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Using surveys to identify stressors in generalized jobs: A direct clustering method

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Abstract

The objective of this research was to develop a method for identifying the tasks involved in a given general-description job and each such task's associated physiological and psychological stress factors. The resulting method consisted of a three-section survey followed by a short interview. The first two sections of the survey provide descriptive information concerning both employee demographics and the physiological burden being placed on the employees, in terms of stress exhibited on specific body parts and the severity of that stress. The third survey section and interview then focuses on identifying correlations between job task and perceived stressors. The primary benefit of the proposed method lies in its potential to identify high-risk tasks in general job categories using relatively expedient and inexpensive techniques and hence to improve the effectiveness and efficiency of on-site analysis. To evaluate the efficacy of the proposed method, a fisheries operation was considered in a pilot study. The results of this study, presented herein, identified eight high-risk tasks. Subsequent on-site analysis quantitatively verified that each of these tasks had been correctly classified by the presented method.

Relevance to industry

Use of the presented method has shown to be both an efficient and cost effective tool, which are traits highly desired by industry and ergonomic professionals.

Keywords: Survey; Ergonomics; Safety; Interview; Matrix; Algorithm

1. Introduction

Companies commonly classify jobs based on skill requirements, difficulty level, and/or associated hazards. Job descriptions range from the very specific to overly general. Given a highly detailed job description, one can, with relative ease, identify that job's scope and its associated tasks. From this information, hazards and safety issues can be identified, prioritized, and assessed for development of controls. Unfortunately, general job descriptions pose a significantly greater challenge. Such jobs tend to have major tasks/duties that change seasonally or according to a production cycle. Additionally, workloads involved in each task can range in frequency and intensity even within a single work cycle. Consequently, no period of observation, regardless of its duration, can be safely assumed to include all activities with high injury potential. This fact implies that the effectiveness of traditional on-site ergonomic and safety evaluations is fundamentally limited for such jobs and hence that a need for alternative methods exists. In this paper, we propose such a method and demonstrate its efficacy using a pilot study.

2. Methodology

The objective of a safety/ergonomic evaluation is to identify the hazards associated with a job. Once identified, administrative or engineering controls can be developed for and applied to each hazard. To maximize its effectiveness,

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this process should be guided by a system of priorities resulting from the initial evaluation. To obtain this information for general-classification jobs, we consider the use of a survey and questionnaire format.

The method presented here resembles a quasi-Delphi study in that information is obtained from "experts" using a questionnaire format. In this context, experts are defined as people who have been on the job longer that one work cycle or in this case one year. Information is obtained from these experts using a three-section questionnaire structured as follows:

- *Section 1: Descriptive information*—Focuses on subject-specific non-identifiable information relative to data stratification, including demographics, work history, and pre-existing injury data.
- *Section 2: Discomfort assessment*—Focuses on the body part discomfort and/or pain that subjects perceive at the end of a day. Mode of data acquisition is a front/back segmented body diagram utilizing a five-point discomfort scale.
- *Section 3: Job specific information*—Focuses on specific physiological and/or psychological stressors that subjects perceive to be making their jobs more difficult to perform. Mode of data acquisition is a checklist with subsequent interview.

For this study, Section 1 was designed to collect anonymous related information such as the age, height, weight, sex, and ethnicity, time on the job, hours worked per week, and hours worked at other jobs. Additionally, the following two safety-related questions were asked:

1. Have you ever had an on the job injury?
2. Was an accident report filled out?

These questions were included to determine the reliability of conclusions drawn from the company's accident reports.

Section 2 was designed to obtain an estimate of the cumulative impact that workers perceived after an average day on the job. Employees were asked to report both the location (body part) and the severity of the discomfort. This information was recorded on an adapted Borg CR10 scale (Borg, 1969). The following severity range was used:

1. minimal (barely noticeable, someone has to ask about it),
2. slight,
3. moderate,
4. severe,
5. unbearable (cannot concentrate or sleep).

Section 3 was intended to identify the unique stress factors that affected employees. Employees were instructed to read the 26 statements (potential stressors) listed in Table 1 and to mark those that they felt were significant stressors in their jobs, i.e., factors that made their jobs more difficult to perform. The factors included in this study are 26 of the most commonly found physiological and psychological stressors in industrial practice. This list was subjectively compiled by the authors from numerous sources and their own personal experience. Sources included:

1. Sub-categories used by the Bureau for Labor Statistics (BLS, 2005).
2. Various ergonomic and human factors checklists (Keyserling et al., 1993; Rylands, 1995; Buchholz et al., 1996).
3. Various book sections (Sanders and McCormick, 1993; Brauer, 1994; Karwowski and Marras, 1999; Hammer and Price, 2001).

Each statement was carefully worded to make it descriptive, yet unbiased. Additionally, it is recommended to use a 27th stressor option, a write-in "Other", which allows subjects to list industry-specific stressors that are not commonly encountered by investigators. Finally, this section concluded with the following three qualitative questions:

1. What is the most difficult task/job that you do and why?
2. What ideas or suggestions do you have for redesigning this job?

Table 1
Physiological and psychological stressors

Stressors
Inadequate leg clearance
Forceful grasping, pressing, pinching objects
Making highly repetitive motions
Bending or twisting of wrist
Carrying moderate to heavy loads
Working in an extremely hot or cold environment
Sitting in chairs with inadequate back support
Sitting for prolonged periods
Holding hands or arms in fixed/awkward posture
Twisting of back
No control over pace or how job is done
Having arms extended with no support
Working with arms and hands above shoulders
Mechanical pressure from objects on fingers, hands, or arm
Lowering or lifting moderate to heavy loads
Pushing or pulling moderate to heavy loads
Bending forward/towards work, working in a stooped posture
Placing hands on vibrating tools or surfaces
Reaching behind you for objects
Rotating arms while exerting force
Gripping tools at awkward angles
Excessive work pace (unrealistic production demands)
Excessive work duration (inadequate rest breaks)
Frequent and extreme variations in work schedules
Working under poor lighting conditions
Hand holds are too large, too small, and/or too slippery

3. When training new employees, what safety topics do you feel should be covered?

Completion time for the questionnaire was approximately 10 min.

Survey procedure: After completion of the questionnaire, the examiner checked for oversights. Next, each of the marked Section 3 stressors was numbered. For each, the employee was then asked, "What job or task were you thinking of when you selected this stressor?" in order to accurately document the employee's intended answer. When necessary, employees were asked to clarify their responses. However, care was taken to avoid guiding or manipulating the intent of the original answer. When an employee failed to identify a specific task, the corresponding stressor was categorized as "general". The result of this entire procedure allows employees to identify not only currently operations/tasks but prior events that happen regularly, sporadically or seasonally.

Understanding the data: The results obtained from Section 1 were summarized using basic descriptive statistics and percentages to give a "snapshot" of the current workforce demographics and characteristics. The results obtained from Section 2 were stratified by body part. The percentage of employees reporting a problem and the average severity rating were then calculated. Finally, the results obtained from Section 3 were evaluated in two steps. First, the answers to the three qualitative questions were summarized in a single document. No classification or descriptive information from Section 1 were correlated to these individual answers. Second, the results of the interview process were summarized in a matrix. Specifically, the matrix records the number of employees that reported concerns for each stressor-task pair. Using a direct clustering algorithm (Chan and Milner, 1981), these results were clustered using the following four steps (adapted for this technique):

1. Formulate the initial matrix: stressors as rows and tasks as columns.
2. Sum the entries for each column and row to the bottom and right of the matrix, respectively. Rearrange rows in ascending order, top to bottom, and columns in descending order, left to right. In case of a tie, the row/column closest to the direction of search is assigned the highest priority.
3. Starting with rows (stressors), and beginning with the first column, move only the rows with entries to the top of the column in descending order while moving empty cell rows lower in the matrix. Repeat this step for all columns $2, \ldots, n$, starting with the first empty cell row in the prior column. Each row should be moved up only once.
4. For the columns (tasks), move all columns with entries in the first row to the left-hand side of the matrix from greatest to least while moving all empty cell columns to the right. Repeat this step for all rows $2, \ldots, n$. Each column should be moved up only once.

The clusters produced by the above actions should be as follows for $n \geqslant 12$:

1. Groupings of cells containing individual values greater than 20% of the individuals participating (n) in the interview process.
2. Groupings of at least two cells containing an average of at least 15% of the individuals participating in the interview process.
3. An individual cell containing a value greater than 75% of the individuals participating in the interview process. A value of 50% can be used for $n \geqslant 50$.

The direct cluster algorithm used here is an adaptation from the work by Chan and Milner (1981), in which they grouped families of parts together during line-balancing optimization. This algorithm has also been incorporated into several traditional industrial and system engineering applications, including developing alternate process route by genetic algorithm (Uddin and Shanker, 2002), using ant colony system approach to cellular manufacturing (Baskar et al., 2004), and analyzing cell formation using fuzzy neural networks (Dobado et al., 2002). Non-traditional applications apply the algorithm to emergency room layout by integrating group technology process, production planning, and clustering (Malakooti et al., 2004).

3. Results

A total of 21 participants were available for the fisheries study. Twenty participated in the study, while one chose not to participate. All 20 were considered to be in a general category job that included both laborers and crew supervisors performing the same physical tasks and activities. Of the 20, 85% were male. Ages ranged from 20 to 53 years old ($\mu = 38$, $s = 2.47$). The average time spent on the job was 8.15 years ($s = 2.19$, range $= 26.6$).

Section 1 of the survey yielded results reflective of the existing workforce's demographics. Additionally, descriptive information were collected, e.g. injury history. The results of Section 2 indicated that the majority of the employees experienced neck, shoulders, and back discomfort/pain ranging from slight to bordering on severe. Table 2 presents the significant results from Section 2. These results suggest that employees are engaging in job tasks that involve a full range of motion and that impact the back and shoulders. However, further examination is needed to determine the source of the problem. The results of Section 3 yielded a rank-order summary of job-specific stressors by count, which are shown in Table 3. The rankings illustrated the employees' perception regarding the difficulty of individual tasks and reflect how each is weighted against total job.

Though both of the prior tables provide helpful general information, neither provides much insight into which tasks should be investigated further and in what order. The

Table 2
Discomfort assessment (Section 2)

Body region	Left/right	Count (%)	Average severity (1–5)			
			Mean	Median	Mode	Standard deviation
Low back	L	10 (50)	2.7	2.3	2.0	0.9
Low back	R	10 (50)	2.6	2.5	2.0	0.9
Shoulder	R	9 (45)	2.3	2.0	2.0	0.5
Base of neck	R	5 (25)	2.8	3.0	3.0	0.4
Upper back	R/L	4 (20)	3.4	3.0	3.0	0.5
Mid back	R	4 (20)	2.7	3.0	3.0	0.7
Base of neck	L	4 (20)	2.6	3.0	3.0	1.1
Shoulder	L	4 (20)	2.6	2.5	2.0	0.8
Wrist	R	4 (20)	2.6	2.8	3.0	0.5

Table 3
Rank order of stressors (Section 3)

Stressor	Count	Rank
Bending forward/towards work, working in a stooped posture	17	1
Working in an extremely hot or cold environment	16	2
Carrying moderate to heavy loads	13	3
Lowering or lifting moderate to heavy loads	13	3
Pushing or pulling moderate to heavy loads	13	3
Excessive work pace (unrealistic production demands)	11	6
Twisting of back	11	6
Forceful grasping, pressing, pinching objects	11	6
Excessive work duration (inadequate rest breaks)	10	9
No control over pace or how job is done	8	10
Placing hands on vibrating tools or surfaces	8	10
Hand holds are too large, too small, or too slippery	8	10
Bending or twisting of wrist	7	13
Rotating arms while exerting force	7	13
Gripping tools at awkward angles	7	13
Frequent and extreme variations in work schedules	7	13
Mechanical pressure from objects on fingers, hands, or arm	5	17
Making highly repetitive motions	5	17
Sitting for prolonged periods	4	19
Working with arms and hands above shoulders	4	19
Having arms extended with no support	4	19
Holding hands or arms in fixed/awkward posture	4	19
Reaching behind you for objects	3	23
Inadequate leg clearance when sitting	2	24
Sitting in chairs with inadequate back support	2	24
Working under poor lighting conditions	2	24
Other (Fill-in)—Footing slippery and/or stuck in mud	2	24
Other (Fill-in)—Specific people allowed to slack off	1	28

clustered matrix produced from the interview responses provides this missing insight. Fig. 1 shows the clustered matrix produced. The clusters (shaded groupings) identify combinations of factors and corresponding tasks that warrant further on-site investigation. Specifically, the following tasks are marked for on-site evaluation:

1. moving baskets of fish,
2. seining,
3. cleaning tanks,
4. feeding fish,
5. masonry,
6. unloading fish,
7. trenching,
8. drilling.

Additionally, *outdoor weather* which is a condition not a task was identified as a problem.

Finally, each task was prioritized using the results shown in Tables 2 and 3. On-site task evaluations were then conducted in a timely and efficient manner based on these results. Tasks not identified in clusters were not prioritized

	Moving Baskets of Fish	Seining; Walking in mud	Cleaning tanks, mopping	Feeding Fish	Masonry	Unloading Fish	Trenching	Biology; Nature of work	Weedeating; Grinding	Wheelbarrow; Concrete work	Painting	Standing Pipes in ponds	Operating equipment	Not enough personnel	Greenhouse work	Drilling (concrete or metal)	Jackhammer; Soil compactor	Cutting bushes	Spawning	Plumbing & electrical work	Equipment maintenance	Handling fish	Turning valves	Outdoor work; Weather
Bending forwards & towards, working in a stooped posture	9	6	3	2	2	1	1	1	1	1	1													
Pushing or pulling moderate to heavy loads	4	5		1		1	1			1		1												
Excessive work duration (inadequate rest breaks)	2	5		1				2					1	1	1									
Twisting of Back	3	4		2		1			1				2			1	1	1						
Excessive work pace (unrealistic production demands)	2	4						2						1										
Lowering or lifting moderate to heavy loads	8	3		3	1	4	1												1					
No control over pace and how job is done		2				1	1	1						1	1									
Bending or twisting of wrist		2					1		1										2	1	1	1		
Holding hands in fixed/awkward positions		2	1				1																	
Carrying of moderate to heavy loads	8	1		4		3	1			2						1								
Forceful grasping, pressing, pinching of objects		1		2	1		2									2			3	1	1	1		
Placing hands on vibrating tools & surfaces		1							2							4	1							
Making highly repetitive motions		1	1				1				1								2	1				
Hand holds are too large, too small, too slippery		1																	1		1	3		
Rotating arms while exerting force		1	1	1																	1		2	
Gripping tools at awkward angles		1	1													1				1	1			
Having arms extended with no support	1	1				1													1					
Working in under poor lighting conditions		1																						1
Working in an extremely hot or cold environment																								15
Frequency and extreme variations in work schedules						1		1																
Mechanical pressure from objects on fingers, hand, wrist, or forearm									1							2								
Working with arms and hands above shoulders			1									1						1		2				
Reaching behind you for objects			1																		2			
Inadequate leg clearance when sitting														2										
Sitting for prolonged periods													1	1										
Sitting in chairs with inadequate back support																								

N=20: GROUP CELL COUNT (4), GROUP AVERAGE COUNT (3), INDIVIDUAL CELL COUNT (15)

Fig. 1. Clustered matrix (fisheries).

unless the initial walkthrough indicated that imminent danger was present. This is due to the ability of the clustering algorithm to not only identify common employee's problems/concerns but to eliminate frivolous issues mentioned by individual employees or small groups with agendas.

An example of a high-priority task which was supported by all sections of the questionnaire and interview method is

Task:	*Moving baskets of fish*
Stressors (count/rating)	Bending forward, working in a stooped posture (9) Lowering or lifting moderate to heavy loads (8) Carry moderate to heavy loads (8) Pushing or pulling moderate to heavy loads (4) Twisting of back (3) Excessive work duration (2) Excessive work pace (2)
Body Part (severity range, percent effected)	Lower back (2.57–2.71; 50%) Shoulders (2.33–2.67; 50%) Upper back (3.33; 22%) Mid back (2.67; 22%) Neck (2.67; 22%)

4. Discussion

The use of this method to identify stressors for general-description jobs has the advantage of being economical, timely and productive when compared to traditional time-study approaches that consider all tasks. This method produces the following results:

1. A descriptive summary of employees' group characteristics and demographics.
2. A "snapshot" of the physiological and psychological burden being placed on the employees at days end (listed by body part and severity).
3. A rank-order summary of those stressors of the job that are perceived by the employees.
4. A listing of the tasks and corresponding factors (stressors), which can be prioritized by the "snapshot" data for on-site analysis.

These results can then be used as a basis for guiding further in-depth studies and job evaluation. For the example presented here, each stressor identified during the initial job-site evaluation was confirmed in the matrix-interview process. Subsequent on-site analysis quantitatively verified that each of these tasks had been correctly classified as posing a significant risk to the workers.

Limitations of this method were found to be in the existing morale of the workforce. It is possible to skew the results of the survey and interview process if the number of dissatisfied employees is sufficiently large or persuasive enough to change the normal interview responses of others. However, this method has proven in two subsequent settings to be accurate as long as this number is less than 20% of the employees participating. In all three instances, the highest rate of disgruntled workers was found to be around one in five or 20%. Each time all areas identified in the survey and interview method were confirmed in the on-site evaluation. But, this is an estimate.

Another limitation seen is the potential for individuals to focus just on recent events, in which they have been involved with. This temporal issue of reporting only the most recent events can only be addressed by the person doing the interviews. It is important for an interviewer to recognize when the same event is being overly reported by a participant. When this occurs, the interviewer should allow the participant to elaborate on the responses being given and all additional information should be noted. This information should not be discarded but retained for later analysis and evaluation.

Finally, while the above results indicate all hazard identified were significant hazards, it cannot show that all significant hazard were reported. Only proper investigation of future accidents, incidents, and injuries can ultimately determine this methods effectiveness in identifying existing job hazards.

5. Conclusion

Survey procedures, in conjunction with clustering methods offer an effective alternative for studying and identifying both physiological and psychological stressors in general-description jobs that involve multiple or irregularly scheduled tasks. Use of the presented method has shown to be both efficient and cost effective by reducing time on-site, which are traits highly desired by industry and ergonomic professionals.

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