, Top external diameter < Height
- Top:Base Ratio between 1.17 – 1.9
- Visibly curved outer face

Conical Straight
- In nearly all cases, Top external diameter < Height
- Top:Base Ratio between 1.17 – 1.9
- Visibly straight outer face

Cylindrical
- Height between 80 – 120mm
- Top:Base Ratio < 1.17

Espresso / Tea cup
- Height < 93mm
- Top external diameter < 93mm
- No particular relationship between Top external diameter and height

* This is the only category in which we accepted vessels with a pedestal base

Latte cups:
- Height < 92mm
- Top external diameter > 93mm
- Top external diameter > Height
- No particular pattern in relation to Top:Base Ratio

Other
- Almost all vessels with pedestal bases (except those that qualify as Espresso)
- Vessels with largely flared top rims
- Vessels that were 'pear shaped'; that is,

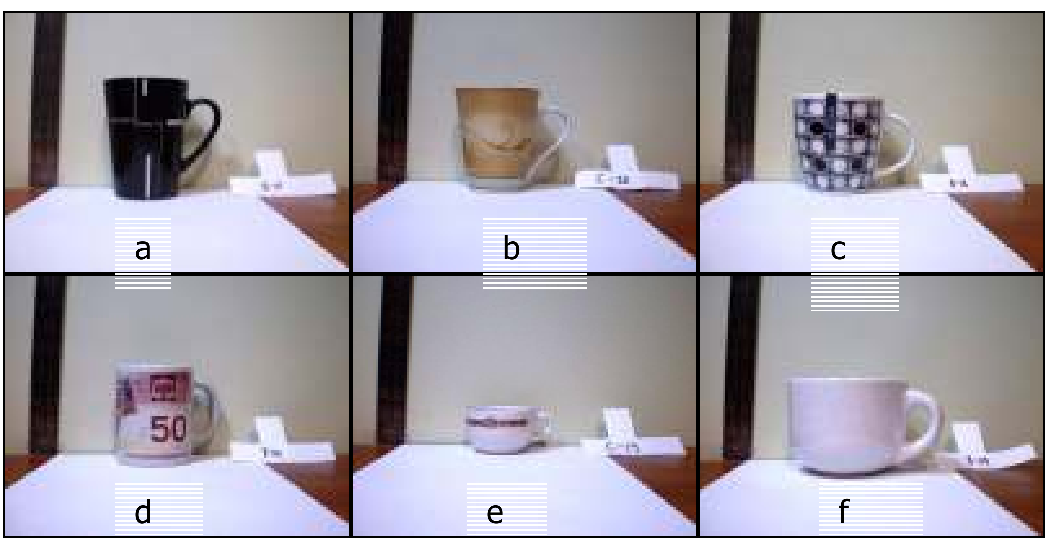

Figure 1. Basic shapes of the six defined groups.

Once completed, we selected the six trait-defined groups (excluding 'others') and looked at any correlations between VVI and a number of other metrical properties such as height, weight, top-base ratio, rim thickness and top:rim ratio. Pearson's R coefficient was also calculated for these correlations. Finally, an ANOVA – single factor test was performed on the distributions of VVIs for the six groups, and the results represented visually.

Results

Due to the large amount of computation involved in this research, it would be inefficient and ultimately uninformative if all tables and graphs were reproduced in this section. Therefore, the data-fiends can refer to the appendix for additional tables, graphs and statistics.

The results display some interesting patterns. The distributions of VVI values for Dollarware and non-Dollarware are displayed in **Figures 2 and 3,** respectively. Their accompanying frequency distribution is visible in **Figure 4**.

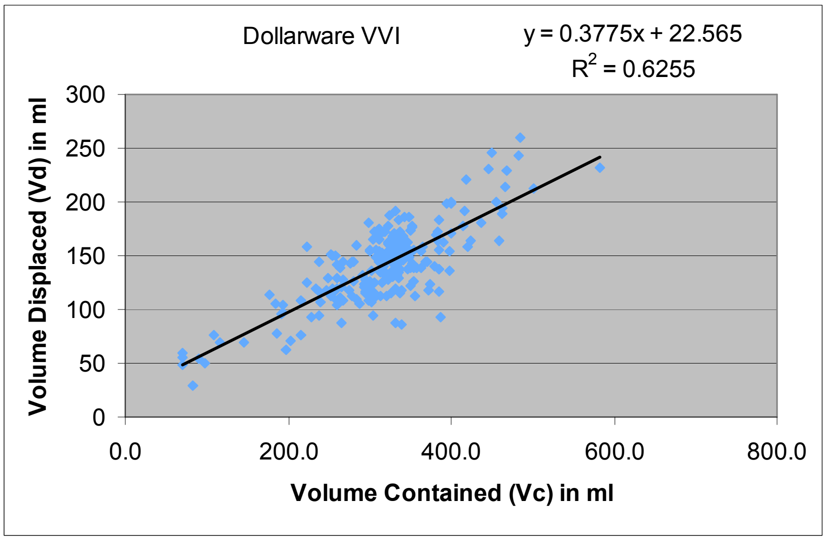

Figure 2: Dollarware VVI scatter plot with calculated regression (n=228)

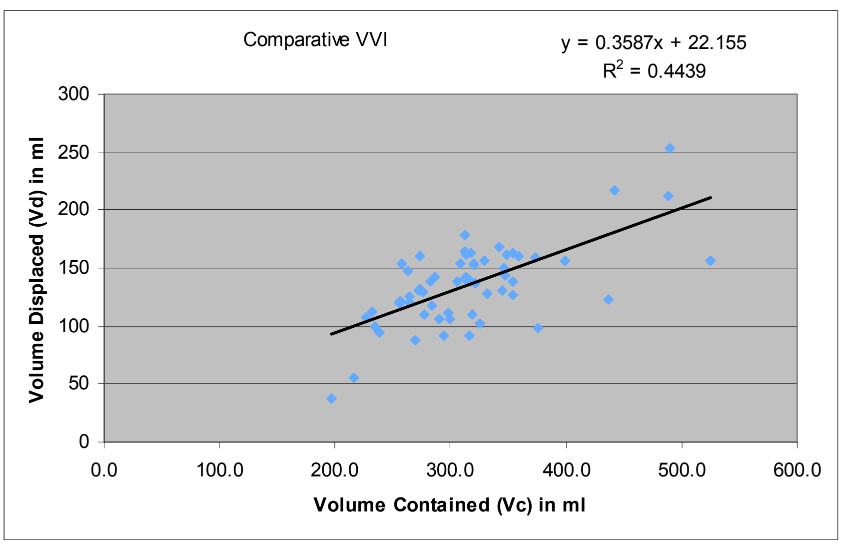

Figure 3: Comparative VVI scatter plot with calculated regression (n=61)

The R^2 for the distribution of Dollarware VVI is .6255, and therefore shows significant correlations between vessel volume contained and volume displaced. Based on the equation, Vd is equal to about 38% of the Vc value for the average Dollarware mug. The comparative sample displays an R^2 of .4439 and is therefore not as significant. It should be noted that a larger sample size would likely result in a slightly more robust correlation, since variability within the sample is accentuated between just 61 vessels. However, this does not necessarily mean that a larger n will result in a significant ($x > .5$) R^2 coefficient. Only a more extensive sampling process can determine whether VVI is significant among Value Village drinking vessels.

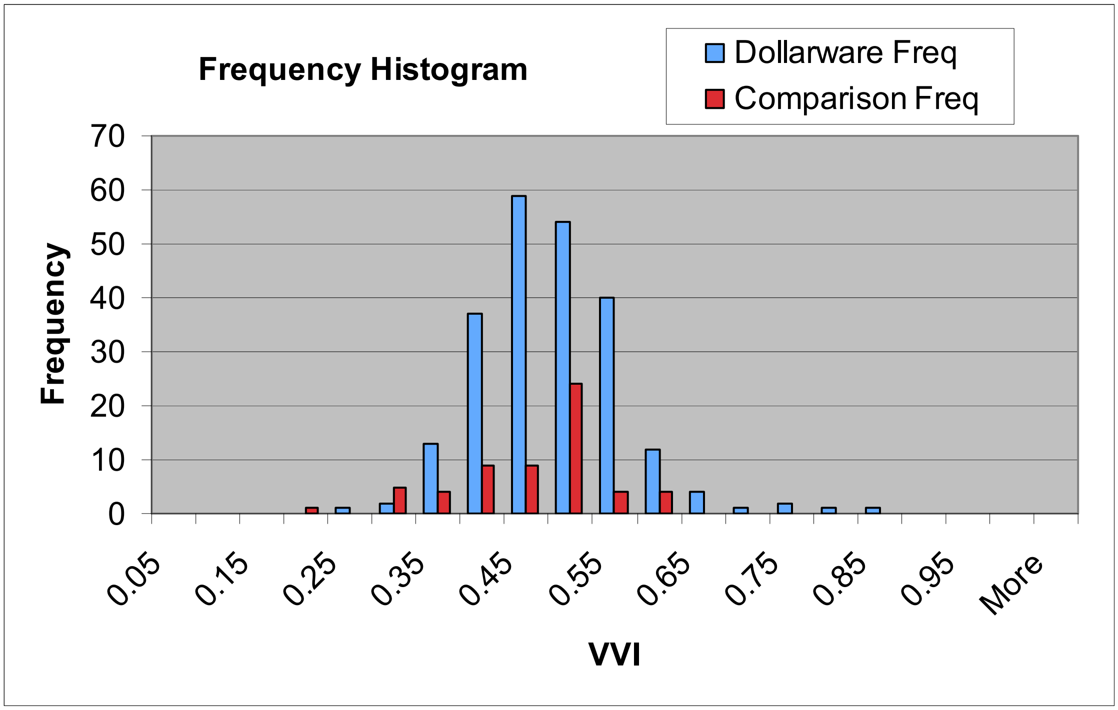

Figure 4: Frequency Histogram for Dollarware and Non-Dollarware VVI

Table 1 shows that with a two-tailed z-test (sufficiently large sample sizes) performed on the VVI samples of Dollarware and non-Dollarware, we get a Z-statistic of 2.19 that exceeds the Z-critical of 1.96, with a P = 0.03. Based on the z-test with an $\alpha = .05$, we reject the null hypothesis which states that the sample mean of Dollarware is equal to the sample mean of non-Dollarware.

	Dollarware	*Value-Village*
Mean	0.457207765	0.430782158
Known Variance	0.006894844	0.007048406
Observations	228	61
Hypothesized Mean Difference	0	
z	**2.188586994**	
P(Z<=z) one-tail	0.014313436	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	**0.028626872**	
z Critical two-tail	**1.959963985**	

Table 1: z-Test for Two Sample for Means (Dollarware vs Non-Dollarware)

Below are **Tables 2 and 3** which display the resulting R^2 coefficients for correlation tests between Vd and Vc (VVI), VVI and height, weight, top:base ratio, rim thickness, and top:rim ratio. All were calculated per isolated group. Table 2 includes Assemblage N into the coefficients, while Table 3 displays the result after N's exclusion.

Groups	VVI all	VVI/Height	VVI/Weight	VVI/T:BR	VVI/Rim	VVI/T:RR
Tall cups	**0,6947**	0,2989	**0,6086**	0,0046	0,1806	0,0758
Cone straight	0,2757	0,0641	0,1413	0,0177	0,2161	0,2876
Cone curved	0,4184	0,0238	0,0294	0,0002	0,1161	0,1610
Cylinder	0,3648	0,0737	0,2224	0,0450	0,0452	0,0002
Espresso/tea cups	0,2643	0,2687	0,0176	0,0030	0,3468	**0,6402**
Latte cups	**0,6958**	0,0298	0,0575	0,4788	0,0489	0,1253
Others	0,0252	0,0238	0,1375	0,0256	0,0240	0,0606

Table 2. R^2 of all correlations in seven groups (all cups). Significant results are bolded.

Groups	VVI	VVI/Height	VVI/Weight	VVI/T:BR	VVI/Rim	VVI/T:RR
Tall cups	**0,6571**	0,4754	**0,5800**	0,0712	0,2096	0,1162
Cone straight	0,2990	0,0478	0,2492	0,0030	0,1625	0,1999
Cone curved	0,4399	0,0323	0,0081	0,0152	0,1540	0,1598
Cylinder	0,3879	0,1637	0,3104	0,0857	0,0454	0,0002
Espresso/tea cups	**0,5293**	0,2358	0,0004	0,0003	0,4420	**0,6241**
Latte cups	**0,8704**	0,0102	0,0950	0,4680	0,0693	0,1462
Others	0,0011	0,2938	**0,8700**	0,0983	0,1187	0,2042

Table 3. R^2 of correlations in seven groups (assemblage N excluded). Significant results are bolded.

Table 4 displays that with an ANOVA test performed on the isolated groups (excluding the 'Others') within Dollarware, we get a F-statistic of 6.45, which greatly exceeds the F-critical of 2.56. The P is equal to 0.00001 (very low chance of random Type-1 error). Based on the ANOVA test with an alpha = .05, we reject the null hypothesis which states that the sample means of each group are similar.

Groups	*Count*	*Sum*	*Average*	*Variance*
Tall	15	6.609626124	0.440641742	0.007452962
Latte	12	5.12626951	0.427189126	0.002181857
Espresso	14	7.674571914	0.548183708	0.030403337
Cone Curved	40	17.80486055	0.445121514	0.005362313
Cone Straight	22	8.949323224	0.406787419	0.004291785
Cylinder	119	55.09905136	0.463017238	0.004162916

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.196338848	5	0.03926777	**6.454646349**	**1.29653 E-05**	**2.255860928**
Within Groups	1.314067072	216	0.006083644			
Total	1.51040592	221				

Table 4: Anova - Single Factor test for six isolated groups within Dollarware

Figure 4 and 5 were created to display the distribution of VVIs among the isolated groups. The frequency histogram proved inefficient for viewing relevant patterns, so we created the complementary area distribution graph. The latter is beneficial, in that it helps to visualize which groups are represented by particular VVIs.

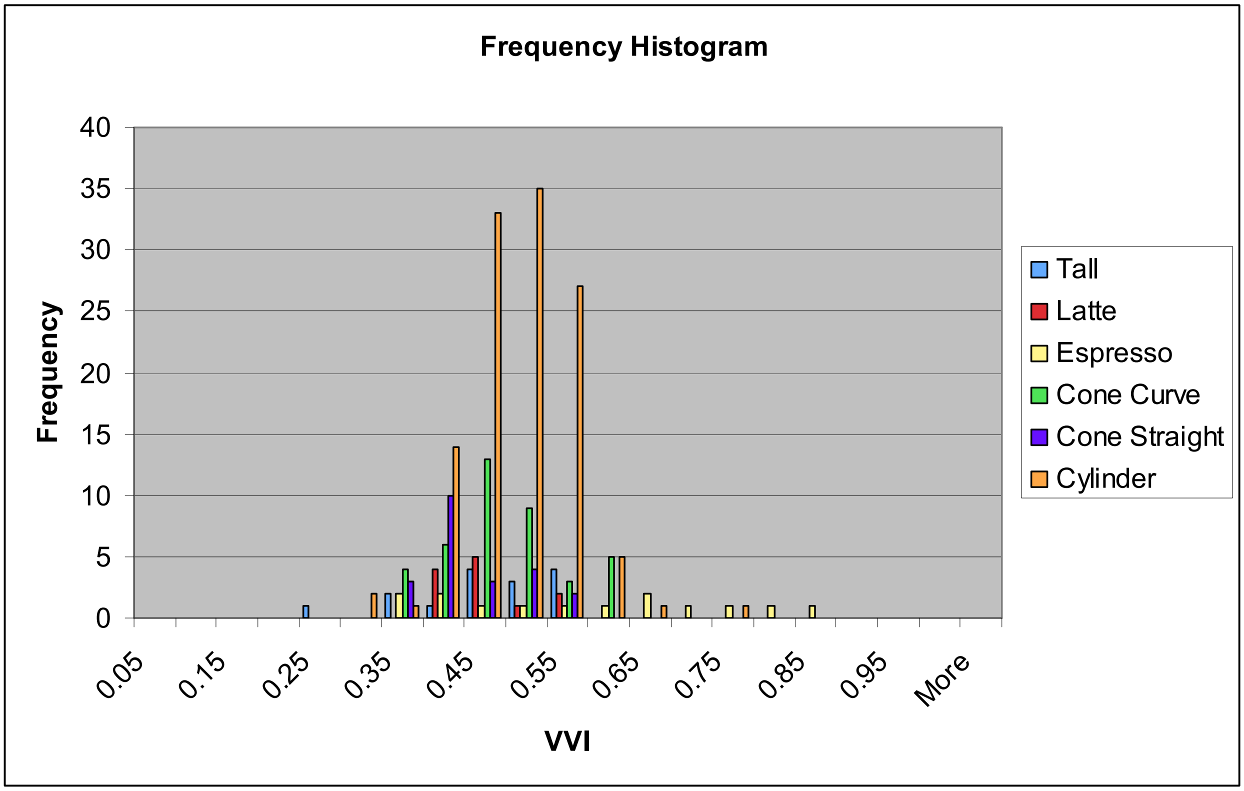

Figure 5: Frequency Histogram for six isolated subcategories of Dollarware VVI

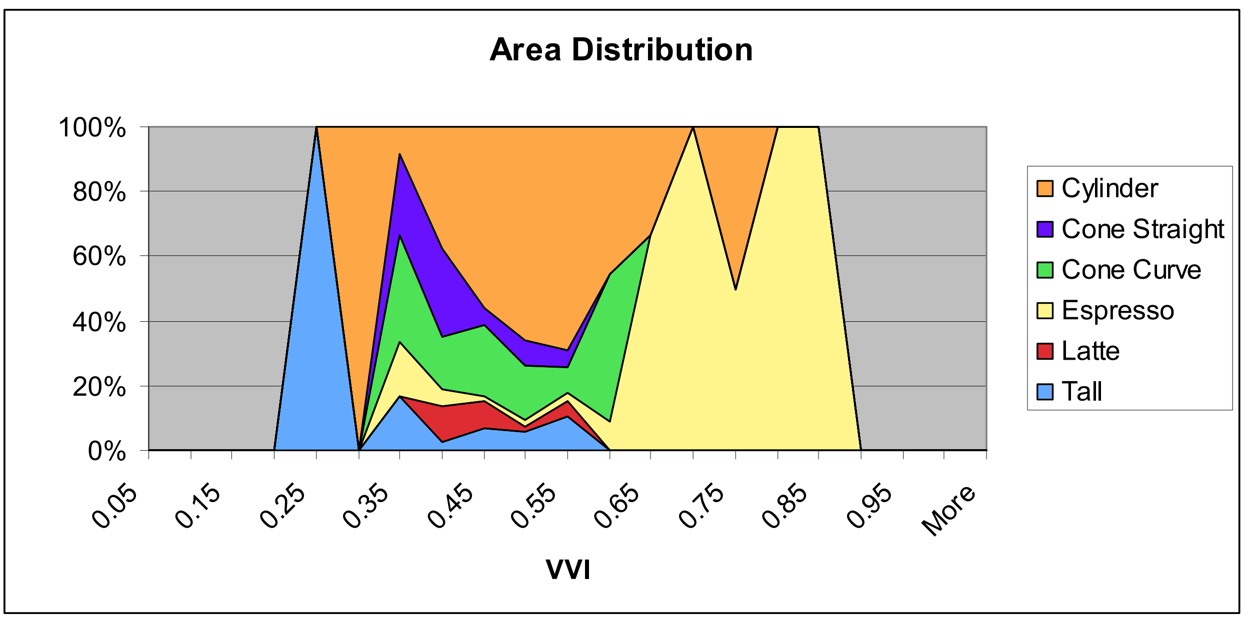

Figure 6: Area Distribution for six isolated subcategories of Dollarware VVI

Discussion

The first half of our analysis is focused on determining whether Dollarware differs from Non-Dollarware (Value Village collection). As displayed in the results, the z-test shows that there is a significant difference between the two average VVIs. Based on **Figure 4**, we see that Dollarware is distributed in a roughly normal pattern. Non-Dollarware is not distributed along the normal curve as significantly, but this could be due to a small sample size. The Value Village collection consists of used and not re-purchased drinking vessels, and is expected to come from an assortment of different qualities, places of origin, time periods, and functions, most of which have fallen out of style. It would be interesting to collect a larger sample to see if in fact the distribution of Value Village ware approximates the normal curve. If it does, we would not expect the distribution to be as robust as the distribution of Dollarware, whose vessels more often share place of origin, quality and function.

The result of the z-test in **Table 1** is interesting, since we now have significant evidence that VVI differs between our test and control samples. How do we interpret this? There are multiple explanations, none of which can be ruled out. First, we must again consider that the smaller sample size of value-village ware has affected our comparison with our Dollarware sample. In contrast, we can also consider that our sample is in fact representative of the un-purchased drinking vessels at Value Village. On one hand, there can simply be a difference in the average Dollarware mug to the average Value Village mug. This can be the result of less restricted requirements as to what makes an acceptable mug for sale at Value Village in terms of form, country of origin (**Appendix D**), and quality. For this we would need to ask, what are the purchasing and selling habits of Value Village management in terms of discount drinking vessels? On the other hand, we can consider a situation where vessel shoppers at Value Village have purchased mugs that 'fill in the gap' of the VVI normal curve for the comparative group, thereby creating the significant difference in the average vessel VVI that we see from the z-test. This would lead to more questions, such as, would we find the same pattern of VVI distribution among available mugs if we were to sample multiple Value Villages? Ideally, future research would require us to survey the flow of mugs in and out of a given (or multiple) Value Villages, and measure their VVIs in order to see whether the VVI curve is normally distributed, whether this more complete distribution is similar to the Dollarware distribution, and what the purchasing habits of Value Village shoppers in Montreal are (and how that affects the overall comparative distribution). Due to these and any other explanations that we may have overlooked, we feel that it would be premature to consider VVI a strong indicator of differences in Dollarware to non-Dollarware, at least until more research is done.

The second half of the analysis centers on identifying whether VVI is useful for isolating groups within Dollarware. Although statistically significant, the results are not as informative as we would expect. Based on **Tables 2 and 3**, we see that few if any strong correlations exist between VVI and other metric attributes. How do we account for these correlations? Those that are significant may be the result of random association, though it would probably be a waste of time trying to dissect some of the more obscure relationships. Although disappointing, this is not surprising. It is clear that the Vessel Volume Index is not robust to individual changes in these tested physical properties. As mentioned in the methodology, elements such as height, rim thickness, and handle shape are all 'smoothed out' when VVI is calculated (mainly in the form of volume displaced, since any of these features can have varying influence on Vd for any mug). For future research, a much stronger statistical test should be incorporated, such as a Principle Component Analysis (PCA) or an Analysis of Variance, both of which can be designed to consider multiple independent variables and how they affect one dependant variable (VVI).

However, there is a promising result in the VVI column in **Table 3**, which shows that 3 of the 7 isolated groups display significant correlations between volume displaced and volume contained (in other words, VVI is significant). The groups that do not show significance may be the result of our own errors in group formation (we need to continue isolating large groups), or of a too restrictive vessel classification (group membership may not be exclusive). As a future revision, we could add criteria to the larger groups in order to narrow our selection, such as dividing conical curved into convex and concave subgroups.

This brings us to the result of the single factor ANOVA test, which yielded a very significant result. How can we account for this? By referring to **Figure 5 and 6**, which shows the frequency distribution and percentage occupied by each group at any VVI value, we see that there are in fact some trends in how vessels differ from each other in terms of their VVI. For example, espresso cups clearly occupy some of the highest VVI values, with Tall cups occupying some of the lowest. In other words, we would expect differences: Tall mugs have ample amount of space within, and don't occupy a proportionately large volume. On the other extreme, espresso and tea vessels occupy very little space, but do not contain a proportionately large amount of liquid. We intuitively expect their average VVIs to be different, and this is essentially what the ANOVA test has revealed. The issue is that even with average VVI statistics available per group, we cannot say with exact certainty which groups differ in their VVIs and to what degree (though it may be easier to distinguish extreme groups like espresso and tall cups). At this point, we do not have a solution as to how we would isolate these differences. T-tests are undesirable, because with every paired test performed, the probability of a Type-1 error would increase. Ideally, we would need to apply one or more multi-factor ANOVA tests to account for particular relationships, but statistics of this nature are beyond the scope of the authors at this time. Moreover, we must consider that making these associations may be stretching the truth. Perhaps our graphs and results do not show strong relationships between VVI and our groups, simply because there are no relationships.

As a general observation, VVI may not help to distinguish vessels' physical features, but we believe that VVI is itself significant. We know that there is a relationship between Vd and Vc, but we are not at the stage where VVI alone can tell us a vessel's function or degree of efficiency. So is the Vessel Volume Index a statistical breakthrough, or should we toss it into the category of numerical nonsense? For now, we like to think of it as something in between, not particularly informative, though not entirely useless.

Additional Considerations for Future Research

Should anyone develop the sudden urge or interest to continue this research, there are certainly a few problems and issues to consider in addition to what has already been addressed in the report. First, there must be a certain degree of error considered in the data collected. Between 27 students and 1 professor alternating jobs, we cannot expect that all data were measured and recorded with equal attention. Although this does not discount our results, it may alter them to an unknown degree. Also, one should be aware of the problems of typology. In our research, we categorized vessels into exclusive groups (no mug could be in more than one group). This definitely affected the correlation coefficients; as a quick comparison performed after our study, we included some mugs (7) that were classified as tall into the conical straight group (if we disregarded height, they fit the latter category). Our R^2 for the VVI increased from 0.299 to 0.6976, an extremely significant improvement. This shows that changes in classification can alter the results. In relation to this, our classification was based on specific user selected traits. Another user may choose different traits, or decide not to classify in this same method at all. This is why we would encourage future research to approach the problem with a new methodology, perhaps by 'working in reverse', that is, starting with VVI as main criteria for classification and exploring whether the groups correlate with any traits. Also, if a future researcher decides to create groups, they should increase the sample size for the Non-Dollarware assemblage so that it too can be classified alongside the Dollarware assemblage for sufficient comparison. As a final note to anyone who chooses to continue researching VVI and Dollarware more generally, we suggest proceeding only if you possess two qualities: first, unwavering patience, and second, a burning desire to know more about a topic than you ever thought could (or should) be known.

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Appendix A: Raw Volume Data
Classified by Group

A→ Tall
A→ Cone Straight
A→ Cone Curved
A→ Cylinder
A→ Espresso
A→ Latte
A→ Other

Specimen	Vc (ml)	Vd (ml)	VVI	Specimen	Vc (ml)	Vd (ml)	VVI
A-01	323.7	161	0.497374112	I-14	420.9	158	0.375386077
A-02	335.7	184	0.54810843	I-15	332.5	192	0.577443609
A-03	311.3	175	0.562158689	I-16	357.3	139	0.389028827
A-04	352.2	177	0.502555366	I-17	304.8	95	0.31167979
A-05	328.2	168	0.511882998	I-18	336.6	159	0.472370766
A-06	327.3	148	0.45218454	I-19	325.5	160	0.491551459
A-07	109.6	77	0.702554745	I-20	307.7	156	0.506987325
A-08	70.2	56	0.797720798	J-01	364.2	159	0.436573311
A-09	274.2	118	0.430342815	J-02	252.8	112	0.443037975
A-10	381.4	170	0.445726272	J-03	315.8	153	0.484483851
A-11	333.2	155	0.465186074	J-04	239.5	107	0.446764092
A-12	259.1	104	0.401389425	J-05	329.5	136	0.412746586
A-13	260.8	141	0.540644172	J-06	340.1	168	0.493972361
A-14	266.6	144	0.540135034	J-07	341.0	163	0.478005865
A-15	455.7	200	0.438885232	J-08	183.5	106	0.577656676
A-16	358.1	139	0.388159732	J-09	228.2	93	0.407537248
A-17	338.6	118	0.348493798	J-10	146.3	70	0.4784689
A-18	343.1	158	0.460507141	J-11	260.2	129	0.495772483
A-19	331.9	157	0.473034046	J-12	256.3	116	0.452594616
A-20	296.2	117	0.395003376	J-13	314.6	125	0.397329943
A-21	459.1	164	0.357220649	J-14	414.3	178	0.429640357
B-01	283.6	110	0.38787024	J-15	233.7	119	0.509199829
B-02	327.5	149	0.454961832	J-16	196.5	63	0.320610687
B-03	330.9	158	0.477485645	J-17	373.9	123	0.328964964
B-04	581.7	232	0.398831013	J-18	327.1	144	0.440232345
B-05	353.6	139	0.393099548	J-19	237.3	95	0.400337126
B-06	311.0	154	0.495176849	J-20	216.1	108	0.499768626
B-07	312.5	113	0.3616	K-01	317.7	172	0.54139125
B-08	337.6	137	0.405805687	K-02	332.4	167	0.502406739
B-09	373.1	118	0.316269097	K-03	315.1	148	0.469692161
B-10	324.3	155	0.477952513	K-04	319.6	172	0.538172716
B-11	329.9	137	0.415277357	K-05	222.9	158	0.708838044
B-12	334.6	162	0.484160191	K-06	304.2	165	0.542406312
B-13	299.9	124	0.413471157	K-07	311.8	170	0.545221296
B-14	341.0	159	0.46627566	K-08	299.8	156	0.520346898
B-15	340.4	163	0.478848414	K-09	246.4	118	0.478896104
B-16	350.6	122	0.3479749	K-10	280.5	144	0.513368984
B-17	223.5	125	0.559284116	K-11	297.7	181	0.607994625
B-18	463.5	195	0.420711974	K-12	257.3	150	0.58297707
B-19	331.9	164	0.494124736	K-13	327.4	163	0.497861943
B-20	330.8	154	0.465538089	K-14	317.3	133	0.419161677
C-01	320.9	112	0.349018386	K-15	253.1	151	0.596602134
C-02	203.5	71	0.348894349	K-16	335.5	160	0.476900149
C-03	317.6	133	0.418765743	K-17	369.5	144	0.389715832
C-04	273.8	118	0.430971512	K-18	70.9	60	0.846262341

C-05	249.6	129	0.516826923	K-19	186.1	78	0.4191295
C-06	329.9	169	0.512276447	K-20	423.9	164	0.386883699
C-07	387.0	93	0.240310078	L-01	325.2	160	0.49200492
C-08	307.1	114	0.371214588	L-02	320.3	134	0.41835779
C-09	238.2	117	0.491183879	L-03	193.1	97	0.502330399
C-10	297.8	108	0.362720403	L-04	193.5	104	0.5374677
C-11	302.6	113	0.373430271	L-05	191.4	96	0.501567398
C-12	336.6	115	0.341651812	L-06	306.4	172	0.561357702
C-13	97.8	50	0.511247444	L-07	311.5	144	0.462279294
C-14	332.2	120	0.361228176	L-08	316.9	145	0.457557589
C-15	328.0	130	0.396341463	L-09	321.6	150	0.46641791
C-16	89.6	54	0.602678571	L-10	321.4	153	0.476042315
C-17	237.7	144	0.605805637	L-11	301.2	154	0.511288181
C-18	278.1	145	0.521395182	L-12	260.0	109	0.419230769
C-19	265.6	88	0.331325301	L-13	266.8	108	0.404797601
C-20	303.2	107	0.352902375	L-14	294.5	115	0.39049236
D-01	347.6	186	0.535097814	L-15	291.4	132	0.452985587
D-02	345.9	137	0.396068228	L-16	292.9	121	0.413110277
D-03	399.2	199	0.498496994	M-01	281.1	126	0.448239061
D-04	348.1	149	0.42803792	M-02	312.9	143	0.457015021
D-05	277.2	143	0.515873016	M-03	308.1	149	0.483609218
D-06	348.3	155	0.445018662	M-04	306.2	111	0.362508165
D-07	400.0	200	0.5	M-05	350.8	173	0.493158495
D-08	355.3	112	0.315226569	M-06	343.1	186	0.542116001
D-09	330.8	171	0.516928658	M-07	279.2	112	0.401146132
D-10	322.9	178	0.551254258	M-08	327.3	148	0.45218454
D-11	215.4	77	0.357474466	M-09	341.0	150	0.439882698
D-12	337.0	172	0.510385757	M-10	500.8	212	0.423322684
D-13	316.6	140	0.442198358	M-11	260.8	120	0.460122699
D-14	351.0	139	0.396011396	M-12	253.8	120	0.472813239
D-15	326.9	153	0.468033038	M-13	264.6	121	0.457294029
D-16	334.6	135	0.403466826	M-14	352.1	178	0.505538199
D-17	398.5	136	0.341279799	M-15	267.3	128	0.478862701
D-18	331.2	133	0.401570048	M-16	300.6	126	0.419161677
D-19	390.7	162	0.414640389	M-17	341.5	146	0.427525622
D-20	177.8	114	0.641169854	M-18	324.2	188	0.579888957
E-01	436.8	180	0.412087912	M-19	82.3	29	0.35236938
E-02	450.4	246	0.546181172	M-20	311.7	165	0.529355149
E-03	345.8	163	0.471370735	N-01	353.2	127	0.359569649
E-04	386.1	137	0.354830355	N-02	317.9	163	0.512739855
E-05	419.0	221	0.527446301	N-03	298.5	111	0.371859296
E-06	311.5	165	0.529695024	N-04	256.2	120	0.468384075
E-07	337.9	148	0.437999408	N-05	437.3	123	0.281271438
E-08	467.3	229	0.490049219	N-06	300.0	106	0.353333333
E-09	322.2	162	0.502793296	N-07	272.8	132	0.483870968
E-10	385.6	117	0.303423237	N-08	347.5	144	0.414388489
E-11	340.7	148	0.434399765	N-09	272.8	160	0.586510264
E-12	362.6	139	0.383342526	N-10	344.4	131	0.380371661
E-13	446.8	231	0.517009848	N-11	375.9	98	0.260707635
E-14	322.9	161	0.49860638	N-12	488.0	212	0.43442623

E-15	326.6	115	0.352112676	N-13	290.4	106	0.365013774
E-16	263.7	139	0.527114145	N-14	283.2	118	0.416666667
E-17	398.7	154	0.38625533	N-15	311.7	141	0.452358037
E-18	335.6	147	0.438021454	N-16	231.5	112	0.483801296
E-19	263.7	111	0.420932878	N-17	316.0	92	0.291139241
E-20	485.0	260	0.536082474	N-18	197.4	37	0.187436677
F-01	283.2	160	0.564971751	N-19	489.8	254	0.518579012
F-02	115.7	69	0.596369922	N-20	313.7	142	0.452661779
F-03	336.1	151	0.44927105	N-21	258.2	154	0.596436871
F-04	379.4	140	0.36900369	N-22	226.8	107	0.471781305
F-05	385.9	155	0.401658461	N-23	311.8	178	0.570878768
F-06	286.9	105	0.365981178	N-24	264.8	120	0.453172205
F-07	394.0	198	0.502538071	N-25	286.4	142	0.495810056
F-08	382.8	172	0.449320794	N-26	262.7	147	0.559573658
F-09	353.5	155	0.438472419	N-27	318.2	110	0.345694532
F-10	466.8	214	0.458440446	N-28	305.5	138	0.451718494
F-11	371.3	144	0.387826555	N-29	311.9	164	0.525809554
F-12	339.2	86	0.253537736	N-30	309.0	154	0.498381877
F-13	385.3	138	0.358162471	N-31	319.6	152	0.475594493
F-14	385.4	183	0.474831344	N-32	294.7	92	0.31218188
F-15	400.7	171	0.426753182	N-33	321.8	137	0.425730267
F-16	417.0	192	0.460431655	N-34	342.5	168	0.490510949
F-17	349.4	174	0.497996566	N-35	398.9	156	0.391075458
F-18	254.7	150	0.588928151	N-36	269.5	88	0.326530612
F-19	362.8	154	0.424476295	N-37	255.4	120	0.469851214
F-20	325.3	149	0.458038733	N-38	317.1	138	0.435193945
F-21	331.8	87	0.262206148	N-39	275.2	130	0.472383721
G-01	321.8	128	0.397762585	N-40	348.7	162	0.464582736
G-02	324.5	133	0.409861325	N-41	329.5	156	0.473444613
G-03	334.7	129	0.385419779	N-42	282.3	139	0.492383989
G-04	292.8	124	0.423497268	N-43	331.7	128	0.385890865
H-01	351.9	154	0.437624325	N-44	524.5	156	0.29742612
H-02	345.6	156	0.451388889	N-45	313.8	162	0.51625239
H-03	305.8	125	0.408763898	N-46	256.7	122	0.475262953
H-04	303.1	136	0.4486968	N-47	442.1	217	0.490839177
H-05	313.2	135	0.431034483	N-48	320.6	154	0.480349345
H-06	341.1	150	0.439753738	N-49	234.2	99	0.422715628
I-01	327.6	154	0.47008547	N-50	354.0	138	0.389830508
I-02	333.2	132	0.396158463	N-51	324.9	102	0.313942752
I-03	294.9	117	0.396744659	N-52	353.2	163	0.461494904
I-04	70.9	49	0.691114245	N-53	264.0	126	0.477272727
I-05	462.6	189	0.408560311	N-54	373.3	159	0.425930887
I-06	332.9	142	0.426554521	N-55	272.6	130	0.476889215
I-07	327.7	167	0.50961245	N-56	276.6	129	0.46637744
I-08	351.7	143	0.406596531	N-57	277.9	110	0.395825837
I-09	382.7	164	0.4285341	N-58	359.6	160	0.444938821
I-10	295.3	128	0.433457501	N-59	215.9	55	0.254747568
I-11	301.9	118	0.3908579	N-60	345.4	150	0.434279097
I-12	482.6	243	0.503522586	N-61	238.8	94	0.393634841
I-13	325.6	163	0.500614251				

Appendix B: Descriptive Statistics for Dollarware, Non-Dollarware, and Dollarware Subgroups

	Dollarware	Comparison
Mean	0.457207765	0.430782158
Standard Error	0.00549914	0.010749309
Median	0.45218454	0.452358037
Mode	0.45218454	#N/A
Standard Deviation	0.0830352	0.083954784
Sample Variance	0.006894844	0.007048406
Kurtosis	3.041949938	0.382395743
Skewness	0.891826375	-0.627529027
Range	0.605952264	0.409000194
Minimum	0.240310078	0.187436677
Maximum	0.846262341	0.596436871
Sum	104.2433705	26.27771165
Count	228	61
Confidence Level (95.0%)	0.010835893	0.021501812

	Tall Stats	Latte Stats	Espresso Stats	Cone Curved Stats	Cone Straight Stats	Cylinder Straight Stats	Other Stats
Mean	0.440641742	0.427189126	0.548183708	0.445121514	0.406787419	0.463017238	0.479079995
Standard Error	0.02229045	0.013484116	0.046601147	0.011578334	0.013967146	0.0059146	0.031901415
Median	0.44927105	0.41672928	0.553808683	0.430657164	0.39140769	0.460122699	0.491183879
Mode	#N/A	#N/A	#N/A	#N/A	#N/A	0.45218454	#N/A
Standard Deviation	0.086330542	0.046710348	0.174365527	0.073227817	0.06551172	0.064520663	0.105805024
Sample Variance	0.007452962	0.002181857	0.030403337	0.005362313	0.004291785	0.004162916	0.011194703
Kurtosis	0.420507869	-0.340571698	-1.195626911	-0.411938595	-0.432677546	1.943055846	-0.397488949
Skewness	-0.85451331	0.613372839	0.235356886	0.435736043	0.363633799	0.035081254	-0.765125238
Range	0.305871095	0.151725363	0.525651654	0.280333037	0.241798059	0.455300308	0.324534199
Minimum	0.240310078	0.357474466	0.320610687	0.316269097	0.303423237	0.253537736	0.281271438
Maximum	0.546181172	0.509199829	0.846262341	0.596602134	0.545221296	0.708838044	0.605805637
Sum	6.609626124	5.12626951	7.674571914	17.80486055	8.949323224	55.09905136	5.269879948
Count	15	12	14	40	22	119	11
Confidence Level (95.0%)	0.04780826	0.029678339	0.100675658	0.023419392	0.029046269	0.011712517	0.071080782

Appendix C: VVI Frequency Distribution for Six Isolated Groups

VVI Bin	*Tall*	*Latte*	*Espresso*	*Cone Curve*	*Cone Straight*	*Cylinder*
0.05	0	0	0	0	0	0
0.1	0	0	0	0	0	0
0.15	0	0	0	0	0	0
0.2	0	0	0	0	0	0
0.25	1	0	0	0	0	0
0.3	0	0	0	0	0	2
0.35	2	0	2	4	3	1
0.4	1	4	2	6	10	14
0.45	4	5	1	13	3	33
0.5	3	1	1	9	4	35
0.55	4	2	1	3	2	27
0.6	0	0	1	5	0	5
0.65	0	0	2	0	0	1
0.7	0	0	1	0	0	0
0.75	0	0	1	0	0	1
0.8	0	0	1	0	0	0
0.85	0	0	1	0	0	0
0.9	0	0	0	0	0	0
0.95	0	0	0	0	0	0
1	0	0	0	0	0	0

Appendix D: Vessels' Country of Origin (excluding those identified as 'China')

Specimen	Country	Specimen	Country	Specimen	Country	Specimen	Country
A-08	Unknown	**G-04**	Unknown	**M-19**	Unknown	**L-06**	Korea
A-11	Unknown	**H-03**	Unknown	**N-01**	Unknown	**M-08**	Korea
A-13	Unknown	**I-04**	Unknown	**N-02**	Unknown	**N-03**	Korea
A-14	Unknown	**I-09**	Unknown	**N-04**	Unknown	**N-06**	Japan
A-15	Unknown	**I-14**	Unknown	**N-05**	Unknown	**N-07**	Japan
A-19	Unknown	**I-17**	Unknown	**N-08**	Unknown	**N-14**	Japan
A-21	Unknown	**I-20**	Unknown	**N-09**	Unknown	**N-15**	Greece
B-04	Unknown	**J-01**	Unknown	**N-10**	Unknown	**N-16**	Korea
B-05	Unknown	**J-02**	Unknown	**N-13**	Unknown	**N-18**	England
B-12	Unknown	**J-04**	Unknown	**N-15**	Unknown	**N-24**	USA
B-18	Unknown	**J-05**	Unknown	**N-17**	Unknown	**N-32**	USA
C-02	Unknown	**J-08**	Unknown	**N-19**	Unknown	**N-34**	Korea
C-13	Unknown	**J-09**	Unknown	**N-19**	Unknown	**N-42**	Thailand
C-16	Unknown	**J-11**	Unknown	**N-21**	Unknown	**N-44**	Poland
C-17	Unknown	**J-12**	Unknown	**N-22**	Unknown	**N-48**	Korea
C-18	Unknown	**J-14**	Unknown	**N-23**	Unknown	**N-49**	France
C-20	Unknown	**J-15**	Unknown	**N-25**	Unknown	**N-52**	Korea
D-01	Unknown	**J-19**	Unknown	**N-26**	Unknown	**N-61**	Japan
D-02	Unknown	**K-01**	Unknown	**N-27**	Unknown		
D-04	Unknown	**K-02**	Unknown	**N-28**	Unknown		
D-06	Unknown	**K-03**	Unknown	**N-30**	Unknown		
D-09	Unknown	**K-09**	Unknown	**N-31**	Unknown		
D-11	Unknown	**K-18**	Unknown	**N-33**	Unknown		
D-12	Unknown	**L-01**	Unknown	**N-37**	Unknown		
D-14	Unknown	**L-02**	Unknown	**N-38**	Unknown		
D-17	Unknown	**L-09**	Unknown	**N-41**	Unknown		
E-01	Unknown	**L-10**	Unknown	**N-43**	Unknown		
E-05	Unknown	**L-12**	Unknown	**N-45**	Unknown		
E-07	Unknown	**L-13**	Unknown	**N-46**	Unknown		
E-09	Unknown	**M-04**	Unknown	**N-47**	Unknown		
E-11	Unknown	**M-07**	Unknown	**N-50**	Unknown		
E-14	Unknown	**M-10**	Unknown	**N-54**	Unknown		
E-15	Unknown	**M-11**	Unknown	**N-55**	Unknown		
E-18	Unknown	**M-12**	Unknown	**N-57**	Unknown		
E-19	Unknown	**M-13**	Unknown	**N-59**	Unknown		
F-13	Unknown	**M-15**	Unknown				
F-20	Unknown	**M-16**	Unknown				