Journal of Workplace Learning

The role of natural abilities, intrinsic characteristics, and extrinsic conditions in air traffic controllers' vocational development

Laura Pylväs Petri Nokelainen Hilkka Roisko

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Laura Pylväs, Petri Nokelainen and Hilkka Roisko
School of Education, University of Tampere, Tampere, Finland

Received 23 July 2013
Revised 26 June 2014
22 August 2014
Accepted 1 September 2014

Abstract

Purpose – The purpose of this paper is to apply the Developmental Model of Vocational Excellence (DMVE) in the domain of air traffic control and to describe the characteristics and predictors related to air traffic controllers' (ATCO) vocational expertise and excellence. Based on DMVE, the study analyses the role of natural abilities (gifts), intrinsic characteristics (self-regulatory abilities) and extrinsic conditions (domain and non-domain specific factors) in ATCOs' vocational development.

Design/methodology/approach – The target population of the multiple case study consisted of ATCOs in Finland ($N = 300$), of which 28 were interviewed. The interviewees represented four different airports. Initially, three key personnel interviews were conducted to validate the structured theme interview instrument that was subsequently used for the 28 interviews. The data set also included the ATCOs' aptitude test scores and training records. Employee assessments were used to determine their on-the-job performance level (expertise vs excellence). The research questions were examined using theoretical concept analysis. The qualitative data analysis was conducted with content analysis and Bayesian classification modelling.

Findings – The findings indicate that cognitive skills, self-reflection, volition and goal-orientation are considered to be ATCOs' most important vocational characteristics in addition to interpersonal, intrapersonal and spatial skills. The main differences between the ATCOs representing vocational expertise and those representing vocational excellence were related to self-regulation; motivation and volition in particular proved to be somewhat stronger in the latter group.

Research limitations/implications – It was acknowledged that there are limitations in the present study. First, the four airports were not selected randomly. Although they represent different types of airports (and ATCO job profiles) in Finland quite well, future studies should include comparative aspect to airports in other countries. Second, the number of participants ($N = 28$) in the study was quite small, limiting generalization of the results to the target population ($N = 300$). Future research on this domain should be extended to include also quantitative measurements, allowing more generalizable results. Third, although the analysis for the research question 3 was based on a technique that is not sensitive to missing values (BCM), missing data in ATCOs' aptitude test scores, training records and employee assessments added uncertainty to the results.

Practical implications – ATCOs' highly controlled and pre-defined work presents a challenge to work motivation, which is seen as one of the determining factors in safety in air traffic controlling (ATC). In the future, more emphasis should be placed on the prerequisites of professional development such as leadership (human resource management, feedback, employees' opportunity to influence),

The study was supported by a research grant from the Finnish Funding Agency for Technology and Innovation.

Journal of Workplace Learning
Vol. 27 No. 3, 2015
pp. 241-263

1366-5626
DOI 10.1108/JWL-07-2013-0049

working environment (physical and social environment), educational possibilities and career progression, as well as professional benefits (salary and working hours).

Originality/value – Although ATC is a fairly studied topic since 1970s, most studies related to ATCOs have concentrated on training, learning on the job, cognitive capacity and processing and stress tolerance. This study extends the emerging research in the field on self-regulation by adopting DMVE to investigate its role, alongside natural abilities and domain and non-domain specific factors, to vocational talent development in different skill acquisition stages.

Keywords Self-regulation, Vocational training, Air traffic controller, Multiple intelligences theory, Vocational excellence, Vocational expertise

Paper type Research paper

Introduction

Air traffic has been steadily increasing during the past decades[1]. The thousands of flights that are made every day around the world are stretching the capacity of airports and making air traffic an increasingly complex system to manage. Air traffic controllers' (ATCO) work covers air traffic control, air traffic advice, flight information and emergency procedures with the aim of expediting air transport and maintaining aviation discipline (Costa, 1995). They simultaneously control aircraft taking off and landing and make observations of the work environment with the help of various kinds of information technology equipment (Finavia, 2013).

Changes in air traffic controlling (ATC) are setting new expectations for ATCOs' life-long learning and emphasizing a need for research into human factors. Even if the ATC system relies more and more on automation, human factors have an essential role in maintaining the efficiency and safety of air traffic control (Jha *et al.*, 2011). Several characteristics cause complexity, uncertainty and dynamicity, making the work vulnerable to human error (Ryymin *et al.*, 2011; Teperi, 2012).

First, it is vital that individual controllers are not subjected to physical or mental overload due to high traffic density and complexity (Kirwan, 2001). They need to constantly change specified and regulated operating methods to maintain high safety standards and minimize economic costs of aeronautical activities. Second, researchers have found that the automation of work generally requires multivalent planning ability, understanding of complex situations and problem-solving skills (Costa, 1995). In addition, as a result of automation, monotonous and strictly formalized and standardized work models have become more common, which highlights the importance of self-regulation, motivation and meaningfulness of work (Ruohotie, 1994; Wickens *et al.*, 1997).

The purpose of this study is to apply the Developmental Model of Vocational Excellence (DMVE, Nokelainen *et al.*, 2013; Nokelainen, 2014) in the domain of ATC and to describe the characteristics and predictors related to ATCOs vocational expertise and excellence. More specifically, the study analyses the role of natural abilities (gifts), intrinsic characteristics (self-regulatory abilities) and extrinsic conditions (domain and non-domain specific factors) in ATCOs' vocational development. The model is empirically tested with an interview data collected from 28 Finnish ATCOs and analyzed with both content analysis and Bayesian methods.

This study extends earlier research into vocational excellence (Korpelainen *et al.*, 2009; Nokelainen *et al.*, 2009; Nokelainen, 2010, 2014) by giving an insight into the acquisition of vocational excellence in highly skilled and safety-critical vocations. This

study relates to the emerging research on self-regulation in ATC (Yeo and Neal, 2008; Yeo *et al.*, 2009) by investigating of the role of intrinsic characteristics (self-regulation) to vocational talent development. It is also related to earlier research and discussion of ATCOs' tasks, qualifications and professional identity (Ackerman *et al.*, 1995; Hopkin, 1995; Wickens *et al.*, 1997; Palukka, 2003) by adopting a new theoretical framework for analyzing the role of gifts (natural abilities), intrinsic characteristics (self-regulatory abilities) and extrinsic conditions (domain and non-domain specific factors) in ATCOs' vocational development. By focusing on these factors during different skill acquisition stages, this study bridges gaps in the existing literature and provides new information on human factors in ATC.

We further investigate if these factors are related to ATCOs on-the-job performance. In this study, the work-related performance has two levels: "expertise" and "excellence". Due to highly selective entrance tests (Wickens *et al.*, 1997), all operative ATCOs are considered experts in their vocational field[2]. However, as stated earlier, it is important to recognize factors that are related to ATCOs professional growth and ability to work throughout their career. Individuals who have performed exceptionally well over a long period of time represent vocational excellence in this study. Participants of this study were classified into these two categories by a panel of experienced operative superiors.

To address the research goal, the following research questions were formulated:

RQ1. What characteristics and environmental factors determine air traffic controllers' initial interest in this field of work, their perseverance in acquiring a vocational skill, and their mastery of the skill?

RQ2. What are the differences in characteristics between the air traffic controllers representing vocational expertise and those representing vocational excellence?

RQ3. Does air traffic controllers' performance during training or in the entrance examination predict vocational excellence in working life?

This paper begins with introducing the theoretical framework consisting of the components related to vocational talent development. The next section describes the methods of the study, and is followed by the results of the interview data analysis. Finally, the results and their theoretical and practical implications are discussed.

Theoretical framework

Gagné's (2004, 2010) Differentiated Model of Giftedness and Talent (DMGT) distinguish the two usually intertwined concepts of giftedness and talent. The DMGT contains six components:

(1) chance (e.g. genes);

(2) gifts (natural abilities: intellectual, creative, socio-affective and sensori-motorical);

(3) intrapersonal characteristics (motivation, volition, self-management, personality);

(4) environmental conditions (milieu, important persons, events);

(5) developmental process (informal and formal learning and practicing); and

(6) talents (systematically developed skills).

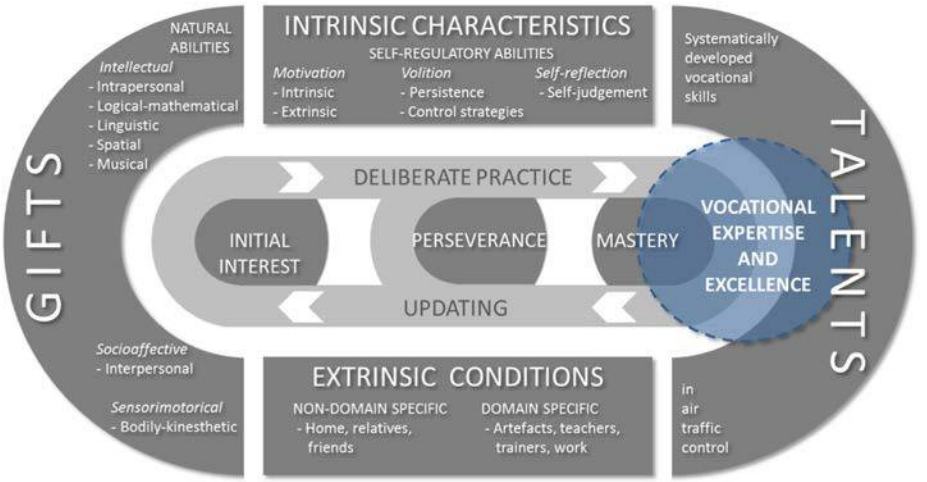
Nokelainen and his colleagues have studied professional excellence in the context of mathematics (Finnish and US Academic Olympiad teams, see, Nokelainen *et al.*, 2007; Nokelainen and Tirri, 2010) and vocational excellence in the context of World Skills Competitions (Finnish, UK and Australian teams, see, e.g. Nokelainen, 2014, 2010; Nokelainen *et al.*, 2009, 2012, 2013; Ruohotie *et al.*, 2008). Based on Gagné's DMGT, the Developmental Model of Vocational Excellence (DMVE, Nokelainen, 2014) illustrates the process of developing natural abilities (gifts) into vocational and professional skills (talents). Intrinsic characteristics (self-regulation) and extrinsic conditions (domain and non-domain related factors) help or hinder this process, which requires learning (and constantly updating) the skills through deliberate practice.

The model in Figure 1 has been constructed on the basis of DMVE. It illustrates the theoretical framework applied in this study to analyze ATCOs vocational excellence.

Natural abilities

In this study, we use Gardner's (1983, 1993, 1999) Multiple Intelligence (MI) theory to investigate the natural abilities (gifts) component of the model of vocational excellence (Figure 1). We apply the original seven-dimension version of the MI theory:

(1) linguistic;
(2) logical – mathematical;
(3) musical;
(4) spatial;
(5) bodily-kinesthetic;
(6) interpersonal intelligence; and
(7) intrapersonal intelligence.



Source: Nokelainen (2014)

Figure 1.
Vocational excellence in air traffic control

This domain-specific model of intelligence has been criticized to underestimate the role of general processes (intelligence as a general construct, e.g. Cattell, 1963) in intellectual development (Demetriou and Kazi, 2006). However, based on an overarching theory of cognitive organization and development, Demetriou *et al.* (2011) state that intelligence has both of these natures. Domain-specific intelligence is, indeed, present in one component of their theory, namely, "special structural systems" that "constitute a set of mental processes that interface with several environmental domains" (p. 603). This is also in line with the holistic approach of DMGT (Gagné, 2004, 2010) to exceptional talent development.

Intrinsic characteristics

In this study, we have applied Zimmerman's model of self-regulation to investigate the intrinsic characteristics component of the model of vocational excellence (Figure 1). The term "self-regulation" refers to the process by which self-generated thoughts, feelings and actions are planned and systematically adapted as necessary to affect one's learning and motivation (Schunk and Ertmer, 2000; Zimmerman, 2000). Research has shown that successful learners can monitor and regulate these triadic elements: volition, motivation and self-reflection (Kitsantas and Zimmerman, 2002; Zimmerman, 1989, 1998; Zimmerman and Kitsantas, 2005). Similarly, Demetriou *et al.* (2011) see self-regulation as an essential component of the consciousness system in their integrated model of the architecture and development of the mind.

Motivational processes help the learner formulate decisions and promote decision-making, whereas volitional processes guide the subsequent enactment of the decision (Corno, 1989). According to Ruohotie (2005), it is especially intrinsic goal orientations (emphasizing competence development) that are connected to vocational excellence. Volition includes persistence, the will to learn, endeavor/effort, mindfulness in learning and intrinsic regulation and evaluation processes, as well as various control strategies (e.g. allocation and control of resources, as well as emotional attentiveness and motivational control strategies) and methods of processing knowledge. In the research examining ATCOs' work, sustained attention has been termed "vigilance". An expanded view of vigilance refers to detection, discrimination and diagnosis of unusual conditions, as well as speed of response (Wickens *et al.*, 1997).

According to Bandura (1986), processes of self-reflection make it possible for individuals to evaluate their experiences and thought processes. Self-reflection is congruent with intrapersonal skills describing, one's understanding and reflecting of one's own skills, capacities and feelings. Self-reflection leads to attribution interpretations, whereby an individual interprets the reasons for success or failure. According to Weiner (1974), individuals are constantly searching for understanding of why an event has occurred. The learner may interpret the failure of a strategy as the result of too little effort (control beliefs) and then increase his or her subsequent efforts. He or she may also attribute the failure to a lack of ability (efficacy beliefs) when the reaction will most likely be negative in sense of increasing efforts. However, both attribution interpretations (control and efficacy beliefs) can lead to both positive and negative self-reactions, as they are under one's own control. An increase in the sense of control strengthens one's tolerance of stress and commitment to the task and helps the learner to identify the best learning strategies in a given situation (Zimmerman, 1998; Zimmerman and Kitsantas, 1997). Positive reactions fortify intrinsic goal-orientation

and positive interpretations of oneself as an employee, such as beliefs in one's own competencies and opportunities (Nokelainen *et al.*, 2007).

Extrinsic conditions

The third component in the model involves external factors related to the development of vocational talent (Figure 1). First section consists of domain-specific individuals (colleagues, trainers, superiors, etc.) and factors (artifacts, expectations related to career, etc.) that are directly related to the development of talent. The second section consists of individuals (parents, other relatives, neighbors, fellow students, etc.) and factors (media, books, films, music, etc.) that are indirectly related to the development of vocational talent (Greenspan *et al.*, 2004; Nokelainen, 2014). Based on Connell *et al.* (2004), we analyze the operation of these factors through intrinsic and extrinsic motivation.

Earlier research has shown that the role of both teachers and trainers is important in all of the early stages of vocational development (initial interest, training, mastery). Intrinsic goal orientation proved to be more important than extrinsic goal orientation in the development of interest in a vocational field and mastery of the skill. During the training, extrinsic goal orientation was reportedly more important than intrinsic goal orientation. Greenspan *et al.* (2004) have reported similar findings in their studies of the arts. The results also showed that when the mastery level was achieved, securing future employment and challenging job opportunities becomes one of the most essential factors. (Nokelainen, 2014).

Deliberate practice

According to a social–cognitive view of self-regulation, expertise develops from both external support and self-directed practice sessions (Zimmerman, 2006). Both of these factors are essential for exceptional talent development (Bloom, 1985). In social – cultural theories of workplace training, learning is becoming a process located in the framework of participation rather than inside the learner (Hager, 2013). According to Mezirow (1995), learners must become critical of their own assumptions to transform their frame of reference. Critical reflection on their own experiences leads to a perspective transformation through communicative learning, emphasizing the importance of dialogue with others. However, even if collective learning is starting to receive significant attention, it is not replacing notions of individual learning (Hager, 2013).

As shown in Figure 1, deliberate practice is essential in different skill acquisition stages; in most fields, it takes 10 years to become an expert (Ericsson *et al.*, 1993). Later research has shown that the 10-year rule is not absolute: in some fields (e.g. chess, sport), total mastery of the skill takes about six years, and in others (e.g. music, science), to reach the top level, it takes 20-30 years of deliberate practice (Ericsson, 2006). Ericsson's relative approach to the study of experts' characteristics assumes that the fundamental capacities and domain-general reasoning abilities of experts and non-experts are almost identical. The major difference between experts and novices is that the former are more knowledgeable, through deliberate practice, than the latter. (Chi, 2006.) The model applied in this study is based on a different approach: the goal of an absolute approach is to understand how truly exceptional people perform in their domain of expertise (Chi, 2006).

Vocational expertise and excellence

Gifted individuals with an exceptionally high level of natural abilities (intellectual, creative, socioaffective, sensori-motorical), intrinsic characteristics (self-regulation and personality) and auspicious extrinsic conditions (physical, cultural and sociological milieu, important individuals, activities, accidents) may reach the level of vocational excellence through deliberate practice (Nokelainen, 2014). Individuals who do not meet all of these conditions may still become competent professionals (vocational expertise) through deliberate practice. Competence refers to individual's potential capacity to deal with job-related situations and tasks according to certain formal or informal criteria set by someone else (Ellström, 1997). Following this, qualification is seen as a competence that is required by the work and implicitly or explicitly determined by individual qualities (Ellström, 2001). Mulder (2011) has defined trichotomy of approaches of the concept of competence:

- competence and behavioristic functionalism;
- competence as integrated occupationalism; and
- competence as situated professionalism.

The third approach refers to professional associations (e.g. pilot associations) and local actors' (e.g. airline executives) influence "on the desired competence fields and the extent to which the professionals need to be proficient in these fields" (Mulder, 2015). In this study, a panel of experienced operative superiors assigned participants into "expertise" and "excellence" groups on the basis of each individual's on-the-job performance.

Methods

Design

The target population of the study consisted of air traffic controllers (ATCO, $n = 300$) who work in 27 airports in Finland. To understand the qualifications and skills required of ATCOs on the job, we began the study in 2011 by interviewing three persons (manager, air traffic controller and trainer, human resource specialist) who had more than 10-years' work experience in the field. Duration of these interviews varied from 60 to 90 minutes. We then proceed to develop a semi-structured interview instrument on the basis of these key personnel interviews and existing research.

The interviews of 28 ATCOs were conducted in 2011 in four Finnish airports and included interviewees from provinces ($n = 7$, 25.0 per cent) and cities ($n = 21$, 75.0 per cent). The work tasks differ between the one- or two-person air traffic control units in the provinces and the units comprising several employees and posts found in the larger cities. These airports were selected to represent different types of airports (and ATCO job profiles) in Finland. The selection of interviewees within the target units was random, as the participation in interview sessions was based on their pre-determined work shifts. The research data also included the interviewees' aptitude test scores and training records.

Relating to the *RQ2*, the division between ATCOs performing at the level of expertise ($n = 9$, 32.1 per cent) and excellence ($n = 17$, 60.7 per cent) was made by a panel of experienced operative superiors. The classification was made on the basis of ATCOs on-the-job performance. As all operative air traffic controllers have high level of knowledge and expertise (Costa, 1995), the panel used the following criteria to judge the merits of the participants:

- safe working (low number of critical incident reports);
- effective air traffic control (aim at the maximum capacity);
- overall perception of air traffic services;
- understanding the guidelines and regulations; and
- self-initiative and commitment.

This job performance-related information (missing $n = 2$, 7.1 per cent) was concealed from the researchers until the content analysis of the interview data was completed.

Participants

The participants of the study included 28 ATCOs, of which eight were females (28.6 per cent) and 20 were males (71.4 per cent). Their age average was 37.9 years ($SD = 38.0$). Participants were interviewed with a semi-structured interview instrument. Duration of interviews was from 50 to 90 minutes.

Most of the interviewees ($n = 25$, 89.3 per cent) had been at least six years in air traffic controlling. Half of the interviewees ($n = 14$, 50.0 per cent) had another professional qualification and all of the interviewees ($n = 28$, 100.0 per cent) had earlier work experience from another professional field. A little more than half of the group had been familiar with aviation before undergoing ATCO training, having experience of private piloting ($n = 6$, 21.4 per cent) or military aircraft ($n = 9$, 32.1 per cent). After graduating from ATCO training, most of the interviewees ($n = 22$, 78.6 per cent) were placed in provincial airports. The minority ($n = 6$, 21.4 per cent) was placed in a larger city, Helsinki-Vantaa Airport (usually based on exceptional training performance).

Instrument

The semi-structured interview was based on the significance of self-regulation and cognitive and social features in vocational talent development (Greenspan *et al.*, 2004; Nokelainen, 2008; Zimmerman, 1998). It contained two sections:

(1) characteristics (self-regulation and natural abilities; see Table I for details); and

(2) vocational talent development (initial interest, perseverance and mastery; see Table II for details).

Analyses

The research questions were examined using theoretical concept analysis. The qualitative interview data analysis took the form of quantitative and qualitative content analysis (*RQ1* and *RQ2*) of the textual empirical data using a sophisticated analysis tool, NVivo. The content analysis of the data is highly systematic (Schreier, 2014). As the framework of the analysis in this study is based on the existing theory, directed (or deductive) content analysis approach was used (Hsieh and Shannon, 2005). The empirical data were examined and categorized according to the theoretical concepts related to the theoretical models used in the study (Tuomi and Sarajärvi, 2002). Unit of analysis, a meaningful piece of text in the interview transcript (e.g. "The most important thing is to stay motivated. To be good or even better than before.") was assigned a code relating to a theoretical concept (e.g. "intrinsic goal orientation"). Frequency counts (n_c) of codes for each theoretical concept are presented in Tables I and II. Qualitative content analysis was applied to examine latent and more context-dependent meanings

Initial interest in the work field	
Aviation and ATCO's profession	(n_c = 19, 26.0%)
Family	(n_c = 14, 19.2%)
Suitable background	(n_c = 11, 15.1%)
Career change	(n_c = 10, 13.7%)
Professional benefits	(n_c = 7, 9.6%)
Access to working life	(n_c = 6, 8.2%)
Friends	(n_c = 5, 6.8%)
Curriculum	(n_c = 1, 1.4%)
Total	(n_c = 73, 100.0%)
Perseverance in acquiring a vocational skill	
Volition and motivation	(n_c = 30, 26.8%)
Curriculum and teaching	(n_c = 16, 14.3%)
Training performance	(n_c = 12, 10.7%)
Social environment	(n_c = 12, 10.7%)
Ambition	(n_c = 12, 10.7%)
Competition	(n_c = 9, 8.0%)
Confidence in skills	(n_c = 8, 7.1%)
Access to working life	(n_c = 5, 4.5%)
External expectations	(n_c = 5, 4.5%)
Earlier experiences	(n_c = 3, 2.7%)
Total	(n_c = 112, 100.0%)
Perseverance in acquiring mastery of the skill	
Leadership and personnel policy	(n_c = 37, 19.8%)
Working tasks and aviation	(n_c = 23, 12.3%)
Working environment	(n_c = 23, 12.3%)
Professional responsibility	(n_c = 21, 11.2%)
Workplace training and professional development	(n_c = 19, 10.2%)
Ambition	(n_c = 14, 7.5%)
Possibility to influence	(n_c = 13, 7.0%)
Professional benefits	(n_c = 11, 5.9%)
Career progression	(n_c = 9, 4.8%)
Social environment	(n_c = 9, 4.8%)
Skilled co-workers	(n_c = 8, 4.3%)
Total	(n_c = 187, 100.0%)

Note: n_c = Frequency counts of codes in the interview data

Table I. Characteristics and environmental factors determining air traffic controllers' initial interest in this field of work, their perseverance in acquiring a vocational skill and their mastery of the skill

(Schreier, 2014). The meaningful pieces of the interviews were analyzed in the context of their use and thematic criterion was utilized for segmentation (see quotations). The qualitative content analyses provided more descriptive examination of the data (Krippendorff, 2004; Schreier, 2014.)

In addition to theoretical concept analysis, Bayesian methods (Bernardo and Smith, 2000) were applied in this study as they work robustly with small samples and allow the use of nominal indicators (textual or numerical data) and prediction with the model derived from the empirical evidence (Nokelainen, 2008; Nokelainen and Silander, 2014). A specific technique, Bayesian Classification Modeling (BCM, see Nokelainen, 2008), was used to select the most probable predictors of vocational

Table II.
Vocational characteristics of the air traffic controllers representing vocational expertise and those representing vocational excellence

Characteristics	Employees representing vocational expertise (n = 9, 32.1%)	Employees representing vocational excellence (n = 17, 60.7%)	All interviewees (n = 28, 100%)
Self-regulatory abilities			
Intrinsic goal-orientation	(n_c = 14, 13.2%)	(n_c = 29, 15.4%)	(n_c = 48, 15.1%)
Extrinsic goal-orientation	(n_c = 15, 14.2%)	(n_c = 24, 12.8%)	(n_c = 44, 13.8%)
Volition	(n_c = 16, 15.1%)	(n_c = 28, 14.9%)	(n_c = 46, 14.5%)
Control beliefs	(n_c = 6, 5.7%)	(n_c = 16, 8.5%)	(n_c = 24, 7.5%)
Efficacy beliefs	(n_c = 4, 3.8%)	(n_c = 4, 2.1%)	(n_c = 8, 2.5%)
Natural abilities			
Linguistic	(n_c = 5, 4.7%)	(n_c = 2, 1.1%)	(n_c = 7, 2.2%)
Cognitive	(n_c = 22, 20.8%)	(n_c = 41, 21.8%)	(n_c = 67, 21.1%)
Spatial	(n_c = 3, 2.8%)	(n_c = 11, 5.9%)	(n_c = 15, 4.7%)
Intrapersonal	(n_c = 11, 10.4%)	(n_c = 15, 8.0%)	(n_c = 29, 9.1%)
Musical	(n_c = 0, 0.0%)	(n_c = 3, 1.6%)	(n_c = 3, 0.9%)
Bodily-kinesthetic	(n_c = 1, 0.9%)	(n_c = 1, 0.5%)	(n_c = 2, 0.6%)
Interpersonal	(n_c = 9, 8.5%)	(n_c = 14, 7.4%)	(n_c = 25, 7.9%)
Total	(n_c = 106, 100.0%)	(n_c = 188, 100.0%)	(n_c = 318, 100.0%)

Note: n_c = Frequency counts of codes in the interview data

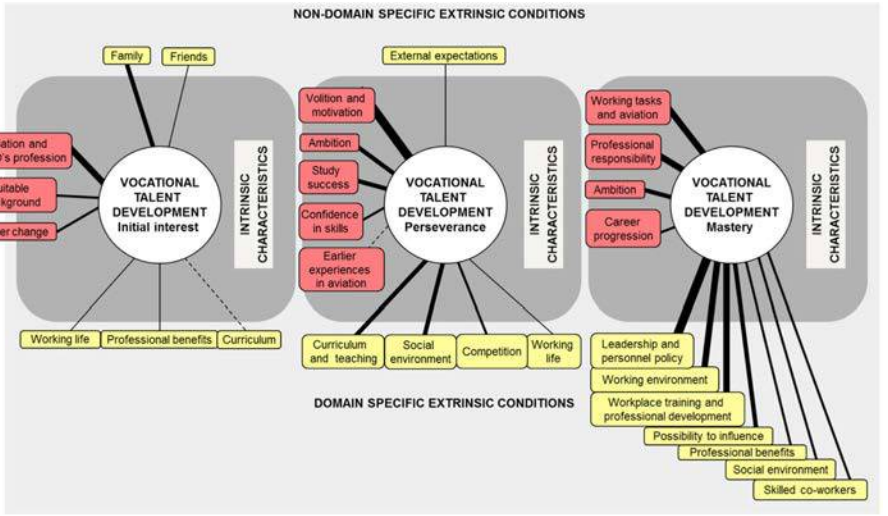
excellence (*RQ2* and *RQ3*), and to increase the research validity of qualitative methods in a confirmatory way.

The input data matrix for BCM contained the following variables: 12 characteristics (such as "intrinsic goal orientation", "volition" and "control beliefs"; see Table II), "job performance", "entrance examination success" and "study success". The numerical values for the 12 characteristics variables were based on the code frequencies from preceding theoretical concept analysis. For instance, if John had mentioned "intrinsic goal orientation"-related information three times during the interview, his value (code frequency) for that variable would be 3. "Job performance" variable had two textual values assigned by an external panel ("expertise" and "excellence"). "Entrance examination success" variable had also two values based on final ranking in the tests ("good" = others and "excellent" = top 40 per cent). "Study success" variable represents overall study success during ATCO training (5 = excellent, 1 = poor). BCM was used to search with a data mining approach for a model that contains the most probable predictors (*RQ2*: 12 characteristics variables; *RQ3*: "entrance examination success" and "study success" variables) for the class variable (*RQ2* and *RQ3*: "job performance"). The classification accuracy of the model is provided and compared to the baseline classification accuracy (i.e. classifying the cases without the model). All computations were performed with the B-Course computer program (Myllymäki *et al.*, 2002).

Results

RQ1. What characteristics and environmental factors determine air traffic controllers' initial interest in this field of work, their perseverance in acquiring a vocational skill, and their mastery of the skill?

The interviewees' strongest motivation (Figure 2 and Table I) to apply for ATCO training was their interest in aviation and the profession of ATCO (n_c = 19, 26.0 per



Notes: The line width represents the significance of each characteristic; the wider the line, the more significant the interviewees considered the characteristic in question

Figure 2.
Characteristics and environmental factors determining air traffic controllers' initial interest in this field of work, their perseverance in acquiring a vocational skill and their mastery of the skill

cent). Most of the interviewees had some earlier connections to aviation in their family background (n_c = 14, 19.2 per cent) or peer group (n_c = 5, 6.8 per cent). About a third of the interviewees also mentioned having a suitable background (n_c = 11, 15.1 per cent) for ATCO work, such as experience of military training or air force or private piloting, and one-fourth of the interviewees were interested in ATCOs' professional benefits (n_c = 7, 9.6 per cent) such as salary, working hours, professional status and work stability. The potential for crossover into a new career (n_c = 10, 13.7 per cent), the general employment situation, such as the recession and unemployment situation (n_c = 6, 8.2 per cent), as well as the concise curriculum (n_c = 1, 1.4 per cent), were also brought up as motivational factors for applying for ATCO training.

According to the interviewees, ATCO training requires volition and motivation (n_c = 30, 26.8 per cent) to maintain perseverance in studying (Table I). The challenges are mostly faced during the theoretical part of the studies. A lot of detailed information has to be learned in a short time without a real contact into practice. Hence, earlier experiences of aviation simplify the learning process. On the other hand, the intensive and time-limited study schedule is also seen as practical and well organized and therefore simple to follow. The role of the teachers, with their expertise, enthusiasm and learning acumen is acknowledged in motivating and supporting students (curriculum and teaching, n_c = 16, 14.3 per cent). The supportive social atmosphere (n_c = 12, 10.7 per cent), training performance (n_c = 12, 10.7 per cent), ambition (n_c = 12, 10.7 per cent), positively orientated competition (n_c = 9, 8.0 per cent), confidence in one's own skills (n_c = 8, 7.1 per cent), access to working life (n_c = 5, 4.5 per cent) and external expectations (n_c = 5, 4.5 per cent), as well as previous experience and desire for a career change (n_c = 3, 2.7 per cent), also affected perseverance during the training period.

In working life, encouragement, fair leadership and workable personnel policy (n_c = 37, 19.8 per cent) played a significant role in supporting the ATCOs' commitment to work (Table I). Effective human resource management was considered to be one of the critical aspects of leadership; sufficient human resources (workload, quality assurance, etc.) were seen as an important factor in ensuring well-being at work.

Leaders are expected to be aware of ATCOs' everyday work to comprehensively benefit from their expertise.

The most important factors strengthening perseverance in mastering a skill in ATCOs' working life are interesting, challenging and varied work tasks along with a continuing interest in aviation (n_c = 23, 12.3 per cent), as well as an efficient work environment (n_c = 23, 12.3 per cent) (Table I). The optimal working environment consists of reliable equipment and technology, adequate working space, good ergonomics and a sufficient infrastructure at the airport. The interviewees also underlined their professional responsibility and commitment to meeting safety and client service expectations (n_c = 21, 11.2 per cent) and their personal ambition and will to succeed (n_c = 14, 7.5 per cent). A motivating work includes workplace training and educational opportunities (n_c = 19, 10.2 per cent) that encourage employees to independently develop their competencies. The opportunity to influence one's own working tasks and organizational development (n_c = 13, 7.0 per cent), professional benefits such as salary and working hours (n_c = 11, 5.9 per cent), career progression (n_c = 9, 4.8 per cent), social environment (n_c = 9, 4.8 per cent) and skilled co-workers (n_c = 8, 4.3 per cent) were also considered meaningful environmental factors for well-being, commitment, and motivation at work.

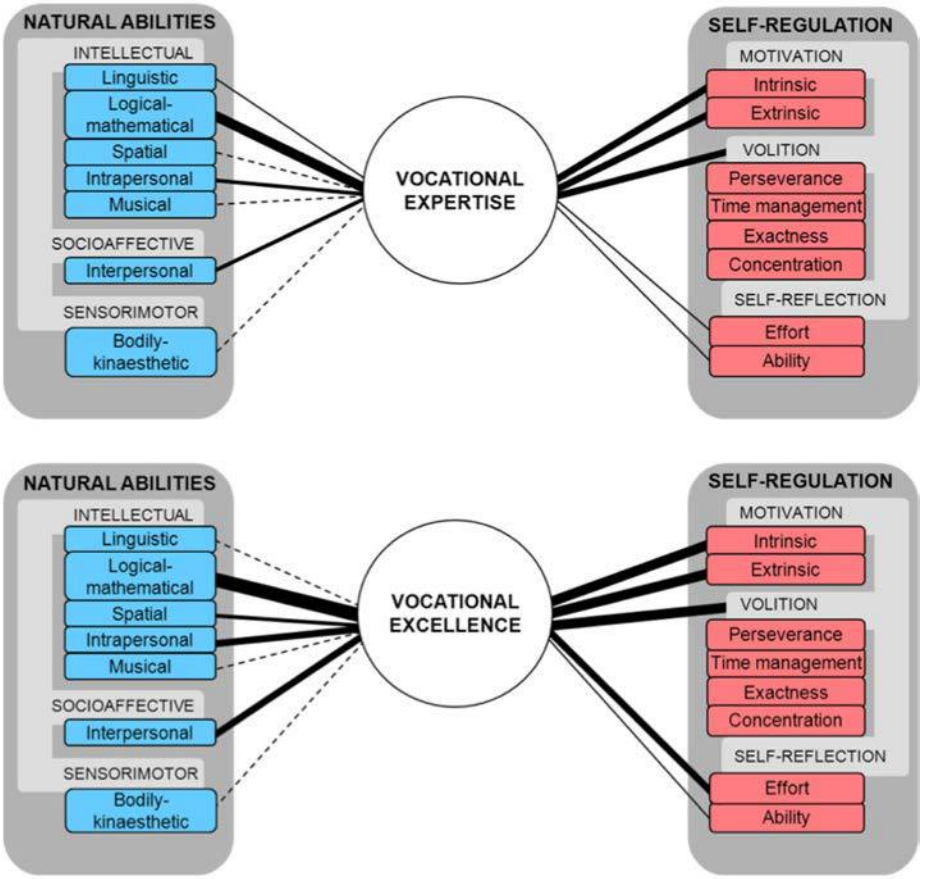
RQ2. What are the differences in characteristics between the air traffic controllers representing vocational expertise and those representing vocational excellence?

The research results indicate that ***goal-orientation*** has an important role for ATCOs' with vocational expertise (Figure 3 and Table II). Intrinsic goal-orientation (n_c = 48, 15.1 per cent) was linked to individual ambition, as well as strong interest in air traffic control and aviation. Extrinsic goal-orientation (n_c = 44, 13.8 per cent) consisted of various factors such as professional benefits (working hours, salary), professional status, professional responsibility and positively orientated competition between ATCOs (emphasized during the training period). Classification accuracy of the BCM was 89.3 per cent, which was clearly better than the baseline value of 60.7 per cent (i.e. predicting without the model). Bayesian analysis supported the qualitative analyses, emphasizing the importance of intrinsic goal-orientation. It also illustrated that the employees representing vocational excellence had a stronger intrinsic goal-orientation than the employees representing vocational expertise:

> […] natural ambition of wanting to be good. Air traffic controllers perhaps generally have strong professional pride.

Interesting and rewarding work; that is the basis of wanting to stay in this job until retirement.

Volition (n_c = 46, 14.5 per cent) is also considered to be one of ATCOs' most important vocational characteristics. Concentrating on the work requires not only volition and sustainability but also the ability to regulate vitality from peak periods to quiet traffic periods. Determination and perseverance are considered to be the basis of



Notes: The line width represents the significance of each characteristic; the wider the line, the more significant the interviewees considered the characteristic in question

Figure 3. Vocational characteristics of the air traffic controllers representing vocational expertise and those representing vocational excellence

problem-solving and decision-making as one needs to be able to trust one's own skills in any circumstances. In addition, ATCOs' work requires exactness, carefulness and time management skills to meet the official requirements of air traffic control. In the interviews, volitional differences between the ATCOs were related to exactness, carefulness and time management skills. In Bayesian analysis, volition appeared slightly higher among the employees representing vocational excellence (Figure 3 and Table II):

> The precisely defined work practice, consistent revising and structured training system ensure that individual habits vanish. There are only small differences [between ATCOs]. I am different to other ATCOs in the sense that I read all the regulations and instructions carefully and precisely, and try to think […] the majority waves them aside. It reflects on work, even if it is not a safety-critical issue.

> […] *but* I still consider myself more precise than the majority […] a bad air traffic controller has delays, good air traffic controllers do not cause delays, and this is something that pilots appreciate because of the strict time limits.

Self-reflection: success in working life was more often seen as a result of one's efforts (control beliefs, $n_c = 24$, 7.5 per cent) than as a result of one's abilities (efficacy beliefs, $n_c = 8$, 2.5 per cent). Active self-reflecting and practicing, leading to routines, were considered to increase the potential for success in working life. However, unsuccessful performance was more often seen as a result of difficult circumstances (bad weather, non-functioning equipment, etc.) than something that was under one's own control. Some abilities were considered by a few of the interviewees as inborn and therefore impossible to be learned, i.e. it is impossible to achieve a high level of skill by practicing:

> With your own input and motivation you are able to keep going.

> One can influence one's own success.

> Being able to perform like that is probably partly a result of having genetic, physical, and mental abilities.

Based on the results of Bayesian analysis, attribution interpretations turned out to be one of the main differences between the employees representing vocational expertise and those representing excellence. The ATCOs representing vocational expertise emphasized the significance of effort for success during the training period and the importance of abilities for success in working life. The ATCOs representing vocational excellence did not see effort as having a big role in training success. Furthermore, they did not stress the importance of effort or ability during working life.

In reference to Gardner's (1983, 1993) multiple intelligence (MI) theory, the seven dimensions of natural abilities were being identified in the context of ATCOs' work. *Logical-mathematical skills* ($n_c = 67$, 21.1 per cent) were seen as the most fundamental of all the characteristics in ATCOs' work, including the following cognitive skills: perceptive skills (situation awareness, predicting of coming situations), simultaneous skills (ability to concentrate on many things at the same time), fluent problem-solving and reasoning capabilities and learning skills (ability to assimilate new information fluently), as well as the capacity to apply theories to everyday life. The significance of *intrapersonal skills* ($n_c = 29$, 9.1 per cent), i.e. one's understanding of one's own skills, capacities and feelings, was also considerable. Vocational development was described as a process whereby new information is assimilated into old routines and knowledge; vocational learning implies reflecting on earlier performance. Interviews showed some differences between the ATCOs' abilities to reflect on their own performance even if it was not a distinctive factor between vocational expertise and vocational excellence according to the Bayesian analyses:

> When you have dealt with the same kind of situation several times, the last one will always go best. Better performances are always a result of learning something from the previous time.

> One must be mentally healthy; something unexpected will happen in everyone's career and you must be able to handle it by yourself; with the help of the others as well, but above all by yourself.

> There are two kinds of air traffic controller, also in here [workplace]. Some are always learning and they know that some things could have been done better. The others, however, do not get involved and continue working the same way. I am amazed by that and I'll try to fix the performance.

> Some employees need more ready-made solutions; other employees are able to assess different alternatives, even in a short time.

Stress tolerance and regulation, calmness and good nerves in particular were considered to be vital in ATCOs' work. The interviewees underlined the importance of resistance to pressure in decision-making; the ability to make quick decisions and take responsibility for those decisions. An important part of ATCOs' work is to be able to mentally process the stress after unsuccessful performances.

The importance of ***interpersonal skills*** (n_c = 25, 7.9 per cent), social skills, communication skills, understanding of others and collaborative orientation was also acknowledged as an important part of successful air traffic control even if ATCOs' work consists largely of independent work and only partly of group work. However, extrovert characteristics were not included in important vocational characteristics. Instead, ideal teamwork was even described in one of the interviews such as "top quality and non-verbal". Another specific vocational characteristic of ATCOs' work was ***spatial ability*** (n_c = 15, 4.7 per cent), the ability to deal with spatial, three-dimensional, information.

Less often mentioned vocational characteristics based on MI theory were linguistic skills, bodily-kinesthetic skills and musical skills. The work language and terminology in air traffic controlling is mostly English, which requires ***linguistic skills*** (n_c = 7, 2.2 per cent) and the ability to communicate in international work environments. Linguistic skills include good memory: awareness of detailed regulations and other professional information. Only two references were related to ***bodily-kinesthetic skills*** (n_c = 2, 0.6 per cent). One was that verbal communication, including the voice and speech rhythm, has to remain calm and clear when communicating with pilots or other ATCOs. The other reference to bodily-kinesthetic skills was connected to motor skills that are part of the advanced routines. ***Musical skills*** (n_c = 3, 0.9 per cent) were referred to in the context of hobbies.

RQ3. How does air traffic controllers' performance during training or in the entrance examination predict vocational excellence in working life?

BCM was performed to answer the research question. Job performance (with values of "expertise" and "excellence") was the class variable in the analysis, and the predictor variables were the ATCOs' entrance examination ranking and overall study success during ATCO training. Classification accuracy was 100.0 per cent, which was clearly better than the baseline value of 55.6 per cent. The results indicated that success in the entrance examination or during the training period did not predict vocational excellence in working life, as neither of these predictor variables was selected to the model.

Discussion

The findings of this study are in parallel with those of earlier research (Korpelainen *et al.*, 2009; Nokelainen *et al.*, 2009; Nokelainen, 2010, 2014), showing that cognitive skills (logical-mathematical skills, problem-solving, perceptive skills, learning

skills, simultaneous skills), self-reflection (control beliefs, stress tolerance), volition (perseverance and determination, exactness and carefulness, ability to concentrate, time management skills) and goal-orientation (extrinsic and intrinsic motivational factors) are recognized the most important characteristics of vocational expertise. Interpersonal skills (social skills), intrapersonal skills (ability to understand and analyze one's own performance) and spatial skills (conceptual understanding of three-dimensional information) were also among the acknowledged characteristics of ATCOs.

The main differences between the ATCOs representing vocational expertise and those representing vocational excellence were related to self-regulation. Motivation and volition proved to be stronger among the employees representing vocational excellence. Findings of the current study are in accordance with previous research. Yeo and Neal (2008) studied factors related to changes in subjective cognitive effort during simulated ATC tasks. They showed that participants with high level of Conscientiousness (indicated by perseverance, see Figure 3) were self-disciplined and committed to their goals. Another study (Yeo *et al.*, 2009) showed positive relationship between mastery-approach (i.e. intrinsic motivation to master a specific skill, see Figure 3) and performance in an ATC task.

Control beliefs, on the other hand, was considered a less significant factor in training performance among the employees representing vocational excellence. In working life, both control and efficacy beliefs were considered even less important factors. The result validates the connection between the intentional conceptual change (Limón Luque, 2003) and vocation-specific skills (Ruohotie, 2003). This finding is also in line with recent research on psychometric, cognitive and developmental psychology. According to Demetriou *et al.* (2011), the processes of the human mind during problem-solving are organized into four systems:

(1) specialized structural system (SSS);

(2) representational capacity system;

(3) inference system; and

(4) consciousness system.

The first system involves mental processes connected to environmental domains. In this study, this refers to the domains of the MI theory (natural abilities). The second system represents representational and information processing needs (episodic integration, executive control) between the first (SSS) and fourth systems (consciousness). The third system is responsible for connecting and integrating information and operations (conceptual change, meta-representation) in relation to the current goal between the first and fourth systems. The fourth system monitors, controls and regulates processes activated at a given moment. This system is presented by intrinsic characteristics in our model (Figure 1). Learner needs to be competent in regulating his/her own performance but also have sufficient vocation-specific skills to apply the skills in practice. Competent self-regulators have all the necessary skills to provide the conditions for change as they both are able to regulate their vitality, stress, anxiety, boredom and other feelings, and have sufficient vocation-specific skills – in ATCOs' work, this means particularly strong cognitive skills.

Intrapersonal skills, the skills of analyzing work, were also recognized as one of the essential strengths in air traffic control. Teperi and Leppänen (2011) examined ATCOs' work processes from the perspective of organizational crisis, in a case organization, that was followed by an intervention and project evaluation. The research results indicated that the new approach to the supervision of work, which is based on self-reflection, is workable in practice and increases employees' motivation to change their way of acting and developing work in the unit. However, Teperi and Leppänen (2010) note that even if organizations have the means to maintain employees' basic professional skill level, there is a lack of an integrated model for organizational learning at all levels of air traffic management that weakens the methods and aims related to vocational development such as self-reflection, feedback and sharing information. In this study, the differences between the employees representing vocational expertise and those representing excellence demonstrated the same occurrence of varying methods of analyzing work processes that challenges vocational development. Environmental factors, such as workplace training, giving and receiving feedback, and opportunities to influence, proved to have an impact on increasing employees' motivation in vocational development.

Conclusions and implications

Work expectations are increasing in air traffic controlling, as controllers are required to perform their work safely, effectively, flexibly and in an environmentally friendly and customer-orientated manner, while coping with steadily increasing air traffic (ICAO, 2011, 2013). At the same time, technology is increasingly supporting or completely replacing traditional human functions and the work is becoming more pre-defined and monotonous. Kirwan (2001) stresses the importance of reconciliation of the controller and technology; automation in the growing air traffic management industry requires new competencies and raises questions of motivation. The human dimensions of job satisfaction and role meaningfulness are sometimes underplayed even if such factors as motivation and reaction to stress can be determining factors in system performance and safety.

This study examined vocational expertise and vocational excellence in relation to air traffic controllers (ATCOs) in the context of their working life. It also focused on features related to ATCOs' developmental pathways from initial interest in the work field to perseverance in acquiring a vocational skill during the training period and mastery of the skill in working life. The results of this study confirm the significant role of human factors, especially self-regulatory abilities, motivation, and volition, in air traffic controlling alongside automation technology.

The development of ATCOs' vocational expertise or excellence was seen as a process occurring in the working context, where new information is assimilated into old routines and knowledge by analyzing own performance. The results showed some differences between the ATCOs' levels of intrapersonal skills (understanding of one's own skills, capacities and feelings). The most important domain-specific and non-domain-specific factors that strengthen perseverance in acquiring mastery of a skill in working life are interesting, challenging and varied work tasks, an interest in aviation, and strong professional pride and commitment. The importance of other professional factors such as leadership (human resource management, feedback, opportunity to influence), working environment (physical and social environment), educational possibilities,

professional benefits (salary and working hours) and career progression was also emphasized.

The research results indicate that success in the entrance examination or during the training period does not predict vocational excellence in working life. This is in parallel with Billett's (2001) notion that highly detailed and prescriptive vocational education curricula should be more relaxed and practice-oriented to promote skills needed in working-life. He further suggests that vocational education pathways "should assist individuals in developing greater breadth of understanding about their occupation and associated fields" (Billett, 2011, p. 243). However, the entrance examination system and ATCO training appear to provide a sufficient basis for ATCOs' vocational development. First, nearly all students graduate from ATCO training, as the multiphase entrance examination eliminates all but high-performing students. Random selection of the interviewees included 17 out of 28 employees representing vocational excellence. Although ATCO training is not tertiary, but secondary-level education, more than one-third of the interviewees had a right to study in a university or polytechnic institution of higher education. Second, the interviewees considered that the training offered the necessary learning content for progression into working life that also follows vocational development in the work context. However, to support the development of vocational excellence in ATCO training or modify entrance examinations design, greater account may need to be taken of the significance of self-regulation skills along with vocation-specific skills; students are assumed to be aware of the potential usefulness of self-regulation processes but in fact need motivation to self-regulate (Zimmerman, 2001).

The critical question arising from the research is how organizations can recognize and benefit from ATCOs' vocational excellence in comparison with vocational expertise; whether vocational excellence brings any additional value to ATC. The basic system performance may not require vocational excellence as all ATCOs are expected to maintain the same high professional level in their work, but as discussed earlier, motivation can be seen as one of the determining factors in safety. Compared to non-safety-critical vocations, which offer more variation in using vocational excellence potential (Nokelainen, 2014; Nokelainen *et al.*, 2009), ATCOs' pre-defined work may require new positions, responsibilities or career pathways in the future from organizations to benefit from vocational excellence and to keep employees representing vocational excellence motivated in their chosen career.

Limitations

We acknowledge that there are limitations in the present study. First, the four airports were not selected randomly. Although they represent different types of airports (and ATCO job profiles) in Finland quite well, future studies should include comparative aspect to airports in other countries. Second, the number of participants ($N = 28$) in the study was quite small, limiting generalization of the results to the target population ($N = 300$). Future research on this domain should be extended to include also quantitative measurements, allowing more generalizable results. Third, although the analysis for the *RQ*3 was based on a technique that is not sensitive to missing values (BCM), missing data in ATCOs' aptitude test scores, training records, and employee assessments added uncertainty to the results.

Notes

1. Number of air transport passengers has steadily increased 2004-2012 from 1.9 to 2.9 billion (The World Bank statistics, http://data.worldbank.org).
2. For instance, in Finland, applicants are tested in multiphasic examinations in such areas as general giftedness, personality, spatial skills, stress tolerance, ability to concentrate and language skills. The intake of new students is only approximately 2-3 per cent of applicants (Finavia, 2013).

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Corresponding author
Laura Pylväs can be contacted at: laura.pylvas@uta.fi