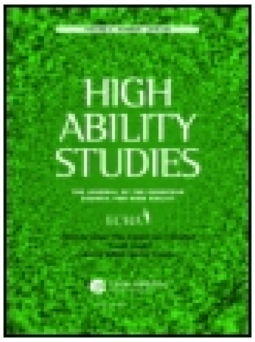

High Ability Studies

ISSN: 1359-8139 (Print) 1469-834X (Online) Journal homepage: http://www.tandfonline.com/loi/chas20

Achieving scientific excellence: An exploratory study of the role of emotional and motivational factors

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HIGH ABILITY STUDIES, 2016
http://dx.doi.org/10.1080/13598139.2016.1264293

Achieving scientific excellence: An exploratory study of the role of emotional and motivational factors

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ABSTRACT
This study investigates the perceived role of psychological factors in achieving excellence in scientific research. Six outstanding scientists aged 33–42 were interviewed. Data were analyzed inductively resulting in three main dimensions: personality traits and characteristics, psychological skills and processes, and task-specific strategies. Researchers highlighted the importance of emotional factors and motivational processes to achieve and sustain scientific excellence. Flexible coping, emotion regulation, and goal setting were emphasized and described as particularly important in dealing with rejections, setbacks, and team management issues. Persistence and adaptive perfectionism were key individual characteristics which helped participants in nurturing and sustaining motivation. This study suggests that the specific impact of emotional, motivational, and other psychological skills at different stages of excellence development is relevant; yet, further investigation is needed.

KEYWORDS
Scientific excellence; motivation; emotion; psychological skills; performance science

Introduction

Discoveries and innovations in scientific research result from the work of both individuals and teams that perform at very high levels. Scientific excellence is multifaceted; it comprises a dynamic combination of psychological, social, and contextual factors that interact in a complex and unique way for each individual. As a scientific concept, excellence is rarely defined but often encapsulated in many definitions and theories of expertise (e.g. Ericsson, Roring, & Nandagopal, 2007), talent and giftedness (e.g. Dai, 2009; Gagné, 2013), creativity (e.g. Heller, 2007; Kaufman & Baer, 2005), wisdom (e.g. Baltes & Staudinger, 2000), and eminence (e.g. Simonton, 1999). In an effort at clarification, Shavinina (2009b) suggests different variations of the concept such as potential excellence and excellent achievement, individual and corporate excellence, and even situational and permanent excellence. Variations of excellence seem therefore to result from and vary according to the theoretical framework adopted, the identification and assessment criteria used, as well as the contexts and areas of performance. Based on consensual features shared by different theoretical models, we assume excellence as a quality of individuals that demonstrates achievement far above average, with high

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significance in the contexts of the acquisition and manifestation of domain-specific expertise, as well as distinguishable psychological characteristics (superior cognitive, personality, motivational, emotional, and social characteristics), expert knowledge, and extraordinary skills to deal with complex (personal, social, and professional) situations.

The scientific study of excellent performance and eminent individuals has inspired researchers since the nineteenth century. Galton's (1869) pioneering investigations became milestones in the study of exceptionality, explaining outstanding performance as a result of hereditary factors and relating these to superior cognitive abilities. Lewis Terman's longitudinal study (1925) with individuals with extremely high IQ demonstrated that social background, special abilities as well as personality and interests accounted for the understanding of giftedness. Terman's study also refuted the belief that talent and giftedness were some kind of mental and social disorder and that gifted individuals were socially inept. Despite being one of the most influential studies to psychological research of talent and eminence, Terman's main study is based on a gifted group that had come from ideal family backgrounds with stable and stimulating environments, and yet it failed to predict adult success (Simonton, 2016). Personality differences and diversifying experiences along with domain-specific assessment seem to play a bigger role than just IQ in identifying talent and eminence (Simonton, 2016). Roe (1953) studied the impact of environmental influences in professional choices and career success as well as personality and social skills of scientists and artists. Roe suggested that a high degree of skill along with optimal educational environments that promoted autonomy and independence were core factors that contributed to the development of scientific talent. By the early 1950s, the study of the gifted and talented had abandoned unidimensional conceptions of excellence to consider a variety of motivational, social, and cognitive (e.g. creativity) variables. The humanistic movement along with new conceptions of intelligence and a renewed interest on creativity prompted more comprehensive approaches to research into high abilities, expertise, and talent. Studies by Zuckerman (1996), Albert (1992), Bloom (1985), Gardner (1993), and Wallace and Gruber (1989) exploring the lives and careers of eminent scientists have also triggered new research questions based on the observed diversity and complexity of determinants in the pathway to excellence in science. The interest in the psychological study of eminent scientists encouraged researchers to formally develop a "psychology of science" and thereby better comprehend the determinants of scientific excellence. Simonton (1988, 1991, 1999) and Feist (2006b) have been leading the research in this field, specially by investigating creativity, personality, and eminence in science. The initial enthusiasm in the 1980s and 1990s led to a growing number of studies focusing on the personal characteristics of scientists (e.g. personality, motivational, cognitive, or/and emotional), the nature of scientific work, and the underlying psychological processes and strategies, but the field developed in a fragmentary manner (Lounsbury et al., 2012). Feist (2006b) stated that psychology of science, as a formal scientific field and when compared with other metasciences, is still developing. Recent studies of scientific excellence (e.g. Grosul & Feist, 2014; Jindal-Snape & Snape, 2006; Lounsbury et al., 2012; Simonton, 2014; Van Leeuwen, Visser, Moed, Nederhof, & Van Raan, 2003) have focused more on scientific productivity, achievement criteria, and measures of scientific excellence than on understanding what makes an excellent scientist over and above scientific outputs. In a constantly changing and increasingly demanding scientific environment, understanding how individual characteristics and psychological processes impact the lives and work of scientists remain relevant.

Several studies (e.g. Heller, 2007; Lubinski, Benbow, Shea, Eftekhari-Sanjani, & Halvorson, 2001; Shavinina, 2009a) that investigated the determinants of scientific talent concluded that it requires the right mix of cognitive ability, educational opportunities, and other non-cognitive attributes such as motivation, sustained commitment, and specific preferences. While the role of intelligence and superior cognitive abilities seems to matter at early ages, its determinant value in adulthood is still debatable (Simonton, 2016). Recent reports (e.g. Lubinski, Benbow, & Kell, 2014; Park, Lubinski, & Benbow, 2008; Wai, 2014) suggest that intelligence and extraordinary cognitive abilities discriminate the best adult performers in academic domains; in addition, non-intellectual determinants need to be assessed "to paint a more comprehensive portrait of exceptional human potential" (Kell, Lubinski, & Benbow, 2013, p. 658).

Motivational factors such as enjoyment, self-actualization, and passion are often suggested as explanatory variables to excellent performance (Amabile, 2001; Bloom, 1985; Feist & Barron, 2003; Heller, 2007; Immordino-Yang & Damasio, 2007). Intrinsic motivation, sustained commitment, persistence to achieve goals, high expectations, and specific interests have been identified as motivational features of excellent scientists (Heller, 2007; Lubinski et al., 2001). For example, Jindal-Snape and Snape (2006) investigated the role of intrinsic and extrinsic factors in the motivation of scientists concluding that most scientists were driven by their curiosity and motivation to do high-quality science but did not value external motivators. Ryan and Deci (2000, p. 69) affirmed that "motivation produces" and consequently individuals who seek environments where they can fulfill their psychological needs will be able to sustain the natural tendency to mastery, authentic interest, enjoyment, exploration, and assimilation. More recently, Vallerand et al. (2007) suggested that passion toward an activity can have a central effect on the development of a person's identity. Positive associations between harmonious passion and well-being, deliberate practice, persistence, and mastery goals have been found, whereas obsessive passion seems to be a mixed source of investment (Mageau et al., 2009; Vallerand et al., 2007). The relationship between the two types of passion and excellent performance is still ambiguous. It is suggested (Mageau et al., 2009; Vallerand et al., 2007) that harmonious passion is a flexible psychological state that can lead to high levels of performance enabling the individual to choose persisting in an activity that is productive but does not threaten the individual well-being. Motivational and emotional aspects have been widely acknowledged as key explanatory concepts of scientific excellence but its specific impact upon scientific performance at different stages of the scientific career has been less explored. Recent research into high abilities has focused mainly on young populations (e.g. Monteiro, Almeida, Vasconcelos, & Cruz, 2014; Stoeger, 2015) and despite the wealth of research (biographical, cross-sectional, longitudinal, and qualitative) into adult scientists' cognitive and non-cognitive characteristics, the investigation of scientists' perceptions of the role of motives and emotions to their performance still needs additional investigation.

With regard to personality, specific traits have been associated to scientific creativity and achievement, though its direct impact on the development of a successful career in science is unclear (Brown, Lent, Telander, & Tramayne, 2011; Feist, 2006a; Feist & Barron, 2003; Grosul & Feist, 2014). Findings on personality traits of scientists such as conscientiousness, openness to experience, extraversion and optimism, and its association with scientific motivation and creativity have been inconsistent (Feist & Barron, 2003; Lounsbury et al., 2012; Salgueira, Costa, Gonçalves, Magalhães, & Costa, 2012). For example, Lounsbury et al. (2012) concluded that scientists when compared with non-scientists scored significantly higher in openness, intrinsic motivation, and tough-mindedness but significantly lower in assertiveness, conscientiousness, emotional stability, extraversion, optimism, and visionary style. The same authors also concluded that the characteristics where scientists scored low (e.g. emotional stability, optimism, and extraversion) were associated to scientists' well-being and career satisfaction. In contrast, Salgueira et al. (2012) found that conscientiousness was predictive of engagement in scientific research while high extraversion had the opposite effect.

In the past decade, research has also established the fundamental role of effective management of emotional resources as well as anxiety and stress management strategies to develop optimal psychological states, well-being, and superior performance (e.g. John & Gross, 2004; Jones, 2012; Lazarus, 2000; Pekrun, Elliot, & Maier, 2006). In educational contexts, emotions have an impact on the development of cognitive flexibility and originality for decision-making, problem-solving, and adaptability to unexpected situations (Immordino-Yang & Damasio, 2007; Schutz, Hong, Cross, & Osbon, 2006). There is a regulatory, adaptive, and motivational function in basic emotions such as interest, joy, sadness, and fear (Izard, 2007). We may then infer that these are also fundamental skills for excelling in science. The study of emotions and emotional regulation in performance domains such as sports has been wealthy, but in science is still modest.

Recently, Simonton (2014, p. 67) stated that "the phenomenon of exceptional achievement is much too complicated to permit simplistic, one-sided explanations." Multiple and vague definitions as well as diverse criteria are used to identify excellent performers, especially in adulthood (Lounsbury et al., 2012; Shanteau, Weiss, Thomas, & Pounds, 2002), and not always considering the specific and differential requirements of a disciplinary field (Simonton, 1991, 2016). Performance criteria have been used to measure scientific excellence, including counting citations or number of publications, and these seem to be indeed predictive of career success. However, it is acknowledged that there are variations in scientists' outputs that lead to different scientists' impact (i.e. a scientist who is awarded a Nobel prize compared with a nationally renowned scientist) (Shanteau et al., 2002; Simonton, 2003; Wai, 2014). Therefore, care should be taken when performance criteria are used as "gold standards" in fields where absolute answers seldom exist and variety is a constant. Consequently, the psychological study of excellent scientists aiming to understand the processes leading to scientific impact, whether this is evaluated by productivity indicators, social recognition, or inspirational leadership, remains pertinent.

Qualitative methods have been widely chosen to investigate excellence in various domains, including science (e.g. Shavinina, 2009b; Sosniak, 2006; Wallace & Gruber, 1989; Yin, 2009). Investigating scientific excellence using a qualitative and comprehensive approach focusing on the individual's perceptions allows for capturing the complexity of the phenomenon (excellent performance) and the uniqueness of the individual (excellent scientist). As an example, we can ask: Were they the best students of their class? What influenced their choices? What distinguishes them from their peers? Which strategies do they use to sustain success? What is of utmost importance for them when committed to achieve excellence? Guided by these and additional questions on the psychological and social factors to achieve scientific excellence, the aim of this study is to describe the specific psychological characteristics and processes of developing excellence from the voice of outstanding scientists.

Materials and methods

Participants

Six of the most prominent Portuguese scientists were informed of the aims of the study and agreed to participate. Table 1 shows participants' background information. At the time of data collection, participants' ages ranged from 33 to 42 years old. All scientists worked as independent researchers, four of them at independent laboratories and two at Portuguese state university research centers as full-time professors. Nowadays, they are highly productive scientists and internationally renowned in different fields (e.g. molecular and cellular biology, physics, and medicine). Participants are identified throughout the text according to gender and order of the interview (e.g. SF1 = scientist female interview1; SM2 = scientist male interview2).

Participants were purposefully sampled by a nomination strategy (Shanteau et al., 2002). For the purpose of this study, early career prominent scientists in a stage of creative accomplishments and productivity were identified by a panel of senior expert scientists (Bloom, 1985; Simonton, 2003). In addition, quantitative indicators were also considered. These included age ranging from 30 to 45 years old, as literature suggests that peak performance in some scientific domains is reached between these ages; and productivity indicators such as having published a minimum of 10 publications on high-impact peer-reviewed and ISI-ranked journals, track record of highly cited papers, being members of major national and international editorial boards, and having received significant international funding for research projects (e.g. Feist, 2006b; Shanteau et al., 2002; Simonton, 1991).

Interview guide

Semi-structured interviews were carried out in order to explore in depth the individual factors in the pathways for excellence (Yin, 2009). An interview guide was especially designed for this study based on the analysis of protocols previously employed in studies

Table 1. Participants' background information.[a]

	Scientist 1 (SF1)	Scientist 2 (SM2)	Scientist 3 (SF3)	Scientist 4 (SM4)	Scientist 5 (SF5)	Scientist 6 (SM6)
Age	38	42	42	33	36	33
Gender	F	M	F	M	F	M
Area	Biology	Physics and chemistry	Medicine	Biochemistry	Biochemistry	Biochemistry
Age of starting independent research	28	31	33	28	29	27
Professional situation	Invited professor/res. fellow	Professor	Professor	Research fellow	Research fellow	Research fellow
Awards/grants	6	2	6	11	6	7
Internationally funded projects	5	7	8	–	6	12
Editorial boards/ referees	Yes	Yes	Yes	Yes	–	Yes
Peer-reviewed papers	>30	>70	>20	>20	>10	>20

Notes: SF1 = scientist female interview1; SM2 = scientist male interview2.
[a]Information gathered at the time of data collection (2008–2010).

with exceptional individuals (see Araújo, Cruz, & Almeida, 2010; Sosniak, 2006). The interview consisted of a semi-structured protocol exploring the following areas in a fluid and flexible sequence: (1) educational path; (2) past achievements and current performance; (3) expertise acquisition; (4) personality characteristics; (5) significant others; (6) social networks; and (7) relationships within professional community. For the purpose of this paper, only data resulting from the analysis of individual factors were considered.

In order to gain a deeper understanding of participants' responses, clarification and elaboration follow-ups were used during the interview allowing the interviewer to move the focus from the general to the specific and participants to expand on their answers (Seidman, 1998). After an introduction and briefing, participants were asked about their educational path as an introduction to the interview process. The final section concluded the interview and participants were asked for additional comments.

Data analysis

Interviews were audio and video recorded, transcribed verbatim, and then sent to participants for verification. Interviews lasted between 60 and 120 min. The material was coded and analyzed using a hybrid analysis strategy (Fereday & Muir-Cochrane, 2008; Mayring, 2000; Schilling, 2006). Computer software MAXQDA (2007) was used to assist qualitative content analysis as well as storing, managing, and presenting data.

In preparation for the coding process, a theoretically oriented protocol was created to guide the extraction of information from texts, to identify main themes associated with excellence, and to facilitate analysis within and between cases. This protocol was flexible enough to extract the most relevant information from texts inductively in order to explore in depth the meanings and experiences of the participants (Creswell, 2007; Yin, 2009). The content analysis process was assisted by a codebook that consisted of setting clear definitions of *meaningful unit of analysis* and their boundaries, main *dimensions,* and the rules for categorization. The codebook was then applied to a sample from the transcriptions by three independent researchers to test coding rules, code descriptions, and to clarify cases of doubt. Each *meaningful unit of analysis* (i.e. the comprehensive segments of the text that express one idea or episode) was assigned one or more codes in order to better understand the richness of the participant's statements, and grouped into categories and subcategories. As a formative check of consistency, the codebook was discussed within the research team until consensus on the categorization process and analysis was reached (Schilling, 2006). At the end of the coding task, codes were revised and the categorization system was discussed within the research team, and reorganized if necessary.

Validity procedures (Creswell, 2007; Schilling, 2006) were used to increase data legitimation, namely: data triangulation (using participants' curricula to check information from interviews), investigator triangulation (e.g. data analysis and interpretation was discussed with researchers with expertise in research methodology and expert performance research), and theory triangulation (converging theories of excellence and expert performance). Participants' reactions, commentaries, and objections were taken into account. We have also used peer debriefing as a form of trustworthiness throughout the data analysis by engaging in systematic discussions with expert researchers and an external independent reviewer. Prolonged engagement also contributed to a deeper understanding and a co-construction of meaning between the researcher and participants.

Results

Data are presented according to dimensions that emerged from interviews supported by examples from participants' discourse. Individual factors clustered three main dimensions: *personality characteristics*; *psychological skills and processes;* and *performance-specific strategies*. *Personality characteristics* described more structural characteristics of participants including personality traits and also cognitive abilities and life values. *Psychological skills and processes* described "how they do," strategies and abilities participants habitually employed in their daily work as well as in their personal life. It represents a significant part of the material. Finally, *performance-specific strategies dimension* described in more detail the strategies and abilities that were task-specific in order to understand in depth how participants perform when engaged in a particular task in their specific domain.

Personality characteristics

Perseverance and striving for perfection were highlighted as essential features for goal achievement. Participants assumed their own perfectionist tendencies by stating that "it is always possible to do better" and feeling frequently unsatisfied. Participants also showed concern for doing "more" but doing "well." For instance, one scientist (SM2) said: "I always want to improve myself. I've always had that characteristic of pushing my bottom line and striving for perfection." Participants' persistence and striving for perfection can be also exemplified by the following statement: "if you take responsibility for something, you can't relax while things are not finished and done in the right way; you need to ensure that everything is well on track" (SM6).

As highly perfectionist and performance goals-oriented individuals, participants revealed difficulty in "switching off." Abstaining from eating or sleeping to finish a task or solve a problem was described as a normal consequence of full involvement in the task.

Participants have also highlighted curiosity and openness to new experiences as key features in becoming a scientist: "Obviously, there must be a strong curiosity. Almost an obsession for all this…I don't know any excellent researcher without this" (SF1). Most participants recalled their need to expand and explore their scientific interest beyond what school had to offer them at and from early age. Many of them mentioned the importance of feeling fulfilled in different areas of their lives and the need to be exposed to a wide range of experiences related, as well as those not related, to scientific research (sports, arts, etc.).

The ability to plan ahead, to anticipate and prepare for different scenarios, to adapt accordingly, and to establish priorities were often described as key individual characteristics. Statements such as "I know I can't stay in this task forever so I have to be very organised" and "there will be always things that you somehow leave behind and you need to know how to deal with that" (SF3) show this ability to be organized and flexible. Often, participants were faced with unexpected situations where the ability to respond quickly and effectively was crucial.

Participants identified cognitive abilities, such as self-regulatory and metacognitive abilities as well as creativity, memory, and learning skills, as learning facilitators. Most participants mentioned that they haven't been necessarily the best students of their class but they were good learners and curious students. One participant mentioned that he was not the best student in his class "simply because [he] didn't study, I would rather play football and do programming than study at school" (SM2). In most cases, it was only at university during their postgraduate studies where they found the specific topics of their interest, a stimulating (and competing) peer environment, and developed more sophisticated learning strategies as well as new approaches to learning.

In terms of life values, a strong sense of social responsibility was present in all interviews; these scientists expressed their feelings of duty to contribute to a more sensible and knowledgeable society through their work. Participants felt that a way to "pay back" the investment that was being made on them was by doing exceptional research and also by engaging with the community.

In addition, the importance of seeking balance between professional and personal lives was also mentioned. Recognizing the amount of time and energy expended with work, family was seen a key factor for balance and regulation of their passion for work: "you should ensure that your work is not the only pillar of your existence" (SF5).

Psychological skills and processes

Three groups of themes emerged within this category: motivational, emotional, and task-commitment. Alongside with these components, participants described several individual characteristics that seem to interact dynamically and act as facilitators of successful achievements. Therefore, they will be described along each component when appropriate.

Motivational component

Categories concerning goal setting, motivational sources, full engagement with the task, and sacrifice were grouped into the motivational component. All participants stated the importance of setting clear, realistic but also ambitious goals in their daily lives. This was as specific and embedded into their routines as setting goals according to the multiplicity of daily requests and demands, distinguishing very clearly "what is urgent or a priority" (SF3). As mentioned above, perfectionistic strivings also seemed to prompt participants to set new challenges which enabled them to push themselves and further their limits. Participants showed persistence and full commitment to their goals even when facing sacrifices and difficult choices.

Successful outputs as well as social recognition sustained their motivation and were described as sources of external motivation. Participants were aware of their social responsibility and aspired to do better scientific research, a contribution they felt they needed to give to the development of science which would in turn nurture their own motivation to striving for excellence. As SM6 stated:

> There is a moment in the life of project that is realisation. This happens when you confirm your hypothesis, when you see your results published, when you see other people citing your work. This is what gives you encouragement to continue.

Inspirational peers and mentors were also mentioned as important motivational sources that sustained and nourished their persistence and focus in a task. One scientist described a very productive and successful phase of his career when he and his colleagues worked "perfectly together" (SM2), supported and motivated each other, which was crucial for their success.

In addition, social skills seemed to be essential to ensure a positive and stimulating atmosphere at work. Participants mentioned the importance of promoting and sustaining open communication, setting clear team and individual goals as well as delegating functions and sharing tasks as sources of encouragement and motivation. Social or interpersonal skills were seen as vital to achieve scientific success as it upheld international networking, the dissemination of results, and consequently impact the scientific community.

Emotional component

Emotions and emotional processes were consistently mentioned and most participants reported the emotional intensity in their devotion to work. Strong emotions were experienced in critical moments such as when papers or grants were either accepted or refused, and when other research groups had similar results published first. Critical moments were associated with emotions such as happiness, pride, anger, anxiety, shame, and sadness. As SM6 stated "doing research is a highly painful process." Participants were consensual on the role of passion as the most important motivational force and key factor to achieve excellence. Some of them added that they were "obsessed with the pleasure resulting from achieving goals and successful outputs" (SM2). Despite having moments of stress and anxiety as well as sacrifices and difficult choices to make, participants considered these moments as an inherent part of their job: "that will always happen so it is not a choice" (SF3). Participants recognized that doing scientific work was not just a painful process and acknowledged that: "this is not martyrdom; this is not just doing work: this is pleasure! This is pure delight!" (SM6). SM4 stated:

> Those who do research know that, in the total of the experiments we do, 90 or 95% of the time we will fail. Therefore, only on 5 or 10% of the time things will work and then we know we are on the right track and can move forward. Those 5% must be sufficient to motivate us to carry on.

Due to the intensity of emotional experiences, effective emotion regulation and coping strategies were essential. Having control over which emotions were felt, including when and how these were expressed, was often described as determinant for daily management of hurdles and challenges. Participants also mentioned their role in regulating others' emotional states as, for example, when a member of the team had a paper or grant rejected. Emotion-focused strategies such as controlling emotions, positive reappraisal and positive self-talk were described: "I try to keep calm, I try to not stress about it. I have to do it. I will be able to do it." (SF1). Problem-focused strategies included planning and increased effort such as in this example by SF5: "when something goes wrong, but also when something works fine, it is very important to reflect about it and to learn about the process. It is very important to learn with mistakes." Overall, proactive and flexible coping strategies were frequently employed and many efforts were undertaken in anticipation of certain events in order to cope with the expected demands and frustrations of scientific work. As in the words of SM4, "those who do science at the highest level must be prepared to cope with the demands and potential stressful events that will happen" adding that this is a necessary strategy and quality of those who want to be scientists.

Task-commitment component

Participants described intense commitment to their job, dedicating at least 10 h per day to their professional tasks. All participants often worked at home in the evenings and weekends, dedicating many extra hours of their daily schedule.

Organization skills and time management strategies such as setting clear goals, defining task priorities, and using evaluation and planning skills were described. In the absence of external deadlines, participants set their own deadlines. Self-regulating and time management skills allowed participants to maintain focus in a task and to ensure that goals were reached. As participant SMF3 stated, "I have to make good use of time. I organise my day very carefully. I define priority tasks. 'I will do this at this time'. If I don't have time available, I don't schedule anything more." Most participants mentioned the importance of being methodical and planning effectively in order to finish tasks ahead of time and prevent from having to deal with "last minute" tasks.

Scientific work was seen as extremely demanding but sacrifices were assumed as a natural and a necessary part of their commitment to work, many times bringing along personal and familiar constraints: "if additional time cannot be drawn to professional time, my choice is to take it out from personal time" (SF1).

Participants also described the importance of self-efficacy beliefs and self-regulation to deal with emotional states. Even when facing frustration and unsuccessful situations, they were able to re-evaluate their goals and the strategies used, and to implement new ones when necessary without questioning their ability to achieve. As SF3 stated, "there are moments where I think I will not be able … but that thought doesn't convince me or make feel better. You have to be confident about yourself."

Task performance-specific strategies

Most of the strategies in this section have already been described in the *psychological skills and processes* dimension showing that these skills were developed, assimilated, and applied at different moments to different tasks. Emotional components such as experienced emotions, emotion regulation, and coping were addressed. Anxiety, hope, happiness, and pride were some of the emotions described. Participants stated their satisfaction and passion while describing specific experiences of problem-solving or finishing a project. As one scientist stated (SF5): "I believe [that solving a problem] is similar to the moment when someone wins a competition. Something extraordinary happens and that is very much rewarding!" Stress and anxiety were also interpreted as a trigger to do more and better and often recognized as necessary and normal.

Setting clear goals and increasing effort were essential to keep focus on the task, to sustain motivation, and to control distractions. These strategies acted as regulators of the emotional intensity, combined with other coping strategies such as positive reappraisal of the situation and control of emotions to effectively adapt to the specificities of the situation.

Additional skills and strategies were described such as organizational and time management, metacognitive, and self-regulatory skills.

Discussion

This study explored the individual factors on achieving and sustaining excellence through the voices of a selected group of outstanding scientists. Within the personality characteristics dimension, participants highlighted several traits such as perseverance, adaptive perfectionism, curiosity, and openness to experience as ingredients for achieving excellence. Simonton (2003) stated that those who display an exceptional openness to experience from early childhood would probably reach adulthood with a richer and more diverse associative network. Recent research (e.g. Gaudreau & Verner-Filion, 2012; Stoeber, 2012) also suggested that self-oriented perfectionism, or self-induced high standards, is associated with positive processes and outcomes such as well-being, optimal performance, positive affect, autonomous motivation, and problem-focused coping. In addition, curiosity and nurturing specific interests from early ages seem to put individuals in regular contact with a stimulating collection of experiences. These multiple inputs can be related to a regular hierarchy of associations that results in unexpected associations and successful achievements.

Therefore, personality characteristics seem to play a role in stimulating the development of a scientific mind and extraordinary cognitive skills. Brown et al. (2011) have also shown that personality traits such as conscientiousness are linked to work performance and success through their interaction with self-efficacy and goal setting. Cognitive and self-regulatory strategies seem fundamental to sustaining task involvement, the selective organization of tasks, and accomplishment in science (Bandura, 2006; Simonton, 1991). While cognitive abilities and personality matter to achieve excellence, the experience and perceptions of scientists interviewed in this study showed a more dynamic and complex picture.

Immordino-Yang and Damasio (2007) pointed out that cognitive flexibility and originality for decision-making, problem-solving, and adaptability are mediated by emotional resources. So it is not surprising that passion and a vast range of emotions are extensively present in the discourse of participants. Some authors (Amabile, 2001; Mageau et al., 2009; Richie et al., 1997) have concluded that passion and pleasure toward work are important motivational sources and have an impact on time and energy endowment on tasks. In this study, passion enabled scientists to persist in the task whatever the sacrifices, exhaustion, and barriers faced, and also triggered adaptive coping strategies when these were necessary. Self-regulatory processes, cognitive, emotional, and behavioral, seem to negotiate the way scientists manage the setbacks and hurdles of the profession as well as the development of skills required to achieve excellence. As Bandura (2006, p. 176) stated, "a resilient sense of efficacy provides the necessary staying power in the torturous pursuit of innovations." However, how passion specifically works as a motivational source in achieving excellence in science still needs further clarification. Research has shown that both harmonious and obsessive passion are predictive of deliberate practice and lead to adoption of mastery goals that in turn leads to performance achievement (Vallerand et al., 2007). Findings on obsessive passion suggest that while it seems negatively associated to well-being and positive affect, its impact in performance may follow both positive and negative directions. Participants in this study described their passion to science as an "obsession," more as an autonomous and intrinsic valorization of their activity than controlled by compensatory factors. Participants' motivation is internally driven and even external social recognition is somehow internally regulated and attributed (Jindal-Snape & Snape, 2006; Mageau et al., 2009; Ryan & Deci, 2000). The study of emotions in several performance domains is emergent (e.g. Jones, 2012; Schutz et al., 2006; Stoeger, 2015; Mageau et al., 2009) but its relation with cognition and motivation, especially in scientific research, is still underestimated. Moreover, it is still uncertain how exactly positive and negative emotions are facilitative (or debilitative) to performance, especially in aspects such as decision-making, communication, and self-regulation behaviors.

Data also converge with previous findings (Ericsson et al., 2007) on the crucial role of expert knowledge as well as deliberate practice to achieve high-level performance. Research has shown that precocious involvement and commitment to a specific domain, sustained training, and deliberate practice, as well as supportive environments are contributing factors for successful careers in science (e.g. Ferriman-Robertson, Smeets, Lubinski, & Benbow, 2010; Mumford et al., 2005; Wai, 2014). Considering participants' characteristics and paths, we may conclude that they were able (and demanded) to acquire and develop an array of psychological skills (cognitive, motivational, and/or emotional) throughout their careers that allowed them to manage effectively the hurdles and challenges of performing in science at the highest levels.

Conclusion

Literature in scientific excellence has been focused either on defining excellence by measuring the excellence of scientific outputs or on explaining the origin of scientific talent by focusing on the role of intelligence and personality. However, the study of excellent scientists using comprehensive and qualitative methods to explore their own experiences, perceptions, and characteristics has shown a more complex profile. Findings from this study show that emotional and motivational processes are associated with and required to achieve scientific excellence. Further research is needed in order to gain a deeper understanding of how these emotional and motivational factors specifically develop and act at different stages of a scientist's career as well as its specific impact upon performing excellence in science (Immordino-Yang & Damasio, 2007; MacNamara, Button, & Collins, 2010a, 2010b; Kell et al., 2013). The development of scientific excellence is a multidimensional and complex process that results from the dynamic interaction of individual and social factors in a domain-specific context. The question persists of how talented students realize their full potential and became outstanding professionals in adulthood. These findings support the importance of nurturing and training psychological skills (e.g. emotion regulation, coping, and communication skills) in educational settings from early ages. Additional research on the study of emotional regulation and motivational qualities of successful scientists and its development through their educational path is required (e.g. John & Gross, 2004).

As a final point, a number of limitations need to be considered. The descriptive, exploratory, and non-generalizable nature of this study confines the conclusions to a number of reflections that will hopefully inform further research. Yet, we believe that our methodological choices met the main questions asked in this study. These results provide significant ideas for future research but care is needed in dissemination and generalization. Comparisons with other groups of scientists at different career stages (students, early career researchers, and senior researchers) and in different scientific areas (STEM, social sciences, and life sciences) can be explored in future research to determine the specific impact of emotional and motivational factors upon the development of excellence in laboratory settings. Finally, we acknowledge the need of further refinements on the interview guide as well as the design and implementation of prospective and longitudinal studies to further explore these findings. The broad range of topics that emerged, although allowing for a comprehensive picture of scientists' profiles and career pathways to achieve excellence, limited the thorough examination of specific topics. Studies looking at, for example, the role of emotions and emotional regulation in the laboratory setting, the interaction between emotion regulation, coping strategies, and perceived career success and satisfaction, and the mechanisms to nourishing motivation through the stormy journey of a scientific career would shed light on the emotional and motivational profiles of successful scientists. Investigating the specific psychological skills and processes scientists develop and use at different career stages, as well as the commonalities and differences when compared with other performers will then create new knowledge of the impact of these profiles on sustained excellence and career satisfaction in scientific performance.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This study was conducted at the Psychology Research Centre, University of Minho, and supported by the Portuguese Foundation for Science and Technology and the Portuguese Ministery of Education and Science through the National Strategic Reference Framework (QREN-POPH/FSE grant number SFRH/BD/30667/2006).

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