Faculty Participation in the *Center for the Advancement of Teaching*, 1998-2004

An Application of the Chi-square Probability Distribution

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This study was reviewed and approved by the chair of the *Internal Review Board* (*IRB*) of Xavier University of Louisiana.

"The committee reviews research proposals which involve the use of human subjects. Any faculty member at Xavier who is using human subjects, or any research proposal which involves Xavier and uses human subjects must have the approval of the Xavier IRB. Use of human subjects includes tissues derived from them, such as skin, blood, organ, etc. Most surveys administered to students require IRB approval (except those conducted in the classroom as part of the educational process or those involving observation of public behavior)." (*Faculty Handbook*, August 2003)

Acknowledgement

Thanks to the staff of Xavier's *Office of Institutional Research* for their help in compiling some of the data, namely the race/ethnicity data.

Contents

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Introduction

- *Center for the Advancement of Teaching*
  - coordinates faculty development initiatives
  - is an interdisciplinary, collaborative academic unit that seeks to focus the University's efforts aimed at advancing the art of teaching at all levels
  - creates opportunities for Xavier faculty to develop new teaching strategies and to incorporate the use of technology in educationally effective ways
  - supports Xavier faculty collaboration with preK-12 schools or teachers

Introduction *(cont.)*

- Purpose of this study is to investigate several questions about
  - proposals submitted to the *Center*
  - proposals that were funded
  - proposals that were not funded.
- Is the **gender** distribution of faculty who submitted proposals to the *Center* during 1998-2004 the same as the gender distribution of all full-time university faculty?

Introduction *(cont.)*

- Is the **race/ethnicity** distribution of faculty who submitted proposals to the *Center* during 1998-2004 approximately the same as the race/ethnicity distribution of all full-time university faculty?
- Is the distribution of faculty by **division** for those who submitted proposals to the *Center* during 1998-2004 approximately the same as the distribution of faculty by division for all faculty?
- Is the distribution of faculty by **department** for those who submitted proposals to the *Center* during 1998-2004 approximately the same as the distribution of faculty by department for all faculty?

Introduction *(cont.)*

- Similar questions for
  - Proposals that were funded
  - Proposals that were not funded

Study Design and Procedures

- Data collection
- Data verification
- Coding data

Data Collection

- CAT staff generate *Excel* spreadsheet
- For each faculty who submitted proposals during 1998-2004
  - Faculty name
  - Gender
  - Race/ethnicity
  - Division or department
  - List of proposals submitted. For each,
    - Other faculty participating in the proposal
    - Identify proposals funded & those not funded

Data Verification

- An essential step in any statistical analysis
- 146 faculty submitted proposals (individual or joint proposals)
  - Total of 251 proposals
    - 209 funded
    - 42 not funded
- Generate a *Lotus 1-2-3* spreadsheet of aggregate information
- Input data into *SPSS* (statistical program)

Coding Data – 10 cases (faculty)

Appendix: Random Listing of Cases (Faculty)

Case Summaries (partial information) in Random Order

Prtc = Total Number of Participants in Proposals
Prop = Number of Proposals Submitted
Fund = Proportion of Proposals Funded

	Division	College(or Dv)	Gender	Race/Ethnicity	Prtc	Prop	Fund
1	Natural Sci & Math	A&S (excl Ed)	Male	Other	6	2	0%
2	Soc Sci & Bus Adm	A&S (excl Ed)	Male	Other	6	5	80%
3	Arts & Humanities	A&S (excl Ed)	Male	Caucasian	4	2	100%
4	Division of Educ	Div of Educ	Female	Caucasian	3	1	100%
5	Other	A&S (excl Ed)	Female	Black/Afr Amer	4	1	100%
6	Natural Sci & Math	A&S (excl Ed)	Female	Black/Afr Amer	1	1	100%
7	Soc Sci & Bus Adm	A&S (excl Ed)	Male	Caucasian	21	3	100%
8	Natural Sci & Math	A&S (excl Ed)	Male	Other	3	2	50%
9	Natural Sci & Math	A&S (excl Ed)	Male	Caucasian	2	1	100%
10	Division of Educ	Div of Educ	Male	Black/Afr Amer	5	1	0%

Descriptive Statistics

- XU Faculty: *University Profile 2003-2004*
  - Why use the 2003-2004 faculty data?
    - Small changes in distributions
    - See Appendix A of the full report for details
- Faculty submitting proposals to CAT during 1998-2004

32. Xavier University Full - Time Faculty
Total Headcount by Rank, Gender and Race/Ethnicity
Fall Semester 2003[1]

Race/ Ethnicity	Gender	Professor		Associate Professor		Assistant Professor		Instructor		Totals	
		#	%	#	%	#	%	#	%	#	%
Black/Afr. American	Male	7	3.0%	10	4.2%	12	5.1%	6	2.5%	35	14.8%
	Female	3	1.3%	8	3.4%	25	10.6%	3	1.3%	39	16.5%
											31.4%
White	Male	22	9.3%	20	8.5%	30	12.7%	2	0.8%	74	31.4%
	Female	7	3.0%	13	5.5%	27	11.4%	8	3.4%	55	23.3%
											54.7%
Other[2]	Male	9	3.8%	5	2.1%	10	4.2%	0	0.0%	24	10.2%
	Female	0	0.0%	5	2.1%	4	1.7%	0	0.0%	9	3.8%
											14.0%
TOTAL	Male										56.4%
	Female										43.6%
	TOTAL	48	20.3%	61	25.8%	108	45.8%	19	8.1%	236	100.0%

36. Student/Faculty Ratio
Fall Semester 2003[1]

	FTE FACULTY[2]		
Arts & Humanities			
African American Studies	3.00		
Art	5.25		
Communications	15.75		
English	21.50		
Language	9.25		
Music	7.06		
Philosophy	6.00		
Theology	7.50		
Total Arts & Humanities	**75.31**	**14,629**	**13.0**
Division of Education[5]			
Undergraduate Education		829	
Graduate Education		1,191	
Total Division of Education	**17.17**	**2,020**	
Natural Sciences & Mathematics			
Biology	30.17	7,510	
Chemistry	26.58	6,266	15.7
Computer Science	10.00	1,014	6.8
Mathematics	16.67	4,989	20.0
Physics/Pre-Engineering	6.84	1,534	15.0
Total Natural Sciences & Math	**90.26**	**21,313**	**15.7**

36. Student/Faculty Ratio
Fall Semester 2003[1], *cont.*

	FTE FACULTY[2]	Student Sem. Hrs.[3]	Student/Fac. Ratio[4]
Social Sciences & Business Administration			
Business Administration	11.00	2,391	14.5
History	9.00	2,454	18.2
Political Science	3.25	918	18.8
Psychology	7.50	2,259	20.1
Sociology	4.25	1,614	25.3
Total Social Sciences	**35.00**	**9,636**	**18.4**
Total College of Arts & Sciences	**217.74**	**47,598**	**15.2**
Total College of Pharmacy	**39.00**	**7,755**	**13.3**
TOTAL UNIVERSITY	**256.74**	**55,353**	**14.9**

Used *FTE* for Division and Department analyses

Statistical Methodology

- Chi-square (χ^2) goodness of fit
  - A hypothetical example
  - Thousands of jellybeans!
- Hypotheses tested

Chi-square Goodness of Fit

- Consider a barrel of tens of thousands of jellybeans of $k = 6$ different colors
- Suppose the proportions of each color are P_i, $i = 1, 2, \ldots, 6$
- If we were to draw a random sample of size n, we expect to have $n \cdot P_i$ of color i
- Now, draw a single random sample of n jellybeans
- Let n_i, $i = 1, \ldots, 6$, denote the number of jellybeans in the sample of color i

Chi-square Goodness of Fit *(cont)*

- Compute the following statistic:

$$\chi^2 = \sum_{i=1}^{6} \frac{(n_i - E_i)^2}{E_i}, \text{ where } E_i = n_i P_i$$

- Replace all the jellybeans in the barrel
- Repeat this process of randomly selecting *n* jellybeans, noting the colors, and computing the χ^2 statistic

Chi-square Goodness of Fit *(cont)*

- The result of this repeated sampling process is a large set of computed χ^2 statistics.
- The distribution of these statistics is approximately the χ^2 distribution with $k - 1 = 5$ degrees of freedom.
- The theory of the Chi-square goodness of fit test is based on the notion of repeated sampling.
- In practice, we draw one sample and compare the computed χ^2 statistic against the theoretical distribution.

Chi-square Density Function

$$f(y)=\begin{cases}\dfrac{y^{\lambda/2-1}\cdot e^{-y/2}}{2^{\lambda/2}\cdot\Gamma(\lambda/2)}, & y\geq 0\\ 0, & y<0\end{cases}$$

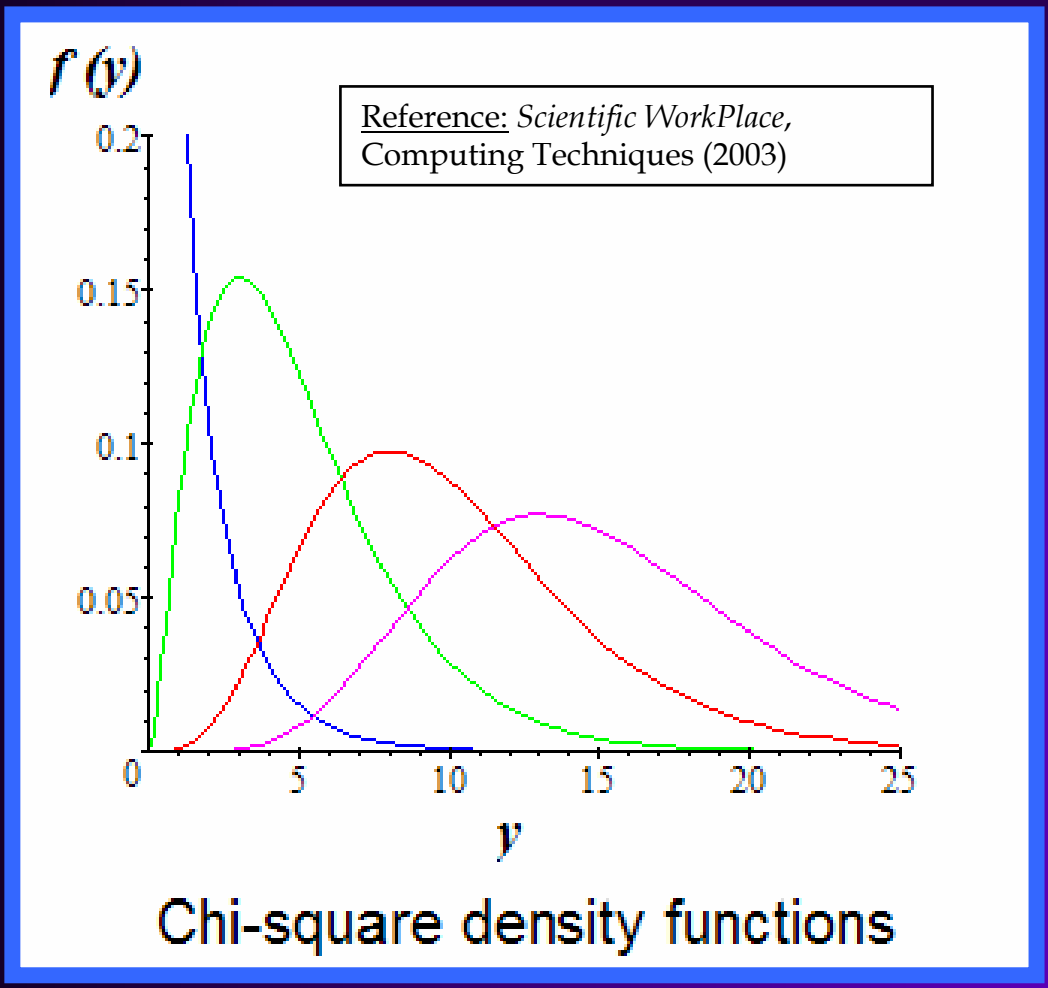
where $\Gamma(t)=\int_0^{\infty} e^{-y}\cdot y^{t-1}dy$ is the Gamma function.

The parameter λ is called the degrees of freedom (df).

Chi-square Density Function

- Characteristics of any continuous probability density function (pdf)
- Chi-square pdf is skewed to the right
- Chi-square pdf is a single parameter function
  - Degrees of freedom (λ)
  - Mean of the distribution (λ)
  - Variance of the distribution ($2\ \lambda$)

χ^2 Probability Density Functions (pdf's)



$df = 1$

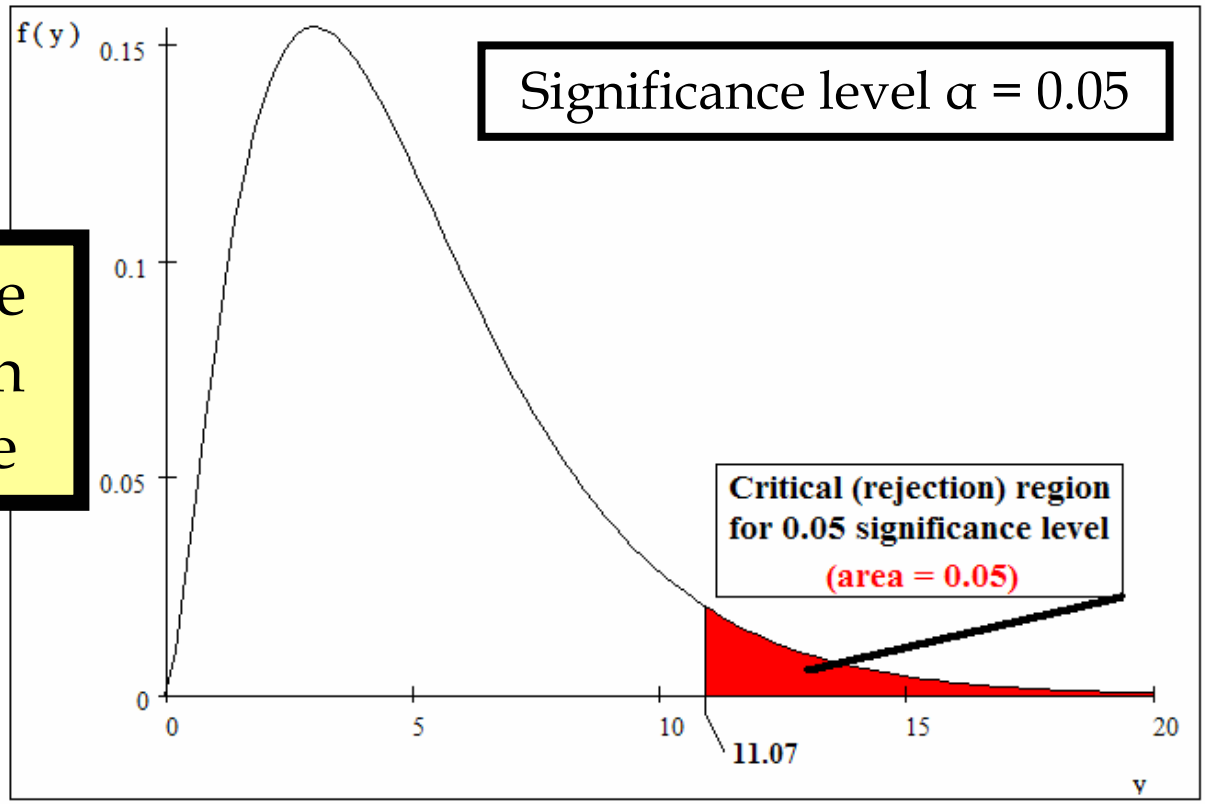
$df = 5$

$df = 10$

$df = 15$

Chi-square pdf for *df* = 5

From the jellybean example



Chi-square Density Function (*df* = 5)

Notation Used in Hypotheses

- $p_{\text{<subscript>}}$ represents the proportion of faculty submitting proposals (sample proportions)
- $P_{\text{<subscript>}}$ represents the proportion of all XU faculty (population proportions)

Hypotheses: Gender

- Null hypothesis
  - The gender distribution of faculty submitting proposals to CAT is the same as the gender distribution of all XU faculty.
  - H_0: $p_{\text{male}} = P_{\text{male}}$ and $p_{\text{female}} = P_{\text{female}}$
- Alternative hypothesis
  - The gender distribution of faculty submitting proposals to CAT is different from the gender distribution of all XU faculty.
  - H_a: $p_{\text{male}} \neq P_{\text{male}}$ or $p_{\text{female}} \neq P_{\text{female}}$

Hypotheses: Race/Ethnicity

- Null hypothesis
  - The race/ethnicity distribution of faculty submitting proposals to CAT is the same as the race/ethnicity distribution of all XU faculty.
  - H_0: $p_{\text{black}} = P_{\text{black}}$ and $p_{\text{white}} = P_{\text{white}}$ and $p_{\text{other}} = P_{\text{other}}$
- Alternative hypothesis
  - The race/ethnicity distribution of faculty submitting proposals to CAT is different from the race/ethnicity distribution of all XU faculty.
  - H_a: $p_{\text{black}} \neq P_{\text{black}}$ or $p_{\text{white}} \neq P_{\text{white}}$ or $p_{\text{other}} \neq P_{\text{other}}$

Hypotheses: Division

- Null hypothesis
  - The distribution by division of faculty submitting proposals to CAT is the same as the distribution by division of all XU faculty.
- Alternative hypothesis
  - The distribution by division of faculty submitting proposals to CAT is different from the distribution by division of all XU faculty.

Hypotheses: Department

- Null hypothesis
  - The distribution by department of faculty submitting proposals to CAT is the same as the distribution by department of all XU faculty.
- Alternative hypothesis
  - The distribution by department of faculty submitting proposals to CAT is different from the distribution by department of all XU faculty.

Results and Conclusions

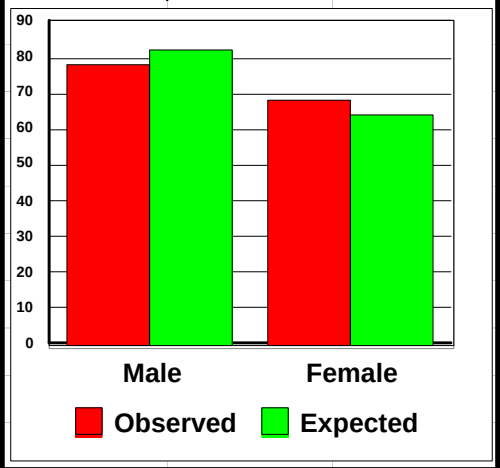
- Gender
- Race/ethnicity
- Division
- Department

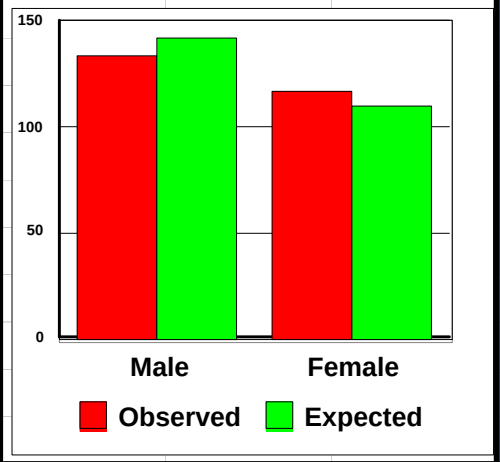
- By number of faculty
- By proposals submitted
- By proposals funded
- By proposals not funded

16 separate Chi-square tests

Results: Gender (part 1)

Gender	(a) Unweighted			(b) Weighted by Number of Proposals Submitted		
	Observed	Expected	Residual	Observed	Expected	Residual
Male	78	82.3	-4.3	134	141.6	-7.6
Female	68	63.7	4.3	117	109.4	7.6
Total	146			251		
Chi-Square	0.526			0.927		
df	1			1		
Asymp. Significance	0.468			0.336		

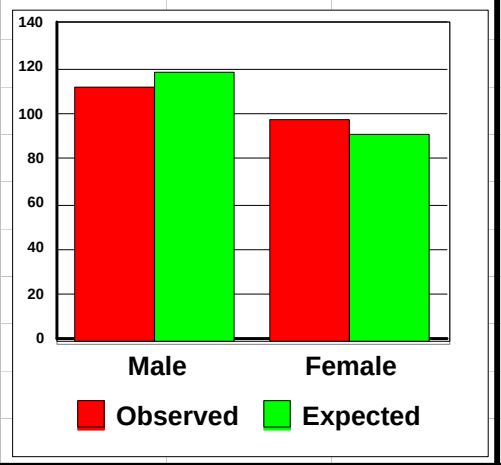




Differences not statistically significant

Results: Gender (part 2)

Gender	(c) Weighted by Number of Proposals Funded			(d) Weighted by Number of Proposals NOT Funded		
	Observed	Expected	Residual	Observed	Expected	Residual
Male	112	117.9	-5.9	22	23.7	-1.7
Female	97	91.1	5.9	20	18.3	1.7
Total	209			42		
Chi-Square	0.672			0.276		
df	1			1		
Asymp. Significance	0.412			0.599		

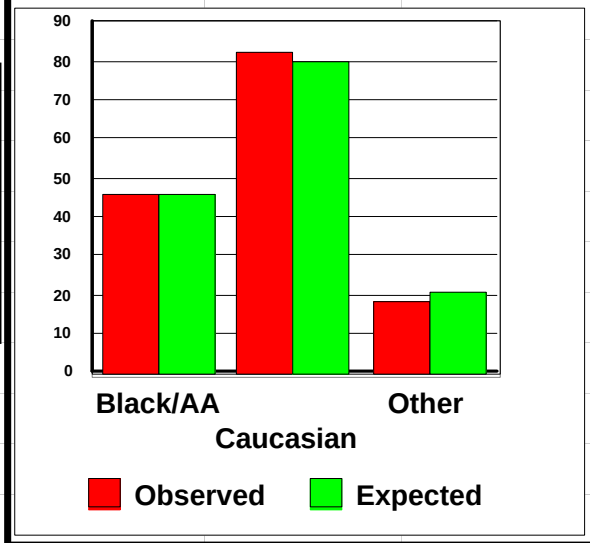


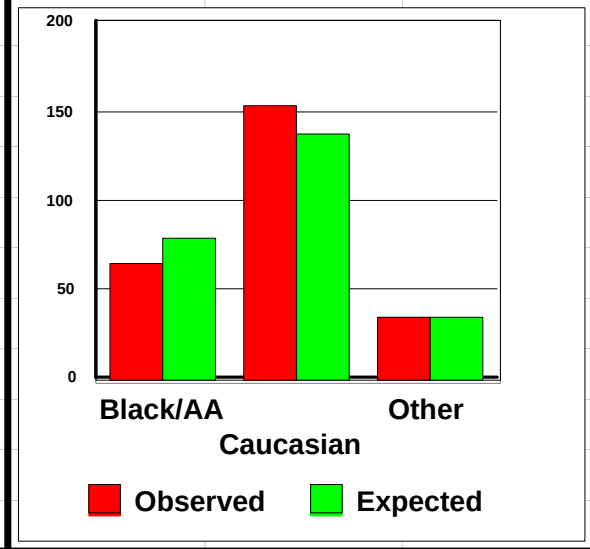
Differences not statistically significant

Results: Race/Ethnicity (Part 1)

Race / Ethnicity	(a) Unweighted			(b) Weighted by Number of Proposals Submitted		
	Observed	Expected	Residual	Observed	Expected	Residual
Black/African American	46	45.8	0.2	64	78.7	-14.7
Caucasian	82	79.8	2.2	153	137.2	15.8
Other	18	20.4	-2.4	34	35.1	-1.1
Total	146			251		
Chi-Square	0.346			4.605		
df	2			2		
Asymp. Significance	0.841			0.100		

Differences not statistically significant

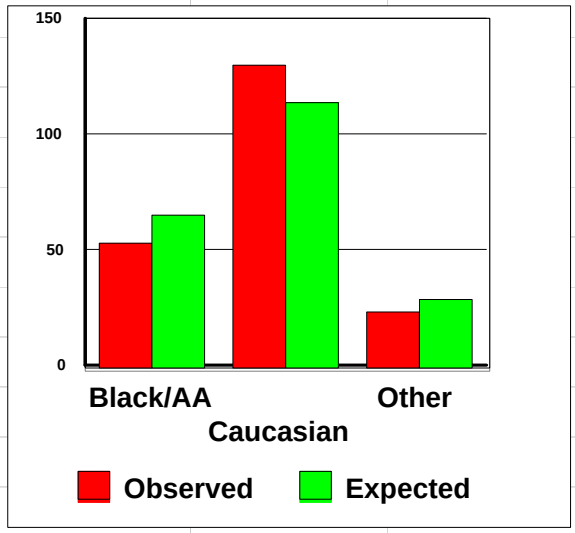


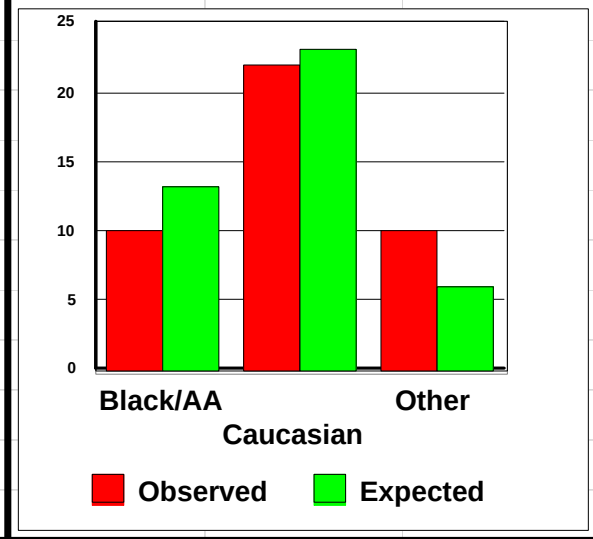


Results: Race/Ethnicity (Part 2)

Race / Ethnicity	(c) Weighted by Number of Proposals Funded			(d) Weighted by Number of Proposals NOT Funded		
	Observed	Expected	Residual	Observed	Expected	Residual
Black/African American	54	65.5	-11.5	10	13.2	-3.2
Caucasian	131	114.2	16.8	22	23.0	-1.0
Other	24	29.2	-5.2	10	5.9	4.1
Total	209			42		
Chi-Square	5.424			3.706		
df	2			2		
Asymp. Significance	0.066			0.157		

Differences not statistically significant

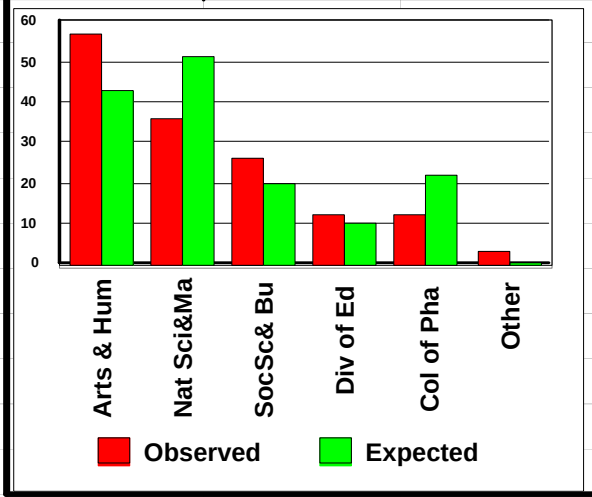


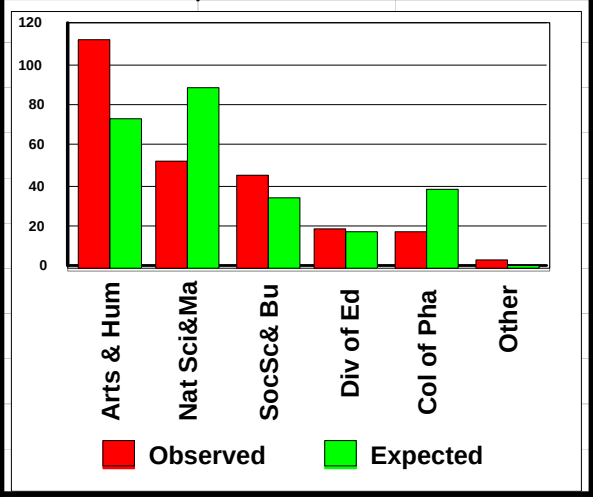


Results: Division (Part 1)

Division	(a) Unweighted			(b) Weighted by Number of Proposals Submitted		
	Observed	Expected	Residual	Observed	Expected	Residual
Arts & Humanities	57	42.8	14.2	113	73.6	39.4
Natural Sciences & Math	36	51.3	-15.3	53	88.2	-35.2
Soc.Sci. & Bus.Adm.	26	19.9	6.1	45	34.2	10.8
Division of Education	12	9.8	2.2	19	16.8	2.2
College of Pharmacy	12	22.2	-10.2	18	38.1	-20.1
Other	3	0.0	3.0	3	0.0	3.0
Total	146			251		
Chi-Square	626.841			402.097		
df	5			5		
Asymp. Significance	0.000	** Significant		0.000	** Significant	

Differences are statistically significant



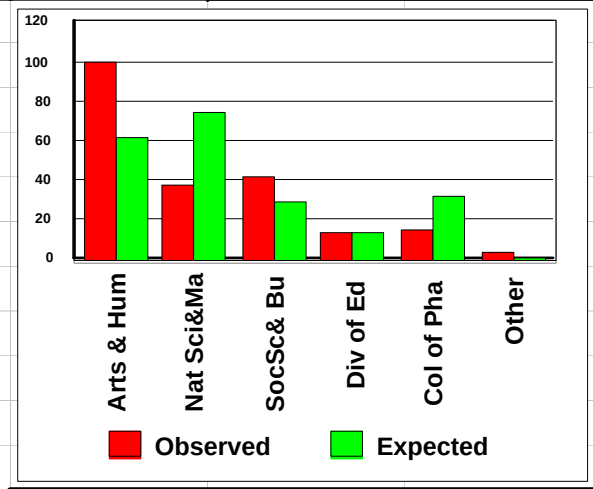


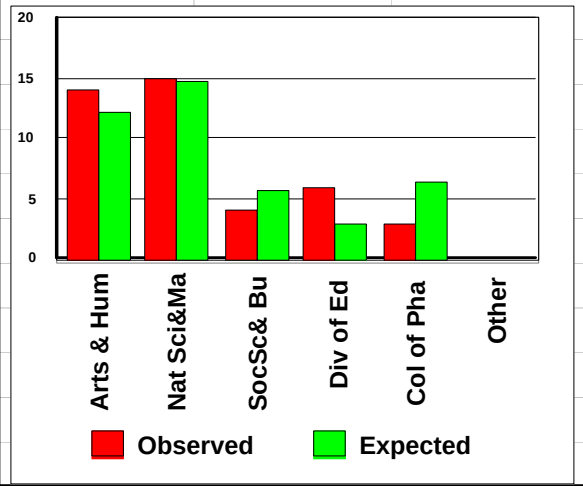
Results: Division (Part 2)

Division	(c) Weighted by Number of Proposals Funded			(d) Weighted by Number of Proposals NOT Funded		
	Observed	Expected	Residual	Observed	Expected	Residual
Arts & Humanities	99	61.3	37.7	14	12.3	1.7
Natural Sciences & Math	38	73.5	-35.5	15	14.8	0.2
Soc.Sci. & Bus.Adm.	41	28.5	12.5	4	5.7	-1.7
Division of Education	13	14.0	-1.0	6	2.8	3.2
College of Pharmacy	15	31.7	-16.7	3	6.4	-3.4
Other	3	0.0	3.0			
Total	209			42		
Chi-Square	479.412			6.165		
df	5			4		
Asymp. Significance	0.000	** Significant		0.187		

Differences statistically sig.

Differences not statistically sig.





Department	(a) Unweighted			(b) Weighted by Number of Proposals Submitted		
	Observed	Expected	Residual	Observed	Expected	Residual
African American Studies	5	1.7	3.3	5	2.9	2.1
Art	2	3.0	-1.0	2	5.1	-3.1
Biology	12	17.2	-5.2	21	29.5	-8.5
Business Administration	6	6.2	-0.2	13	10.7	2.3
Chemistry	5	15.1	-10.1	6	26.0	-20.0
Communications	13	9.0	4.0	26	15.4	10.6
Computer Science	7	5.7	1.3	7	9.8	-2.8
Education (Division)	12	9.8	2.2	19	16.8	2.2
English	16	12.2	3.8	33	21.0	12.0
History	10	5.1	4.9	17	8.8	8.2
Languages	7	5.3	1.7	15	9.0	6.0
Mathematics	10	9.5	0.5	17	16.3	0.7
Music	5	4.0	1.0	6	6.9	-0.9
Pharmacy (College)	12	22.2	-10.2	18	38.1	-20.1
Philosophy	4	3.4	0.6	14	5.9	8.1
Physics/Pre-Engineering	3	3.9	-0.9	3	6.7	-3.7
Political Science	3	1.9	1.1	4	3.2	0.8
Psychology	5	4.3	0.7	8	7.3	0.7
Sociology	1	2.4	-1.4	2	4.2	-2.2
Theology	5	4.3	0.7	12	7.3	4.7
Other	3	0.0	3.0	3	0.0	3.0
Total	146			251		
Chi-Square	641.455			429.386		
df	20			20		
Asymp. Significance	0.000	** Significant		0.000	** Significant	
	10 cells (47.6%) have expected frequencies less than 5			4 cells (19.0%) have expected frequencies less than 5		

Department	(c) Weighted by Number of Proposals Funded			(d) Weighted by Number of Proposals NOT Funded		
	Observed	Expected	Residual	Observed	Expected	Residual
African American Studies	5	2.4	2.6			
Art	2	4.3	-2.3			
Biology	16	24.6	-8.6	5		
Business Administration	10	8.9	1.1	3		
Chemistry	5	21.6	-16.6	1		
Communications	24	12.8	11.2	2		
Computer Science	7	8.1	-1.1			
Education (Division)	13	14.0	-1.0	6		
English	30	17.5	12.5	3		
History	17	7.3	9.7			
Languages	8	7.5	0.5	7		
Mathematics	9	13.6	-4.6	8		
Music	4	5.7	-1.7	2		
Pharmacy (College)	15	31.8	-16.8	3		
Philosophy	14	4.9	9.1			
Physics/Pre-Engineering	2	5.6	-3.6	1		
Political Science	3	2.7	0.3	1		
Psychology	8	6.1	1.9			
Sociology	2	3.5	-1.5			
Theology	12	6.1	5.9			
Other	3	0.0	3.0			
Total	209			42		
Chi-Square	513.159					
df	20					
Asymp. Significance	0.000	** Significant				
	6 cells (28.6%) have expected frequencies less than 5			Chi-Square Test cannot be performed for this data.		

Discussion

- Gender and race/ethnicity distributions of faculty participating in funded activities of the CAT matches the corresponding distributions of full-time faculty.
- There are some differences with respect to division and with respect to department.
- Asymptotic significances (*p*-values) were used in these analyses. (Similar to approximating a binomial distribution with a normal distribution.)
  - Analyses using exact *p*-values might yield additional insight.
- Multiple significance testing (16 in this report) increase the risk of *Type 1* errors (rejecting a true null hypothesis).
- Alternative analyses (e.g., logistic regression models) should be considered.

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