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Statistical examination of hair color as a potential biasing factor in hair analysis[☆]

Tom Mieczkowski Ph.D.^{a,*}, Richard Newel^b

^a*Department of Criminology, The University of South Florida, 140 Seventh Avenue South, DAV 258,
St. Petersburg, FL 33701-5016, USA*

^b*University of South Florida The Chiles Center, Tampa, FL, USA*

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Abstract

We review eight different data sets in this paper for the purposes of assessing the possibility that reported color of hair can produce a systematic bias in the interpretation of hair assays. We review studies or data sets that include heroin and its metabolites, cocaine and its metabolites, MDMA and its analogs, and amphetamine and methamphetamine. The studies have utilized a variety of different degrees of color categorization, ranging from the simple dichotomy of brown and black, to a high of 12 categories. The mean number of categories reported approaches 6 (mean=5.875). There are a total of 2791 data points in this analysis. We utilize two major statistical techniques for assessing significance; one-way analysis of variance, and Tukey's Honestly Significant Difference procedure. In circumstances where only dichotomous contrasts are possible, one-way analysis of variance is used. In contrasts involving three or more categorical groups, Tukey's procedure is used. In circumstances where the homogeneity of group variances is not sustained by the Levene statistic, we use the Tamahane procedure, allowing an assessment that assumes unequal variances. The analysis of this data fails to discern a significant color effect. We speculate that it may be that variance is large in many domains affecting analyte recovery from hair. In large groups these variations tend to regress towards a typical or mean value. Thus the data here show that while there are group or aggregate differences in these 'typical' values, they are not great when considered in relation to the within-group variations which exist for those values. It is our view that color may play a role in the accumulation of drugs in hair, however it is likely to account for only a very small part of the complex process of drug accumulation. © 2000 Elsevier Science Ireland Ltd. All rights reserved.

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*Corresponding author. Tel.: +1-727-553-1585; fax: +1-727-553-1526.

E-mail address: mieczkow@bayflash.stpt.usf.edu (T. Mieczkowski)

Introduction

This paper examines the relationship between hair color and hair assay outcomes for several categories of commonly abused drugs. The objectives of this examination are several. One goal is to determine if statistically significant relationships can be established between particular hair colors and hair assay outcomes. A second goal is to measure the strength of any significant associations that may be uncovered. We shall also spend some time discussing the possible interpretations and implications of the data presented. Because this paper analyzes a very substantial amount of data from several studies, we shall not develop the historical issues related to hair color and hair analysis in depth. Those researchers who have been involved with the development of hair analysis are generally familiar with the controversies and questions that have arisen about the possible effects of color on the results of chemical assays using hair samples (1). Since coloration of hair involves the presence of various types of melanin in different concentrations and proportions, it is logical to question the impact color may have on drug concentration (2). Several researchers have well demonstrated that melanin does bind materials, including abused drugs (3). Several studies using animal models and several studies using *in vitro* techniques have demonstrated a difference in concentration that appears to be related to hair color (4,5). These findings have been reported for several *in vivo* studies as well (6,7,8,9). These findings suggest that the issue of hair color deserves further scrutiny. We accept the premise that melanin binds drug, which we believe to have been conclusively shown. We also believe that melanin in its various forms binds drugs differentially based upon the particular characteristics of the compounds in question. In essence, some drugs bind well to melanin, other not well at all. However, it is important to bear in mind that the establishment of melanin binding does not in itself substantiate a claim that melanin concentration plays a major or significant role in accounting for the total quantity of analyte accumulated in hair. This is a separate issue.

There are several important caveats to bear in mind when contemplating the extent of the role of melanin in the drug binding process. First, it is well demonstrated that drugs bind in hair in the absence of melanin, so that binding occurs to protein materials in hair. Second, melanin by weight constitutes a relatively small fraction of total hair mass. Those who have examined this in some detail have reported generally a 0.1-5% range for the mass fraction of melanin (10). Thus the appropriate consideration to make is whether hair which varies by melanin content and type (i.e., varies in color) demonstrates a differential which can be considered as important for the purposes of hair assay interpretation. That is, does melanin variation make an important or measurable contribution to total drug bound into hair? Or does melanin make only a relatively small contribution?

We intend to examine this question by reviewing studies that have reported findings allowing us to compare the concentration of drugs recovered by hair analysis to hair color. For each of these reports we will determine whether or

not a statistically significant difference exists for drug concentration (expressed as analyte/unit mass of hair) between hair color categories. In those cases where we identify significant differences, we will measure the strength of association between the variables to provide an estimate of the size of the contribution. It is important to bear in mind that the determination of statistical significance has a narrow and technical meaning. Significance in this regard should simply be understood to mean that the relationship is unlikely to be accounted for as a random chance event. The probabilities of that event being random are expressed as a "p" value. In this study we will use the least stringent of the generally accepted p values, .05. It is important to bear in mind that a relationship may be statistically significant, but it does not mean the relationship is "strong" or "important" in a conventional sense. The ability to detect significant relationships increases when samples have large N values. However, those relationships may be very weak, and have little influence on a particular conceptualization that is being explored or tested. Thus a finding of significance must have an associated measure of the strength of association. Strength of relationships can be evaluated in many ways. One of the most popular methods is to utilize a mathematical index of strength such that as the value of the number increases the strength of the association increases. These associations are designed to have an intuitive appeal, and are often constructed to vary between 0 and 1.

Analytic Method

We have selected several data sets for analysis. The primary two criteria for the selections were very simple. Selected data sets had quantitatively recorded the outcomes of hair assays for commonly abused drugs, and they had also reported the hair color of the samples, so that the association between assay value and hair color could be established. There are 8 distinct data sets described in this paper. They were chosen based on a review of the literature, and represent, to the best of our knowledge, the extant material that meets the above-described criteria. A listing of these studies is included in the bibliography.

In evaluating these data sets we follow the same general protocol for each study. First the study is identified, and a table presents the relevant aggregate descriptive data. This consists of the assayed drug, the color categorizations, the mean values and measures of dispersion for the assay, and the 95% confidence interval upper and lower boundaries. In studies where the number of assays is very large we also produce a frequency distribution table for the hair color. An analytic table then follows this descriptive material or set of tables which utilize a statistical procedure to examine the relationships between all categorical variable states. In most circumstances we use Tukey's HSD (Honest Statistical Difference) procedure. In some cases the number of categories is less than three, and a one-way ANOVA is used in those situations. We have examined for significance at a $p = .05$ criteria in order to apply the most generous requirement to attain significance. In the following series of tables the column labeled "significance" should be examined for values of .05 or less. Values in this range indicate statistical significance.

In analyzing the large N data sets we applied a number of supplemental examination procedures to the data which we do not present here because of the limitations of length. We utilized multiple procedures in order to determine that outcomes for the Tukey procedure were not idiosyncratic. Tukey's procedure requires the assumption of equality of variance between compared groups. If this assumption was not met, we employed alternative procedures that assume unequal variances, primarily Tamahane's T2 procedure. There were no differences in statistical outcome that resulted from alternate procedure. As well, we also tested, when indicated, the Tukey's procedure outcome by some standard transformations of the data in order to control the effects of the dispersion measures. Again, none of these transformations resulted in any variation in significance determination. In some circumstances, as noted in the analysis, Tukey's procedure cannot be applied since it requires at least three categorical contrasts and two cases per category. Where Tukey's procedure cannot be applied, we utilize a one-way analysis of variance (ANOVA).

Small N Studies

First we shall consider a series of studies which we characterize as small N studies. These studies have 20 cases or less in their data sets. In some cases the authors of these studies merely reported hair color as a part of the data set and made no attempt to analyze the data using this variable. In other cases the color data was reported and inferentially linked to a "race bias" argument by suggesting that hair phenotype is a biomarker for "race type". We utilize the data here only for the purposes of assessing the statistical significance of hair color in relation to the concentration of drug in hair.

Heroin/Opiate Studies

Goldberger et al., 1991

In 1991 Goldberger, Caplan, Maguire and Cone published an article in the *Journal of Analytical Toxicology* entitled "Testing Human Hair for Drugs of Abuse. III. Identification of Heroin and 6-Acetylmorphine as Indicators of Heroin Use" (11). This study utilized hair samples collected from 20 documented heroin users. Hair was characterized as either "brown" or "black" with no further color categorizations reported. For each subject the data reported for the analytic procedure included wash concentrations and extract concentrations in ngs/mg of hair for heroin, 6-acetylmorphine, morphine, and codeine. Since only two color categorizations are used in this study a Tukey's analysis cannot be presented (it requires at least three contrast groups). For the Goldberger et al. data set we present two tables. Table 1 presents the sample's descriptive data for each analyzed drug. This includes the mean value of analyte for each drug or drug metabolite, the standard deviation and standard error, and the range of values associated with the 95% confidence interval for that substance.

Analyte	Hair Color	N	Mean (ng/mg)	Std. Deviation	Std. Error	95% C.I. for the Mean	
						Lower Boundary	Upper Boundary
Heroin	Black	12	1.432	4.425	1.2774	-1.3798	4.243
	Brown	8	.1925	0.4212	0.1489	-0.1597	0.5447
6-AM	Black	12	6.06	19.229	5.551	-6.1519	18.284
	Brown	8	1.309	2.4768	0.8757	-0.7619	3.3794
Morphine	Black	12	.5083	0.7921	0.2287	0.0505	1.0116
	Brown	8	.1575	0.1473	0.0529	0.0343	0.2807
Codeine	Black	12	.3650	0.5527	0.1595	0.0138	0.7162
	Brown	8	.1475	0.1386	0.0490	0.0315	0.2634

Table 1. Descriptive Data Goldberger et al., Hair Analysis for Opiates

Table 2 presents the outcome of a one-way analysis of variance for the Goldberger et al. data.

Analyte		Sum of Squares	DF	Mean Square	F	Significance
Heroin Extract	Between	7.371	1	7.371	.612	.444
	Within	216.630	18	12.035		
	Total	224.00	19			
6-AM Extract	Between	108.623	1	108.623	.476	.499
	Within	4110.364	18	228.354		
	Total	4218.987	19			
Morphine Extract	Between	0.591	1	0.591	1.508	.235
	Within	7.054	18	0.392		
	Total	7.645	19			
Codeine Extract	Between	0.227	1	0.227	1.170	.294
	Within	3.494	18	0.194		
	Total	3.722	19			

Table 2. ANOVA, Goldberger et al., Data for Opiate Categories and Hair Color

Examining the homogeneity of variance for this data by the Levene statistic reveals that the variance for these analytes is homogenous across groups (The Levene values range from .077 to .149). As a review of the significance column in Table 2 shows, neither the parent compound (heroin) nor any of the analytes

attain a significant difference when comparing the two color categories, black and brown hair.

Kintz et al., 1998

In 1998 Kintz, Bundeli, Brenneisen, and Ludes published an article entitled "Dose-Concentration Relationships in Hair from Subjects in a Controlled Heroin-Maintenance Program" in the *Journal of Analytical Toxicology* (12). This reports data collected from individuals who participated in a heroin-maintenance program, and who were given known doses of heroin with known purity. Furthermore, these doses were substantial since these persons were experienced heroin addicts. We emphasize this point because in the literature on hair analysis there are few studies utilizing controlled dosages. And reviewing these studies it is generally true that when used, controlled doses are generally very small in comparison to the reports of *in vivo* consumption as reported by drug abusers.

In the following tables we present the data from the Kintz et al. study and a comparison of hair to recovered drug to determine if there are any significant relationships. We analyze the data using the five color categories reported in the article (black, dark brown, light brown, blond, and red) and the ng/mg concentration in hair of heroin, 6-acetylmorphine, and morphine. Table 3 presents the descriptive information on mean concentration and dispersion measures for the parent drug (heroin) and two metabolites, 6-acetylmorphine (6-AM) and morphine.

Analyte	Hair Color	N	Mean (ng/mg)	Std. Deviation	Std. Error	95% C.I. for the Mean	
						Lower Boundary	Upper Boundary
Heroin	Black	7	1.093	1.583	0.5983	-0.3712	2.557
	Dark Brown	6	1.188	1.418	0.5787	-0.2993	2.676
	Light Brown	4	1.200	0.438	0.2192	0.5024	1.897
	Blond	1	1.750				
	Red	2	1.49	1.175	0.1400	-2.889	3.269
6-AM	Black	7	4.740	2.360	0.8921	2.557	6.923
	Dark Brown	6	5.045	4.122	1.683	0.7198	9.371
	Light Brown	4	3.893	2.409	1.204	0.0594	7.726
	Blond	1	3.400				
	Red	2	0.695	0.445	0.3150	-3.3075	4.697
Morphine	Black	7	2.779	1.359	0.5137	1.5216	4.035
	Dark Brown	6	2.645	1.304	0.5322	1.2770	4.013
	Light Brown	4	2.333	0.392	0.1962	1.7081	2.957
	Blond	1	2.120				
	Red	2	0.975	0.2475	0.1750	-1.2486	3.199

Table 3. Descriptive Data Kintz et al., Hair Assays for Heroin and Metabolites by Hair Color

Tables 4 through 6 are the Tukey comparison matrix for all color comparisons in the Kintz study. Three analytic tables are produced to permit each analyte to be considered separately. Each table displays the outcome for all combinations of hair color contrasted to each other. This includes the mean difference for the two compared categories, the standard error and the 95% confidence interval. The significance column should be read keeping in mind that a criteria value of 0.05 or less must be attained for significance to be established.

Analyte	Hair Color (I)	Hair Color (J)	Mean Difference (I-J)	Std. Error	Significance	95% Confidence Interval	
						Lower Boundary	Upper Boundary
Heroin	Black	Dark Brown	-0.0955	0.728	.999	-2.194	2.00
		Light Brown	-0.1071	0.820	.999	-2.472	2.258
		Red	-0.3971	1.049	.981	-3.422	2.628
	Dark Brown	Black	0.0955	0.728	.999	-2.003	2.194
		Light Brown	-0.0117	0.845	1.000	-2.447	2.423
		Red	-0.3017	1.069	.992	-3.382	2.779
	Light Brown	Black	0.1071	0.820	.999	-2.258	2.472
		Dark Brown	0.0117	0.845	1.000	-2.423	2.447
		Red	-0.2900	1.134	.994	-3.557	2.977
	Red	Black	0.3971	1.049	.981	-2.628	3.422
		Dark Brown	0.3017	1.069	.992	-2.779	3.382
		Light Brown	0.2900	1.134	.994	-2.977	3.557

Table 4. Comparison Matrix, Heroin Data, Kintz et al. Study

Analyte	Hair Color (I)	Hair Color (J)	Mean Difference (I-J)	Std. Error	Significance	95% Confidence Interval	
						Lower Boundary	Upper Boundary
6-AM	Black	Dark Brown	-0.305	1.675	.998	-5.133	4.523
		Light Brown	0.848	1.887	.969	-4.592	6.287
		Red	4.045	2.414	.370	-2.913	11.003
	Dark Brown	Black	0.305	1.675	.998	-4.522	5.133
		Light Brown	-1.153	1.944	.933	-4.449	6.754
		Red	4.350	2.459	.325	-2.736	11.44
	Light Brown	Black	-0.8475	1.887	.969	-6.287	4.592
		Dark Brown	-1.153	1.944	.933	-6.754	4.449
		Red	3.198	2.608	.621	-4.318	10.713
Red	Black	-4.045	2.414	.370	-11.003	2.913	
	Dark Brown	-4.350	2.459	.325	-11.436	2.736	
	Light Brown	-3.1975	2.608	.621	-10.713	4.318	

Table 5. Comparison Matrix, 6-Acetylmorphine Data, Kintz et al. Study

Analyte	Hair Color (I)	Hair Color (J)	Mean Difference (I-J)	Std. Error	Significance	95% Confidence Interval	
						Lower Boundary	Upper Boundary
Morphine	Black	Dark Brown	0.1336	0.644	.997	-1.723	1.989
		Light Brown	0.4461	0.726	.926	-1.645	2.537
		Red	1.804	0.928	.252	-0.8716	4.479
	Dark Brown	Black	-0.1336	0.644	.997	-1.989	1.723
		Light Brown	0.3125	0.747	.975	-1.841	2.466
		Red	1.670	0.945	.326	-1.054	4.394
	Light Brown	Black	-0.4461	0.726	.926	-2.537	1.645
		Dark Brown	-0.3125	0.747	.975	-2.466	1.841
		Red	1.357	1.00	.545	-1.532	4.247
Red	Black	-1.804	0.928	.252	-4.479	0.8716	
	Dark Brown	-1.670	0.945	.326	-4.394	1.054	
	Light Brown	-1.357	1.003	.545	-4.247	1.532	

Table 6. Comparison Matrix, Morphine Data, Kintz et al. Study

As Tables 4, 5, and 6 reveal the Kintz data do not demonstrate a significant association by color. For heroin and morphine the homogeneity of variance requirement is met. The Levene statistic (to determine equality of variance) shows that for 6-AM the homogeneity of variance does not hold (Levene = .020). Transformation on the 6-AM variable by the squares process pushes the homogeneity value to 0.050, which is a borderline acceptable value. Further examination by the Tamahane procedure shows the 6-AM/color contrasts as non-significance ($p = .065$).

Cocaine Studies

Cone et al., 1991

In 1991 Cone, Yousefnejad, Darwin and Maguire published an article entitled "Testing Human Hair for Drugs of Abuse. II. Identification of Unique Cocaine Metabolites in Hair of Drug Abusers and Evaluation of Decontamination

Procedures" in the Journal of Analytical Toxicology (13). This article reported analysis of hair samples from ten "heavy" cocaine users who had high-frequency cocaine-positive urinalysis results while enrolled in a drug treatment program. Although Cone et al. did not analyze the data by the dimension of hair color, they reported hair color as one of the descriptive variables in the study. The following set of tables, which examine the relationship between recovered cocaine and cocaine metabolites and hair color, are derived from this data set. In addition to hair assay and wash data for parent cocaine, the authors also reported values for the following metabolites: benzoylecgonine (BE), ecgonine methyl ester (EME), norcocaine (NC), cocaethylene (CE), and norcocaethylene (NCE). The series of analytic tables that follow vary slightly from the previous tables in that Cone et al. reported only two categories of hair color; black and brown. Since Tukey's procedure requires at least three categorical variable conditions in order to do contrasts, a one-way analysis of variance is performed to evaluate this data. Table 7 provides the descriptive statistics for recovered analytes.

Analyte	Hair Color	N	Mean (ng/mg)	Std. Deviation
Cocaine	Black	8	10.66	4.319
	Brown	2	11.10	6.647
BE	Black	8	1.10	0.590
	Brown	2	1.70	1.131
EME	Black	8	1.000	0.824
	Brown	2	0	0
NC	Black	8	0.275	0.301
	Brown	2	0	0
CE	Black	8	0.837	0.897
	Brown	2	0	0

Table 7. Descriptive Data Cone, Yousefnejad et al., Hair Assays for Cocaine and Metabolites by Hair Color

Table 8 reports the outcome from a one-way analysis of variance. Since there are only two color categories reported for the hair, a one-way analysis of variance is used to examine the mean differences.

Analyte		Sum of Squares	DF	Mean Square	F	Significance
Cocaine	Between	0.306	1	0.306	0.14	.909
	Within	174.739	8	21.842		
	Total	175.045	9			
BE	Between	0.576	1	0.576	1.239	.298
	Within	3.720	8	0.465		
	Total	4.296	9			
EME	Between	1.600	1	1.600	2.689	.140
	Within	4.760	8	0.595		
	Total	6.360	9			
NC	Between	0.121	1	0.121	1.524	.252
	Within	0.635	8	0.079		
	Total	0.756	9			
CE	Between	0.650	1	0.650	0.910	.368
	Within	5.719	8	0.715		
	Total	6.369	9			

Table 8. ANOVA, Cocaine and Metabolites, Cone, Yousefnejad, et al.

As Table 8 indicates no significance value attain .05 or less and thus the analysis of variance fails to demonstrate a significant effect by color for the five analytes. The Levene test indicates the homogeneity of variance assumption holds for cocaine, BE, and cocaethylene. It does not for EME or norcocaine. Transformation by squares on EME attains a Levene value of 0.06 and subsequent reanalysis also fails to show significance.

Henderson, Harkey, et al., 1998

In 1998 Henderson, Harkey, Zhou, Jones, and Jacob published an article entitled "Incorporation of Isotopically Labeled Cocaine into Human Hair: Race as a Factor" in the *Journal of Analytical Toxicology* (14). This article reported cocaine hair assay data on 15 subjects and included hair color as a variable. There are three hair color categorizations reported for these subjects: black, brown, and gray-brown. Because of the method the authors use to report the cocaine concentration in hair there are two alternative ways to view the data. One is to calculate the concentration of drug per 10 mg hair segment. The second is to consider the concentration value as a total summation across all segments. We have analyzed the data by both methods, and in neither case did the data attain significance for any hair color/concentration comparisons. In the interests of conserving space we present here the data for the per/case totality of

cocaine across concentration measures. Table 9 reports descriptive measures for this data and table 10 reports the analytic results for these 15 subjects.

Analyte	Hair Color	N	Mean (ng/mg)	Std. Deviation	Std. Error	95% C.I. for the Mean	
						Lower Boundary	Upper Boundary
Cocaine	Black	8	5.4213	4.3790	1.5482	1.7603	9.082
	Brown	5	2.432	2.3709	1.0603	-0.5119	5.376
	Gray-Brown	2	0.7250	1.025	0.7250	-8.487	9.937

Table 9. Descriptive Data Henderson et al., Hair Assays for Cocaine by Hair Color

Table 10 is the analytic outcomes for the comparison values as determined by Tukey's procedure. The Levene statistic indicates homogeneity of variance is met ($p = .145$) for the data set. As Table 10 reveals, there is no significant difference for cocaine concentration when comparing outcomes by hair color.

Analyte	Hair Color (I)	Hair Color (J)	Mean Difference (I-J)	Std. Error	Significance	95% Confidence Interval	
						Lower Boundary	Upper Boundary
Cocaine	Black	Brown	2.9893	2.067	.350	-2.5254	8.5039
		Brown-Gray	4.6963	2.867	.268	-2.9512	12.3437
	Brown	Black	-2.9893	2.067	.350	-8.5039	2.5254
		Gray-Brown	1.7070	3.034	.842	-6.3863	9.8003
	Gray-Brown	Black	-4.6963	2.867	.268	-12.3437	2.9512
		Brown	-1.7070	3.034	.842	-9.8003	6.3863

Table 10. Comparison Matrix, Cocaine, Henderson, et al.

Larger N Studies

The studies in the previous section were characterized as small N studies since the number of subjects constituting the sample generally numbered 20 or less. While small N studies can be suggestive, their biggest limitations are the restrictions on statistical analysis that can be performed and the volatility or instability of the data by shifts in a single value for a single case. Furthermore, such studies place high demands on the power of a statistical procedure to avoid

β error, and thus make the discovery of significant but small effects very difficult. In the next section we examine the outcome from a series of studies which utilize larger sample sizes. With larger size samples there is a general increase in the confidence of effects identified in a data set. While this does not make the data generalizable (only proper selection techniques can do this) it does enhance the identification of effects within the sample, and in general produces more data stability.

We will examine data from four sources, looking at several different categories of drugs. First, we review data taken from a study on MDMA and analogs in hair done by researchers at the University of Glasgow. Then three other groups of samples are examined; these include a study of probationers in Pinellas county, Florida, and two data sets provided by commercial toxicology laboratories, Associated Pathologists Laboratory in Las Vegas, Nevada and the Psychomedics Corporation of Culver city California..

The Glasgow Study: MDMA and Its Analogs

The following material are data from a study conducted at the University of Glasgow and under the auspices of the Centre for Criminology at the university. This particular study collected hair specimens from volunteers at "rave" parties with the intent of assessing hair samples for the presence of amphetamine, methamphetamine, 3,4-methylenedioxyamphetamine (MDA), 3,4-methylenedioxyethamphetamine (MDEA), and 3,4-methylenedioxymethylamphetamine (MDMA). There were 232 subjects who donated hair specimens. The specimens were divided and tested at two laboratories, 139 at the University of Glasgow and 93 at Tricho-Tech, Ltd. in London. Hair color is only available for the 139 specimens tested at Glasgow and these samples constitute the data reported here.

Color	Frequency	Percent
Gray	2	1.4
White	1	0.7
Blond	19	13.7
Red	5	3.6
Dark Red	1	0.7
Light Brown	34	24.5
Medium Brown	45	32.4
Dark Brown	31	22.3
Black	1	0.7
Total	139	100.0

Table 11. Distribution of Hair Color, Glasgow Sample

The frequency distribution for the hair color categories for these specimens is shown in Table 11. The following five tables (Table 12 to Table 16) provide the descriptive statistics for the five tested drugs (AMP, MAMP, MDA, MDMA, MDEA) for the cases from the Glasgow laboratory.

Analyte	Hair Color	N	Mean (ng/mg)	Std. Deviation	Std. Error	95% C.I. for the Mean	
						Lower Boundary	Upper Boundary
AMP	Grey	0					
	White	0					
	Blond	1	2.50			2.5	2.5
	Red	0					
	Light Brown	2	54.04	61.73	43.65	-500.576	608.676
	Medium Brown	5	3.660	4.223	1.888	-1.584	8.904
	Dark Brown	3	2.767	2.272	1.312	-2.878	8.411
	Black	0					

Table 12. Glasgow Study, Descriptive Data, Amphetamine (AMP) Data by Hair Color

Analyte	Hair Color	N	Mean (ng/mg)	Std. Deviation	Std. Error	95% C.I. for the Mean	
						Lower Boundary	Upper Boundary
MAMP	Grey	0					
	White	0					
	Blond	1	2.5				
	Red	3	2.033	0.8386	0.4842	-0.4998	4.1167
	Light Brown	8	5.687	10.813	3.823	-3.352	14.727
	Medium Brown	8	8.40	9.287	3.283	0.6359	16.164
	Dark Brown	7	2.714	1.682	0.636	1.158	4.270
	Black	0					

Table 13. Glasgow Study, Descriptive Data, Methamphetamine (MAMP) by Hair Color

Analyte	Hair Color	N	Mean (ng/mg)	Std. Deviation	Std. Error	95% C.I. for the Mean	
						Lower Boundary	Upper Boundary
MDA	Grey	0					
	White	1	1.00				
	Blond	2	3.35	0.495	0.350	-1.097	7.797
	Red	0					
	Light Brown	5	2.00	3.320	1.485	-2.123	6.123
	Medium Brown	6	2.60	3.209	1.310	-0.768	5.968
	Dark Brown	5	0.70	0.612	0.2739	-0.063	1.460
	Black	1	0.100				

Table 14. Glasgow Study, Descriptive Data, Methylenedioxyamphetamine (MDA) by Hair Color

Analyte	Hair Color	N	Mean (ng/mg)	Std. Deviation	Std. Error	95% C.I. for the Mean	
						Lower Boundary	Upper Boundary
MDMA	Grey	1	0.20				
	White	0					
	Blond	6	1.500	1.958	0.7996	-0.5554	3.5554
	Red	3	0.633	0.1528	0.0881	0.2539	1.0128
	Light Brown	13	8.846	22.772	6.316	-4.915	22.607
	Medium Brown	14	2.050	4.149	1.109	-0.3458	4.446
	Dark Brown	18	5.772	13.428	3.165	-0.9055	12.450
	Black	1	0.800				

Table 15. Glasgow Study, Descriptive Data, Methylenedioxymethylamphetamine (MDMA) by Hair Color

Analyte	Hair Color	N	Mean (ng/mg)	Std. Deviation	Std. Error	95% C.I. for the Mean	
						Lower Boundary	Upper Boundary
MDEA	Grey	0					
	White	0					
	Blond	2	3.75	0.0707	0.050	3.114	4.385
	Red	0					
	Light Brown	7	3.00	4.608	1.742	-1.261	7.261
	Medium Brown	5	5.12	6.320	2.826	-2.727	12.967
	Dark Brown	8	1.15	1.640	0.580	-0.2215	2.521
	Black	1	1.00				

Table 16. Glasgow Study, Descriptive Data, Methylenedioxyamphetamine (MDEA) by Hair Color

Because several of the color categories have less than two cases, a Tukey process cannot be performed on the array. A one-way analysis of variance, however, can be done, and Table 17 displays the results of the one-way ANOVA.

Analyte		Sum of Squares	DF	Mean Square	F	Significance
AMP	Between	4227.73	7	603.963	.466	.818
	Within	3892.32	4	1297.44		
	Total	8120.06	11			
MAMP	Between	164.446	7	23.492	.310	.941
	Within	1440.64	19	75.823		
	Total	1605.09	26			
MDA	Between	18.385	7	2.626	.324	.929
	Within	97.345	12	8.112		
	Total	115.730	19			
MDMA	Between	488.755	7	69.822	.352	.925
	Within	9531.43	48	198.571		
	Total	10020.18	55			
MDEA	Between	54.017	7	7.717	.378	.901
	Within	306.033	15	20.402		
	Total	360.05	22			

Table 17. One-Way ANOVA, Glasgow Study, Hair Assays by Hair Color

As Table 17 reveals, there is no significant effect identified by the analysis of variance for the Glasgow data set. As noted, a Tukey's procedure cannot be done with data matrices that have cells with less than two cases. However, if we delete the color categories for MDMA which fail to attain a cell N of 2 (these are colors gray, white, and black) we can do a Tukey's significant difference procedure. This is shown in Table 18. We select MDMA because it was the drug of primary interest in the research project. MDMA ("Ecstasy") is the typical drug of choice for at raves, and was the most frequently detected substance. In eliminating the [N > 2] cells we lose only 2 cases, and comparison N for MDMA is only reduced from 56 to 54.

