

Patterns of Feedback on the Bridge to Independence: A Qualitative Thematic Analysis of NIH Mentored Career Development Award Application Critiques

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Abstract

Background: NIH Mentored Career Development (K) Awards bridge investigators from mentored to independent research. A smaller proportion of women than men succeed in this transition. The aim of this qualitative study was to analyze reviewers' narrative critiques of K award applications and explore thematic content of feedback provided to male and female applicants.

Method: We collected 88 critiques, 34 from 9 unfunded and 54 from 18 funded applications, from 70% ($n=26$) of investigators at the University of Wisconsin-Madison with K awards funded between 2005 and 2009 on the first submission or after revision. We qualitatively analyzed text in the 5 critique sections: candidate, career development plan, research plan, mentors, and environment and institutional commitment. We explored thematic content within these sections for male and female applicants and for applicants who had received a subsequent independent research award by 2014.

Results: Themes revealed consistent areas of criticism for unfunded applications and praise for funded applications. Subtle variations in thematic content appeared for male and female applicants: For male applicants criticism was often followed by advice but for female applicants it was followed by questions about ability; praise recurrently characterized male but not female applicants' research as highly significant with optimism for future independence. Female K awardees that obtained subsequent independent awards stood out as having track records described as "outstanding."

Conclusion: This exploratory study suggests that K award reviewer feedback, particularly for female applicants, should be investigated as a potential contributor to research persistence and success in crossing the bridge to independence.

Introduction

THE CONTRIBUTIONS OF FEMALE PHYSICIANS and scientists enrich academic cultures and drive research innovation.^{1,2} Women are also more likely than men to study women's health issues³ and, as leaders, are more likely to broaden institutional research aims to include more topics relevant to the health of women and girls.³⁻⁵ Advancing women in academic medicine and biomedical research, therefore, is important both for ensuring the future competitiveness of U.S. science and technology and for addressing persistent health disparities.^{1,3} Although women and men have been near parity in early career stages since the 1990s, higher rates of attrition and slower rates of advancement have

left women underrepresented in high ranking and leadership positions.⁶⁻¹⁰

Obtaining research program funding from the National Institutes of Health (NIH) is an important determinant of career advancement for faculty in academic medicine and biomedical research.¹¹ Traditionally, junior faculty compete for NIH Career Development (K) Awards—K01s support investigators with research doctorates (*i.e.*, PhD), and K08s and K23s support clinical doctorate holders (*e.g.*, MD, DDS, or clinical PhD) performing basic or patient-oriented research, respectively.¹² K awards protect 75% of the recipient's time for a period of 3 to 5 years to develop a research program under the guidance of an experienced mentor.¹² The overarching purpose of the K award is to prepare

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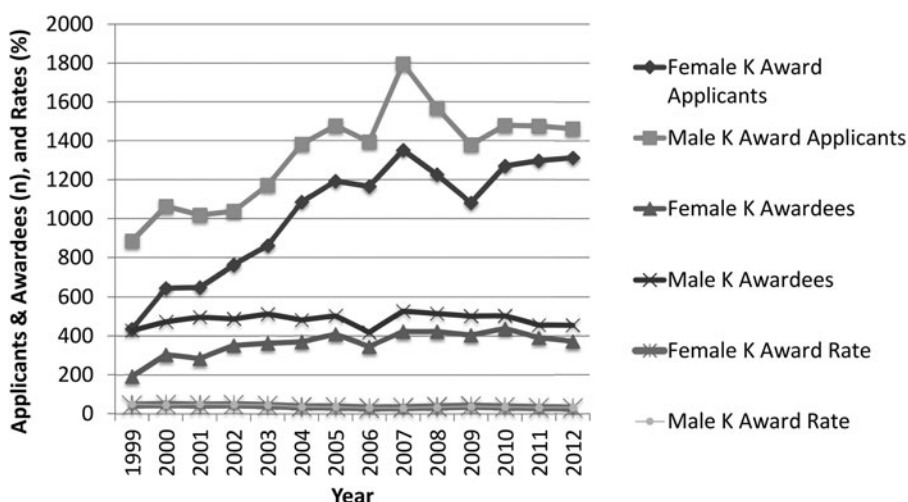


FIG. 1. Female and Male K Award Applicants,¹⁵ K Awardees,¹⁶ and K Award Rates:¹⁷ 1999–2012. K award applicants and awardees reflect raw counts for each year, and show that slightly more male than female investigators applied for¹⁵ and received¹⁶ K awards between 1999 and 2012. K award rates reflect the percentage of awardees out of total applicants for each year, and show near identical (overlapping) K award rates¹⁷ for male and female applicants between 1999 and 2012.

investigators for research independence, traditionally realized through subsequent receipt of an investigator-initiated award such as an NIH R01.¹² The transition from mentored to independent research, called “the bridge to independence,” is a pivotal career juncture for research faculty because research independence is a strong determinant of career persistence, tenure, promotion and advancement to leadership.¹¹

Figure 1 displays the numbers of applicants and awardees, and award rates for male and female investigators who applied for K awards between 1999 and 2012.^{13–20} The median age of investigators who apply for K awards is 37.¹⁸ Although slightly more male than female investigators apply for K awards each year, similar award rates are observed for male ($M=37.5\%$) and female applicants ($M=36.9\%$; Fig. 1).^{13–20} Despite these promising data, a more troubling trend occurs at the transition to R01 funding: Proportionately fewer female than male K awardees apply for subsequent R01 awards ($M=56.7\%$ vs. 68% ; Fig. 2),^{16,21–23} and female K awardees have lower R01 award rates than males ($M=65.3\%$, vs. 71.6% ; Fig. 2).^{13,14,18–23} On average, over half ($M=55\%$) of K awardees obtain first R01s at the age of 41, approximately 5 years after receiving their K awards, but the percentage increases to 83% after ten years.^{18,20} Pohlhaus et al. found that female K awardees experience a longer transition to independence than males;^{20,24} even so, their longitudinal analyses showed that K01 awardees from 1999–2000 were the only group where R01 application and award rates eventually equalized for male and female investigators.²⁰ By comparison, male K08 and K23 awardees had higher short- and long-term R01 application and award rates than female K awardees.²⁰ Taken together, these data suggest that lower R01 application and success rates are associated with the attrition of female K awardees at “the bridge to independence.”^{12,14,25,26} NIH has called for further exploration into factors that contribute to this disproportionate loss of women.¹⁸

Studies of K awardees find that women receive lower salaries, fewer resources (including less administrative and technical support), experience more unfair treatment, and face more barriers to developing mentor relationships and negotiating work-life balance than men.^{13,27–30} Interviews with former K awardees and their mentors by DeCastro et al. have also revealed that research career persistence can hinge on the ability to respond proactively to critical feed-

back from peer review, and that male scientists may be more resilient than females to negative feedback.²⁸ To our knowledge, no prior study has examined the feedback that K awardees receive in their application critiques.

In NIH’s system of peer review, each K award application is evaluated by 2–5 peer reviewers who assign scores and write narrative critiques³¹ based on the overall impact/priority of the research and 5 additional criteria: the quality of the candidate, mentor(s), research plan, career development plan, and environment and institutional commitment to the candidate.³² In this qualitative study, we derived recurring themes from the written critiques of unfunded and funded K award applications. We further qualitatively explored thematic content in critiques of male and female investigators’ applications and in critiques of applications from K awardees with and without subsequent independent awards.

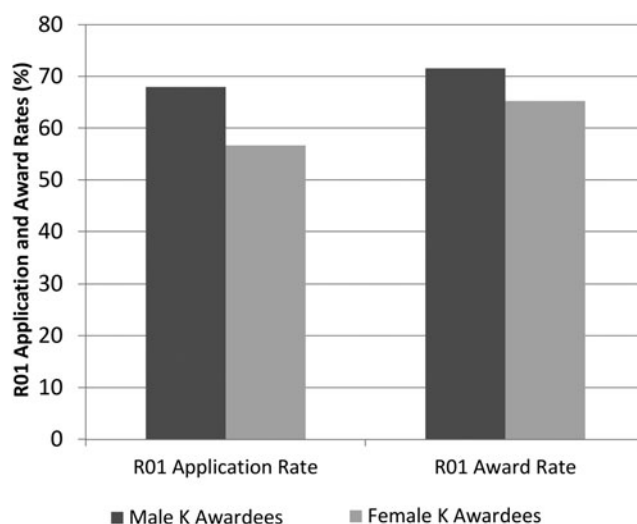


FIG. 2. Differences in Male and Female K Awardees’ Subsequent R01 Application and Award Rates. Application rates show a higher percentage of male than female investigators with K awards from 1999–2000 applied for subsequent R01 awards within 8 years of K award receipt, as reported by Pohlhaus et al.²⁰ Award rates show a higher percentage of male than female K awardees received R01 awards between 1999 and 2012.²³

Materials and Methods

The Institutional Review Board (IRB) of the University of Wisconsin-Madison approved all aspects of this research. In June 2011, we queried NIH's public access database to identify all Principal Investigators (PI) at UW-Madison with K01, K08, or K23 applications funded on the initial submission or after revision between 2005 and 2009. We then invited PIs, via three rounds of email letters, to send us PDF copies of their NIH Summary Statements (*i.e.*, the files that contain NIH peer reviewers' critiques) from unfunded and funded submissions of the indicated award. K award recipients provided consent through email exchange and could request withdrawal of their materials from the study.

We assigned unique identifiers (IDs) to each applicant, application, and critique. We recorded award type, year, funding outcome, NIH institute, and applicant sex (using a strategy similar to Jagsi et al.¹³). We de-identified critiques of institutional and investigator information, removed all identifiers of applicant sex (*e.g.*, pronouns) and imported critiques as Word documents into the NVivo qualitative software program (QSR International Pty Ltd., Version 10, 2012).

We qualitatively examined K award critiques to identify themes.³³ The four authors (AK, MD, KR, MC) read each critique. Three of the authors (AK, MD, CR) examined the critiques line-by-line to identify meaningful segments of text (codes)³³ within the 5 major criteria used to evaluate K award applications. Once we agreed on the content and labeling of codes, two authors (AK, CR) reviewed 5 critiques with an inter-rater agreement of 88–96% (Cohen's kappa coefficient). They then applied these codes to all critiques. Through iterative coding and discussion we coalesced coded text segments into organizing themes. Once themes were identified we re-identified the sex of applicants and explored whether patterns in reviewers' feedback were consistent for male or female investigators. In May 2014, we searched NIH's public access database for subsequent R01 or other independent awards for each K investigator. We used this information to divide critiques and their associated themes into two groups: those belonging to investigators with, and without, subsequent independent awards. We then explored whether thematic patterns varied across critiques in these two groups.

Results

Table 1 describes our sample. Out of the 26 total K awardees from UW-Madison between 2005 and 2009, 10

male and 8 female investigators (70%, $n = 18/26$) participated. Participants were 95% ($n = 17/18$) white. Half of participants had their K award applications funded on the first round of submission ($n = 9$, 50%), and half ($n = 9$, 50%) had their K award applications funded after revision. Each summary statement contained between 2–6 critiques. This generated 88 total critiques: 34 from 9 unfunded and 54 from 18 funded applications. Five investigators received K01 (28%), five received K23 (28%), and eight received K08 (44%) awards. Similar proportions of male and female investigators pursued clinical, behavioral, and laboratory-based research, and applications were funded by 13 NIH institutes. All participating investigators were at least 5 years beyond the receipt of their K awards in May 2014 when we completed searches for independent funding (Table 1).

We describe themes that emerged within each review criteria section in critiques for unfunded (Table 2) and funded (Table 3) applications and present illustrative text. Thematic patterns were similar across critiques of K01, K08, and K23 applications. Themes that are reported occurred across all critiques from single investigators' unfunded or funded applications, for the majority of investigators' K01, K08, and K23 applications, except where we highlight dissimilarities in thematic patterns for male and female applicants or for subsequent independent awardees. We report counts and/or the percentage of investigators whose unfunded or funded application critiques contained each theme to characterize their scope across our sample. Although we coded text blinded to applicant sex and subsequent award status, we have reinserted pronouns in brackets for easier reading and used asterisks (*) to indicate text that is from a K award critique for an investigator with a subsequent independent award.

Candidate

The Candidate section in K award critiques evaluates the quality of applicants' academic and research records, commitment and potential for future independence, and letters of reference.³²

Critiques of unfunded applications

The primary theme in the Candidate section of critiques from unfunded applications was low productivity. This theme surfaced in critiques from 88% ($n = 8/9$) of K awardees' unfunded applications.

TABLE 1. PARTICIPATING K AWARDEES CATEGORIZED BY APPLICANT SEX, WHETHER K AWARD AS FUNDED ON THE FIRST SUBMISSION OR AFTER REVISION, AND SUBSEQUENT INDEPENDENT AWARD STATUS

Applicant Sex	K Awardees With Subsequent Independent Awards			K Awardees Without Subsequent Independent Awards		
	K Award Funded on First Submission $n = 7/18$ (38%)	K Award Funded After Revision $n = 5/18$ (28%)	Total $n = 12/18$ (67%)	K Award Funded on First Submission $n = 2/18$ (11%)	K Award Funded After Revision $n = 4/18$ (22%)	Total $n = 6/18$ (33%)
Male Investigators $n = 10/18$ (56%)	$n = 3/7$ (43%)	$n = 4/7$ (57%)	$n = 7/10$ (70%)	$n = 2/3$ (67%)	$n = 1/3$ (33%)	$n = 3/10$ (30%)
Female Investigators $n = 8/18$ (44%)	$n = 4/5$ (80%)	$n = 1/5$ (20%)	$n = 5/8$ (63%)	—	$n = 3/3$ (100%)	$n = 3/8$ (37%)

TABLE 2. UNFUNDED NIH K AWARD CRITIQUES: OVERALL THEMES FOR EACH CRITERION SECTION AND SUBTLE VARIATIONS FOR MALE AND FEMALE K AWARD INVESTIGATORS AND APPLICANTS WITH AND WITHOUT SUBSEQUENT INDEPENDENT AWARDS

<i>Unfunded NIH K Award Application Critiques</i>		
<i>Critique Section</i>	<i>Variations in Themes</i>	
	<i>Applicant Sex</i>	<i>Subsequent Independent Award Status</i>
Candidate	Low productivity generated doubt about female but not male applicants' potential for future independence.	The single female investigator who went on to obtain a subsequent independent award was the only investigator without productivity concerns.
Career Development Plan	Career Development Plans were characterized as overambitious only for female applicants.	Negative comments about independence potential surfaced only for female K awardees <i>without</i> subsequent independent awards.
Research Plan	For male applicants, concerns were directed at problems with the proposal and were followed by advice. For female applicants, concerns were directed at perceived deficiencies in the ability of the applicant.	Identified themes did not appear to vary by applicants' subsequent independent award status.
Mentor	Identified themes did not appear to vary by applicant sex.	Identified themes did not appear to vary by applicants' subsequent independent award status.
Environment and Institutional Commitment	Identified themes did not appear to vary by applicant sex.	Identified themes did not appear to vary by applicants' subsequent independent award status.

TABLE 3. FUNDED NIH K AWARD CRITIQUES: OVERALL THEMES FOR EACH CRITERION SECTION AND SUBTLE VARIATIONS FOR MALE AND FEMALE K AWARD INVESTIGATORS AND APPLICANTS WITH AND WITHOUT SUBSEQUENT INDEPENDENT AWARDS

<i>Funded NIH K Award Application Critiques</i>		
<i>Critique Section</i>	<i>Overall Themes</i>	<i>Variations in Themes</i>
		<i>Applicant Sex</i> <i>Subsequent Independent Award Status</i>
Candidate	Strong training background, track-record, and high productivity. Commitment to a research career with clear goals and rationale for K award. Strong letters from mentors that confirm ability.	Female independent awardees' track records were uniformly characterized as "outstanding" and they were the only group without productivity concerns.
Career Development Plan	Clear career goals. Congruency in coursework, development activities, and mentorship that will facilitate obtaining goals and reaching independence. Timeline showing plan to submit future independent grant application.	Identified themes did not appear to vary by applicants' subsequent independent award status.
Research Plan	Straightforward studies with potential for significant knowledge yields. Feasibility of research supported by pilot data. Novel/innovative methods. Clear trajectory toward independence based on congruency between Research Plan and training activities.	When female K awardees' research was described as highly impactful, it was in the context of technical merit, or noted to be in a priority area of the funding agency or institute. This primarily occurred in critiques of applications from females <i>with</i> subsequent independent awards.
Mentor	Mentors are well-established leaders and well funded. Primary and Co-mentors selected. Mentors have clear roles, complementary expertise, and are dedicated to the candidate's independence.	Identified themes did not appear to vary by applicants' subsequent independent award status.
Environment and Institutional Commitment	"Excellent" Environments. Strong evidence of Institutional Commitment to the candidate.	Only for male K awardees <i>with</i> subsequent independent awards did reviewers have concerns about protected time for research, access to technical support, and continuing commitment to the candidate beyond the K award period.

Reviewers' interpretation of low productivity appeared to vary subtly for male and female applicants. For female K awardees, reviewers' commentary about low productivity carried a negative tone. Illustrating this, low productivity led this reviewer to see little promise for future independence, even with affirmation in mentor's letters for this female investigator:

"Of particular concern are XX's relative lack of peer-reviewed publications or other contributions to research...at the moment this application seems to lack a great deal of evidence for the candidate's promise as a future independent investigator, other than very positive comments by (her) prospective mentors."—Female K08 awardee

The negative inference about future success due to low productivity was only made by reviewers in application critiques for the three female investigators without subsequent independent awards. In comparison, the single female investigator with an initially unfunded K award application who went on to obtain a subsequent independent award stood out as having an "outstanding" track-record lacking productivity concerns.

For male applicants, reviewers seemed more willing to take a neutral stance in judging whether low productivity could predict future success. These quotes from three different applicants transmit a tone of encouragement not found in critiques of female investigator's applications with productivity concerns:

"XX's publication record is not overwhelming, but it does show some publication skills, and it should improve as (he) obtains more laboratory experience. It would be good to hear that a first-authored manuscript is going to come soon from XX's fellowship work."—Male, K08 awardee*

"The Principal Investigator has no publication record, so future productivity is hard to predict."—Male, K01 awardee

"Without any publications...it is difficult to assess the applicant's potential to develop as an independent researcher. However, the career development plan is well written and will increase the likelihood of future independence."—Male, K08 awardee*

We observed no apparent variation in thematic content of the Candidate section in critiques of unfunded K award applications for male investigators with or without subsequent independent funding.

Critiques of funded applications

Three overarching themes characterized the Candidate section of funded application critiques: positive remarks about training backgrounds, track-records, and productivity; strong commitment to a research career with clear goals and rationale for K award training; and letters from mentors that confirmed the applicants' ability. These themes surfaced in critiques of 83% ($n=15/18$) of K awardees' funded applications. When combined, these thematic components appeared to make a compelling case for a candidate's promise as an independent investigator as in the following quote:

"This is an eloquently written and exciting application for a K01 award.... XX is presently in the laboratory of XX, an outstanding, well-funded investigator..., a world leader in XX. XX will serve as the mentor (for) this K01 application and has written an excellent letter of support outlining (his) role in the candidate's training.... The research environment is outstanding, and the training plan is appropriate."

The new skills that will be acquired by the candidate are well described. This project will provide a mechanism for XX to launch a successful research career and make major contributions to our understanding of....—Male, K01 awardee

As was the case in critiques of the unfunded application for the female investigator with a subsequent independent award, funded application critiques characterized the track-records of all female K awardees that went on to obtain subsequent independent awards ($n=5/5$) as "outstanding." We observed no other apparent variation in thematic content of the Candidate section in critiques of male and female investigators' funded K award applications or in those of K awardees who did or did not receive subsequent independent funding.

Career Development Plan

The Career Development Plan in K award critiques evaluates how planned training and mentorship will extend prior training and lead to independence.³²

Critiques of unfunded applications

The primary themes in the Career Development Plan section in unfunded application critiques were unclear career goals, and deficiencies in coursework, training activities, and mentor support. Reviewers also expressed concerns when mentors' backgrounds and training activities did not align with professional or research goals. These themes occurred in critiques of 78% ($n=7/9$) of K awardees' unfunded applications, and are apparent in the following excerpts:

"The didactic plan is relatively weak, and overly diffuse, and it is not completely clear how some of it fits in to the ultimate goals of the investigator."—Female, K23 awardee

"In general the career development plan seems consistent with the candidate's career goals with the exception of the mentoring and course work...."—Male, K01 awardee*

"...The career development plan will not expose the candidate to major new intellectual influences or mentoring opportunities."—Male, K23 awardee*

Career Development Plans were characterized as being too ambitious only for female investigators. This theme occurred in critiques of two of the five female investigators' unfunded applications, as seen in these two excerpts:

"In addition, the development plan at times appears overly ambitious, requiring the candidate to take coursework at the rate of one class per semester throughout the 5-year period, prospectively assess...participants as well as engaging in numerous formal and informal mentoring meetings."—Female, K01 awardee*

"While the assembled array of mentors is impressive, and the proposal outlines specific skill areas for each individual, the feasibility of (the Career Development Plan) seems overambitious and unrealistic."—Female, K23 awardee

Specific negative comments about potential for independence surfaced only in unfunded application critiques of the three female K awardees without subsequent independent awards. For example:

"...It remains difficult to see how this candidate would be competitive for R01 funding at the end of the K08 award."—Female, K08 awardee

"(It is) (u)nlikely (that the) candidate will be competitive for (an) R01 after (the) K award...."—Female, K23 awardee

Critiques of funded applications

Themes about Career Development Plans in critiques of funded applications, as exemplified below, included clear goals; balance between coursework, career development activities, mentorship, and research that would allow K awardees to achieve goals and future independence; and timelines that included plans to submit a future independent application. These themes occurred in critiques of all ($n = 18/18$) K awardees' funded applications in our sample:

"The training proposed will complement the candidate's previous clinical and research endeavors. The candidate presented a thoughtful, well organized, and comprehensive Career Development Plan to obtain four important goals.... The proposed plan will continue the candidate's scientific development and complements (her) research experience. (Her) choice of mentors is well-suited to (the) career goals. There are no apparent limitations in the Career Development Plan."—Female, K08 awardee*

"The career development plan is outstanding. In addition to frequent contact with the mentor, there are ample opportunities for the candidate to benefit from a variety of seminars, courses, and fruitful collaborations within and outside the division/department. XX will be allowed to commit 75–80% of (his) time to the proposed studies...will also be able to benefit from formal course (and) has a well laid out plan for obtaining (his) own independent NIH funding...."—Male, K08 awardee*

Research Plan

The Research Plan is evaluated on the overall significance and merit of the design and methodology; the alignment between research, training and career goals; and the inclusion of appropriate protection plans.³²

Critiques of unfunded applications

The primary theme in the Research Plan section in unfunded application critiques was concern about technical, methodological and design flaws. Reviewers also expressed feasibility concerns when applications had no pilot data. These themes occurred in critiques of all ($n = 9/9$) K awardees' unfunded applications in our sample. Subtle variations emerged regarding reviewers' interpretation of problems identified in male and female investigators' research plans. As illustrated in these quotes for two different applicants, the target of criticism for males was more likely to be the proposal than the investigator:

"...The proposal is quite superficial and confused.... It is unclear how...protein (can) be added to the study. There is no preliminary data to support that the added...protein will be.... Overall, there is a great concern on the content of the proposal"—Male, K08 awardee*

"...The protocol again is skimpy and needs further detail.... (Techniques, the PI has likely mastered are not described in sufficient detail for the reviewer...."—Male, K08 awardee*

As exemplified in the remarks below, for female applicants, criticism was more likely to target the ability of the investigator:

"The experience of the investigator in these types of analyses does not appear adequate to justify these studies."—Female, K01 awardee

"...There is concern about the applicant's abilities...."—Female, K08 awardee

"The weakness in the proposal is that the candidate has proposed numerous experiments for which the question or questions often get lost. This may be more reflective of the inexperience of the candidate as a researcher...."—Female, K01 awardee

Reviewers provided all five male investigators, but only one of the four female investigators, advice about how to address criticisms and concerns in critiques of unfunded applications. The following text illustrates how reviewers provided male investigators with detailed advice about how to address concerns:

"In Specific Aim 1, as stated above, experiments will be done with...cell lines. This could potentially introduce information that might not be applicable in vivo, and it is unclear whether these cell lines respond the same way as do native cells taken ex vivo in terms of...." This aim really should be done from...taken ex vivo from normal and...subjects."—Male, K23 awardee*

"There are some weaknesses of the description.... (I)t would be strengthened by acknowledging the studies that do not rely on static measures of.... (I)t would also strengthen the proposed research to add some citations after certain statements such as: 'Relatively little work has directly addressed....' Similarly, add cites to statements like: '...many existing analyses...have typically...focused on....' It also seems that section...could be effectively integrated with this earlier literature review.... A general concern is lack of integration of the research plan. Specifically, it could be more effective to present, for example, a diagram that illustrates the proposed causal pathways and has all four specific aims embedded within it."—Male, K01 awardee

Critiques of funded applications

Three themes characterized strong Research Plans in critiques of funded applications: straightforward studies with potential for significant knowledge gains; use of pilot data to support feasibility; and use of novel or innovative methods. Reviewers also interpreted Research Plans to be strong when they complemented training activities and would advance candidates toward their career goals and independence. These themes occurred in critiques of all ($n = 18/18$) K awardees' funded applications and are exemplified by these excerpts:

"The research plan of this articulately-written proposal is quite straightforward and is backed by a good deal of preliminary data generated with.... In all cases, it seems as though the Principal Investigator has a very good working knowledge of all techniques to be employed, and the experimental methodology to be utilized is quite well delineated. There are clearly presented anticipated outcomes and well-thought-out alternate approaches to the potential pitfalls for each set of experiments. This serves to enhance enthusiasm for this proposal."—Male, K08 awardee*

"Overall, the research plan is well well-written and thoughtfully crafted. The specific aims and background sections provide strong motivation for the project, both in terms of addressing current knowledge gaps in the extant literature as well as in terms of positioning the candidate to develop into an independent researcher."—Female, K08 awardee

In critiques of 90% ($n = 9/10$) of male investigators' funded applications, reviewers characterized the proposed research

as highly significant for solving important problems and leading to independence as illustrated by these quotes from different applicants:

"The research question is of the highest scientific merit given the world-wide prevalence of XX infection and the lack of therapies."—Male, K08 awardee*

"The field of XX needs young physician-scientists, particularly, those working on XX.... The focus of work is important and doable and could lead to a lifetime of studies.... It is highly expected that the proposed courses and research will not only further XX training to become an independent physician scientist but will allow (him) to make significant contributions in the field."—Male, K08 awardee*

By comparison, as illustrated in this example, most female applicants (75%, $n=6/8$) had their research characterized as moderately significant in critiques of their funded applications:

"The issues being addressed are of moderate significance.... Nevertheless, they will provide a vehicle for excellent training and generation of some useful information. The research plan is considered excellent."—Female, K08 awardee*

When reviewers did comment that female investigators' research would be highly impactful, it was likely to be in the context of technical merit or funding agency's priority. This praise occurred in critiques of two female investigators' applications who went on to obtain independent awards:

"The research questions are biomedically important and the hypotheses appear to be testable."—Female, K23 awardee*

"The proposed research is highly relevant to (agency's) goals and priorities."—Female, K08 awardee*

Only Research Plans proposed by female investigators were described specifically or indirectly as being too ambitious. This theme occurred in critiques of 38% ($n=3/8$) of female investigators' funded applications, as seen here:

"There is concern that this may be overly ambitious given the 2 year timeline proposed and the candidate's other training- and clinical-related activities."—Female, K23 awardee*

"The recruitment goals are ambitious.... Although the institutional support is strong, it seems likely that recruitment will require more of the candidate's effort than is acknowledged or discussed."—Female, K08 awardee*

Mentor

In K award critiques, Mentors are evaluated on their track records for research support, productivity, and mentorship, and the appropriateness of their backgrounds to train, evaluate and guide mentees.³²

Critiques of unfunded applications

We identified two major themes in the Mentor section. The first—problems with Mentors' track records—referred to insufficient evidence of research support or previous mentoring of junior investigators to independence. This theme occurred in critiques of 55% ($n=5/9$) of K awardees' unfunded applications, as illustrated here:

"The only ongoing grant that is extended to XX will be finished soon. The pending grant needs to be approved before the current K01 can be funded."—Male, K01 awardee

"The mentor and co-mentor indicate combined training of nine investigators in addition to the applicant since...all are still in postgraduate training positions.... It is, therefore, not possible to judge whether this particular mentored environment produces independent investigators."—Male, K08 awardee*

The second—problems with the Mentoring Plan—referred to unclear roles for Mentors or missing details in the Mentoring Plan. This theme occurred in critiques of 88% ($n=8/9$) of K awardees' unfunded applications. For example:

"...No detail is provided on what specific mentoring will be done or what milestones are being set for the applicant. Each mentor describes meetings and input, but these descriptions lack any detail."—Male, K23 awardee*

Within this theme, reviewers often pointed out where Mentors should have provided more guidance in application planning and writing as in this remark:

"...(T)here appear to be numerous areas in which the mentor could have provided needed guidance."—Female, K01 awardee*

Funded application critiques

Three themes surfaced in the Mentor section of funded application critiques: Mentors were well established leaders in their fields, with strong records of mentorship and research support; K awardees had Co-Mentors in addition to their Primary Mentor; and Mentors had clear roles, complementary expertise, and were dedicated to the candidate's transition to independence. These themes occurred in critiques of all ($n=18/18$) K awardees' funded applications in our sample and are exemplified by this quote:

"The mentor for this candidate, XX, is outstanding and committed to the career development of the candidate. XX is a leader in the field. (He) has several R01 awards in the area of research relevant to the candidate's application and will provide an essential role in the mentoring of the candidate as well as assist in the goal of achieving independence for the candidate. The prior history of successful mentoring of junior faculty by XX is outstanding."—Male, K01 awardee

Environment and Institutional Commitment

The Environment and Institutional Commitment to the Candidate in K award critiques is evaluated on the quality of the environment; and the guarantee of 75% protected time for research and support for career development.³²

Critiques of unfunded applications

The primary theme in the Environment and Institutional Commitment section of unfunded application critiques was inadequate evidence of institutional commitment to the candidate. This theme occurred in critiques of 44% ($n=4/9$) of K awardees' unfunded applications in our sample, as this remark illustrates:

"The letter of institutional commitment from...states that the candidate would be offered a 'full-time appointment with 75% protected time to conduct research should (she) receive this award.' The K23 program announcement specifies that institutional commitment to the candidate cannot be contingent upon receipt of the K23 award. The level of institutional

support, as stated in the application, fails to comply with NIH award requirements.”—Female, K23 awardee

We found no apparent variation in thematic content of critiques for unfunded applications from male and female awardees or for those who did or did not receive subsequent independent funding.

Funded application critiques

“Excellent” Environments and “strong evidence” of Institutional Commitment were the primary themes in funded application critiques. These themes occurred in critiques of 83% ($n=15/18$) of K awardees funded applications, as this quote illustrates:

“Overall, the institutional components constitute a rich and supportive environment... The research facilities and educational opportunities are extensive. The environment will provide everything required for the candidate to complete the stated objectives. The University Department of XX will appoint XX as Assistant Professor (and) will support the candidate dedicating 75% of time and effort to research and personal development.”—Male, K23 awardee*

We found that concerns about insufficient “protected time,” access to technical support, and continuing commitment to the candidate beyond the scope of the K award period surfaced in critiques of 43% ($n=3/7$) of K award applications for male investigators with subsequent independent awards, but in none of the critiques from female investigators’ applications.

Discussion

The purpose of this research was to examine the content of feedback reviewers provided a sample of K award investigators in critiques of their unfunded and funded applications, and to explore the possibility that themes varied for male and female applicants, or for investigators who obtained subsequent independent awards. Results revealed many similar types of criticism and concerns across K awardees’ unfunded application critiques (Table 2) and similar positive remarks in critiques of funded applications (Table 3). Despite these similarities, subtle variations in feedback patterns surfaced for male and female K awardees. Notably, productivity concerns, and problems with the Research Plan appeared to lead reviewers to more readily question female than male K awardees’ ability for research and potential for independence. Reviewers also appeared to be more willing to describe complex training and Research Plans as overambitious when female applicants proposed them. By comparison, reviewers frequently offered male applicants detailed advice following criticism, viewed their research as highly significant, and expressed optimism for their future independence despite productivity concerns. Reviewers also expressed concerns about insufficient “protected time,” access to technical support, and continuing commitment to the candidate beyond the scope of the K award period only for male investigators—particularly for those who went on to obtain subsequent independent awards.

Even though all applications in our study were eventually funded (suggesting a similar quality of proposed research) and all applicants were at the same university, the subtle variations in tone and content of feedback in reviewers’ remarks about male and female K awardees’ applications could

be attributable to objective differences in the applications. However, given the disproportionate loss of women transitioning from K awardee to independent investigator, our observations deserve discussion in the context of research on: the impact of gender-based assumptions on evaluation of men and women in male-typed domains (*i.e.*, fields assumed to require stereotypical masculine traits for success) and the differential impact of performance feedback on men and women in these domains.

Evaluation of men and women in male-typed domains

Stereotype-based assumptions that women are “communal” (*e.g.*, nurturing, dependent, supporters) and deficient in the “agentic” stereotypical-masculine traits (*e.g.*, decisive, independent, leaders) can lead evaluators to judge women as less competent and capable of success than men in male-typed domains like science where ability is linked to agentic traits.^{1,34–37} Consequently, reviewers require less proof of inability (*e.g.*, flaws and mistakes) to confirm the implicit assumption of women’s incompetence, and greater proof of ability (*e.g.*, higher quality work, prior achievements and awards) to confirm women’s than men’s competence in male-typed fields.^{1,35–38} This type of gender bias is pervasive and similarly impacts judgments made by male and female evaluators.^{35–37,39} It often occurs unintentionally, and in opposition to consciously-held egalitarian beliefs.³⁹ Studies also show that a strong belief in personal objectivity⁴⁰ and being under time pressure³⁷ can increase reliance on unconscious (“implicit”) assumptions, so busy scientists may be particularly vulnerable to the influence of stereotypes on judgment when conducting peer review.

Our findings are congruent with this body of research. When evaluating a K award applicant with low productivity, the inadvertent influence of gender stereotypes would be expected to lead reviewers to more easily question and disconfirm the ability and potential for future research independence of a female than a male applicant. Similarly, the implicit assumption of women’s lower competence in science would predict that reviewers would more readily view complex Career Development and Research Plans as too “ambitious” for female but not male investigators.^{41–44}

The inadvertent influence of gender stereotypes may differentially impact evaluation of female and male applicants in other ways. King et al. found that male managers in the energy industry were significantly more likely than female managers to report that they had received critical feedback,⁴⁵ which can be a source of valuable advice for performance improvement.^{46,47} We similarly found that reviewers were more likely to follow criticism with advice for male applicants. Reviewers’ concerns about insufficient “protected time,” access to technical support, and continuing commitment only for male investigators with subsequent independent awards also finds support in other research. Holliday et al. found that gender stereotypes contributed to unequal distribution of administrative and technical resources^{48,49} and Carr et al. found female faculty in academic medicine, particularly those with children, were the least likely to have administrative and institutional research support.⁵⁰ Such gender inequalities in personnel support combine with other identified barriers^{13,27–30} to disadvantage women in launching or sustaining research careers.

Additionally, we found that reviewers more often remarked that male investigators' projects were highly significant. This observation finds support from studies showing that in male-typed domains similar or identical work is more highly valued when performed by a man than a woman.^{34,35,37,38,51–53}

Female investigators with subsequent independent awards in our study stood out as having track records described as "outstanding" by reviewers (Table 3), whereas male investigators who received subsequent independent awards received a wider range of positive and negative remarks from reviewers (Tables 2 and 3). These findings align with studies showing that women have to show unambiguous evidence of strong past performance and greater numbers of accomplishments than men to earn strong ratings.^{51,54,55} If women need to outperform men in NIH peer review, this may contribute to female K awardees' lower application and award rates for NIH R01s seen nationally (Fig. 2).^{13,18,20,23,24} Although our work is qualitative, this finding is consistent with other research on NIH grant critiques: Kaatz et al. documented more praise and descriptors of competence and ability in female independent investigators' funded R01 application critiques compared to those of males.⁵⁶

Response to performance feedback in male-typed domains

DeCastro et al. interviewed former K awardees and their mentors.²⁸ Results revealed that an important facilitator of research career persistence is the ability to reframe negative feedback from peer review processes in ways that can be advantageous for improving the quality of the work.²⁸ Findings also indicated that junior male scientists may be more likely to learn this skill set than female scientists because men generally have broader mentor networks and greater access to resources,^{25,26,28–30} and that male and female scientists may interpret feedback from peer reviewers in different ways, such that men may be more resilient than women to negative feedback.²⁸ DeCastro et al.'s findings align with experimental studies showing that women are more adversely affected than men by negative performance appraisal. For example, Biernat and Danaher provided female vs. male participants with identical moderately negative written performance feedback in a male-typed domain (leadership).⁵⁷ Female participants interpreted the feedback to mean their performance was objectively worse and experienced a greater loss of domain interest.⁵⁷ In the context of K award critiques, the damage of negative feedback on female applicants may be greater than similar feedback given to male applicants in terms of its potential impact on career persistence.

Findings from our study also suggest that an applicant's sex may have, however unintentionally, led reviewers to provide different feedback to male and female applicants. For example, although reviewers identified low productivity and problems with research plans in both male and female investigators' application critiques, commentary to female investigators regarding these concerns was notably more negative and contained explicit statements regarding doubt about ability for research and independence. Based on Biernat and Danaher's work,^{36,57} one would predict that this type of feedback would lead female investigators to experience

greater loss of interest in a research career. Although we cannot rule out that the content of the investigator's proposal was actually less meritorious, it is still notable that in our sample the female K awardees who received highly negative performance feedback did not go on to obtain subsequent independent awards. Potentially relevant to the lack of persistence of these women are studies which demonstrate that simply reading reviewers' commentary about a member of a stereotyped-group can heighten the influence of stereotypes on judgment.^{36,58} Mentors, division chiefs, and department chairs read K award critiques. Negative feedback from NIH reviewers, assumed to be scientific experts, that voices concern about female K awardees' future success might have adversely affected the willingness of supervisors to provide female investigators with sufficient resources to launch independent research careers. This supposition aligns with Holliday et al.'s study showing that female K awardees received fewer administrative and technical resources and experience more bias than their male counterparts.^{48,49}

Viewed through the lens of this body of research, the subtle differences we found in reviewers' feedback to male and female K awardees may contribute to the persistently higher rates of attrition for female investigators on the "bridge to independence." Our findings are not generalizable as this is an exploratory qualitative study. However, our findings suggest that further research into gender differences in grant critiques is needed to test the extent to which findings from this study generalize to the overall population of K awardees, and to identify the causes and consequences of the differences in reviewers' feedback we observed in critiques of male and female investigators' K award applications. Research to examine applicant and mentor reactions to reviewer feedback may prove particularly worthwhile, potentially pinpointing targets for interventions to prevent the loss of talented female investigators from research careers. Such interventions might include boosting female scientists' coping self-efficacy,⁵⁹ teaching reviewers about the impact of applicant gender on performance expectations,^{8,37,38,60} or enhancing mentor relationships for female K awardees.^{28,29,61–63} The loss of female researchers at the transition to independence remains a costly and unresolved problem that perpetuates women's underrepresentation in high ranks and leadership and ultimately impedes the competitiveness of U.S. science and technology.^{1,60}

Limitations

Our findings are limited in generalizability by the qualitative design of the study. Our sample is also limited to critiques from 70% of K award applications that were funded between 2005 and 2009 at UW-Madison. All investigators who participated in our study were at least five years beyond the receipt of their K award. Many investigators, particularly women, transition to independence over a longer period of time than five years,^{13,18,20,24} so it is possible that more of the K awardees in our sample will yet obtain independent awards. Additionally, we would not have captured post-K award independent research awards if the sources were not reported in NIH's public access database. This study evaluated K award critiques before NIH changed its peer review process in 2009—shortening the length of critiques, implementing a broader range for impact/priority scores, and

use of criteria scores. Future studies are needed to test formal hypotheses about the extent to which reviewers' feedback in the current NIH format differs in critiques of K award applications from male and female investigators in ways that may influence their persistence in research careers.

Conclusions

The NIH Mentored Career Development (K) Award traditionally bridges junior investigators from mentored to independent research. Nationally, fewer women than men succeed in this transition. This exploratory study suggests that reviewer feedback for K awards, particularly for female applicants, should be investigated as a potential contributor to research persistence and success in crossing the bridge to independence.

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