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A General Model

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Summary

Background

The hospitalization rate for injuries varies widely across U.S. Navy enlisted occupations. Logic suggests that this variation is related to occupational demands. Previous research showing that higher accident rates occurred in occupations that demand physical exertion and fast reaction times supported this view. However, the estimated effects of those demands may have been biased by the omission of other important contributors to accidents.

Objective

The primary objective was to construct a complete profile of occupational characteristics that predict accident rates. The profile must be complete to ensure unbiased estimates when modeling the influence of occupational characteristics on accident rates. The prior focus on ability demands was expanded to include generic tasks, working conditions, and activities.

Methods

Accident rates for 57 entry-level occupations were available for the periods 1970–1974 and 1980–1994. Ratings by senior enlisted personnel described tasks, working conditions, activities, and ability demands of each occupation. Correlation and regression analyses provided the basis for identifying occupational characteristics associated with higher accident rates.

Results

Six indices were reliable positive correlates of accident rates: Physical Ability, Perceptual Speed and Skill, Work with Machinery, Poor Working Conditions, Manual Labor, and Miscellaneous. These 6 composites defined a single higher-order factor that predicted accident rates. Neither the composites nor any individual item in the original ratings was a consistent predictor of accident rates controlling for this general factor. The impact of omitted variable bias was evident in a sharp reduction in the estimated effect of physical ability demands on accident rates when the other hazard elements were included in the predictive model.

Discussion

The results provide a simple approach to modeling occupational differences in accidents. The evidence showed that many occupational characteristics can be ignored because they are not related to accident rates. The remaining occupational characteristics can be treated as a “General Hazards” factor. One implication of these findings is that attempts to estimate the effects of individual job characteristics on accidents at the occupational level of analysis will yield results with wide confidence intervals. Several hazards are highly correlated at this level, so the variance inflation factor for the confidence interval will be substantial. A second implication is that all of the elements in the general hazards construct should be included when analyzing individual accidents. Any exclusion makes it likely that estimates of the effects of the factors that are studied will overstate their impact. The uncertainty in isolating individual effects might be reduced by developing causal models that describe the relationships among the general hazard components. Future research could also benefit from limiting the criterion to accidents occurring on the job.

The hospitalization rate for injuries varies widely across U.S. Navy enlisted occupations (Chesson & Hilton, 1988; Ferguson, McNally & Booth, 1985; Gunderson & Colcord, 1982; Marcinik, 1981). Injury rates logically are related to occupational ability demands. Occupations that demand physical exertion and fast reaction times generally have higher injury rates (Vickers, Hervig, & White, 1997; Vickers & Hervig, 1998).

Some potentially important occupational influences on accident rates were absent from the previous studies. Those studies focused on ability demands to provide a basis for estimating the effects of physical training programs. While that focus was appropriate in the context of the general goals of the prior work, enlisted occupations also involve working conditions, generic tasks, and specific behaviors (Carter & Biersner, 1982; Reynolds, Barnes, Harris, & Harris, 1992). For example, the previous focus on ability demands restricted attention to 5 of 26 factors identified by Reynolds et al. (1992) in their detailed analysis of job characteristics. Some of the omitted factors, such as poor working conditions, probably contribute to accidents.

Omitted characteristics could result in a misleading model of accidents. At a minimum, the contribution of occupational characteristics to accident rates could be underestimated. This loss of explanatory power would occur if the omitted characteristics contribute to accident rates. The omissions also could bias estimates of the effects of ability demands. Bias would occur if any omitted variables contributed to accident rates and correlated with physical ability demands (cf., James, Mulaik, & Brett, 1982). In this case, the effects of the omitted variable would be assigned to the variable that is present in the model. Occupational profiles suggest that some of the variables omitted from previous studies correlate with ability demands (Carter & Biersner, 1982; Reynolds et al., 1992). Thus, the essential questions are whether the omitted variables correlate with accident rates and, if so, how much bias this introduces into the estimated effects of demands on accidental injury rates. This report addresses these issues.

Methods

Accident Rates

Accident diagnoses corresponded to the general category of injuries and poisoning in the *International Classification of Diseases*, 9th Revision, Clinical Modification (i.e., ICD-9-CM; Medicode, Inc., 1991). Table 2 of Ferguson et al. (1985) provided accident rates for 1970 through 1974. Epidemiological Interactive System (EPISYS, Jaeger, White, & Show, 1996) provided accident rates for 1980 through 1994. All rates were for men. In each case, rates were based on discharge diagnoses recorded in administrative databases for the U.S. Navy Bureau of Medicine and Surgery. The two sets of hospitalization rates differed in one important respect. Ferguson et al. (1985) were able to exclude intentional injuries from their computations. EPISYS does not include this level of detail, so intentional injuries could not be excluded. EPISYS rates include both intentional and unintentional injuries.

Occupational Condition Ratings

Ratings of occupational demands were taken from Reynolds et al.'s (1992) Job Activities Inventory, an instrument that included ratings of occupational requirements for 107 different job-related characteristics. Each characteristic was rated for its importance to job performance. The ratings were made using a 5-point scale with "Not Very Important," "Somewhat Important," "Important," "Very Important," and "Extremely Important" as response anchors. These responses were scored 1, 2, 3, 4, and 5, respectively. Respondents also had the option of responding "Not Applicable." Reynolds et al. (1992) treated this response option as missing data. However, the

present analyses interpreted this response as evidence that the characteristic in question simply was not a factor in the occupation. A “Not Applicable” response therefore was assigned a score of 0 in the computations. One reason for this decision was that the Reynolds et al. (1992) procedure produced average scores that were based on just a subset of raters when “Not Applicable” was chosen by some rater(s) in an occupation. This response option was a concern because it was used by a sizable proportion of the respondents for some characteristics in some occupations. When this was the case, the average score for the remaining respondents, each of whom assigned some importance to the characteristic, would be misleading. That average would overestimate the importance of the attribute by ignoring individuals who essentially said the characteristic was irrelevant. For example, consider an extreme case in which 29 of 30 raters said an attribute was not applicable to their job. The 30th rater assigns the characteristic a rating of ‘5’ for some reason. Treating that job characteristic as “Extremely Important” for the occupation would not be reasonable. Scoring “Not Applicable” as “0” would reduce the average to 0.17, a figure between “Not Applicable” and “Not Very Important.” The latter score appeared to be more representative of the likely relevance of the attribute to the occupation.

Appendix D of Reynolds et al. (1992) provided frequency distributions for the responses to all 107 items for each occupation. This information was converted to a text file using an optical character reader program, OmniPage Professional 14 (Nuance, Burlington, MA). The resulting text was reviewed to verify the accuracy of the conversion from image to text. Some occupations had missing data for some items because the available copy of the appendix was incomplete. Attempts to obtain a complete copy of the appendix were unsuccessful.

Establishing the appropriate level of analysis for describing occupational risk factors was an issue for this study. This issue was explored by creating item composites to represent Reynolds et al.’s (1992) factors. These composites were included in the analyses along with the individual items.

Twelve tasks and working conditions were identified a priori as likely to influence accident rates. In the task domain, repetitive lifting and lifting heavy objects could cause overexertion, an established contributor to musculoskeletal injuries (Bernard, 1997). Work that requires attention to body position and balance also implies an increased risk of accidents if the person is not able to maintain that attention. Working conditions that make it more difficult to perform a physical task or that could impair awareness of hazards seemed likely to increase the risk of accidents. Task difficulty could increase when work must be performed in cramped spaces or under conditions that are generally perceived as hazardous. Situational awareness could be adversely affected by loud noise, poor lighting, or the presence of distractions. Vibration could be a distraction and could also affect task difficulty by increasing the rate of fatigue. Temperature extremes could affect the strength and endurance, digital manipulation, and other factors that may be needed to safely perform task. Protective clothing implies increased exposure to hazards and is likely to reduce situational awareness (e.g., by restricting peripheral vision) and dexterity (e.g., gloves). Based on these and similar logical considerations, 12 of the 81 items that Reynolds et al. (1992) classified as tasks or behaviors were identified a priori as likely to be associated with higher accident rates. The selected items were: Work cramped/uncomfortable, Work with loud noises, Work in enclosed area (hot), Work in area with vibration, Work with poor lighting, Lift heavy objects, Work in hazardous situations, Wear protective clothing regularly, Sense bodily position/balance, Work under distractions, Cold, and Perform repetitive physical tasks. The specific items for which predictions were made are identified by asterisks in Tables A-7 through A-14 of Appendix A.

Analysis Procedures

All analyses were performed with the SPSS-PC 12.0 computer package (SPSS, Inc., 1998a, 1998b). Occupational scores and rates were weighted by the person-years of observation for the accident criterion to allow for the precision of the dependent variable. Reynolds et al. (1992) reported high reliability for occupational differences in all ratings, so weighting for those differences would have had little effect on the analyses.

The significance criterion for the study was based on a Bonferroni significance criterion (cf., Green, Thompson, & Poirer, 2001) that treated the analyses as involving 28 independent significance tests. Therefore, a result was significant if $p < .0018$ (i.e., $.05/28$) to maintain an approximate analysis-wide error rate of 5%.¹

The Bonferroni criterion was applied as a 1-tailed significance test. The justification was that occupational causes of accidents can only increase the accident rate. This unidirectional effect implies a positive correlation between occupational characteristic and accident rates if the occupational characteristic truly causes accidents.² Given the sample size of 57 occupations, this argument led to designating $r \geq .38$ as the critical value for a statistically significant association.

Results

Results are presented for plausible causes of accidents. A significant positive correlation was the criterion for identifying a potential cause. The restriction to positive associations reflected the belief that a true cause could only increase the frequency of accidents. Negative associations could arise and might even be significant. However, these associations were assumed to reflect the zero-sum nature of work-related exposures. If occupational incumbents spend a large proportion of their work time on risk-free tasks, their overall risk exposure will be low and their probability of being injured will be below average. The reduced likelihood of injury does not derive from an actual causal influence of the characteristics of the safer occupation.

Potential causes were considered individually and as elements of a composite. Relative strength of association was the primary criterion for choosing the level of aggregation. Composites aggregated items that Reynolds et al. (1992) assigned to the same dimension in their factor analyses. If one characteristic in a set influenced accidents and others did not, the active ingredient should produce larger correlations. Combining the active characteristic with the inert characteristics should yield a composite with relatively weak associations.

¹The Bonferroni criterion could have been based on 107 significance tests, the number of individual items considered as predictors. However, the Bonferroni adjustment is conservative if the significance tests are not truly independent. A conservative criterion would ensure that the analysis-wide error was absolutely certain to be less than 5%, but this certainty would be gained at the cost of lower statistical power. This problem could not be ignored because Reynolds et al.'s (1992) factor analysis demonstrated that many items were moderately to strongly related to other items. A Bonferroni criterion based on the number of factors plus the largely independent items was an acceptable compromise, particularly in light of the fact that the association had to replicate over time to be considered important.

²Negative associations can occur, but those associations were not regarded as indicating causal effects. Instead, negative correlations were treated as reflecting the zero sum nature of risk exposure. Time spent on low-risk occupational tasks or in low-risk settings is time that is not spent at risk. If hazards have less opportunity to affect one occupation than another, the low-exposure occupation should have a lower accident rate. The job conditions in the lower-risk occupation do not have a causal effect in the usual sense of the term.

Table 1. Task Correlates of Accident rates.

Predictor	1980-1994 ¹	1970-1974 ²
<i>Working with Machinery</i>	.556	.701
Repair machinery	.517	.711
Operate machinery	.548	.785
Perform damage control activities	.550	.375
Operate electrical machinery	.355	.507
<i>Individual Item</i>		
Fabricate/construct/repair metal structures ³	.458	.698

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al. (1985).

³From *Construction Activities* factor (see Appendix A).

Thus, the presence of an item with stronger associations to the accident rates than other items in the set and the composite representing the set suggested that the item was the causal influence in the set. Appendix A provides greater detail on the psychometric rationale for these criteria.

Tasks and Accident Rates

Reynolds et al. (1992) reduced 21 generic task items to 6 task factors plus 1 isolated task. One factor, *Working with Machinery*, and one item dealing with fabrication of metal structures were likely causes of accidents. Reviewing the results for *Working with Machinery* illustrates the process for determining when to reduce a set of items to a composite.

The composite was appropriate to represent the item set. All item-level correlations were positive and large enough to satisfy the Bonferroni significance criterion. The item composite was the best predictor for the period from 1980 to 1994. Two individual characteristics provided somewhat better prediction for a period from 1970 to 1974, but those items were not the strongest individual predictor of the 1980–1994 rate. Overall, the composite produced a larger correlation than the items in 6 of 8 comparisons. The composite provided a simple summary measure representative of the general tendency for items in this set to appear as potential causes of injury.

Table 1 also includes a single item assigned to Reynolds et al.'s (1992) *Construction Activities* factor. As shown in Appendix A, all item-level correlations were positive, but the item for fabrication of metal structures produced stronger correlations than the composite for both injury rates. The correlations for this item also were much stronger than those for any other individual item. The pattern of correlations therefore suggested that fabricating metal structures was the active ingredient in this item set.

Table 2. Job Behavior Correlates of Accident Rates

Predictor	1980-1994 ¹	1970-1974 ²
<i>Poor Working Conditions</i>	.546	.816
Work cramped/uncomfortable ^a	.399	.660
Work with loud noises ^a	.461	.755
Work in enclosed area (hot) ^a	.456	.548
Work where easily become dirty	.547	.799
Work in area with vibration ^a	.532	.818
Work in polluted air	.524	.837
Work with poor lighting ^a	.611	.557
Lift heavy objects ^a	.466	.712
Work in hazardous situations ^a	.419	.682
<i>Manual Labor</i>	.358	.547
Set up/adjust machines/equipment	.248	.321
Use tools for precise operations	-.030	.007
Take apart/assemble equipment	.193	.320
Use handheld tools ^b	.438	.592
Use stationary machinery/equipment ^b	.563	.787
Perform tasks requiring moderate detail ^b	.439	.554
Use physical measurement devices ^b	.475	.583
Inspect products/objects/materials/equipment	.229	.442
Perform tasks requiring extreme detail	.099	.193
Wear protective clothing regularly ^{a, b}	.427	.714
Follow set procedures	.330	.414
Use devices that apply something ^b	.621	.760
<i>Individual Items</i>		
Accept responsibility for others' safety	.470	.608
Be responsible for asset/property damage	.405	.583
Watch for frequent events	.394	.383
Judge distances to objects	.548	.475
Communicate by signal	.542	.612
Sense bodily position/balance ^a	.443	.618
<u>Perform repetitive physical tasks^a</u>	<u>.575</u>	<u>.681</u>

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

^aItem identified a priori as a likely cause of accidents.

^bItem included in *Manual Labor* composite for later analyses.

The analyses suggested that only 5 of 21 task items represented likely causes of accidents. Four items could be combined into a composite, so the original set of 21 potential causal factors was reduced to 2 predictors.

Job Behaviors and Accidents

Reynolds et al. (1992) classified 60 items as “behaviors,” but this grouping may include two distinct classes of job elements. The items covered working conditions (e.g., cramped work spaces) as well as specific behaviors (e.g., use handheld tools). Reynolds et al.’s (1992) “job behaviors” label for the category has been retained to reflect the fact that the factors were identified in a single analysis. The 60 behaviors reduced to 7 factors and 9 miscellaneous items. The analyses reduced this domain to 2 composites, *Poor Working Conditions* and *Manual Labor*, and 7 individual items (Table 2).

The composite was the clear choice to represent *Poor Working Conditions*. All items produced moderate to strong positive correlations. None of the individual items consistently performed better than the composite.

A composite of 6 items was appropriate for *Manual Labor*. Those 6 items produced correlations that were larger than the corresponding correlations for the full 12-item composite. The remaining 6 items in this set produced weak correlations. The 6 predictive items must have been at least moderately correlated in Reynolds et al.’s (1992) analyses or they would not have been assigned to the same factor. The basic rule for forming a composite was that the items must be positively related to one another and uniformly produce positive correlations to the accident rates. The 6 items met those criteria and therefore were treated as a composite index. The *Manual Labor* name was retained for the composite to identify the content and the original source of the items in subsequent analyses.

The 7 miscellaneous items in Table 2 were taken from 3 different Reynolds et al. (1992) factors. *Signal Processing* and *Administration and Logistics* each provided 2 items. One item came from the *Technical Data Handling* factor. The reasons for choosing items over the composites for the factors can be found in Appendix A. The other 2 items in Table 2 were not assigned to any Reynolds factor.

These analyses also confirmed a priori predictions. Ten of 12 items that had been identified a priori as likely to influence accident rates met the significance criterion. This correspondence can be placed in perspective by noting that 21 of 60 items produced comparable associations. Given this overall rate, 12 items chosen at random would yield, on average, 4.25 substantial correlates of accident rates. The observed number for the 12 predictions was ~2.5 times this expected value, so the convergence between predictions and evidence is not likely to be the result of chance.

Ability Factors

Ability demands were studied previously (Vickers & Hervig, 1998, 1999; Vickers, et al., 1997). However, the data entry methods available at the time of the prior studies limited the analyses to 8 of 26 items in the domain. The items included 4 items defining physical abilities plus the item with the highest loading on the other 4 ability factors identified by Reynolds et al. (1992). The present analysis included the 21 items that Reynolds et al. reduced to 5 factors (Physical Ability, Cognitive Ability, Dexterity and Fine Motor Control, Perceptual Skill, and Communication) plus 5 miscellaneous items.

The composite adequately represented *Physical Ability* (Table 3). All items in this composite produced strong and positive correlations. The composite was a stronger predictor in 7 of 8 comparisons to individual items.

Table 3. Ability Factor Correlates of Accident Rates

Predictor	1980-1994 ¹	1970-1974 ²
<i>Physical Ability</i>	.553	.712
Strength	.514	.692
Flexibility	.540	.703
Stamina	.543	.703
Body Balance	.572	.681
<i>Perceptual Skill</i>	.552	.485
Reaction Time	.455	.379
Sound Localization	.626	.632
Vision	.516	.441
Speed of Perception	.116	-.023
<i>Individual Items</i>		
Visualization	.599	.609
Coordination	.695	.763
Control Precision	.562	.621
Rate Control	.639	.699

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Once again, the correspondence between factor loadings and item correlations was the only reason to question the use of a composite. This result is not surprising given that the factor loadings only covered the narrow range from .778 to .899.

Perceptual Skill can be represented by a composite after dropping an item. The “speed of perception” item was clearly inconsistent with the general pattern defined by the other items. This item had a weak factor loading on *Perceptual Skill* (.43045) and might actually be more closely related to *Cognitive Ability*, an alternative factor for which the item had nearly as large a loading (.42054). The remaining items therefore were treated as a composite.

Reynolds et al. (1992) assigned the first 2 miscellaneous items in Table 3 to factors that clearly were not related to accident rates (cf., Appendix A). The discordance between the composite and the individual items was not surprising given that each item had a small factor loading. The last 2 items in Table 3 were miscellaneous items that Reynolds et al. (1992) did not assign to any factor.

Miscellaneous Composite

The relationships among the 12 miscellaneous items were examined to determine whether this set of variables could be simplified. Principal components analysis indicated that the items could be reduced to two linear composites. The first principal component accounted for 55.2% of the variance ($\lambda_1 = 6.63$). The second principal component accounted for 14.3% of the variance ($\lambda_2 = 1.72$). The third principal component ($\lambda_3 = 1.00$), which accounted for 8.3% of the variance, met Kaiser’s (1960) criterion for extracting a component (i.e., $\lambda \geq 1.00$), but was not

Table 4. Correlations Among Composite Risk Indicators

Physical Ability	1.000					
Perceptual Skill*	.344	1.000				
Working with Machinery	.708	.505	1.000			
Poor Working Conditions	.863	.399	.842	1.000		
Manual Labor*	.764	.401	.797	.847	1.000	
Miscellaneous Component 1	.799	.643	.710	.829	.823	1.000
Miscellaneous Component 2	-.467	.536	-.077	-.269	-.147	.000

*Based on a subset of items with substantial correlation to accident rates.

greater than expected by chance (Cota, Longman, Holden, Fekken, & Xinaris, 1993). Thus, 2 components were extracted to represent the miscellaneous items.

All 12 items had positive loadings $>.55$ on the first component, except for a loading of .35 for the item dealing with monitoring the situation for frequent events. That item was the primary marker for the second component, with a loading of .78 on that component. Thus, the 12 items effectively reduced to a linear composite, *Miscellaneous Composite 1*, representing 11 of the 12 items, plus a second composite, *Miscellaneous Composite 2*, that was closely identified with an individual item. Both composites were retained for the following analysis to obtain a complete picture of the associations among composite indicators that could represent causal influences on accident rates.

Associations Among Composite Measures

Five of the 7 composites that summarized the job characteristics that might affect injury rates were strongly positively correlated (Table 4). The exceptions were *Perceptual Skill*, which produced generally moderate positive correlations, and *Miscellaneous Component 2*. The exceptions were moderately correlated with each other ($r = .536$).

The pattern of correlations in Table 4 suggested that the set of predictors could be further reduced by defining a higher-order factor based on the composite indicators. Principal component analysis produced a first component that accounted for 64.2% of the variance ($\lambda_1 = 4.49$). The second component also was large enough to rule out chance as the basis for the result ($\lambda_2 = 1.63$). The third component clearly was trivial ($\lambda_3 = 0.36$).

The only composite that did not load on the first factor was *Miscellaneous Component 2* (-.166). With respect to the first factor, the loading for *Perceptual Skill* (.553) was distinctly less than the size of the next smallest loading (.879). *Poor Working Conditions* produced the largest factor loading (.948). The loadings on the second component indicated that this variable was defined largely by *Perceptual Skill* (.756) and *Miscellaneous Component 2* from the item analysis (.947).

The convergence of the component structures derived from the analysis of miscellaneous items and the set of item composites was noteworthy. Both analyses identified a large first component and a small second component. All of the indicators had moderate-to-large positive loadings on the first component. Large loadings on the second component were limited to

Table 5. Composites as Predictors of Accident Rates

			Partial Correlations ^a	
	EPISYS	Ferguson	EPISYS	Ferguson
Physical Ability	.553	.708	-.165	.004
Perceptual Skill	.600	.513	.320	-.037
Poor Working Conditions	.547	.816	-.237	.137
Manual Labor	.514	.738	-.284	-.174
Working with Machinery	.556	.711	-.072	-.111
Miscellaneous Component 1	.676	.770	.353	.165
Miscellaneous Component 2	.018	-.202	.193	-.088

^aControlling for *General Hazards* (see text).

variables that dealt with monitoring the work environment, including the rapid recognition of frequently occurring events.

Scores for the first principal component were saved to represent the higher-order common factor, *General Hazards*. Partial correlations were computed to determine whether any of the primary composites had significant additional predictive power after controlling for their associations to *General Hazards* (Table 5). Only *Miscellaneous Component 1* produced partial correlations with the same sign. In that case, the partial correlations were positive but too weak to be considered cumulatively significant.

Item-Specific Variance

Common factors by definition do not include specific item variance. Thus, individual items might still have some predictive power beyond that provided by the composites. This possibility was examined by computing partial correlations of individual items with accident rates controlling for the 6 composite predictors. Only 3 of 107 items showed promise as predictors of accident rates: repetitive physical tasks (EPISYS partial $r = .259$; Ferguson partial $r = .535$), repetitive mental tasks (EPISYS partial $r = .299$; Ferguson partial $r = .331$), and use of application devices (EPISYS partial $r = .248$; Ferguson partial $r = .371$). Thus, even when items produced consistent positive correlations, only 1 of 6 correlations met the Bonferroni criterion of $r \geq .38$.³

Omitted Variable Bias

The reduced set of predictors provided the context for a test of omitted variable bias. The tests focused on the conditions for omitted variable bias. Bias will occur when two conditions are satisfied. First, some causal influence(s) on the dependent variable must be missing from the model. Second, the omitted influence(s) must be correlated with some predictor(s) that are in the model being tested.

³Additional regression analyses suggested that repetitive mental tasks might merit further consideration as an isolated predictor of accidents. The mental repetition item produced a stable regression coefficient (EPISYS, $b = 272.75$, $t = 3.42$, $p = .001$; Ferguson, $b = 256.60$, $t = 3.98$, $p < .001$) in a regression that also included *General Hazards* as a predictor. The corresponding coefficients for repetitive physical tasks were stable, but did not satisfy the significance criterion (EPISYS, $b = 158.65$, $t = 2.20$, $p = .033$; Ferguson, $b = 134.77$, $t = 2.26$, $p < .029$). The regression slopes for the use of application devices were not significant at even the $p < .05$ level.

Omitted variable bias was likely in previous studies that linked *Physical Ability* to occupational accident rates. As Table 4 clearly demonstrates, the requirement that Physical Ability be correlated with some plausible causes of accidents that were not in the model clearly was met. Table 5 shows that the omitted variables were moderately to strongly related to the accident rates, so they are plausible causes of accidents empirically as well as logically.

The magnitude of omitted variable bias was determined by fitting 3 regression models to the data. Physical Ability was the only predictor in the first model. The second model added the 4 composites from Tables 4 and 5 that were originally identified in Reynolds et al.'s (1992) factor analysis. This step provided an estimate of omitted variable bias that might be typical of studies that identified a set of accident risk factors and constructed a priori scales for those factors. The third model added the composite representing the miscellaneous item correlates of accident rates. This model was analogous to what might be expected in studies with an exploratory component designed to search for factors that might be important even though they were not identified at the beginning of the study.

The regression coefficient for Physical Ability estimated the causal effect of this variable in each model. With Physical Demands as the sole predictor in the model, the slope was 172.23 for the EPISYS data and 277.00 for the Ferguson data. When Working Conditions, Working with Machinery, Perceptual Skill, and Manual Labor were added to the equation, the slopes were 86.14 and 47.32, respectively. Adding the miscellaneous variables as a diffuse indicator of job hazards actually reversed the sign of the effect to yield -13.36 and -22.04, respectively.

Discussion

Omitted variable bias is a significant concern for accident research. The problem can be illustrated by considering the relationship between the present findings and previous results regarding physical ability demands. Previous work demonstrated that physical ability demands were related to accident rates. This relationship has a plausible causal interpretation based on conceptual models (Chaffin, Herrin, & Keyserling, 1978) and epidemiological research (Bernard, 1997). The present study identified other occupational characteristics that were moderate-to-strong predictors of accident rates and showed that those characteristics were strongly correlated with physical ability demands. The apparent effects of physical ability demands were markedly reduced when analyses controlled for those other associations. In fact, the apparent causal effect was eliminated all together when the analysis included the miscellaneous items. Given the pattern of associations in the set of job characteristics and their relationships to the accident criteria, similar results would be expected for the other occupational factors.

The basic problem may be that an occupation is too broad a framework for accident analyses. This level of analysis can help divide occupational characteristics into those that are likely to influence accident rates and those that are not. This assertion is supported by the fact that only 38 of 107 occupational characteristics and 5 of 18 factors met reasonable criteria for establishing a plausible cause of accidents. Each of these characteristics may contribute to individual accidents, but they are confounded with other potential explanations when accidents are aggregated into overall rates. As a result, it is not possible to confidently define the causal effect of each individual facet. As a consequence, it is not possible to estimate the effects of redesigning tasks, modifying work spaces, and so on.

A model based on a general hazards construct is one way out of the uncertainty. The attempt to isolate individual causal factors is abandoned in favor of a model that acknowledges that risk factors occur in combination. The model may provide accurate prediction of accident rates, but it provides little insight into how to reduce the accident rates. The general hazard approach suggests that accident reduction programs should adopt 1 of 2 courses of action. One option is to change any individual hazard component that is easy to modify. The other option is to try to change all of the hazard components at once. Either approach is likely to be inefficient if the set of predictors includes a subset of characteristics that are the active ingredients in the mix. Further modeling efforts clearly would be needed to provide a strong basis for accident reduction programs. These efforts could introduce results of safety studies that focus on individual accidents. These studies could extend the model of occupational differences to include direct and indirect effects of occupational characteristics. For example, machinery may not cause accidents as much as it generates physical ability demands that lead to overexertion.

The findings are not all gloom, doom, and difficulty. The present analyses restrict the range of factors to consider in modeling accidents. Only 38 of 107 job characteristics rated in the Reynolds et al. (1992) study were relevant to accident rates. The findings should also help avoid a rush to judgment in the sense of adopting the first explanation for an accident that comes along. Instead, the evidence strongly points to the need to examine multiple values. Providing a general framework for searching the set of possible contributing factors should help avoid confirmatory bias in the research context (Bentler & Dudgeon, 1996).

The study had several strengths. The investigation covered a wide range of occupations. The cumulative person-years of observation made it possible to obtain reliable estimates of the accident criteria even though hospitalization for injury is a relatively rare event. Each occupation was described by an extensive profile of job characteristics, so it is unlikely that important factors were overlooked. The ratings used to measure the characteristics were highly reliable, so negative findings cannot readily be attributed to attenuation by measurement error. The accident criteria reflected relatively severe accidents, so the associations cannot be dismissed as representing trivial events in the workplace. The criteria refer to accidents that clearly involve meaningful costs to the Navy. The criterion measures span the quarter century from 1970 through 1994. The results are not likely to represent some temporary events. This stability in the face of changes in technology and personnel policies implies that the problem is not likely to disappear spontaneously.

The study strengths were balanced by study limitations. The composite accident criterion was one limitation. Injuries can be intentional. Accidental injury can occur on the job or away from the workplace. Occupational characteristics directly affect only 1 of these 3 sources of accidents. The ideal criterion would focus on workplace accidents. Instead, the EPISYS criterion combined intentional injuries with accidental injuries. The Ferguson criterion was somewhat better as it was limited to accidental injuries. This difference may explain why the Ferguson rates were more strongly related to occupational characteristics. Rates based solely on workplace accidents produced stronger associations in earlier work (Vickers & Hervig, 1999). That line of inquiry was not pursued in this study because the EPISYS criteria could not be decomposed. This problem made it impossible to replicate any important effects. Further decomposition should be a topic for subsequent studies.

Aggregate accident criteria may be the reason for a diffuse model. Suppose individual accidents could be attributed to a single causal factor. A study of the overall accident rate combines all of the individual accidents. Any variable that contributes to some of the accidents will be correlated with the overall rate. When several causal factors occur in combination, their

association to the overall rate will be inflated by their noncausal correlation to the accidents produced by co-occurring factors. From this perspective, the results are useful primarily for defining the range of factors that may be related to accidents.

Restriction of the accident criterion is another potential limitation. The analyses were limited to accident rates for men. Ferguson et al. (1985) restricted their analyses to men because there were no women in many occupations at the time of their study. This decision was reasonable at the time, but the wider dispersion of women in today's Navy means that results based solely on men must be treated with caution.

Omitted variable bias cannot be ruled out completely. Personnel composition was not examined. Prior research has indicated that accident rates are higher in occupations with above-average scores on several personality characteristics, most notably higher hostility, impulsiveness, excitement seeking, and disagreeableness and lower gregariousness (Vickers & Hervig, 2005). Differences in personality composition were largely independent of occupational ability demands. This relative independence extends to other occupational characteristics as might be expected given their strong associations to physical ability demands. If so, omitted variable bias is unlikely because one key condition is not satisfied (James et al., 1982). However, independence should be confirmed.

Occupational differences in accident rates are related to a wide range of occupational characteristics. Those characteristics commonly occur together, so it is difficult to clearly define the effects of specific characteristics. The attendant risk of omitted variable bias, which was clearly demonstrated for physical ability demands, cannot be ignored. Until more detailed evidence is available, treating occupations as generally hazardous is more constructive than focusing on individual characteristics. The present findings provide a starting point for refining this abstract model.

The results are constructive from the overall modeling perspective despite the very general structure of the model at this point. Twenty-five years ago, Ferguson, McNally, and Booth (1981, p. 1) noted that "Job demands, work activities, and environmental exposures presumably vary widely as a function of Navy occupation . . . It would be of interest to determine if such variations are associated with differences in injury risks." This study divided a large set of occupational characteristics into those that are and those that are not plausible causes of accidents. Simple logic might have defined nearly the same categories, but logic alone would not have underscored the competition among explanations implied by correlations among the potential causal variables. Explanatory models must allow for the fact that potential causes of accidents occur in combination. The major challenge is how to accurately understand the effects of specific characteristics in the context of other potential causal factors. For example, are there causal effects of working with machinery that arise directly from interactions with the machines? Are there indirect effects produced by the types of tasks or the working conditions that arise from the presence of machinery in the work space? Is the apparent association inflated by the correlation between the presence of machinery and other causal factors? In all likelihood, all of these questions can be answered in the affirmative. The problem is to partition the apparent effects into direct, indirect, and spurious sources of association. This perspective implies that the models must extend to the job characteristics–injury rate profile. Models must also consider the associations among the job characteristics to fully understand the pattern of causal effects. That understanding would be useful for accident-reduction programs. The risk factor profile developed here provides an empirically defined frame of reference for pursuing this problem in U.S. Navy enlisted occupations.

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Appendix A

Full Item Level Results With Composite Comparisons

This appendix presents the correlations between accident rates and all 107 items in the Reynolds et al. (1992) job profiles. Reynolds et al. (1992) classified the items into 3 broad categories of tasks, behaviors, and abilities. These broad categories provide the primary basis for grouping items in this appendix. Reynolds et al. (1992) conducted factor analyses within each broad category. Their factor assignments provide the secondary basis for grouping items in this appendix. The composites in the tables in this appendix are the average scores for the items in the set that defined the factor.

Approach to the Choice of a Level of Analysis for Modeling

Only characteristics that were positively related to accident rates were classified as potential causal influences on accidents. The rationale for this restriction was sketched at the beginning of the Results section of this report (p. 3). The identification of potential causal influences also required a decision regarding whether to treat items as individual characteristics or as indicators of the factors identified by Reynolds et al. (1992). The basic criterion was that a composite was a better choice except when one or more items in the set predicted accident rates with substantially better precision than the composite score. This criterion derived from the measurement considerations presented in the following paragraphs.

Decisions about the use of composites were based on 3 general criteria. The criteria reflected the fact that item variance can be represented as the sum of factor variance, unique item variance, and error variance (Steiger, 1979). The composite was adopted if the pattern of item correlations could be explained by assuming that the shared common factor variance generated the item correlations. If the common factor was a cause:

- All item correlations would be positive.
- Differences in common factor variance would account for differences in item correlations. In particular, items with higher factor loadings would have stronger correlations because the higher factor loadings imply that the common factor was the source of a larger proportion of item variance.
- The item composite would predict accidents better than individual items. This expectation follows from the fact that the composite would be a more reliable indicator of the underlying common factor than any individual item (Nunnally & Bernstein, 1994).

These idealized results must be treated as qualitative guidelines. Sampling variance will affect correlations and factor loadings. Item factor loadings often were quite similar, so minor sampling variance or weak, item-specific effects on accident rates could change the pattern of item-level correlations.

The criteria for adopting the composite level of analysis can also be viewed from the perspective of an individual item. The question is whether highly correlated items should be treated as a single variable or a set of potentially independent causal influences. Focusing on the individual items involves the risk of inappropriately narrow focus. One might, for example, find that a number of working conditions affected accidents. Noise or vibration might be the strongest

correlate of accident rates, but only trivially more so than other characteristics in the set. A minor difference could represent a chance effect. In such a case, focusing on the single characteristic as “the” causal influence in the set would be misleading. However, in some cases, it might be true that a single characteristic in a set was an isolated causal influence. The association might be linked to item-specific variance rather than to common factor variance. Other items in the set might be related to accidents only because they occurred in combination with this single active ingredient in the mix. The composite score for the set then would also be related to the accident rates. However, the individual item would be a stronger predictor than the composite because the association depended on item-specific variance. The item would reflect that variance more precisely than the composite.

The comments accompanying each item set give the rationale for deciding whether the evidence was consistent with the hypothesis that the items individually represented job characteristics that were empirically plausible as causes of accidents. The comments accompanying each item set also sketch the rationale for deciding whether the set could be reduced to a composite when constructing causal models.

Task Items

Reynolds et al. (1992) defined a task domain that consisted of generic tasks. The tasks were generic in the sense that they were stated at a general level and could be found in a number of occupations. This domain consisted of 21 items. Their factor analysis reduced the item set to 6 factors plus 1 miscellaneous item.

Task Factor 1: *Working with Electronics*. These tasks were not plausible causes of accidents. All correlations were negative.

Table A-1. Working With Electronics

Predictor	1980-1994 ¹	1970-1974 ²
Composite	-.241	-.339
Maintain electronic system	-.249	-.409
Maintain/repair computer systems	-.454	-.520
Repair electric circuits or machinery	-.168	-.157
Operate electronic/other systems	-.138	-.450
Fabricate/construct/repair instruments	-.162	-.113

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Task Factor 2: *Working with Machinery*. This item set could influence accident rates. The common factor variance appeared to be the optimal level for modeling the effects. All of the associations with accident rates were positive. The composite correlations were larger than the corresponding item correlations in 6 of 8 comparisons for the overall accident rate. The relative magnitudes of the item correlations corresponded roughly to the size of their factor loadings.

Table A-2. Working with Machinery

Predictor	1980-1994 ¹	1970-1974 ²
Composite	.556	.701
Repair machinery	.517	.711
Operate machinery	.548	.785
Perform damage control activities	.550	.375
Operate electrical machinery	.355	.507

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Task Factor 3: *Construction Activities*. This item set included some elements that could influence accident rates. The conclusion is restricted to specific elements because the pattern of correlations suggested the effects might be represented best at the item level. All associations were positive, but the item dealing with fabrication of metal structures was a stronger predictor than the factor composite. The associations for fabricating metal structures also were notably stronger than those for other individual characteristics linked to this common factor. Those other associations could be explained by the fact that the other items correlated with fabrication of metal structures.

Table A-3. Construction Activities

Predictor	1980-1994 ¹	1970-1974 ²
Composite	.393	.650
Fabricate/construct/repair non-metal structures	.296	.584
Fabricate/construct/repair metal structures	.458	.698
Work with graphics	.178	.354

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Task Factor 4: *Communications and Cryptology*. This set of items was not a plausible cause of accidents. All correlations were negative.

Table A-4. Communications and Cryptology

Predictor	1980-1994 ¹	1970-1974 ²
Composite	-.303	-.461
Work with rapid communications	-.083	-.324
Work with cryptography/intelligence	-.263	-.395
Operate computer systems	-.580	-.767

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Task Factor 5: *Administrative Activities*. These items were not plausible causes of accidents. All correlations were negative (cf., Table A-5).

Table A-5. Administrative Activities

Predictor	1980-1994 ¹	1970-1974 ²
Composite	-.193	-.178
Work with correspondence/personnel needs	-.232	-.215
Work with records or requisitions	-.095	-.079
Work with personal or crew services	-.173	-.180

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Task Factor 6: *Working with Weapons*. This narrow factor might be a weak influence on accident rates. Correlations were positive, but they were too small to meet the established criterion for ruling out chance as a plausible explanation for the trend. This factor did not appear to be a general influence on accident rates. However, these tasks may have a strong effect on accident rates in the subset of occupations that involve handling ordnance.

Table A-6. Working with Weapons

Predictor	1980-1994 ¹	1970-1974 ²
Composite	.247	.174
Assemble/operate conventional ordnance	.239	.167
Work with nuclear ordnance	.259	.165

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Miscellaneous Item. Only 1 of the 21 tasks, performing medical and dental tasks, failed to load on any of the task factors. This item was positively related to accident rates

(EPISYS rate, $r = .126$; Ferguson total rate, $r = .270$; Ferguson on-duty rate, $r = .348$). These associations indicated that any general effect was too weak to be regarded as an important general influence on accident rates.⁴

Summary of Task Associations. The set of task items produced two variables to consider as potential contributors to occupational differences in accident rates. One variable was the item composite for *Working with Machines*. The single item was fabricating metal structures. The other task factors clearly failed to meet either the logical or statistical criteria that were established to identify plausible causes of accidents.

Behavior Items

Behavior items defined the second major domain in the Reynolds et al. (1992) classification. This domain consisted of 60 items dealing with a combination of factors. Some items clearly dealt with behaviors such as using a particular type of tool. Other items dealt with conditions encountered in the work setting. Reynolds et al.'s (1992) factor analyses provided a basis for separating these 2 item categories if it was appropriate, so the distinction is noted here only for descriptive purposes. The factor analyses assigned 51 items to 7 factors. The remaining 9 items are treated as miscellaneous.

Table A-7. Poor Working Conditions

Predictor	1980-1994 ¹	1970-1974 ²
Composite	.546	.816
Work cramped/uncomfortable*	.399	.660
Work with loud noises*	.461	.755
Work in enclosed area (hot)*	.456	.548
Work where easily become dirty	.547	.799
Work in area with vibration*	.532	.818
Work in polluted air	.524	.837
Work with poor lighting*	.611	.557
Lift heavy objects*	.466	.712
Work in hazardous situations*	.419	.682

*Item selected a priori as likely causal influence on accident rates.

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Factor 1: *Poor Working Conditions*. The factor composite can adequately represent the item set. All item correlations were positive and large enough to meet the Bonferroni significance criterion for both of the accident criteria. The composite was a stronger predictor than the

⁴ The associations would have been stronger if the Corpsman and Dental Technician occupations had been included. However, those occupations were omitted because prior work indicated that their inclusion distorted the general pattern of associations between accident rates and occupational factors (Vickers et al., 1997). A model that basically contrasts these occupations with others is less valuable than a model with more general application. The high accident rates in the health professions merit investigation in their own right, but those rates should not be allowed to distort the general pattern of associations for other occupations.

individual item in 16 of 18 comparisons for overall accident rates. The ranking of items based on their association to accident rates did not correspond closely to the ranking based on factor loadings. This minor discrepancy was not sufficient to replace a simple composite with 9 individual items. Later analyses probably would have had to rely on methods such as stepwise regression to select a subset of items to represent the full set. This reduction could lead to a single item such as polluted air representing the full set of items. Such an outcome seemed likely to be seriously misleading.

Factor 2: *Manual Labor*. This item set cannot reasonably be represented by a single overall composite. Item correlations generally were positive, but the associations ranged from zero (e.g., use of precision tools) to strong (e.g., use of application devices, work with stationary machinery). Also, the item correlations did not appear to be systematically affected by common factor variance. Some items with strong factor loadings produced weak correlations, while other items with weaker factor loadings produced strong correlations. Finally, 6 of 12 items produced stronger correlations than the composite. This item set therefore was reduced to a composite of the 6 items with strong positive correlations.

Table A-8. Manual Labor

Predictor	1980-1994 ¹	1970-1974 ²
Composite	.358	.547
Set up/adjust machines/equipment	.248	.321
Use tools for precise operations	-.030	.007
Take apart/assemble equipment	.193	.320
Use handheld tools	.438	.592
Use stationary machinery/equipment	.563	.787
Perform tasks requiring moderate detail	.439	.554
Use physical measurement devices	.475	.583
Inspect products/objects/materials/equipment	.229	.442
Perform tasks requiring extreme detail	.099	.193
Wear protective clothing regularly*	.427	.714
Follow set procedures	.330	.414
Use devices that apply something	.621	.760

*Item selected a priori as likely causal influence on accident rates.

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Factor 3: *Administration and Logistics*. This item set reduced to a pair of relevant items. The use of the composite score in modeling was out of the question. The composite score was not related to the accident criteria. Item-level correlations were not consistently positive. The range of correlations included some moderate negative correlations as well as moderate positive correlations. Substantial positive correlations were paired with relatively weak factor loadings. The item-specific variance for the 2 responsibility items therefore was the logical basis for their association to accident rates.

Table A-9. Administration and Logistics

Predictor	1980- 1994 ¹	1970- 1974 ²
Composite	.037	-.006
Instruct others (skill/knowledge)	.155	.129
Use written materials	-.520	-.426
Keep knowledge current	.016	-.214
Distribute information to others	-.003	-.173
Prepare written materials	-.336	-.391
Inform superior of progress	-.023	.055
Accept responsibility for others' safety	.470	.608
Pay careful attention to detail	-.220	-.134
Be responsible for asset/property damage	.405	.583

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Factor 4: *Technical Data Handling*. This item set did not appear to be related to accident rates. The association between the composite and accident rates was too weak to be important. The item-level correlations included moderate positive correlations and moderate negative correlations. Watching for frequent events was the only item that met the criteria that identified plausible causal influences on accident rates.

Table A-10. Technical Data Handling

Predictor	1980- 1994 ¹	1970- 1974 ²
Composite	.101	.124
Watch for frequent events	.394	.383
Watch for rare, critical events	.276	.167
Use sounds as job information	.324	.399
Code and decode	-.224	-.462
Perform under time pressure	.111	.043
Use technical devices	-.409	-.527

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Factor 5: *Technical and Mathematical Activities*. This item set produced a mixture of small positive and negative correlations. Neither the composite nor any individual item was a plausible causal influence on accident rates.

Table A-11. Technical and Mathematical Activities

Predictor	1980-1994 ¹	1970-1974 ²
Composite	-.039	.095
Use quantitative materials	-.112	-.066
Use advanced mathematics	-.193	-.205
Use basic mathematics	-.012	-.053
Use picture or picture-like information	.269	.298
Use visual displays	-.311	-.374

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Factor 6: *Signal Processing*. This item set could be reduced to a pair of items. The composite met the criteria for a causal influence, but the variation in item-level correlation was substantial. Three of the 6 items met the criteria for a causal influence. The other 2 items clearly fell short of this standard. The item with the most common factor variance (i.e., the largest factor loading) was one of the weak predictors of accident rates. The item with the smallest factor loading was the strongest predictor. In fact, the associations between this item and the criteria were stronger than those for the composite.

Table A-12. Signal Processing

Predictor	1980-1994 ¹	1970-1974 ²
Composite	.435	.551
Work outdoors	.223	.349
Judge distances to objects	.548	.475
Communicate by signal	.542	.612
Use surroundings as information	.199	.044
Drive cars or trucks	.026	.254
Sense bodily position/balance*	.443	.618

*Item selected a priori as likely causal influence on accident rates.

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

The treatment of one item in this set is noteworthy. The item dealing with awareness of body position and balance could easily have been assigned to a different factor. This item had a factor loading of .41676 on *Signal Processing*. The item also had a factor loading of .41002 on *Poor Working Conditions*. Assigning the item to *Poor Working Conditions* would have made this item another element of a set that consistently met the criteria for treatment as a composite causal influence. The trivial difference between the factor loadings is hardly a resounding argument for the current alignment. The concern for individual items therefore could reduce to 2 items each from the *Poor Working Conditions* and *Administration and Logistics* domains.

Table A-13. Working with People

Predictor	1980- 1994 ¹	1970- 1974 ²
Composite	-.307	-.344
Frequent contact with others	-.354	-.395
Attend to needs of others	-.174	-.166
Conduct interviews to meet objective	-.257	-.223
Work under distractions*	-.211	-.407

*Item selected a priori as likely causal influence on accident rates.

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Factor 7: *Working with People*. All of the correlations for this factor were negative.

Miscellaneous Items. Only 1 of 9 miscellaneous items, performing repetitive physical tasks, met the basic criteria for identifying a potential causal influence on accidents.

Table A-14. Miscellaneous Behavior Items

Predictor	1980- 1994 ¹	1970- 1974 ²
Cold*	-.170	-.302
Brief	-.122	-.326
Keyboard	-.612	-.775
Remote control	.316	.278
Entertain	-.095	-.066
Perform repetitive physical tasks*	.575	.681
Perform repetitive mental tasks	.025	-.117
Check accuracy	-.336	-.529
Keep knowledge current	-.287	-.373

*Item selected a priori as likely causal influence on accident rates.

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Summary of Behavior Correlates of Accident Rates. The 60 behavior items included 2 composites, *Poor Working Conditions* and *Manual Labor*, and 7 individual items to consider in constructing causal models of occupational differences in accident rates. The composite for *Poor Working Conditions* included all 9 items in the set defined by Reynolds et al.'s (1992) factor analysis. The composite for *Manual Labor* included only 6 of the 12 items in that set. Therefore, the original set of 60 items was reduced to 22 items describing conditions that might contribute to accident rate differences.

Ability Items

Reynolds et al. (1992) classified 26 items as representing occupational demands for specific abilities. Their factor analyses reduced this domain to 5 factors plus 5 miscellaneous items.

Factor 1: *Physical Ability*. A composite adequately represents this item set. All item-level correlations were positive and between $r = .500$ and $r = .800$. The composite was a stronger predictor of the overall accident rate in 7 of 8 comparisons to individual item correlations.

Table A-15. Physical Ability

Predictor	1980- 1994 ¹	1970- 1974 ²
Composite	.553	.712
Strength	.514	.692
Flexibility	.540	.703
Stamina	.543	.703
Body balance	.572	.681

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Factor 2: *Cognitive Ability*. Only 1 item from this domain, Visualization, was relevant to accident rates. Correlations for other items in the set were consistently small and generally negative.

Table A-16. Cognitive Ability

Predictor	1980- 1994 ¹	1970- 1974 ²
Composite	.081	.103
Reasoning	-.331	-.280
Numerical ability	-.063	-.087
Pattern detection	-.188	-.244
Originality	-.112	-.078
Information ordering	-.084	-.082
Problem sensitivity	.135	.181
Visualization	.599	.609

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Factor 3: *Dexterity and Fine Motor Control*. This item set was the most difficult to evaluate. The composite correlations clearly met the criteria for a potential causal influence. All of the items also met the criteria. However, the coordination item stood out as exceptional in the set. The correlations for this variable were much stronger than the correlations for any other item in the set. The correlations for this item were notably larger than those for the composite.

Table A-17. Dexterity and Fine Motor Control

Predictor	1980- 1994 ¹	1970- 1974 ²
Composite	.649	.643
Dexterity	.418	.362
Speed of movement	.488	.406
Arm-hand steadiness	.450	.463
Coordination	.695	.763

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

These points were particularly noteworthy in light of the fact that the coordination item had the weakest factor loading in the set. Taking these points together, the general pattern of the findings seemed more likely to be attributable to the individual item than to the composite. The decision therefore was to reduce the set to a single item rather than using the composite.

Factor 4: *Perceptual Skill*. *Perceptual Skill* was another item set that was difficult to evaluate. On the whole, the decision was that this set should not be represented by a composite of all 4 items. Instead, a composite was constructed from the first 3 items. The speed of perception item was dropped because it produced correlations that were clearly inconsistent with those for the other items. The inconsistency may be explained by the fact that this item had roughly equal factor loadings for *Perceptual Skill* (.43045) and *Cognitive Ability* (.42054). The accident rate correlations were more consistent with membership in the cognitive ability item set.

Table A-18. Perceptual Skill

Predictor	1980- 1994 ¹	1970- 1974 ²
Composite	.552	.485
Reaction time	.455	.379
Sound localization	.626	.632
Vision	.516	.441
Speed of perception	.116	-.023

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Factor 5. *Communication*. The communication factor was not relevant to accidents. All correlations were negative.

Table A-19. Communication

Predictor	1980- 1994 ¹	1970- 1974 ²
Composite	-.300	-.342
Oral communication	-.160	-.296
Written communication	-.385	-.342

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Miscellaneous Items. Two miscellaneous ability items were relevant to accidents by the criteria employed in this study. Control precision and rate control produced moderate-to-strong positive associations.

Table A-20. Miscellaneous Ability Items

Predictor	1980- 1994 ¹	1970- 1974 ²
Memorization	-.003	-.180
Control precision	.562	.621
Rate control	.639	.699
Attention	-.086	-.152
Time sharing	-.287	-.497

¹Injury rate data from EPISYS (Jaeger et al., 1996).

²Injury rate data from Ferguson et al., 1985.

Summary. The items assigned to the ability domain reduced to 2 composite measures and 4 individual items. Composites were appropriate for *Physical Ability and Perceptual Skill* after dropping an item from the second set.

General Summary

The analyses began with 107 items. The items could be grouped into 3 broad domains defined by Reynolds et al. (1992) or into 21 smaller sets representing 18 factors plus 3 groups of miscellaneous items. The miscellaneous item sets included 15 items. The pattern of associations between these potential predictors and accident rates reduced the original 107 items to 5 composites plus 12 individual items. The composites included 1 measure of task requirements, 2 measures of behavior requirements, and 2 measures of ability requirements. Individual items included 1 task, 7 behaviors, and 4 ability measures. When considered at the level of the broad domains defined by Reynolds et al. (1992), the final set of predictors included 5 of 26 task items, 22 of 60 behavior items, and 11 of 21 ability items, for a total of 38 of 107 items.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT (maximum 200 words) The hospitalization rate for injuries varies widely across U.S. Navy enlisted occupations. Logic suggests that this variation is related to occupational demands. Previous evidence that higher accident rates occurred in occupations that demand physical exertion and fast reaction times supported this view. However, the results may have been biased by the omission of other important contributors to accidents. The present study reduced 107 specific occupational characteristics to 6 composites, Physical Ability, Perceptual Speed and Skill, Work with Machinery, Poor Working Conditions, Manual Labor, and Miscellaneous, that reliably predicted accident rates. The 6 composites could be reduced to a higher-order General Hazards factor. No composites or individual item predicted accident rates controlling for this general factor. The results indicate that it will be difficult to isolate the effect of specific factors that contribute to accident rates when the occupation is the unit of analysis. Analysis of individual accidents should consider each of the elements covered by the General Hazards construct to avoid overstating effects. The primary limitation of the study is that specific hazards might have been identified as important if the analysis had separated accidents occurring on the job from those occurring elsewhere.
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15. SUBJECT TERMS accidents, job characteristics, occupation
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