ARTICLE
A Report on the Qualities, Skills, and Characteristics Desired by Top Neuroscience Graduate Programs

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As neuroscience popularity grows, more and more students are seeking entry into doctorate-granting programs in this field. Currently, the literature lacks clarity regarding which features these programs prioritize when evaluating applications. This study sought to determine the value of specific application components, research skills, and personal characteristics that have historically been desired by graduate schools. Of the 82 top ranked doctorate-granting programs invited to participate, 39 responded. Respondents used a 1 (not at all valued) to 7 (incredibly valued) Likert scale to indicate ratings for 7 common application components (e.g., basic research, academic success, letters of recommendation). Those 7 components were also ranked from 1 (least essential) to 7 (most essential). Similar ratings and rankings were requested for seven areas of research (e.g., rodent research, bench skills, related background knowledge). Finally, respondents used the Likert scale and rankings to indicate the value of various personal characteristics, including persistence and reliability. The results clearly indicated that having basic research experience was the most essential component of the application (mean rating: 6.72; SD: 0.46). Letters of recommendation were the second most valuable component (mean: 6.67; SD: 0.48), with comments indicating that letters provide a means for application committees to best assess the personal characteristics provided in the survey. Collectively, these data highlight the importance of gaining as much research experience as possible if graduate school is a goal for students, and it further informs faculty who engage in undergraduate mentoring on best practices for preparing those students for graduate school.

Key words: Neuroscience; graduate school; application; research; academic success; undergraduate mentoring

Over the past 30 years Neuroscience has arguably experienced more growth than any other field in science, with approximately 450 Ph.D.s being awarded in 2013 alone (Akil et al., 2016). As a comparison, the next highest degree-granting field in science was Health Sciences, with approximately 250 doctorate degrees granted that year. To match this growing interest in graduate school education, more and more undergraduate neuroscience majors are being offered (Ramos et al., 2016), which will ultimately enhance the competitiveness of those applying for entrance into graduate programs. With such rising competition, students will find it increasingly difficult to gain entry into doctorate-granting programs. It is doubtless that such programs desire strong students, but without guidance, even strong students may not properly prepare themselves in the areas that graduate programs desire.

The task of mentoring undergraduate students and preparing them for entry into graduate school often falls onto faculty (Fisher and Zigmond, 2004). Students are advised on best practices for identifying appropriate programs, but may not be fully informed about the specific skills that graduate programs *prioritize* (Fisher and Zigmond, 2004; Mennerick, 2011). There are common recommendations for the application process, such as drafting a strong statement of purpose and procuring outstanding letters of recommendation (Appleby and Appleby, 2006), but these are common among all graduate programs and are not specific to any given field. Faculty may make recommendations to students based on their own experiences, but the requirements are evolving. For example, word-of-mouth indicates that the importance placed on the Graduate Record Exam (GRE) is diminishing, but finding published evidence of this is difficult. There have been recent calls in the literature to place more focus on ethics and on analytical and communications skills (Akil et al., 2016), and while graduate institutions may implement such changes, this does not speak to how these skills are evaluated during admission.

It is therefore unclear exactly which skills or qualities Neuroscience-focused programs desire most when determining who gains entry into their programs. The purpose of this study is to inform faculty who engage in undergraduate mentoring on best practices when making recommendations to students in terms of increasing their competitiveness for graduate programs.

MATERIALS AND METHODS

Identification of relevant programs

Highly ranked doctorate-granting neuroscience programs in the United States were selected from the National Research Council (2011), yielding a total of 82 distinct programs (See Supplementary Material). Primary decision makers (e.g., Chair, Director, Coordinator) for these programs were identified and sent an invitation to provide information using the anonymous and confidential online survey administration platform, Qualtrics. Thirty-nine participants responded (47.5% response rate). Respondents were asked to rate how confident they felt speaking on behalf of their respective program using a 1

(not at all confident) to 5 (highly confident) Likert scale, with an average confidence rating of 4.61 (SD: 0.63). All materials and procedures were reviewed and approved by the university's Institutional Review Board.

Survey questions

The survey began by asking respondents to indicate how admission decisions were made (Committee, Director, Individual Faculty, Other), followed by a question about the types of waivers and stipends offered to accepted students. The remaining questions within the survey queried three different areas: A) General Application Components, B) Research-related Skills, and C) Personal Characteristics of the applicant. For each of these three areas, respondents were provided with unique items within each category and were first asked to individually rate each item as described below. Respondents were then asked to rank those items relative to each other.

A) General Application Components: Using a Likert scale of 1 (not at all important/valued; not a major component of the admission decision process) to 7 (incredibly important/valued; students without this skill would not be taken seriously) respondents were asked to individually rate each of the following application components: 1) previous research experience (basic research experience, publication, national conference presentation, and regional conference presentation), 2) communication skills (written, oral), and 3) academic success (GPA, GRE). Four additional components that may be found in an application were also included: 4) letters of recommendation, 5) relevant coursework, 6) extracurricular activities, and 7) teaching experience. Respondents were then given the opportunity to add any additional skills they felt were valued by their program. The previously presented 7 subcategories were then to be ranked from 1 (least essential skill) to 7 (most essential skill). These application components were derived from my personal experience applying to graduate school, my experience mentoring students as they applied to highly-ranked programs, and published literature (i.e., Fisher and Zigmond, 2004).

B) Research-related Skills: The programs that were contacted for this survey are competitive research-focused programs. To gain a better understanding of the specific previous research skills these programs value, respondents were again asked to use the 1 to 7 Likert scale to indicate the importance of specific types of research experience that may be found in applications. Seven items were presented, and they included 1) bench skills, 2) scientific writing experience, 3) background knowledge in the application area, 4) understanding of statistics, 5) previous rodent handling/data collection, 6) ethics training, and 7) data collection using human participants. As with the application components, the selection of research items was based on personal experience in mentoring undergraduates during their recent applications (within the last 5 years) in addition to my experience as a scientist in the interdisciplinary field of Behavioral Neuroscience. A follow up question allowed respondents to indicate any additional important research skills that were sought in applications to their program. Respondents were asked to rank the 7 provided items in order of importance, again with 7 being the most essential.

C) Personal Characteristics: Finally, respondents were presented with a list of 11 personal characteristics (e.g., open to criticism, persistent, organized, reliable; See Table 1) and asked to rate the importance of each characteristic in considering applications using the 1 to 7 Likert scale. They could provide any additional characteristics and were asked to rank the provided items from 1 (least essential) to 11 (most essential) relative to the other provided characteristics. This list captures core competencies discussed in the literature (i.e., Kerchner et al., 2012).

Respondents were then shown a screen thanking them for their time, and the survey was concluded.

RESULTS

Of the 39 programs that responded, 89.7% stated that admission decisions were made by a formal committee. The remaining programs indicated that admissions were the decision of either a director or individual faculty members. All programs offered research stipends and 33 (84.6%) also offered tuition waivers or additional stipends, such as for teaching.

A) General Application Components: Of the 7 general application components, basic research experience was the most valued (mean: 6.72; SD: 0.46), followed by letters of recommendation (mean: 6.67; SD: 0.48). The least valued component was teaching experience (mean: 2.61; SD: 1.23). Table 1 illustrates the ratings for all items. Within the research category, respondents were asked to rate different forms of research dissemination. A repeated measures ANOVA indicated a significant difference in the assigned value for these items, $F(1, 38) = 160.48$, $p<0.0001$, with basic research being the highest rated, and presentation at a conference being the lowest rated components. While students may feel that publication is essential in order to be competitive for graduate schools, these data do not support that idea. Post hoc analyses indicated that publication was rated higher than conference presentations (regional: $p = 0.001$; international: $p = 0.028$) but significantly lower than simply having basic research experience ($p<0.0001$) (Figure 2). Comments indicated that students who can demonstrate significant contributions to the research process are highly desired.

A common component that respondents stated was also important was a well-written statement of purpose that demonstrated both passion and a good fit with the program. In considering how the seven provided items ranked in comparison to one another, thirty-two respondents stated that basic research experience was the most valuable. Four stated that letters of recommendation were the most valuable, and no one indicated that teaching experience, extracurricular activities, or communication skills were the most valued.

B) Research-related skills: The ratings for the research-related skills revealed that bench skills such as microscopy and pipetting were the highest rated competencies (mean: 5.12, SD: 1.35) and previous experience collecting data from human participants was the lowest rated (mean: 2.97,

SD: 1.69) (Table 1).

When asked to rank the 7 research-related skills, 37.8% of respondents listed background knowledge in the area the student was applying to as the most important, and 27.1% ranked bench skills as the most important skill an applicant could have (Figure 1). Previous research using rodents was also highly valued, with 16.2% stating that was the most essential skill an applicant could demonstrate. Explicit training in research ethics and previous research using human participants were not highly ranked, with only 2.7% of respondents indicating those were the single most important research skill in an application.

C) Personal characteristics: While critical thinking was the most highly rated personal characteristic (mean: 6.57, SD: 0.64) and ability to engage in self-revision was the lowest (mean: 5.47, SD: 0.79) (Table 1), respondents consistently commented that all were equally important. Further, while the characteristics were next ranked as requested in the survey, comments illustrated that no one item was more important than another (e.g., "These are all really important, so it's hard to rank."; "I cannot rank those characteristics."). Additional comments indicated that it was incredibly difficult to use such characteristics to screen applicants, but that students lacking these attributes would likely not be successful if accepted. One respondent stated that letters of recommendation are used to assess these characteristics.

Item	Mean	SD
A) General Application Components		
1) Previous Research Experience		
Basic research	*6.72*	*0.46*
Publication	4.62	1.18
National conference presentation	4.08	1.26
Regional conference presentation	3.90	1.27
2) Communication Skills		
Written Communication	5.53	1.03
Oral Communication	5.41	1.04
3) Academic Success		
GPA	5.49	0.82
GRE	4.50	1.41
4) Letters of Recommendation	6.67	0.48
5) Relevant Coursework	5.51	0.94
6) Extracurricular Activities	3.45	1.37
7) Teaching Experience	2.61	1.23
B) Research-related Skills		
1) Bench skills	5.11	1.35
2) Scientific Writing	4.92	1.08
3) Knowledge in Application Area	4.81	1.68
4) Statistics Knowledge	4.71	1.27
5) Research, Rodent Subjects	4.00	1.68
6) Ethics Training	3.55	1.35
7) Research, Human Participants	2.97	1.69
C) Personal Characteristics		
1) Critical Thinking	6.58	0.64
2) Internal Motivation	6.55	0.76
3) Ethical Behavior	6.39	0.95
4) Work Ethic	6.39	0.86
5) Persistence	6.37	0.85
6) Reliable	6.13	0.93
7) Attention to Detail	5.92	0.85
8) Self-reliance	5.76	0.85
9) Organization	5.68	0.84
10) Ability to Work with Others	5.53	0.95
11) Ability to Revise Self	5.47	0.80

Table 1. Average ratings for individual survey components were given on a 1 (not valued) to 7 (highly valued) scale. Data represent the mean rating and standard deviation for each subcomponent.

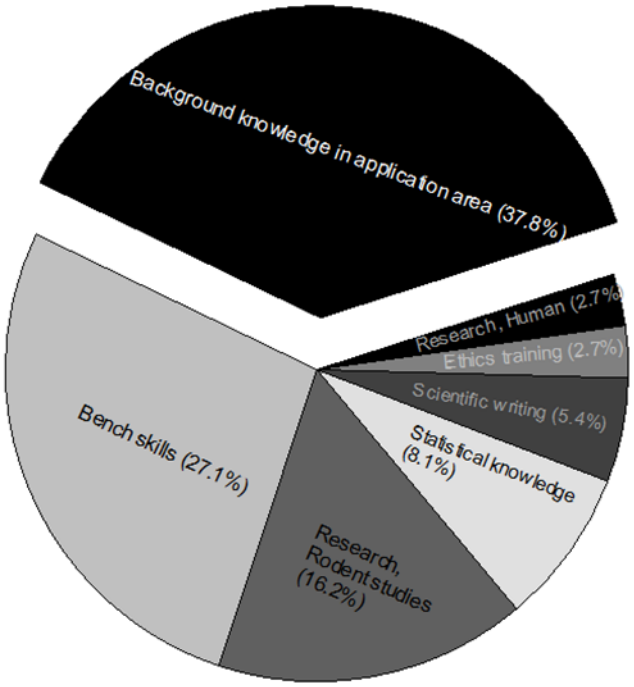

Figure 1. Percentage of programs rating a given research skill as the most valuable when evaluating graduate school applications.

DISCUSSION

The findings from this study indicate that it is essential that undergraduate students wishing to gain entry into neuroscience graduate programs obtain research experience. Ownership over a basic research project was found to be more valuable than any other single aspect of the application, including academic achievement, communication skills, and previous coursework. Letters of recommendation, especially letters that speak to important personal characteristics like critical thinking and reliability, were rated as the second most valuable application component. While extracurricular activities demonstrate that a student is well rounded and can potentially balance multiple demands, students should carefully consider whether the effort needed to excel in those activities should be reprioritized when preparing for graduate school admittance.

Students are often encouraged by faculty to publish as undergraduates, but these data indicate that a lack of publication would not exclude a student from admission so long as their research experience demonstrates initiative and ownership over the work. Articulating ownership is essential to crafting a well-written statement of purpose. However, one can assume that having a publication would

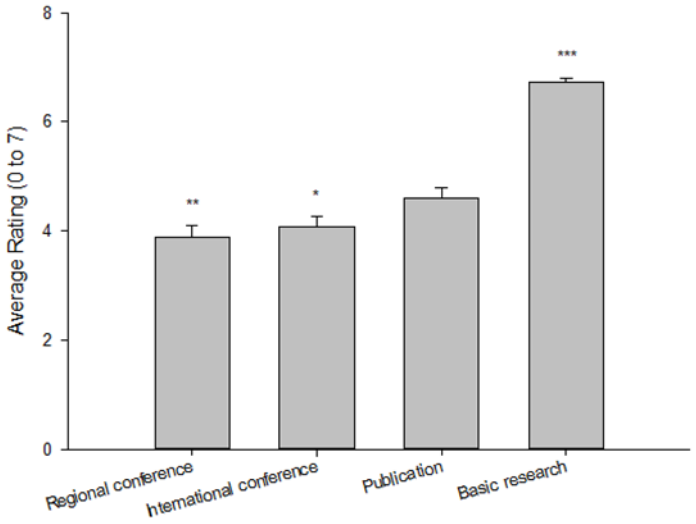

Figure 2. Average rating of the value of various research experiences. While publication was valued over conference presentations, it was not as preferred as basic research experience. *p<0.05, **p<0.001, ***p<0.0001

give a student a competitive advantage. Even though conference presentations were not ranked as equally important to publication, such experiences serve multiple purposes and presentation skills were explicitly listed as important to one respondent. Students learn how to network at conferences, practice defending their ideas, and improve oral communications skills and critical thinking (a highly ranked characteristic in this dataset). Collectively, those abilities would be invaluable in their later careers as well.

When considering specific research experiences, programs seek applicants who have background knowledge in the area they are applying, followed by bench skills such as pipetting, and previous experience collecting data using rodent subjects. Research experience using human participants, explicit ethics trainings, and previous scientific writing were not ranked highly.

A limitation to this study is the use of closed-ended questions. I provided specific application components, skills, and characteristics in an attempt to minimize the hundreds of possible words that may have been provided by respondents, leading to possible subjectivity in later categorizing those concepts. Further, I wanted to provide some direction based on suggestions commonly seen in the literature (Appleby and Appleby, 2006; Fisher and Zigmond, 2004; Mennerick, 2011). Open-ended questions, such as "what do you feel is the most important research skill a student should have?" may have generated a more holistic picture of what graduate schools prioritize. However, only three respondents seemed critical of the closed-ended approach, and it was in regard to the skills portion of the survey ("The skills listed are taught"…after admission; "These are good skills but we do not require them in the application process and expect we will teach them in grad school."). While respondents were invited to provide additional components, skills, and characteristics, the majority (61.5%) stated that they had no such additions, indicating that the provided constructs captured those most valued by these highly-ranked programs. For those who added an additional application component, two themes were present: a statement of purpose that demonstrated passion and a good fit with the program and strong performance during the interview. Comments regarding additional skills not provided in the survey included motivation (1 respondent), presentation skills (1 respondent), scientific competency/hypothesis development (2 respondents), and quantitative/computational background (3 respondents).

It is also worth noting that the current study received responses from only 39 total graduate programs that represent some of the most highly ranked programs in the nation. I targeted such programs with the idea that those would be the most competitive and would be highly sought after by students. However, it is possible that smaller programs or those that are not as highly ranked might not only offer potential advantages to particular students (i.e., smaller labs, more personalized mentoring), they may value very different qualities in their applicants. And, even within highly-ranked programs, those that are cellular versus behavioral would likely place differing values on the skills presented in this study. Due to the anonymity of responses in this dataset, it is not possible to determine which types of programs were represented. If most were from cellular-based programs, it might explain the finding that work with human participants was ranked so low. Future studies could investigate these issues, and the results could perhaps offer students and mentors alternative advice than what is indicated in this report.

Lacking specific skills as an undergraduate may not exclude an applicant from admission. In combination with the data showing that any basic research experience is heavily valued, a possible message for undergraduates is to seek out any opportunities they can, even if the opportunities do not seem like a perfect fit for future goals. However, as noted above, a theme in the comments indicated that students whose backgrounds match the program they are applying to would be more competitive. In the skills area of the survey, three respondents made comments to indicate that applicants would be given higher priority if they had research experience that matched the lab they were applying to. For example, one respondent stated that they ranked rodent research higher than other areas because they used rodent models, but labs utilizing human subjects would place more value on that previous experience. The importance of "goodness of fit" has been strongly implicated in previous research investigating entrance to graduate programs (Karazsia & McMurtry, 2012; Karazsia et al., 2013). If students are unable to obtain research experience that matches the labs they want to apply to, other strategies to improve their fit, such as additional relevant coursework, should be adopted.

As research was rated as the most important application component, these data emphasize the importance of offering research opportunities to

undergraduates. Students at large, research focused institutions have access to more and varied research, but they may not get intensive one-on-one mentoring like those at Primarily Undergraduate Institutions (PUIs). Because mentoring is such an important component of the research experience, there have been increasing calls in the literature to correct limited undergraduate mentoring at research-heavy institutions (González, 2001). Extensive mentoring is more possible at PUIs, but resources for research may be limited. Regardless, affording students with some exposure to research is warranted. It may be that faculty at PUIs can allow students more ownership over projects, a highly sought after skill according to these findings, thereby strengthening the application of students who may have more limited exposure to methodologies compared to competition hailing from larger, research-focused universities. Students in undergraduate neuroscience-based programs are expected to be supported in meeting the competencies queried in this survey, including exposure to various neuroscience principles, opportunities to learn about ethical concerns, and exposure to experimental techniques and design (Wiertelak, 2003). Previous literature has shown a clear need for enhancing "core competencies" such as critical thinking, quantitative skills, and communication skills (Kerchner et al., 2012), and the information gathered in this study reiterates the importance of ensuring that students are granted exposure to these competencies.

In conclusion, while a student who is strong in all areas of an application would obviously be the most competitive for a limited spot in a top-ranked neuroscience program, these results provide guidance on how students can use their undergraduate experience to prioritize their efforts. It may further impel those students who have particular weaknesses to refocus their energy on areas that they can enhance.

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