

# Understanding factors that motivate research performance and career longevity of science, technology, engineering and mathematics postgraduates

Margaret Tan<sup>1</sup>, Jonathan S. Herberg<sup>1</sup>, Celestial Yap<sup>2,3</sup>, Dujeepa D. Samarasekera<sup>4</sup> & Zhi Xiong Chen<sup>2,3,4,5,6</sup>

<sup>1</sup>Institute of High Performance Computing, Agency for Science, Technology and Research (A\*STAR), Singapore; <sup>2</sup>Department of Physiology, Yong Loo Lin School of Medicine, National University of Singapore, Singapore; <sup>3</sup>National University Cancer Institute, National University Health System, Singapore; <sup>4</sup>Centre for Medical Education, Yong Loo Lin School of Medicine, National University of Singapore; <sup>5</sup>KK Women's and Children's Hospital, Singapore; <sup>6</sup>Office of Student Affairs, National University of Singapore

## Abstract

Given the high investments in training and mentoring graduates who have chosen the research career path, and considering a high attrition of these graduates moving on to non-research type of careers, it is important to understand the factors that motivate young scientists to stay on the job as they could make important contributions to a better world with their scientific endeavours. It is in this context that we conducted an exploratory study to understand the factors that may drive the scientists' performance as well as their expectations to remain in the research career paths. We found evidence for an indirect link (through research commitment) between need-for-cognition and career performance as well as evidence of an effect of research commitment on the anticipated research career length. There was also evidence that continuance commitment (but not other extrinsic factors) affects anticipated research career length, and that organisational support is linked to perceived research performance. Implications of our findings for student selection and graduate mentoring are discussed.

**Keywords:** *Research Career Path, Scientist's Motivation, Graduate Mentoring, Intrinsic and Extrinsic Motivations*

## Practice Highlights

- Research commitment and organisational support are predictors of perceived research performance.
- Research commitment and continuance commitment are predictors of anticipated research career length.
- Develop intellectually stimulating curriculum and work tasks to promote research motivation and innovations.
- Develop holistic curriculum to include knowledge management and domain expertise in graduate education.
- Encourage STEM employers to create more attractive careers and conducive workplace culture and conditions.

## I. INTRODUCTION

Building a scientist's expert domain knowledge is a long-term investment. Many years of education guidance and training are required to nurture each scientist to be competent in the field of expertise. Although the bachelor's degree is often the stepping-stone in building a Science, Technology, Engineering and Mathematics (STEM) career, more advanced skills and specialised know-how developed during Masters and PhD programs

are often required in order for a scientist to progress. Beyond PhD studies, a researcher aspiring to be independent requires further exposure to the scientific environment through postdoctoral fellowships. During this period, supervisors play an important role in the education and training of these young scientists, guiding, mentoring and nurturing them to be innovative in developing research that is of relevance to the world. In addition to research experience, the scientist needs

pragmatic skills such as resource management. Yet, globally, young scientists including the best and the brightest, are leaving research careers for other non-research related careers independent of job competition, availability of funding and number of publications (Callaway, 2014; Roach & Sauermann, 2017).

In the early 2000s, when Singapore identified life sciences as the next pillar of economic growth, the government forged ahead to develop this sector, and one of the ways was for the university to become part of the ‘university-government-industry’ trinity to train and prepare the country’s limited human resource for this important sector. Considering that national policies and institutions are obliged to provide long-term and extensive investments to nurture these graduates in order for them to produce research innovations, attract investments, and stimulate economic and intellectual growth, there is an urgent need to understand why increasing number of promising STEM postgraduates opt to leave their scientific career paths to pursue non-research related careers that are not aligned to their prior education and training.

While the reasons for leaving STEM research careers could be due to changing job preferences because of self-perceived inability to do research, and misalignment in the expectation and reality of what research has to offer, the factors for this self-perceived research performance and misalignment in expectation and reality of research careers remain unknown. Therefore, this study aims to investigate and understand the factors that may influence the graduates’ perceived research performance and anticipated career longevity in scientific research paths. Identifying the factors that lead to the attrition of the STEM workforce will help educational institutions to

refine or enhance graduate programs. The findings will also help educational leadership to understand the unmet needs and socio-psychological perceptions of the research scientists, and to address the intrinsic (personalised) and extrinsic (environmental/organisational) factors which may motivate them to persevere towards successful careers in scientific research.

### A. Conceptual Framework

Review of the literature suggests that a scientist’s research career performance and longevity may be rooted in specific motivational tendencies and can be driven by perspectives supported by the organisational culture and environment. It is in this context that the study investigates the factors that determine the scientist’s research career path longevity. We propose a conceptual framework as shown in Figure 1 that takes into account the individual traits such as the need-for-cognition, need-for-closure, and intrinsic motivation in identifying career performance. The two constructs, the need-for-cognition and need-for-closure, are integral to one’s knowledge-seeking motivation, and they are both linked to driving intrinsic motivation that has a direct effect on perceived research performance, which in turn affects the scientist’s choice to remain in the research career. However, we also propose that the commitment to remain in a research career over the long term is moderated by extrinsic factors such as perceived support in the work environment/organisation, supervisor’s support, and work autonomy. In other words, a graduate’s choice to remain in a research career path is influenced by perceived research performance with extrinsic factors in the work environment moderating the relationship.

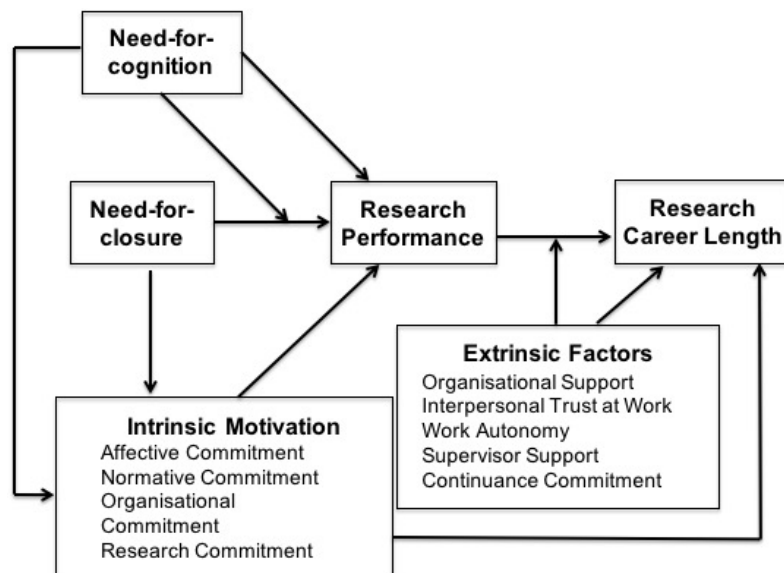


Figure 1. The conceptual framework of cognitive and motivational constructs and their links to perceived research performance and anticipated research career length

Need-for-cognition refers to the extent one gains pleasure from effortful cognitive processing, such as figuring out solutions for difficult puzzles (Cacioppo & Petty, 1982). It has general utility and predictive power in social and educational psychology as a stable personality trait that shapes knowledge-seeking behavioural tendencies across a diverse range of situations (Fortier & Burkell, 2014; Szumowska & Kossowska, 2016, 2017). In our framework, the need-for-cognition is directly linked, as well as indirectly linked, through intrinsic motivation to career performance. As success in a research career path depends on a stable motivation to solve difficult and often long term problems, individuals who have a high need-for-cognition should exhibit better performance through their drive toward pursuing challenging questions out of curiosity. They tend to have a greater inclination to devote time and effort to difficult issues with deep analysis. Further, the need-for-cognition also opens one to new ideas, and facilitates willingness to engage in argument and having differing perspectives (Mussel, 2010). In fact, knowing that accumulating one's knowledge is based on one's prior research, the high need-for-cognition not only contribute to better performance but it should also influence long term career.

Need-for-closure refers to one's need to obtain clear-cut answers to questions. Depending on situational factors, a higher need-for-closure can entail a greater motivation to seek information in carrying out cognitive tasks, or contrariwise a greater resistance to incorporating new information that challenges answers subjectively seem sufficient for getting tasks done (Roets, Kruglanski, Kossowska, Pierro, & Hong, 2015). For instance, if early cues suggest a feasible solution to a problem, a higher need-for-closure can result in a greater resistance to assimilating new information that may later challenge the earlier solution. On the other hand, a higher need-for-cognition can help spur an individual to seek new knowledge when significant uncertainties are made apparent. Thus, an individual's need-for-cognition is a source for a variety of impacts on one's motivation to seek and incorporate new knowledge; as such it is important to specify its roles in the context of determining a scientist's research path and longevity.

The need-for-closure could be viewed as specifying a form of motivated cognition, leading to different goals depending on circumstances, rather than specifying a general lack of motivation for cognitive processing (Kruglanski et al., 2012; Kruglanski & Webster, 1996). In situations of high ambiguity and significant knowledge gaps, such as might be present at the start of a research endeavour, one's need-for-closure can trigger

significant devotions of cognitive effort toward obtaining clear answers. On the other hand, when seemingly satisfactory answers are obtained, a higher need-for-closure can entail goals to avoid acknowledging subsequent conflicting evidence and ambiguities requiring additional research. Hence, we propose that the link between need-for-closure and career performance may be moderated by need-for-cognition. This reflects the idea that different psychological motivations and capacities can interact to influence behavioural tendencies (Fortier & Burkell, 2014; Hill, Foster, Sofko, Elliot, & Shelton, 2016; Szumowska & Kossowska, 2016, 2017). For instance, if one's need-for-cognition is low, a higher need-for-closure may only weakly improve, or even detract from perceived research performance, as one may have a tendency to crystallise knowledge too early in the research process, and be resistant to modifying knowledge based on follow-up research. Experimental evidence supports the notion that individuals with a higher need-for-closure have a higher tendency to "seize" early information cues in cognitive decision tasks, and to "freeze" the knowledge thereby acquired, being less prone to modify knowledge from subsequent information cues (Roets et al., 2015). It is possible that a high need-for-cognition can counteract the knowledge "freezing" tendency in high need-for-closure individuals, thereby sustaining their motivation for further knowledge-seeking behaviours following initial knowledge formation. This is consistent with the finding that individuals high in both needs tend to engage most predominately in information-seeking behaviours indicative of intellectual openness (Fortier & Burkell, 2014; Szumowska & Kossowska, 2016, 2017), which we propose as a key component for successful research careers.

Intrinsic motivation is an essential construct for understanding performance and choice to stay in the career. Motivation generally refers to an individual's inclination to devote effort toward goals; however, intrinsic motivation arises from one's desire for self-improvement and genuine interest, rather than from external pressures (Koestner & Losier, 2002). For intrinsic motivation to be maintained, one's needs for autonomy (sense of self-control), competence (sense of capability) and relatedness (sense of social connectedness and purpose) have to be obtained while one engages in effortful activities toward achieving long-term goals (Ryan & Deci, 2000). Empirical research supports the notion that intrinsic motivation, as compared to more extrinsic forms of motivation, is critical for long-term academic performance (Taylor et al., 2014). In our model, intrinsic motivation has a direct link not only to performance, but also to long-term career choice, i.e. the likelihood of choosing to stay on a given research career path over an extended period of time,

rather than changing careers. Thus, we propose the importance of intrinsic motivation in driving career performance and choice to remain in it.

Extrinsic factors include organisational culture and structure that support the work environment comprising such components as i) perceived support and value (conveyed by the organisation; Lambert, 2000); ii) interpersonal trust at work (Cook & Wall, 1980); iii) work autonomy, which includes approach to perform the tasks (or the degree of choice one has in determining the means and plans for completing the tasks), and scheduling autonomy (or how much flexibility one has in the timing of completion of tasks and goals; Breugh, 1985, 1999) and iv) supervisor support. For research work, a mentor relationship is important to generate interpersonal trust and confidence. By mentor relationships, we refer to the degree of research guidance, coaching, and support that the scientist receives from his or her mentors. Better mentor relationships can lead to an increased motivation to maintain one's career as a research scientist, in addition to sustaining increased performance. Further, extrinsic motivation also involves one's continuance commitment referring to one's inclination to remain in a given job for practical considerations; hence we propose that while better perceived research performance tends to increase anticipated research career length, the strength of this link is moderated by extrinsic factors.

## II. METHODS

Ethical approval was obtained from the Institutional Review Board, National University of Singapore (NUS) to conduct the survey questionnaire investigation. Participants completed an online questionnaire (hosted on SurveyMonkey) that took about 45 minutes to complete. The online survey was conducted over a period of nine months.

### A. Participants

The target respondents consisted of the STEM postgraduate students and PhD fellows. The administrative staff independent of the investigators sent out individual emails to each of the following departments and faculties to seek their approval to disseminate the survey - NUS Yong Loo Lin School of Medicine (12 Heads of Department, Vice-Dean [Research], Assistant Dean [Research] and Vice-Dean [Academic Medicine]), Faculty of Arts and Social Sciences (Vice-Dean, Research), Faculty of Engineering (Vice-Dean, Research), Faculty of Science (Vice-Dean) and NUS Graduate School (Executive Director). Once approval was obtained, their secretaries were requested to send an email invitation containing the survey link to

each of their respective postgraduate students and PhD fellows to participate in the survey.

Participants were given three weeks to complete the questionnaire. Reminder emails were sent to the participants to complete the survey if they had not done so. 92 participants took part in the survey. Among the 63 participants who provided their demographic details, 32 were male and 31 were female. The ages ranged from 21 to 44 years old, with the majority between 25 to 34 years old. On average, they had about 2 to 6 years of research experience. Majority respondents came from Biomedical & Related Sciences (44), with the rest as follows: Engineering & Technology (6), Natural Sciences (excluding Biological Sciences; 4), Social Sciences (3), Agriculture & Food Sciences (2), Biological Sciences (2), Healthcare & Related Sciences (1) and Healthcare Services (1). We used responses from 64 participants for the regression and path analyses on anticipated research career length.

### B. Questionnaire Design

We developed a survey instrument measuring various constructs of the model by adapting validated questionnaires established in the industrial organisation and cognitive psychology literature. The questionnaire consists of four parts as follows – i) 64 closed-ended questions on a 6-point Likert scale, ii) 10 closed-ended questions, iii) 2 ranking questions, and iv) a demographic section. For all scale questions, participants indicate their responses on a six-point Likert scale by indicating whether they “Strongly Disagree”, “Disagree”, “Slightly Disagree”, “Slightly Agree”, “Agree”, or “Strongly Agree”. For each construct, a participant's agreement ratings across the construct's items were averaged (with negatively framed items reverse-coded), to obtain an overall rating for the construct. The appendix shows the questions that we used for the various constructs.

To assess Need-for-Cognition, we utilised eight items from the Caccioppo et al. validated for the need-for-cognition scale (Cacioppo & Petty, 1982). Need-for-Closure was also assessed by eight validated items as well (Roets & Van Hiel, 2011). Organisational Commitment was measured directly through participants' ratings of items from the established Cook & Wall scale (Cook & Wall, 1980), as well as items assessing their Affective Commitment (in relation to their organisation) and their Normative Commitment (to remain in their organisation; Allen & Meyer, 1990), as these latter sets of items pertain to their motivation to remain in their current education or work environment. As a distinct component of Intrinsic Motivation, we included five items measuring the participant's Research Commitment. These items are likely to most directly

reflect intrinsic motivation, as they were adapted from the validated Intrinsic Motivation Inventory (Ryan & Deci, 2000), and contextualised with the aim to assess directly participants' intrinsic motivation for engaging in research tasks in relation to their work or education. Next, our main Extrinsic Factors component, Organisational Support was measured from the validated Lambert et al. scale (Lambert, 2000) which directly assesses the degree of support participants perceive to come from their organisational environment. In addition, we included other organisational-related subscales, which we propose to reflect extrinsic factors in relation to one's research career. These consist of items assessing participant's Supervisor Support, Interpersonal Trust at Work, and Work Autonomy granted by the organisation (Breugh, 1999; Cook & Wall, 1980). Lastly, as an extrinsic factor distinct from organisational factors, we included items to measure participants' Continuance Commitment, or the degree to which they are motivated to remain in their work environment for extrinsic rather than intrinsic reasons (Allen & Meyer, 1990).

To assess participants' perceived research performance, we had five questions, which we intended to indicate how strongly they viewed their level of performance (and their co-workers' view of their performance). In addition, participants indicated their expected research career length in terms of choosing one of five responses, ranging from "less than 2 years" to "more than 10 years", which we coded on a five-point ordinal scale. In addition, we had questions designed to elicit direct feedback from participants regarding their motivations, expectations, and experiences in their work or education environment.

### III. RESULTS

Through our 10 closed-ended questionnaires on the participants' research and career aspiration, the descriptive statistics showed some 84.5% of the participants were motivated to pursue a STEM career as indicated by their early passion or participation in science and research (Question 5). In fact, some 95.3% started to think about attending graduate school even before or during their undergraduate years (Question 6). However, despite their early enthusiasm to pursue a science and research career, it is discouraging that 54.7% intended to continue research in an academic or research setting (Question 7), and worse only 25% see themselves working in research and development beyond 10 years after their PhD (Question 9). Thus, it is not surprising that 23.4% were unlikely/very unlikely to take up non-academia/non-research careers after PhD (Question 8) and for those who were likely/very likely to take up non-academia/non-research careers, they included careers in banking and finance, management and consulting, and corporate positions in biotech and pharmaceutical firms

(Question 10). It appeared that remuneration is an important deciding factor (68.8% cited it) whether or not to stay in research (Question 11); indeed, they also want increases in their current salary (Question 13). The findings also showed that the top two factors influencing participants' decision to stay or leave a research and development career are physical work environment (e.g. equipment, ergonomics, cleanliness – Question 15) and working conditions (e.g. organisation culture – Question 16). In terms of the descriptive statistics, it is a concern to note that participants see the unattractiveness to pursue a scientific research career despite early strong motivation, prior to graduate studies.

Furthering our investigations using the closed-ended questionnaires, we analysed the relationship between our scale-construct metrics and a) participants' self-rated research career performance (as reflected in the mean of the five questions at the end of Part D of the survey; and b) participants' expected research career length, as reflected in their responses (coded as 1 to 5) to the question "How long do you see yourself working in research and development after your PhD?" To address these latter questions, we applied multiple regression analyses and path analyses. Multiple regression analyses were applied for each of our two dependent variables (the metric of self-rated research performance, and of anticipated research career length). For each dependent variable, a stepwise regression was calculated with all the subscale scores initially entered as separate predictors, and with the Akaike Information Criteria (AIC) utilised to select which subscale predictors to keep in the final stepwise model. In addition, for predicting perceived research performance, which was a mean rating across several items, we applied linear multiple regression models, but for predicting anticipated research career length, comprising a single item rating for each participant, we applied ordinal logistic regressions, to avoid in the latter case the more questionable approximation of treating a single-item rating as though it were on an interval scale.

For a more direct test of the proposed links in our conceptual framework, we developed two path analysis models. First, to examine the loadings of the intrinsic motivation and the extrinsic factors constructs on their respective subscale scores, we conducted a confirmatory factor analysis. The indicators for the intrinsic motivation construct were taken as its subscale scores (affective commitment, normative commitment, organisational commitment, and research commitment). The manifest indicators for the extrinsic motivation construct were the scores on the subscales for organisational support, interpersonal trust at work, supervisor support, work autonomy, and continuance

commitment. The fit statistics for this factor analysis was adequate: Confirmatory Fit Index (CFI) = 0.91; Root Mean Square Error of Approximation (RMSEA) = 0.08;  $\chi^2 = 36.60$ ,  $df = 26$ ,  $p = 0.08$ . However, the standardised loadings for affective commitment (.09) and for continuance commitment (.13) were not statistically significant. Therefore, in our initial structural equation model (SEM), we dropped these indicators. The endogenous variable of anticipated research career length was treated as ordinal, with weighted least square mean and variance adjusted estimation applied. This SEM however had poor model fit statistics: CFI = 0.56; RMSEA = 0.23;  $\chi^2 = 412$ ,  $df = 95$ ,  $p < 0.01$ . These fit statistics were improved when a link between Extrinsic Factors and perceived Research Performance was included (rather than, as with our original conceptual model, only having only the link between Extrinsic Factors and Anticipated Research Career Length included): CFI = 0.66; RMSEA = 0.20;  $\chi^2 = 333$ ,  $df = 94$ ,  $p < 0.01$ . However, as these statistics are still far from adequate overall model fit, we settled on a simplified, single-indicator path analysis approach. Intrinsic motivation was represented by the Research Commitment subscale score, as this subscale was most directly relevant in being based on the validated Intrinsic Motivation Inventory, and in the final stepwise model utilising the subscale scores as predictors for perceived Research Performance since Research Commitment and Organisational Support were the only significant subscale predictors. For the regression analysis predicting Anticipated Research Career Length, in the final stepwise model Research Commitment and Continuance Commitment were the only significant predictors. Based on these considerations, we implemented two single-indicator path analysis models. Both utilised Research Commitment as the indicator for Intrinsic Motivation. For the Extrinsic Factors indicator, our first path analysis model utilised Organisational Support, whereas our second one utilised Continuance Commitment. The fit statistics for our first path analysis are substantially improved over the more complicated SEMs: CFI = 0.91; RMSEA = 0.12;  $\chi^2 = 13.0$ ,  $df = 7$ ,  $p = 0.07$ . For our second path analysis, the fit statistics were very strong: CFI = 1.00; RMSEA = 0.00;  $\chi^2 = 5.01$ ,  $df = 7$ ,  $p = 0.66$ . Thus, for the purpose of exploring potentially important causal links among critical variables, our final path analysis models both include one link that was not in our conceptual framework, which is the link between “extrinsic factors” and perceived “research performance”. They also focus specifically on the research commitment component of intrinsic

motivation, and (separately) on the organisational support and on the continuance commitment components of extrinsic factors.

Our results showed that the research commitment component of intrinsic motivation may be the driver in influencing perceived research performance (as it is significant in both the final model output; Table 1, Figures 2 and 3). Organisational support component of extrinsic factors, on the other hand, seems to impact perceived research performance, and is the only significant extrinsic factors subscale in the stepwise regression for predicting perceived research performance (Table 1 and Figure 2). Table 1 shows the final AIC stepwise model, for the intrinsic and extrinsic subscales that affect career performance.

Predictor	$\beta$	$t$	$p$
Research Commitment	.43	4.78	<.01**
Organisational Commitment	.17	1.66	.10
Organisational Support	.21	2.15	.04*
Supervisor Support	.19	1.85	.07

Note: Standardised coefficients,  $t$ -statistics, and  $p$ -values for final model in AIC stepwise regression for predicting perceived research performance (with intrinsic motivation and extrinsic factors broken down into subscales).

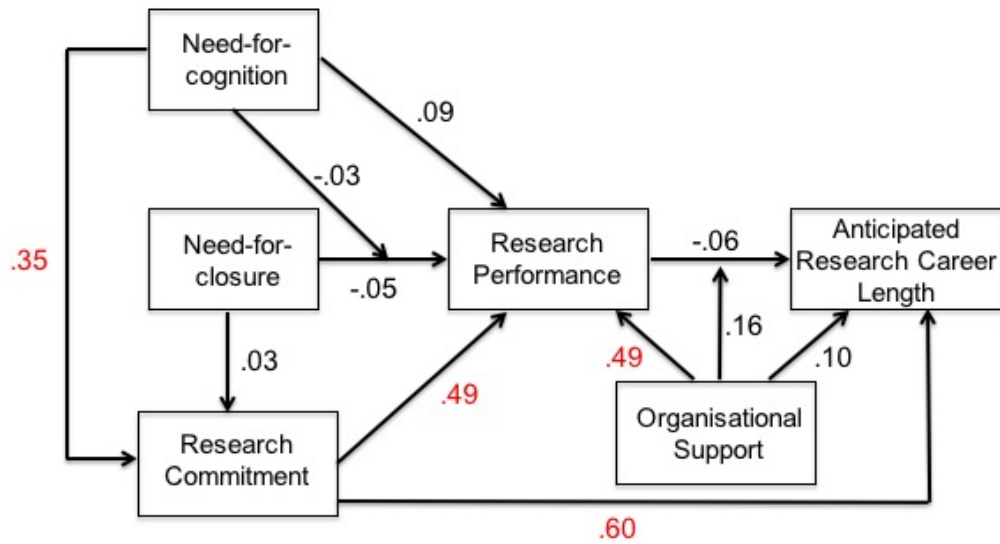
$$\text{Adjusted } R^2 = .54, F(4,66) = 21.68, p < .01$$

$$*p < .05, **p < .01$$

Table 1. Stepwise regression results for perceived research performance with construct subscales

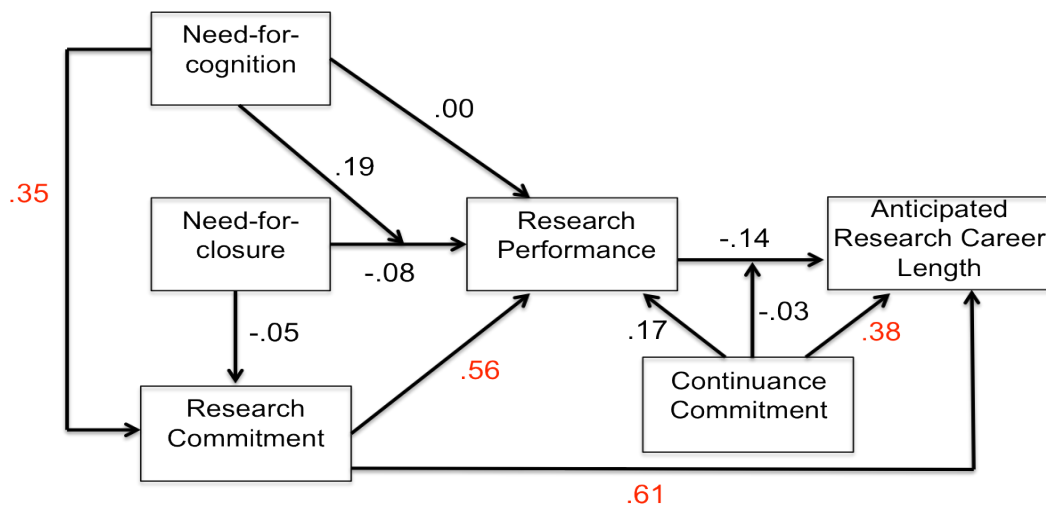
Focusing on the paths in Figure 2 that lead to perceived research performance (in the path analysis with organisational support as the extrinsic factor indicator), we found that the direct link from need-for-cognition is non-significant, whereas that from research commitment is significant. In addition, the indirect link between need-for-cognition and perceived research performance, through research commitment, is statistically significant ( $\beta = 0.17$ ,  $p < .05$ ). Also, the link between organisational support and perceived research performance is significant. Lastly, need-for-closure has no direct or indirect effect on perceived research performance, and there is no interaction effect of need-for-cognition on need-for-closure to influence perceived research performance. In addition, in our path analysis that includes continuance commitment as the extrinsic factor indicator, there is no effect of continuance commitment component on perceived research performance (Figure 3).





Note: The research commitment subscale represents intrinsic motivation, and the organisational support subscale represents extrinsic factors. Links are labelled with standardised coefficients. Coefficients in red are statistically significant.

Figure 2. Path analysis of the conceptual framework (research commitment and organisational support)



Note: The research commitment subscale of intrinsic motivation and the continuance commitment subscale of extrinsic factors are the only subscales with significant beta coefficients. Links are labelled with standardised coefficients. Coefficients in red are statistically significant.

Figure 3. Path analysis of the conceptual framework (research commitment and continuance commitment)

Thus, perceived research performance may be significantly predicted by research commitment, i.e. items assessing intrinsic motivation for research. Furthermore, need-for-cognition may indirectly affect perceived research performance, by influencing research commitment. Organisational support may, in addition, be an important predictor of perceived research

performance. In other words, scientists with high need-for-cognition, high intrinsic motivation coupled with strong positive extrinsic factors may perform better in research, which we proposed might increase the likelihood of them staying on in research careers. However, satisfying their need-for-closure may not necessarily enhance their perceived research performance, or lead them to remain in STEM careers.

Predictor	$\beta$	$t$	$p$
Research Commitment	1.32	4.51	<.01**
Interpersonal Trust	-.43	-1.58	.11
Continuance Commitment	.64	2.47	.01*

Note: Standardised coefficients,  $t$ -statistics, and  $p$ -values for final model in AIC stepwise ordered logistic regression for predicting anticipated research career length (with intrinsic motivation and extrinsic factors broken down into subscales).

\* $p < .05$ , \*\* $p < .01$

Table 2. Stepwise regression results for anticipated research career length with construct subscales

Our stepwise ordinal logistic regression analysis for predicting anticipated research career length that included the individual subscales for intrinsic motivation and for the extrinsic factors scale suggests that research commitment (within intrinsic motivation) and continuance commitment (within extrinsic factors) may be important, as they are the only statistically significant predictors in the final stepwise model (Table 2).

From our path analysis of predictors that affect anticipated research career length, with organisational support as the extrinsic factors indicator, we found no effect from perceived research performance, from organisational support, or from the organisational support by perceived research performance interaction. The only direct link to anticipated career length comes from research commitment (Figure 2). However, the indirect effect of need-for-cognition, through research commitment, is in the marginal area of statistical significance ( $\beta = 0.21, p = .06$ ). In our path analysis that includes continuance commitment as the extrinsic factors indicator, we found a statistically significant effect of continuance commitment on anticipated research career length (Figure 3).

#### IV. DISCUSSION

We believe that this is the first study in Singapore to investigate the factors to determine perceived research performance and anticipated career longevity of scientists in the STEM environment. We envisaged that graduates who are inclined towards and enjoy effortful cognitive activities are likely to do well in research activities. The findings of the study, however, suggest that future education as well as career policies concerning graduate students' recruitment may need to focus on identifying individuals who demonstrate their psychological cognitive trait in pursuing investigative and creative research. In a similar context, academic chairs of graduate schools and institutions should be mindful of designing programs that are geared towards enhancing and sustaining the researchers' cognitive and motivational aspirations.

It is not surprising to note that individuals, who are intrinsically motivated or having stronger commitment to do research are likely to perceive themselves to perform better, but only when organisational support and environment are favourable and conducive. In this context, it appears that programs for training and nurturing graduate students need to focus not only on providing domain knowledge competence but to also understand researchers' aspirations and life purposes, and expressed by participants, they can be as diverse as the need to "provide for family", to pursue "personal achievement" or be a "stepping stone in academia".

Given that organisational culture, supervisory support and their interdependency have been shown to be important in how employees perceive their value to the organisation and reciprocate in kind, our lack of significant correlations could be due to the limitation of the small sample size as our study only obtained about 10 to 20 percent response rate (92 out of estimated 500 to 1000 participants reached) and with only 64 completed usable responses compared to higher response rates and completed usable responses in other studies (Shoss, Eisenberger, Restubog, & Zagenczyk, 2013).

In terms of anticipated career longevity, there is no single factor that is able to predict an individual's likelihood to choose and embark on a long-term research career trajectory. What is striking is that perceived research performance is unable to predict for anticipated career longevity. This suggests that even if an individual performs well in research, there is no certainty that he or she may continue to pursue research as a long-term career. Indeed, our finding confirms previous work showing that postgraduates may leave the research career path independent of publications and funding (Roach & Sauermann, 2017). However, there is evidence to suggest that individual elements of particular factors may be indicative for anticipated career longevity. Specifically, individuals who are committed to research and emotionally attached to the institution are more likely to stay on and be committed in research careers. This suggests that it may be beneficial for graduate mentoring programs to incorporate activities that are likely to enhance emotional bonding of students with their institutions, which in turn may increase their affinity towards research careers. It seems that the findings suggest that research commitment or a passion to do research is a key ingredient to perceived performance success and anticipated career longevity.

Understanding the factors that influence commitments to perceived research performance and anticipated career longevity is important to guide the design of scholarship policies to mitigate declining scholarship and increasing attrition among graduate students pursuing the STEM career paths. Currently, training of graduate students mainly involves undertaking a suite of domain-related course modules and embarking on a research project over a specified period of usually 4 years, leading to a thesis. Students are encouraged to publish but often, this is not a mandatory requirement. These students are also required to support and perform teaching duties as one of the program requirements. For early career scientists, the training is less structured where trainees typically spend an undefined amount of time in a research setting working on various projects. Given that "research can be too mentally challenging and stressful" as cited by a



participant, it is therefore crucial to have effective, supportive and readily approachable mentors. Supervisors of graduate students and early career scientists are typically universities' faculty or research institutes' principal investigators who may not have formal training in mentorship. Currently, in Singapore, there is no systematic training of supervisors on how to supervise and mentor students in a holistic manner. Perhaps, it may be useful to take guidance from best practices for doctoral training in Europe and North America, and contextualise these to local settings and conditions (Barnett, Harris, & Mulvany, 2017).

We would like to suggest that future education and training of graduate students and early career scientists should not only focus on developing programs that build depth and breadth of domain knowledge but they must instil the desire for intellectual contribution to society. Scholarships should enhance the researchers' intrinsic motivation of their research commitment and help them to appreciate their contributions to their research endeavours. Guidelines should be in place to provide supervisors with the necessary guidance for effective and holistic mentorship, and to shift from an output-oriented mindset to a human development-centric mindset. Although we have no evidence from direct feedback to suggest a link between organisational support and continuance commitment, nevertheless, given that forms of organisational support such as physical work environment and working conditions are the top two factors influencing participants' decision to stay or leave a scientific research career, this may suggest a potential link between organisational support and continuance commitment. In brief, we believe these changes would alter mentor-mentee behaviour and relationship, creating a conducive and trusting environment with strong organisational and supervisory support for fostering meaningful research that is aligned to each organisation's goals and objectives.

## V. LIMITATIONS

A limitation of this study is that the sample sizes are small, and as the study is a questionnaire survey, only perceived research performance and self-declared expected research career length were used. We acknowledged that research performance could be measured more objectively in terms of number of academic publications and citations, however, our definition of research performance also encompasses subjective aspects which are harder to evaluate such as having an inquisitive mind, taking initiatives to explore innovations, providing ethical scholarly behaviour that includes collaborations. We note that self-declared expected research career length may not reflect reality, and it would have been more realistic to evaluate actual

periods that the scientists stayed on in their successful research careers versus those who did not. However, this is logistically challenging to carry out with potentially more confounding variables that are difficult to define.

## VI. CONCLUSION

In conclusion, we hope that our findings will provide insights to implore domain curriculum developers and prospective research-oriented employers to incorporate intellectually stimulating learning or work components that will motivate and strengthen research commitment. Indeed, education policymakers should explore areas of support that are lacking in graduate education while policymakers of research institutes should provide making research careers and workplace conditions more conducive and attractive for retaining scientific talents. Indeed, the many issues surrounding STEM career deserve attention and especially in the context that many young scholars who aspire to do research at the onset eventually choose to leave their research careers (Kavallaris et al., 2008). For instance, participants cited that "career stability is very limited" as projects are based on research funding; consequently it has been touted as having weak career development prospects when funding runs out. Researchers also often cited that they are "underpaid in the research field" and "pay for them is very low, relative to other industries". Hence, having adequate annual leave considering that they tend to work long hours to finish a project, better remuneration that is more comparable to other industries, and greater assurance towards a clearer career roadmap would ensure a more research continuance commitment.

We hope that other researchers would replicate this study to delve deeper into the importance of understanding the cognitive and psychological needs of the researchers, enhancing research commitment in the community and developing strong organisational ties in influencing research performance and commitments as well as longevity in research careers among graduate students and early career scientists.

## Notes on Contributors

Dr Margaret Tan, PhD, was a senior scientist at A\*STAR prior to setting up SmartWerkz, an AI-driven ontological system that delivers immersive extended reality skills coaching to facilitate effective application of knowledge assets. She was also an Associate Professor at NTU and NUS specialising in knowledge management and organisational behaviours.

Dr Jonathan Herberg, PhD, has worked over five years as a research scientist (cognitive psychologist) at A\*STAR IHP. He obtained his PhD in Psychology

from Peabody's Cognition and Cognitive Neuroscience Program at Vanderbilt University. His research includes experimental and educational psychology, collaborative learning, human-computer interaction, psychometrics and predictive analytics.

A/Prof Celestial Yap, MBBS, PhD, is the Education Director for Health Professions at the Department of Physiology and an Affiliate Associate Professor from the National University Cancer Institute. She is also the Integration Lead Educator in undergraduate medical curriculum. Her research interests include medical education and graduate research training.

Dr Dujeepa D. Samarasekera, MBBS, MHPE, FAMS, FAcadMED, FAMEE, is the Director of Centre for Medical Education, National University of Singapore and the President of the Western Pacific Regional Association of Medical Education. He also consults for the Singapore Ministry of Health on medical education matters.

Dr Zhi Xiong Chen, PhD, is the Deputy Education Director from the Department of Physiology and the Assistant Dean of Students at NUS. He is also the Integration Lead Educator in undergraduate medical curriculum and a Joint Scientist at KKH. His research interests include health professions education.

#### Ethical Approval

This research received approval from the NUS-Institutional Review Board (NUS-IRB Ref No. B-15-256). Consent was obtained from participants for the research study.

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#### Declaration of Interest

The authors report no conflict of interest. The authors alone are responsible for the content and writing of the article.

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\*Zhi Xiong Chen  
Department of Physiology,  
Yong Loo Lin School of Medicine,  
National University of Singapore,  
2 Medical Drive, MD9, Singapore 117593  
Tel: +65 6516 3231  
E-mail: zhixiong\_chen@nus.edu.sg

Appendix: Questionnaire on Understanding Scientists' Aspirations in Pursuing Career Longevity

1. Part A

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
I really enjoy a task that involves coming up with new solutions to problems.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It's enough for me that the job gets done; I don't care how or why it works.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I like to have the responsibility of handling a situation that requires a lot of thinking.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The notion of thinking abstractly is appealing to me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I feel relief rather than satisfied after completing a task that required a lot of mental effort.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I prefer a task that is intellectual and difficult to one that is important but require little thoughts.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I prefer to think about small, daily projects to long-term ones.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I usually end up deliberating about issues even when they do not affect me personally.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## 2. Part B

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
I find that a well ordered life with regular hours suits my temperament.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I don't like to be with people who are capable of unexpected actions.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I do not usually consult many different opinions before forming my own view.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I feel uncomfortable when I don't understand the reason why an event occurred in my life.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
When I have made a decision, I feel relieved.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I feel irritated when one person disagrees with what everyone else in a group believes.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I don't like situations that are uncertain.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I dislike it when a person's statement could mean many different things.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### 3. Part C

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
Even if the organisation is not doing well, I would be reluctant to change to another employer.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I would be very happy to spend the rest of my career with this organization.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I feel myself to be part of the organization.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I think that I could easily become as attached to another organization as I am to this one.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
To know that my work has made a contribution to the organization would please me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I do not believe that a person must always be loyal to his or her organization.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I was taught to believe in the value of remaining loyal to one organization.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If I got another offer for a better job elsewhere, I would feel it is alright to leave my organization.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am quite proud to be able to tell people who it is I work for.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I think people move from company to company too often these days.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I think I am good in conducting my research.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I actively seek out/create opportunities to further my research.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I aspire to distinguish myself as a renowned scientist in my field of research.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Doing research is fun for me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I think the topics and questions I research are interesting.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



4. Part D

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
My employer provides benefits for me to balance my work and personal life.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My employer values my contribution to the organisation.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If given the chance, my employer would take unfair advantage of me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My company's benefits have helped me get through some bad times.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My employer supports my working conditions with adequate resources.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am able to modify my job objectives (on what I am supposed to accomplish).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I am able to choose the approach to go about doing my job (the procedures to utilize).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have been given sufficient degree of independence/freedom to pursue my research.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have some control over what I am supposed to accomplish.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have some control over the scheduling of my work activities (when I do what).	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My supervisor is strict and is hardly around when I need to seek advice.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
My supervisor is helpful when I have personal matter to attend to which interfere with my work.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My supervisor supports me to attend seminars and conferences to further my knowledge domain.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My supervisor coaches, guides and give suggestions to improve my projects.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My supervisor burdens me with works that are not beneficial to my career progression.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My supervisor is not open to my ideas and can be suffocating in my research.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My supervisor feels that I am important and is supportive of my contribution.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall, I have a good supervisor who cares and nurtures me in my career advancement.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I can trust my team members to lend me a helping hand if I need it.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I believe I can rely upon my team members to do as they say they would do.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I think most of my colleagues are friendly and supportive of each other.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I socialise with my team members outside organisation time.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I feel confident that management will always try to treat me fairly.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
I am not afraid of what might happen if I quit my job without having another one lined up.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Too much in my life would be dumped if I decide that I want to leave my organization now.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Leaving this organisation would require considerable professional sacrifice.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
It would be hard for me to leave my organization right now, even if I wanted to.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Right now, staying with my organization is a matter of necessity as much as a desire.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My co-workers value my contributions highly.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My co-workers may have trouble finding a suitable replacement if I leave the team.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My supervisors view me as a highly valuable contributor to the knowledge domain.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have diverse skills and am confident of employability for better positions in my field.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I would rate my overall professional performance at work highly.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

5. Which of the below best describes your motivation to pursue a career in STEM

- Participation in science club activities, competitions, talks by scientists.
- Participation in research attachments/student research projects.
- My parents/teachers/friends suggested that I should do a PhD.
- I have a passion for research.
- Other than the above

6. Approximately when, if ever, did you start to think about attending graduate school?

- Before undergraduate school
- During undergraduate school
- Within two years of finishing undergraduate school
- More than two years after finishing undergraduate school
- When no jobs were offered

7. Which career track do you see yourself in eventually?

- I intend to continue in the research field in an academic setting.
- I intend to continue research but in the industry setting.
- I'm not motivated anymore to stay in research field.
- I have the passion for research but won't continue because the career is not rewarding.
- I intend to take up a 'teaching-track' position with less/no research.
- I intend to switch to a completely new career/profession
- I have no idea; I just go with the wind.

8. How likely are you to take up non-academia or research careers after PhD?

- 1=very unlikely
- 2=unlikely
- 3=unsure
- 4=likely
- 5=very likely

9. How long do you see yourself working in research and development after your PhD?

- Less than 2 years
- Between 2 to 4 years
- Between 4 to 6 years
- Between 6 to 10 years
- More than 10 years

10. Which of the following non-academia careers are you most interested in?

- Banking and finance
- Management and consulting
- Investment and private equity
- Pharmaceutical/Biotech corporate positions
- Others (Please specify)

11. Will the remuneration or salary be a factor to your decision not to stay in the research field?

- Yes
- No

Please elaborate.

12. Do you think the current remuneration that you are holding is fair and sufficient?

- Yes
- No

Please provide reasons for your answer.

13. What do you think should be improved or included in your current remuneration scheme?

- Increased monthly salary
- Provide better medical insurance and benefit
- Provide computer allowance
- Provide better annual conference allowance
- Provide housing rental allowance
- Provide allowance for purchasing of reference books
- Others (please specify)

14. In the next 5 years, your most likely career plan is to:

- Build/continue your R&D career in your current organization?
- Pursue an R&D career outside your current organization (within Singapore)?
- Pursue an R&D career outside Singapore?
- Pursue other non-R&D, STEM-related careers? (e.g. IP management, research administration, industry/business development, education)



15. How much would each of the following factors motivate you to STAY in a R&D (research and development) career? Please rank each factor from 1 (most important) to 8 (least important).

<input type="text"/>	Personal interest
<input type="text"/>	Opportunity to contribute to society
<input type="text"/>	Intellectual satisfaction
<input type="text"/>	Work life balance / flexible working hours
<input type="text"/>	Job security
<input type="text"/>	Career advancement or progression opportunities
<input type="text"/>	Physical work environment (e.g. equipment, ergonomics, cleanliness, etc.)
<input type="text"/>	Working conditions (e.g. organisation culture)

16. How much would each of the following factors influence your decision to LEAVE a R&D (research and development) career? Please rank each factor from 1 (most important) to 8 (least important).

<input type="text"/>	Poor / uncertain career progression
<input type="text"/>	Low job availability / low job stability
<input type="text"/>	Unsatisfactory salary package
<input type="text"/>	Too many projects / too long hours
<input type="text"/>	Poor physical work environment (e.g., equipment, ergonomics, cleanliness, etc.)
<input type="text"/>	Poor working conditions (e.g. organisation culture)
<input type="text"/>	Lack of social life
<input type="text"/>	Loss of interest in R&D (research and development)