PSYCHOSOCIAL FACTORS, WORKLOAD, AND HUMAN ERROR IN A SIMULATED PHARMACY DISPENSING TASK

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Summary.—Participants filled 42 orders on a task designed to simulate components of filling prescriptions. Task factors included objective workload of 70- versus 80-min. to complete the task and perceptions of workload dimensions using the NASA Task Load Index. The proportion and pattern of data-entry, counting, and product-selection errors were compatible with those found in pharmacy field-sites. Significant other relationship stress, field-dependence, and an 80-min. workspace predicted data-entry errors. Mistakes in product selection were associated with low GPA, high social stress, the NASA Task Load Index dimension of less concern with performing well, and a 70-min. workspace. Relationship of data to corresponding information in the pharmacy literature and to assumptions of a cognitive-systems performance model was discussed.

Sequential, self-paced, repetitive tasks wherein the output of one part serves as the input for the next component are very common. Examples include dispensing drugs in a pharmacy, directing aircraft in an air traffic control facility, filling warehouse orders, cooking meals, and writing computer programs. Such tasks rely upon both conscious and automatic cognitive processes to set goals, plan and make decisions, as well as to coordinate and monitor the execution of the components. Cognitive failures can occur at any point in the sequence, and, if undetected, such errors may be repeated or amplified as successive components unfold. Depending upon the setting, the consequences of such errors may include financial losses, inconvenience, psychological distress, and physical injury.

Filling a prescription has several repetitive and interdependent components and making mistakes has potentially serious consequences. Estimates vary for the number and proportion of errors that are due to a pharmacist or pharmacy technician committing an error. Studies using on-site inspectors suggest that outpatient and community pharmacy outlets have a modal rate of error of 3–5% of all prescriptions filled (i.e., 300–500 in 10,000 prescrip-
tions filled) *inside of the pharmacy* (Abood, 1996; Grasha & O'Neill, 1996). The range of such mistakes across outpatient and community pharmacy outlets is approximately 1–24% of prescriptions filled (Allan-Flynn, Barker, Gibson, Pearson, Berger, & Smith, 1996). The majority of such mistakes represent data-entry errors but wrong-drug, wrong-strength, wrong count, and drug interaction mistakes are also included in such data. Conservative estimates in ambulatory and outpatient settings indicate that 0.87–1.6% of the in-pharmacy mistakes were potentially injurious to patients (Guersey, Ingram, Hokanson, Doute, Bryant, Blair, & Galvan, 1983; Abood, 1996).

How many of the in-pharmacy mistakes find their way into patient hands is not known with any precision. A recent study, however, of 100 prescriptions obtained from a random sample of independent and chain pharmacies using a disguised patient technique showed that 4% of the prescriptions given to consumers contained clinically significant errors (Allan, Barker, Malloy, & Heller, 1995). And a recent study of 36 chain pharmacy outlets indicated that the number of mistakes leaving a pharmacy depends upon several factors. They include the number of additional checks made on completed work, the counseling of patients when prescriptions are picked up, and how much consumers are alert to possible misfills (Grasha, Reilly, Schell, Tranum, & Filburn, 2000). As pharmacists currently fill more than 3 billion prescriptions a year (Proctor, 1999), even a small rate of error translates into a large number of mistakes, so gaining a better understanding of why they happen and how to control and prevent their occurrence is an important issue.

Attempts to understand the basis for such errors in outpatient and community pharmacies have focused on factors associated with the process of filling prescriptions, e.g., illumination, interruptions in workflow, environmental distractions and noise, facility design, technology, poorly designed product labels, and workflow (cf. Abood, 1996; Grasha & O'Neill, 1996). While such efforts have helped to reduce the incidence of errors, the current numbers of mishaps are considered a problem. Our work on the correlates of such errors has used pharmacy field-sites, surveys of pharmacy personnel, as well as a high-fidelity pharmacy simulation task to examine among other things the role that psychosocial factors play in such mishaps. The study to be reported in this paper employs a pharmacy simulation task that mimics several psychomotor components of filling an actual prescription. The parts of the dispensing task simulated include entering data into a computer database from an order card, selecting a product from a shelf, counting the correct amount of the product, and then placing the materials into a bag. The patterns in the rates of data-entry, counting, and product-selection errors that occur in this simulated task are comparable to those found within an outpatient or community pharmacy (Grasha & Schell, 1999; Grasha, Schell, Reilly, & Tranum, 1999). Thus, the task can be used for identifying variables believed to be associated with such errors as well as interventions that might counteract them.

The variables associated with dispensing errors are examined in the context of how the information-processing system fails to perform and the factors that affect such failures. A Cognitive-Systems Model has been used to guide our work in this area (Grasha, 1995, 2000a; Grasha & O'Neill, 1996; Grasha & Schell, 1998). This model suggests two avenues for understanding human error on a dispensing task. One examines how the sensory register, working memory, and long-term memory components of the cognitive system are interdependent and how they affect performance. Mistakes, for example, can occur if any part of the system fails to perform for a variety of reasons.

For example, the sensory register might not capture needed task information because sensory input may be degraded by such things as poor lighting or the presence of sensory noise from equipment or the talking of other coworkers. Working memory may fail in part because the amount of work exceeds cognitive resources, or distractions and interruptions interfere with the retrieval of information or the ability to check on-going activity for accuracy. Or, pharmacists working on a dispensing task might take shortcuts to meet time constraints such as incorrectly assuming that a prescription from a particular physician was similar in all respects to others recently filled. A short-term memory buffer in working memory may be affected by interference among structurally or semantically similar prescription information such as look-alike, sound-alike, and spell-alike medications. Also, when under stress, the ability to reconstruct needed information from long-term memory could be adversely affected or information needed was not present in long-term memory due to a lack of experience, training, or improper encoding.

The latter aspect of the model has allowed us to test a variety of interventions designed to reduce error proneness *in simulated and actual pharmacies* including (a) having pharmacy personnel have visual and hearing screenings to identify sensory deficits, (b) the use of computer mounted copy strips to provide good visual angles on prescription information, (c) providing high-intensity task lighting and magnification devices to improve visual acuity, (d) self-monitoring of errors detected and corrected to enhance attention to personal error tendencies and patterns, and (e) performance feedback and goal setting to enhance knowledge of performance and motivation to perform. The latter interventions are part of recently completed work both in the laboratory simulation and in pharmacy field sites (Grasha, et al., 2000; Grasha & Schell, 2000).

The second component of the model examines the interplay of objective task and environmental elements, e.g., number of orders completed,
work pace, illumination, and how such factors combine with a variety of psychosocial factors to affect performance. Included in the latter realm are subjective components of the task and environment such as perceived workload, task-induced moods, and perceptions of the adequacy of lighting and other psychosocial factors. The underlying assumption, supported by the empirical outcomes of our research to date, suggest that task, environment, and interpersonal qualities, e.g., cognitive failure tendencies, field-independence-field-dependence, Type A behavior pattern, inadequate resources for coping, interpersonal relationship problems (e.g., coworker and supervisor tension, social life and significant other stress), organizational norms and procedures, and extraorganizational influences outside of the immediate work environment (e.g., tension from other jobs, roles, and demands) affect accurate performance.

Acting alone and in combination, stress and tension from the latter domains affect performance in one or more ways. (1) They increase the rate at which information is processed and subsequently the amount of information handled. When processing capacity is exceeded, mistakes become more probable. (2) Ruminations and thoughts about stressful events may distract people when completing a critical component of a task or prevent them from checking their work in a timely manner. Mistakes may go unnoticed. (3) They increase stress leading to the use of various heuristics, biases, and shortcuts to meet task demands. People may change work patterns, rhythms, workplace strategies, or rely upon responses that were similar to what was done before, most frequently used, or recently employed. Such decisions may encourage inaccurate performance. (4) They facilitate the use of past habits that interfere with more recently learned and adaptive ways of managing a task and thus reduce the transfer of training.

This Cognitive-Systems Model or framework is an important part of our laboratory and field site work. Gaining insights into how various components independently and jointly affect performance in self-paced sequential processing tasks is one of our goals. Our work is just beginning to examine such issues, and there is very little research in particular on the relationship of psychosocial factors to this problem. There is, however, reason to believe that they are important. We do know from other work that a field-independent cognitive style is associated with fewer dispensing errors (Allan, 1994; Allan-Flynn, et al., 1996) as are rejections in the rate at which information is processed (Cantor, 1997, 1998). And, poor team working relationships, authoritarian supervisory styles, and beliefs that mistakes will be held against them were associated with fewer medication errors reported and intercepted (Edmondson, 1996). Finally, our interest in psychosocial factors and error fits into other contemporary work in the skills literature. There, evidence of psychosocial influences on accurate performance can be found in studies of individual differences in skill acquisition (Ackerman, 1992), motor vehicle accidents (West & Hall, 1997), pilot error (Aikov, Gaynor, & Borowsky, 1985), and attentional task performance (Matthews, Davies, & Lees, 1990).

Current Study

Unlike other studies, the current one examined different types of errors as a function of several psychosocial and task factors in the Cognitive-Systems Model. Given the lack of a comprehensive body of research on the relationship of psychosocial factors to human error on a dispensing task, specific hypotheses were not formulated. Instead the role of the intrapersonal, interpersonal, extraorganizational, and task domains of the model on errors were explored. *Intrapersonal* factors in the model examined included age, education (number of years in school), sex, academic ability (GPA), error proneness, resources for coping, field-independence-field-dependence, and Type A behavior tendencies. *Interpersonal* sources of influence involved tension in relationships with a significant other and in one's social life and *Extraorganizational* influences examined were nonsimulation job tension, i.e., from part- or full-time jobs participants held, and tension associated with their roles as students.

Task influences included the amount of time participants were assigned to complete a set of 42 orders, i.e., 70 versus 80 min. (objective workload), and perceptions of workload measured by the NASA Task Load Index (TLX). Our interest in the relationship of objective workload to dispensing errors parallels that in other occupational groups where issues of task overload, stress, and perceived workload are examined for their contributions to performance (cf. Hancock & Meschkati, 1988; Parasuraman & Mouloua, 1996). A simple linear relationship between objective measures of workload on performance accuracy is not necessarily the norm, and research suggests that subjective perceptions of workload also must be taken into account. In effect, people have different thresholds for workload and when it becomes dysfunctional.

Similar issues apply to a dispensing task and the relationship of workload to performance is more complex than previously thought (Chi, 1999). For instance, a review of the findings from studies conducted at pharmacy field sites yields large discrepancies about the purported negative effects of prescription workload. In some cases, moderate correlation coefficients (r ranging from .40 to .56) to strong associations (r = .78) between prescription workload and error are reported (Gueunsey, et al., 1983; Rupp, DeYoung, & Schondelmeyer, 1992; Allan, 1994). In contrast, data from other sources (Kristner, Keith, Seargeant, & Hokanson, 1994; Grasha, 1998; Grasha, et al., 1999) yield relatively weak statistical trends (r is about .10). Generally when cumulative counts of errors over time are employed, such relationships
hold. When corrections for differential opportunities to make errors are en-
acted, i.e., the base of orders from which errors occur are equated, such rela-
tionships do not appear. The design of this study allowed the relative con-
tributions of objective and subjective levels of workload on errors to be exam-
ined when the baseline of orders filled were the same for all participants.

Three issues were explored: (a) the extent to which objective and sub-
jective workload measures predict errors on a simulated dispensing task, (b)
the identification of psychosocial factors that were associated with errors on
a simulated pharmacy task, and (c) how task and psychosocial factors com-
bine to predict errors.

Method

Participants

The sample of 76 undergraduate students were from introductory and
advanced psychology courses in the day and evening programs of the uni-
versity. Each volunteered to participate for up to three hours in the tasks
required for this study in exchange for extra credit. In this group were
29 men and 51 women between 21 and 47 years of age, with a mean age of
24.3 yr. (SD = .6). Participants had completed an average of 3.0 yr. of college
(SD = .9) and held a self-reported mean GPA of 2.87 (SD = .5) out of a max-
imum 4.00 GPA.

Simulation Workspace

A 4.45-m × 3.60-m room equipped with a two-way mirror was used.
The workstation consisted of a small black desk chair on rollers, four 1.5-m
× .75-m tables arranged in a U-shape with 3 m between the edges of the right
and left tables. Each table had one 90-cm × 45-cm × 30-cm off-white
colored portable shelf with a lower and upper surface for stacking bottles.
The workspace area directly to the left and right of the computer keyboard
used for counting materials and bagging orders was 45 cm × 60 cm in each
direction. A Macintosh SE-30 computer with a 22.5-cm screen, keyboard,
and mouse was positioned directly in the center of the workstation.

The portable shelves were arranged with one located directly to the
right and a second located directly to the left of the computer positioned in
front of a participant. The remaining two portable shelves were on each of
the two side tables directly to the right and left of where a participant sat.
When normally seated at the workstation, the distance from a participant’s
eyes to the center of the computer screen was 45 cm, with a mean visual an-
gle across participants to the center of the screen of 25°. When sitting at the
edge of a table directly in front of a shelf, the distance to the front surface
of each of the four shelves was 30 cm.

Sources of light included four overhead fluorescent lighting fixtures and

an outside window covered with translucent blinds located on the wall adja-
cent to the right side of the workstation. Lumination on the work surface
where participants filled orders was 657 lx, and the light levels measured
from the front surfaces of the upper and lower shelves also measured 657 lx.
The ambient background of light measured in the center of the room was
877 lx.

A small 20-cm × 14-cm pharmacist’s counting tray was positioned 15
cm to the left of the keyboard. In addition, a standard clear acrylic
office in-box tray that held sixty 3.125-cm × 17.5-cm Ziploc plastic bags
was positioned in the center of the left side-table. A small 15-cm × 8.75-cm
digital clock was positioned near the left-hand corner of the right side-table.
A stack of 7.5-cm × 12.5-cm white index cards, used for the written order
cards, were positioned next to the right-hand edge of the shelf on the table
top.

Pharmacy bottles containing the materials used in this study were posi-
tioned 3.75 cm from the front edge of each shelf. Materials were stocked in
different types of bottles. Two of the sets of the opaque off-white col-
ored bottles were 1.400 ml (10 cm × 5 cm in diameter in size). The other
two sets of bottles were clear plastic Tupperware containers and were either
small 100 ml (6.375 cm × 5 cm in diameter) or medium 185 ml (7.5 cm ×
7.5 cm in diameter). Product names for simulation materials were printed on
3-cm × 7.5-cm computer labels using 10-point bold, black, Times Roman
type and were glued to the front surface of the bottles.

A visually homogeneous workspace was created to simulate conditions
found in a pharmacy work area. Thus the computer, shelves, and bottles
were off-white and thus similar in color. In addition a 5-m × 0.9-m white
cardboard screen covered the rear of the workstation and white sheets of
fabric covered the table surfaces to further enhance the homogeneity of the
visual field. A virtual tour of the pharmacy simulation workspace can be
found at http://hompages.uc.edu/~grasha/

Materials

Products dispensed.—Different colors, sizes, shapes of beads, nuts, and
washers, paper clips, and pieces of Trix cereal were used to simulate the dif-
fers sizes, shapes, and colors of drugs found in a pharmacy. As in a phar-
macy, there were different and uneven amounts of each size, shape, and col-
or of the materials used. Beads were either round, donut shaped, cylindrical,
oval, or long. They came in colors of gold, white, yellow, red, purple, or-
ange, silver, cream, black, and blue and either small, medium, or large sizes.
Not all bead shapes were manufactured in each color, shape, and size but
those available allowed for 96 combinations of shape, color, and size to be
used. Six types of paper clips combining red, yellow, or blue colors and me-
dium or large sizes were employed. Standard metal hardware nuts came in three sizes of small, medium, or large while the metal hardware washers were either medium or large.

Materials were sorted by color, size, shape, assigned labels, and placed in one of 96 pharmacy bottles. Each bottle held about two to three dozen pieces of each of the product. Beads were labeled by shape, size, and color, paper clips by size and color, common hardware nuts and washers were identified by size, and pieces of Trix cereal were labeled only by color.

The following are several examples of labels used on the bottles in the simulated pharmacy. For example, gold, silver, and white oval beads came in three sizes and the bottles were marked accordingly. The designation BEADS-GL 1.0 on the label indicated medium-size gold beads while BEADS-GL 10.0 represented large silver beads. Beads that were not round were identified by color only. Thus, the label BEADS-D-RD represented donut shaped, red beads while BEADS-O-YL indicated oval shaped, yellow beads. The label CLIPS-CL 1.0 signified medium blue paperclips while CLIPS-CL 10.0 identified large red paperclips. NUTS .10 designated a bottle that contained small nuts while NUTS 1.0 and NUTS 10.0 represented medium and large items of this product, respectively. Washers were either medium or large with corresponding labels of WASHERS 1.0 or WASHERS 10.0. TRI-X-YL on a label signified yellow pieces while TRI-X-PU indicated that purple pieces of the cereal were in the bottle.

To simulate drugs that had similar spellings and sounds, each type of BEADS, CLIPS, NUTS, WASHERS, and TRIX described above had a duplicate set that was spelled BEEDS, CLEPS, NOTS, WASHERS, and TREG. The duplicates were identical to the original materials they represented except for a tiny dot or line that was hand-painted on the surface of each piece. The original and duplicate sets of materials totaled 96 bottles. As in a pharmacy, all materials were arranged on the shelves in alphabetical order by type of material.

Order cards.—Orders were handwritten in script or hand-printed on 7.5-cm × 12.5-cm white index cards. To provide variety in the written orders, there were four different handwriting and printing styles and four different colored pens used across the order cards. Care was taken to ensure that the handwriting and printing was legible. Each card contained the name of the ordering party, a company affiliation, the item requested and the quantity, and any special instructions for that item. All information was fictitious except for the name of the item and the quantity needed.

Computer database.—Information from the order cards was typed into a computer database, i.e., Microsoft Works 3.0. The database was set up to accept information from the index-card stimuli in the order written on the card. A timing routine was established in the database so that the total time between entering the data for one order and the beginning of the next order, i.e., the interorder interval, could be automatically recorded.

Psychological Tests

Participants were given a packet of three pretests and were instructed to complete them within 24 hours of arriving for the simulation phase of the study. The pretests consisted of the Cognitive Failures Questionnaire (Broadbent, Cooper, Fitzgerald, & Parkes, 1982), a 25-item test to identify their propensity for slips and lapses in various situations in their daily lives. A short version of the Group Embedded Figures test was employed to identify field-dependence–field-independence tendencies. Subscales of the Holistic Stress Test (Grasha, 1990; Crowe & Grasha, 1992; Short & Grasha, 1995) also were given. These included Job Stress, i.e., factors contributing to overall workplace tension on a full- or part-time job outside of the simulation; Relationship Stress, i.e., in a relationship with a significant other; Social Life Stress; Type A Behaviors; Student Stress; and the Resources for Coping subscale. The last one examined a variety of coping strategies people employ to manage stress and is based on Hobfoll's (1989) coping resource-allocation model.

After completing the simulation, the NASA Task Load Index that assesses perceived workload (Hart & Staveland, 1988) was administered. The workload index is a multidimensional measure that provides a global measure of workload on a scale of 0 to 100. This index also identifies specific components of workload along three dimensions imposed by the observer (Mental, Physical, and Temporal) and three dimensions related to the interaction of the observer and the task (Frustration, Performance Concerns, and Effort). This index is considered one of the strongest self-report measures of mental workload (Nygren, 1991; Hill, Iavecchia, Byers, Zaklad, & Christ, 1992).

Design and Procedure

Participants were randomly assigned to one of two groups after arriving for the simulation and were required to wear any corrective eyewear during the time spent on task. Groups were objectively defined by the 70- versus 80-min. periods they were given to complete 42 randomly selected orders for materials contained in the 96 bottles. The pretest packets were collected from participants as they arrived. They were oriented to the workspace and instructed to sit in front of the computer. Participants were told that the purpose of the study was to examine the factors involved in the performance of the task of filling orders.

Practice consisted of initially having the experimenter coach and guide subjects through the process of filling an order. This sequence consisted of typing the information from the order card into the computer database.
Next, the product ordered was selected from a bottle on one of the four shelves, the requested quantity was counted, and the order card and the product were then placed in a plastic Ziploc bag. The completed order was then placed in a large bag on the floor to the immediate left of the participant’s chair. A new order could not be started until the one preceding it was completed. Participants were instructed to strictly follow the latter prescribed sequence.

After this preliminary stage of instruction and guided practice, subjects were allowed a 15- to 20-min. supervised practice session filling six additional orders to become more familiar with the materials and the process of completing orders. They self-paced themselves during training and were not told how much time they would be allowed or the number of orders they would have to fill after the training phase was over. After training, they were given the opportunity to ask any additional questions and were given a 5-min. break. After the brief break, participants were then told they would have either 70 or 80 min. to fill 42 additional orders. They also were reminded that they could keep track of the time remaining using a digital clock located on the workspace table to their right. As an aid to tracking time remaining, subjects were reminded that they would have 42 orders or seven additional sets of six orders remaining to complete the task.

Participants were reminded that the experimenter would be observing them work from behind the two-way mirror. They also were informed that the experimenter would collect completed orders they had dropped into the large bag on the floor every 15 min. "to aid in restocking items after the simulation was over." After gathering each batch of orders every 15 min., the experimenter immediately double-checked each one for errors in the observation room. After completing the simulation, the NASA-TLX was administered and subjects were debriefed about their reactions to the study and the general issues and goals of the research project.

**Results**

**Incidence of Error**

A total of 3,108 orders were filled in the simulation, and mistakes were made on 447 of the orders (14.4%). There were no statistically significant differences in the proportion of errors made by men (14.8%) or women (14.0%; $F < 1.00$). Thus the data for men and women were combined for further analyses. And, in line with the pharmacy literature, three types of errors were examined. Data-entry errors included misspelling information on the order card or failing to place information from the order card into the database (13.9% of such mistakes). Placing more or less of the materials in the bag than the number ordered constituted a counting error. Selecting the wrong products either by name, e.g., CLEPS instead of CLIPS, or by size (10 instead of 1.0) were labeled selection errors. Overall, out of the 447 total errors, there were 222 data-entry errors (48.6%), 117 counting mistakes (25.6%), and 115 selection errors (25.1%). Of the data-entry mistakes, misspelling information on the order card accounted for 191 errors (86.1%), and 31 errors (13.9%) occurred when participants omitted information on the order card during data entry. Selecting the wrong product accounted for 101 of the product-selection errors (86%) and picking the wrong size for 16 (14%).

To explore whether the three types of mistakes were associated, intercorrelations among the arcsine transformations of the proportion of data-entry, counting, and selection errors were examined. Correlation coefficients were obtained for data-entry and counting errors ($r_{xy} = .40$, $p < .001$), product-selection and counting errors ($r_{xy} = .31$, $p < .01$), product-selection and data-entry errors ($r_{xy} = -.03$, $ns$). Data-entry and counting errors had the strongest association, whereas product-selection mistakes correlated better with counting than with data-entry mishaps.

**Objective Workload, Perceived Workload, and Error**

Participants allocated less time in the 70-min. group completed 1,506 orders and made 214 errors (14.2%). Those with more time in the 80-min. group finished 1,602 orders with 233 (14.5%) completed incorrectly. Neither the number of orders completed or the number of errors between the 70- and 80-min. groups were statistically significant (all $t$-test values $< 1.00$). Also, there was no relationship between the total time participants in each group took to complete the task and the errors they made. The correlation coefficients among the total amount of time participants used to finish 42 orders and the corresponding overall proportions of data-entry, counting, and product-selection errors were for data-entry $r_{xy} = .15$, counting $r_{xy} = -.02$, selection $r_{xy} = .03$, and total error $r_{xy} = .09$. No $rs$ were significant. Finally, the relationship of perceived workload to errors was compatible with the latter findings. With one exception, the correlation between the workload index dimension of concern for performance and selection errors ($r_{xy} = -.28$, $p < .05$), the other correlation coefficients among the TLX dimensions of mental demand, temporal demand, effort, task frustration, and physical demand, as well as the composite score with each type of error were not significant ($rs$ ranged from $-.22$ to $.09$).

**Psychosocial Factors, Task Factors, and Error**

An expectation of the Cognitive-Systems Model was that human error is partly related to tension from a combination of factors within the model. The overall goal was to examine the merits of this general expectation in the data of this study. Work with the model is still in formative stages so it was not possible to predict a priori which variables within each source of the
### TABLE 1

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Four sources of influence considered in this enquiry should be associated with error. Thus, the regression analyses are exploratory and the outcomes are best interpreted as descriptive of the role such factors played in the current study. The descriptive statistics and zero-order correlation coefficients among the variables used in these analyses are shown in Table 1.

Three forward stepwise regression equations were used to obtain a final model for each type of error. The dependent variable was an arc sine transformation of the overall proportion of data-entry, counting, and selection errors. After screening for outliers on each dependent variable (using a criterion of 3 SDs above and below the mean), four participants were eliminated from the data-entry distribution and two each from the counting and product selection error distributions. To ensure the models were as compatible as possible, these participants, i.e., eight in all, also were removed from the regression analyses of each dependent variable and not just those where they were outliers. Thus, all analyses were based upon 68 participants.

The general factors that influence performance in the Cognitive-Systems Model were used to select variables to be considered for the final models. Four general sources of influence on performance from the model were present in this study and included Task (NASA-TLX composite scores and six subscale scores; workspace); Intrapersonal (age, education in years, sex, GPA, error proneness, resources for coping, field-independence-field-dependence; Interpersonal (significant other and social life stress); and Extrarorganizational (outside of simulation job stress, students' role stress). In all, there were 19 variables to be considered as potential independent variables for the regression analysis.

To screen the variables for those to be used in determining a final model, the following process was used to allow variables from each component of the model to be considered. For each of the three types of error, standard regression analyses using only specific variables within the task, intrapersonal, interpersonal, and extrarorganizational sources of influences were first conducted, i.e., 12 analyses in all. The initial standard regression analysis for the task component used the six parts of the perceived workload index and not the composite score. Otherwise, the variables entered for the other factors in the model were those listed in the last paragraph.

To be considered for the final model, each of the independent variables met at least two of the following three criteria. It had to be a statistically significant independent predictor of the dependent variables, the highest ranked independent variable in a set of joint predictors, or it had to account for at least 3% of the unique variance in prediction.

Since work with the Cognitive-Systems Model continues to be a work in progress, the regression analyses were exploratory and attempts were made to be inclusive rather than exclusive. The 3% of variance accounted
for criterion initially may appear to be a relatively weak one. However, our pharmacy-simulation work is designed to identify variables associated with error that can be further explored in our work in pharmacy field-sites. Using the reported 3 billion prescriptions of 1999, one variable that might continue to account for 5% of the variance in prediction in the field would be associated with at least 90 million dispensing errors inside a pharmacy. Thus, any variable that accounted for 5% of the variance and met at least one of the other two criteria was included in the final model.

A summary of the final regression analyses for data-entry and product-selection dependent variables are shown in Table 2. None of the variables in the initial regression analyses for counting errors met two of the three criteria listed above and thus no final model is presented. The largest $R^2$ was associated with selection errors (.23), followed by data-entry mistakes (.21). In line with expectations of the Cognitive-Systems Model, the data-entry and product-selection errors were associated with variables from the intrapersonal, interpersonal, and task sources of influence. Extraorganizational sources of influence, i.e., outside of simulation job stress and student-role stress, did not meet the criteria for inclusion in the final model equations for data-entry or product-selection errors.

<table>
<thead>
<tr>
<th>Variables Entered at Each Step</th>
<th>$\beta$</th>
<th>$\Delta R^2$</th>
<th>$\beta$</th>
<th>$\Delta R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Significant Other Stress</td>
<td>.23*</td>
<td>.08</td>
<td>-.32+</td>
<td>.11</td>
</tr>
<tr>
<td>2. Field Dependence/</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Independence</td>
<td>-.24*</td>
<td>.06</td>
<td>.23*</td>
<td>.06</td>
</tr>
<tr>
<td>3. Education, yr.</td>
<td>-.25+</td>
<td>.04</td>
<td>-.20</td>
<td>.04</td>
</tr>
<tr>
<td>4. Workload Group</td>
<td>.18</td>
<td>.03</td>
<td>-.13</td>
<td>.02</td>
</tr>
</tbody>
</table>

Note.—Each numbered step is progressive and represents the variable entered at that step in combination with those entered during any previous steps in the analysis. For example, at Step 4, the variable entered is shown but should be understood that variables entered during Steps 1, 2, and 3 also were present.

Data-entry errors were associated with higher stress in significant other relationships, field-dependence, less education, and a relatively easier workload, i.e., the 80-min. group. Higher incidences of product-selection mistakes were related to a relatively lower GPA, high social stress, field-dependence, and to a relatively harder workload, i.e., the 70-min. group.

**Discussion**

**Objective Workload, Perceived Workload, and Error**

Overall 14.4% of the orders were filled incorrectly with more data-entry than counting or product-selection errors occurring. This is within the 1% to 24% range of dispensing errors noted earlier than occur in pharmacy settings. Similarly, the prevalence of data-entry errors relative to counting and selection mistakes also is compatible with the pharmacy literature (Abood, 1996). A finding that has not been previously reported in the literature was the statistically significant bivariate correlation of data-entry and product-selection mistakes with counting errors. However, data-entry and product-selection were not related, i.e., $r_{ps} = -0.03$, ns, suggesting that the two responses may have somewhat different cognitive precursors.

With one exception, whether participants had 70 or 80 min to complete the 42 orders, i.e., their objective workload and their perceptions of workload as assessed by the NASA Task Load Index were not independently associated with data-entry, counting, selection, or total errors. That one exception was the statistically significant correlation observed between the TLX dimension of performance concern and selection errors. The failure to find a simple relationship between workload and error is compatible with that reported elsewhere in analyses of data from outpatient and community pharmacies (Kistner, et al., 1994; Grasha & O'Neill, 1996; Grasha, 1998). Generally, when the ratio of errors to prescriptions filled is used as the dependent variable, as opposed to cumulative counts of error over time, a correlation between workload and error is not obtained. It is also possible, however, that the experimentally defined 70- and 80-min. workload manipulation used in this simulated pharmacy task was not strong enough to produce an independent effect. The variations between the 70- and 80-min. group may not have been large enough to produce a workload effect. Currently we are examining the effects of other time intervals on task performance.

**Psychosocial Factors and Error**

The general expectation of the Cognitive-Systems Model was that factors associated with the domains of influence on the cognitive system examined in this study, i.e., task, intrapersonal, interpersonal, and extraorganizational factors, should jointly be associated with error. Exploratory multiple regression analyses provided partial support for this expectation. At least one predictor from the task, intrapersonal, and interpersonal sources of influence was present in the final models for data-entry and product-selection errors. None of the extraorganizational predictors emerged as significant predictors. Nor did any of the predictors from the four sources of influence meet the two criteria to be included in a model for counting errors.
In the regression analyses of errors, some similarities were noted and the variables identified as predictors were related to a general class of factors associated with human error in pharmacy and other settings in the literature. Thus, there is reason to believe that the outcomes were stable and were not instances of a chance collection of variables. Several aspects of the data support the latter generalization.

First, field dependence appeared in each regression model as a correlate of both data-entry and product-selection mistakes. A similar association of field-dependence with overall error was obtained in outpatient pharmacy settings (Allan, 1994; Allan-Flynn, Barker, Gibson, Pearson, & Berger, 1999). In the latter work, 80% of the mistakes were label errors suggesting that poor data-entry is a major problem in prescription accuracy and that field-dependence was associated with the problem. A related finding has been reported among pharmacists in retail settings where 12% of the pharmacists responsible for 33% of the overall errors were tested as field-dependent (Grasha, et al., 2000). They were not detail oriented and were easily distracted by nontask-relevant stimuli.

Furthermore, the relationship of workload to each type of error also was a common predictor in both regression models as was an interpersonal source of stress. While workload was a common predictor for both data-entry and product-selection errors, its effects were in opposite directions. A relatively easy workload, i.e., 80 min., was associated with data-entry errors while a relatively difficult workload was correlated with product-selection errors, i.e., 70 min. Similar effects of objectively defined workload in combination with other factors on selection and data-entry errors also were observed among pharmacists and pharmacy technicians (Grasha, 1998; Grasha & O’Neill, 1998). In the present data, interpersonal tension also was a predictor of both types of mistakes but the source of the tension was different, i.e., stress in a relationship with a significant other versus social life stress for data-entry and product-selection errors, respectively.

The latter findings are not unusual. The general issue of interpersonal tension in human error has been reported in other areas. Among airplane crews, conflicts and poor communication were contributors to pilot error (Foushee, 1984). Interpersonal tension with supervisors and other team members was associated with fewer errors reported and intercepted among pharmacist, physician, and nurse health-team members (Edmondson, 1996).

Such tension, however, does not necessarily have to originate in the workplace to affect performance. Domestic problems were important precursors in crashes of commuter airplanes (Baker & Guohua, 1993). And, interviews and focus group outcomes with pharmacists indicated that such issues were problems for them as well (Grasha, 1995, 20006; Grasha & O’Neill, 1996). Pharmacists frequently reported that errors happened when they were distracted by thoughts of conflicts with spouses, problems with children, and other nonjob-related issues. Finally, such data support other findings showing that family and social life concerns contribute to 20% of the variability in predicting job stress and satisfaction (Crowe & Grasha, 1992). Such data as well as those from the current enquiry suggested that arousal and mental stimulation from interpersonal concerns on and off the job not only have implications for job satisfaction but for accurate performance on a variety of tasks including the filling of orders or dispensing drugs.

Conclusions

The outcomes of this study suggested that psychosocial factors were associated with the types of errors people made on a simulated pharmacy task. The results also indicated that objective workload and perceptions of subjective workload alone were not related to dispensing errors. Objective and subjective workload appeared to affect error when in combination with other psychosocial factors.

More work is needed to examine such relationships in detail and to test their generalizability to other settings. While the simulation task approximates what happens in aspects of filling prescriptions, it does not currently mimic the variety of clinical judgments about legal limits, drug interactions, and appropriateness of prescription information for a patient. Also, factors such as interruptions, irregular noise, and inadequate lighting were not present in the current form of the simulation as they often are in a pharmacy environment. What effects such things might have in conjunction with psychosocial factors needs to be explored. Finally, other factors that might affect the cognitive system directly and thus reduce human error on a pharmacy task should be investigated. This would include the effects of such things as performance feedback, the periodic monitoring and recording of errors to increase sensitivity to them, devices such as exaggerated lettering on product labels to improve product identification, and additional lighting in the workplace to improve visual discriminations when reading order cards.

REFERENCES

Adler, V., Gaylor, J., & Borowczyk, M. (1985) Pilot error as a symptom of inadequate stress and coping. Aviation, Space, and Environmental Medicine, 56, 244-247.


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