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Job Analysis and Cognitive Task Analysis in National Security Environments

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Abstract. The critical cyber-infrastructure of the United States is under a constant barrage of attacks. Adversaries (foreign and domestic) attack this nation's systems in order to test their design and limits; to steal information (spy); to damage the system; and embed malware which can be deployed at a later time. The ability of the United States' military and federal civilian departments to detect, delay, and respond to these attacks is essential to our national security. Identifying the best personnel to place in these critical occupations requires understanding the knowledge, skills, abilities and other factors (KSAOs) necessary to successfully complete important job tasks. It is also beneficial to understand the cognitive aspects of the job and when cognitive load is too high; when cognitive fatigue is setting in; and how these affect job performance. These factors are identified and measured by Industrial-organizational psychologists using the methods of job analysis and cognitive task analysis.

Keywords: job analysis, cognitive task analysis, work analysis, cybersecurity, NASA-TLX

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1 The Challenge of Person-Job Fit

While nearly anyone can do any job with enough training there are advantages to putting the best people in those job positions from the start and serious disadvantages to having poorly qualified people doing jobs. It is funny, and accurate, to say that no one should be subjected to hearing this researcher play Johann Sebastian Bach's *Ascension Oratorio* on the piano as he has no expe-

rience, knowledge, skills, abilities, or other factors (KSAOs) to support this effort. For this reason, some jobs have very specific criteria that, if identified and used in selection, can save organizations money, can minimize turnover and training costs, and lower on-the-job injury rates[1]. In contrast, placing the best people in the best fit jobs can also boost employee morale, team performance, and corporate knowledge retention (minimizing "brain drain" caused by attrition)[2]. In addition to KSAOs, some job criteria are even legally deemed necessary for a given job - these are BFOQs (bona fide occupational qualifications). For example a city may require a firefighter to be able to carry a simulated-human weighing 150lbs for a distance of 100 feet during a simulated rescue exercise[3,4]. This type of simulation might represent a life or death scenario on-the-job.

1.1 The Challenge for Cyber Defenders

There is a new cold war which is the persistent existence of escalating cyber warfare. As this technology emerged and continues to evolve foreign policy has been slow to react; the cost barrier to entry has been lowered; the lines between nation states, paramilitary groups, and common hackers have blurred; the value of information has gone up; and the origins of attacks have been obscured - hindering the ability to place blame during diplomatic negotiations. For all of these reasons, the job being executed by our country's cyber defenders is of great importance and having the best cyber defenders in those jobs is imperative.

1.2 The Challenge for the Decision Maker

Placing the best-fit cyber defender in your organization, be it in the United States Air Force, a national laboratory, a nuclear power plant, or even a large private sector corporation, hinges on a human's choice. When a job is posted and ten resumes arrive, how is the best job candidate selected? How does the selection team discriminate between candidates which are experts and those which are novices? These questions become harder when applicants' resumes contain similar certifications (ISACA, CISM, CASP, ISC2, CISSP, GSEC, GCIH, GIAC), and similar experience with tools (EnCase Enterprise, SANS SIFT, SPLUNK). When applicants all look the same, what should the decision be based on, their personality during the interview; their college GPA; or the perceived pedigree of their college? This hiring challenge extends beyond

cyber defenders and is generally faced by people in almost every organization, every day, for one job position or another.

If the job is important to the organization and it is a resource constrained organization that cannot hire all of the job candidates, a trained work analyst (Industrial-Organizational Psychologist) should conduct a job analysis. If the job you are hiring for requires many mental tasks (analysis, creativity, memorization, decision making) having that expert conduct a cognitive task analysis (CTA) is also advisable.

2 Job Analysis and Cognitive Task Analysis

Job analysis and CTA are the scientific methods for systematically breaking jobs down into their component parts (observable tasks and unobservable tasks, respectively) and analyzing the relative importance of those tasks[5].

2.1 Job Analysis

Job analysis (aka work analysis) in its simplest form is the systematic decomposition of a job into individual job tasks. The U.S. Department of Labor's O*Net website is a valuable resource and starting point for many job analyses. While a basic job analyses only identifies the job tasks, the majority of job analyses go beyond this and collect additional data based on the needs and resources of the project.

The most common additional data to collect during job tasks are: 1) The knowledge, skills, abilities, and other factors (KSAOs) needed in order to successfully perform the job; 2) related subtasks (when tasks can be broken down further); 3) the equipment, machines, tools and technology (EMTTs) utilized by employee to successfully perform the job; 4) related organizational competencies (ex. Leadership, Dutifulness); and 5) various task ratings (difficulty, importance, frequency, complexity, or criticality). What additional data is collected is determined by the need of the project and the resource limitations. The person conducting the job analysis should always ask, "What mission is this job analysis supporting"; "What deliverables are needed to support that mission"; and "What resources do I have access to?"

The quality of the job analysis is highly linked to the resources available. Is a trained work analyst (I-O psychologist, human factors analyst, etc.) hired to

do the work? If it is a national organization will a representative sample of SMEs from multiple sites/states be used? Will the person conducting the job analysis be given access to six SMEs, 12 SMEs, or none at all? Will they conduct a two-hour, full day, or even a week-long workshop with the SMEs? If, they are not allowed to pull the workers away from their job tasks for a job analysis workshop, how long will they be allowed to follow around the workers to observe their work and ask questions while they are doing the work? If no SMEs are available to provide job task ratings, how much time will they be allotted to collect ratings from incumbents and how many incumbents will they be allowed to have rate the job tasks. Will there be time to train the job task raters on how to accurately provide task ratings? These are a few of the most critical resource-related questions to ask, though many others exist as well [ex. Is there an available training room to use; does it have a projector; are their work computers with internet access which can be used to collect their job task ratings; does this need human subjects board (HSB) or institutional review board (IRB) approval].

Once a job analysis has identified the most critical and frequently completed job tasks, which KSAOs support completing these job tasks, and the tools/software (EMTTs) used to complete the task – these factors can be used to effectively hire the best candidates. These factors can be used to tailor a formalized recruitment and selection (hiring) process, or they can simply be used as factors to properly weight resume items for comparison purposes.

Legality

A brief note: Before making any personnel decisions, always review all local and federal laws to ensure compliance. Special attention should be paid to Title VII of the Civil Rights Act of 1964, the Americans with Disabilities Act (ADA), the Rehabilitation Act, the Fair Labor Standards Act, the federal Equal Pay Act, Age Discrimination in Employment Act (ADEA), and the Immigration Reform & Control Act. The U.S. Equal Employment Opportunity Commission (EEOC) is responsible for enforcing these laws and ensuring protected classes are not discriminated against in the workplace. There webpage on EEOC Regulations is a good resource[6]. An excellent resource is the Uniform Guidelines on Employee Selection Procedures[7]. In Section 14.C.2 these Uniform Guidelines state that a job analysis utilizing specific criteria should be used as a content validity study for selection procedures.

Similarly, section 14.D.2 states that the same job analysis should be conducted to establish construct validity related to selection procedures.

Supporting Job Analysis Tools

In the most basic cases, paper-based job analysis forms can be used. Several software solutions are also available to conduct job analysis, such as Auto-GOJA or PAQ's Occupational Assessor. Microsoft Excel or Access database forms are also common solutions based on their mass-availability, even if they typically offer less usability/process flow. Sandia National Laboratories created a flexible job analysis software called Job Task Linker (JTL) in order to conduct job analyses with SMEs. This software walks SMEs through a series of tasks including but not limited to verifying the currency and accuracy of job tasks; identifying duplicate tasks; rating tasks on the factors of difficulty, importance, frequency, duration, and complexity; linking the tasks to all relevant organizational competencies, knowledges, skills, abilities and other factors. Job Task Linker is currently undergoing updates but may be released as open source software in the future.

2.2 Cognitive Task Analysis (CTA)

Cognitive Task Analysis (CTA) has become more popular in recent years. It was developed to assess the non-observable, cognitive aspects of jobs (ex. decision making, analysis, problem solving, etc.) and on the cognitive workload associated with those tasks. Cognitive task analysis is the systematic process of identifying all of the cognitive tasks, sometimes called goals, of the job.

The gold standard for a CTA is the National Aeronautics and Space Administration's Task Load Index (NASA-TLX)[8]. Other methods include the subjective workload assessment technique (SWAT) and the workload profile (WP) though these have received much less attention. While it exceeds the scope of this paper to cover the differences between the three methods, research by Rubio, Díaz, Martín, and Puente highlights the various strengths and weaknesses of each of these[9].

The CTA is a helpful tool for identifying cognitive tasks which cause a high cognitive workload and are executed under time pressure which can lead to errors. Areas of the job which are more prone to errors may need additional

training; tools to handle the additional cognitive load and time pressure, or that job task may need to be redesigned in order to reduce errors/risk.

NASA-TLX

Briefly, the NASA-TLX (Task Load indeX), created by Hart and Staveland begins by identifying the work tasks. Then, while they are completing the task or directly following their completion of that task, SMEs or incumbents rate the tasks on six factors: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort and Frustration. The SMEs or incumbents then provide a rating from zero to 100 in increments of five on each factor, for each task. In the final step, SMEs provide weights for each task to allocate how much each factor matters for each task. To read the detailed instructions see Hart and Staveland's 1988 article[10]. To support these efforts, NASA provides free NASA-TLX software which can be downloaded from the website[11].

It should be noted that the NASA-TLX step of having SMEs weight each factor takes a great deal of time and for this reason, many researchers have abandoned this step. The truncated version which simply identifies the tasks and collects ratings on the six factors (without collecting factor weights) is called the TLX or Raw-TLX. This is a good alternative when time or access to SMEs doing the job in real-time is constrained[8].

3 Strategic Advantage

The vast majority of threats to national security involve humans. Our nation's cyber defenders and cyber incident responders are people trying to detect, delay, and respond to threats launched by other people. We need the best cyber war fighters available to stand up against our adversaries. To do this we need to recruit and select the very best personnel for the job.

The security vulnerability assessment steps of detecting, delaying, and responding are notably similar to US Air Force Col. John Boyd's OODA loop. The OODA loop, with its steps of observing, orienting, deciding, and acting, was taught to fighter pilots to provide them with a strategic advantage over their enemies during a dynamic combat event[12]. Hiring and training pilots to cycle through this loop faster than their adversary was a strategic advantage

then, just as selecting and training the best cyber defenders is an advantage today.

To accomplish this, key decision makers need to be convinced of this strategic competitive advantage, and also of the legal risk mitigation, which these scientific processes yield. For most large organizations, the benefits far outweigh the costs. In some cases one job analysis can cover hundreds or thousands of hires for a single occupation.

4 Conclusion

The cyber defense community and their leadership need to dedicate themselves to elevated levels of personnel selection and analysis. Our cyber defenders have a very difficult job and our adversaries know how to exploit our weaknesses. This nation's government and private industries can fight back by hiring the most intelligent, resilient, diverse, creative, talented, motivated, and team-oriented cyber defenders which have the least weaknesses to be exploited.

These elevated levels of personnel selection and analysis will be achieved by conducting proper job analyses and cognitive task analyses which can lead to data driven organizational decisions. Out of the job analysis and CTA new job descriptions can be written, targeted recruitment can be utilized, effective selection (hiring) systems can be created, promotion systems can be linked to key success factors and occupational competencies, new training materials can be created, training material can target key material using a DIF analysis (task difficulty, importance and frequency). In sum the whole organization's human resource (HR) system can fall into line around the findings of these work studies – maximizing person-job fit[13].

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