Running Head: FAA SHIFT WORK SURVEY

A Structural Analysis of the FAA 1999 Shift Work Survey

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Abstract

Shift work has been shown to be injurious to some. Because shift work can be harmful it is important to understand the personal and environmental characteristics that result in that harm. In 1999, the FAA collected survey data from shift workers, including Flight Service Specialists (FSS), and Certified Professional Controllers (CPC). These data were submitted to multiple-groups path analyses that attempted to replicated the C. Smith et al. (1999) model as well as fitting an analysis that placed personality variables as predictor rather than outcome variables. Additionally, these data were analyzed using structural equation models. The model positing personality variables as predictors best fit the data, both in the path analysis and the structural models. CPCs and FSSs showed the same patterns of relationships among the variables, with age, sleep flexibility, coping style and emotional problems predicting environmental variables that resulted in negative health outcomes. The models suggest that critical junctures for remediations and interventions are coping behaviors, sleep strategies, and somatic anxiety.

A Structural Analysis of the FAA 1999 Shift Work Survey

Approximately 14.5 million full-time workers regularly work an alternate shift, that is they work nights, evenings, rotating shifts, or split shifts. This is almost 15% of the workforce, and although this percentage has steadily declined since 1997, it still represents a substantial proportion of the workforce. Of these 14.5 million workers, most (53.5%) work alternate shifts because it is 'the nature of the job'. Only 13.3% list personal preference as the primary reason for their shift work. (("Workers on Flexible and Shift Schedules in 2001," News Release 02-225, April 2002, U.S. Department of Labor))

Shift work has been shown to have deleterious effects on the health of employees. These effects may be substantial, such as sleep disruption, altered affect, and decreased alertness resulting in poorer performance. Long-term effects may include chronic fatigue, sleep disorders, and psychological and physical illnesses (L. Smith et al., 2004).

Research has found that the relationship between work schedules and health depends on a number of elements, many of which are amenable to intervention (see Totterdell, 2005, for a review). These include workplace and social environments (e.g. characteristics of the work schedule, characteristics of the job, domestic environment), and individual differences and behaviors (e.g. personality, exercise habits). Others (Haider, Kundi, & Koller, 1981; Kundi, 1989, as cited in Totterdell, 2005) propose that shift work interferes with the dynamic equilibrium that holds between work, sleep, and family. Thus, both external and internal influences have been shown to predict long-term consequences of shift work (L. Smith et al., 2004).

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Environmental and Social Factors

Environmental and social factors play an important role in adaptation to shift work. Takahashi and colleagues found that workers who reported a good fit to job content, higher job satisfaction, and fewer problems in social and family life, also reported better adaptation to the shift schedule (Takahashi et al., 2005). Family situation and housing conditions have been shown, not surprisingly, to facilitate sleeping at odd hours (Rutenfranz, Knauth, and Angersbach, 1981), which in turn is likely to aid adaptation to shift work (Takahashi et al., 2005).

Social disturbances are important predictors of shift work adaptation because shift work schedules increase the difficulty of participating in family and leisure activities, especially when others in the household or social circle are not shift workers (Colligan and Rosa, 1990). The conflicts we all experience between limited time and social activities are exacerbated by shift work. These conflicts can lead to marginalization or social isolation when institutions become involved (e.g. civic groups, sports teams, political or cultural organizations; Costa, 1996).

Individual Differences

Age, health, personality, coping strategies, and other individual differences have been shown to be related to adaptation to shift work. Takahshi, et al. (2005) found that increases in perceived adaptation were associated with younger age, eveningness (being a "night owl", not a "morning lark"), fewer problems in social and family life, and more undisturbed sleep in the daytime before the first night shift.

Circadian rhythm concepts based on questionnaire measures have been successful in predicting shift work tolerance (e.g., Vidacek et al., 1995). For example, individuals

who are categorized as evening rather than morning types, because they tend to wake up and go to sleep later and prefer activities later in the day, appear to adjust better to night work (see Harma, 1993). In relation to age, older shift workers experience more problems than younger shift workers because circadian adjustment becomes more difficult with age (Parkes, 2002).

There is also evidence that shift work tolerance is greater for individuals who are more flexible in their sleeping habits or who can overcome drowsiness more easily (e.g., Costa, Lievore, Casaletti, Gaffuri, & Folkard, 1989). The predictive powers of these measures for shift work tolerance are small but greater than those of other individual difference measures (Kaliterna, Vidacek, Prizmic, & Radosevic-Vidacek, 1995).

Finally, a host of other variables have been implicated in adaptation to shiftwork. Mental and behavioral strategies adopted by shift workers also appear to influence their adjustment to the schedule. For example, use of effective coping strategies, commitment to shift work, and physical fitness have all been associated with less disturbance (Harma, 1993; C. Smith et al., 1999). Neuroticism has also been linked to poor shift work tolerance (e.g., Parkes, 2002), suggesting that other personality variables may be important predictors of adaptation to shift work.

Physical and Mental Health Outcomes

Shift work is associated with a number of negative health outcomes, including gastrointestinal disease, cardiovascular disease, and decreased mental health.

Gastrointestinal disorders. A number of studies have reported increased incidence of gastrointestinal disorders (including appetite disturbance, abdominal pains, and peptic ulcer) in shift workers (Costa, 1996). There are a number of possible explanations

including changes to neuroendocrine functions due to altered sleep patterns, changes to meal times (and other circadian synchronizers), and changed content of meals (including increased carbohydrate intake). Costa (1996) found that perturbations of the link between mealtimes and circadian phases of the gastrointestinal tract can be an important factor in explaining digestive troubles often complained of by shift workers. Also, changes in food quality (prepackaged, cold) and interrupted meals can contribute to gastrointestinal complaints. Increased use of stimulant drinks (coffee, tea, caffeinated sodas) as well as increased use of tobacco and alcohol can yield dyspepsia, constipation, heartburn, flatulence etc.

Cardiovascular diseases. Shift work and long work hours have also been linked with increased risk of cardiovascular diseases (Costa, 1996; White & Beswick, 2003). Based on an assessment of 17 studies that have examined the risk for shift workers, Boggild and Knutsson (1999) estimated that male and female shift workers have a 40% increase in cardiovascular disease risk. However, not all of the large-scale studies in that review found an association. A number of possible mechanisms have been proposed to explain the heightened risk of cardiovascular disease for shift workers including circadian disruption, social disruption, health behaviors (e.g., diet, smoking, alcohol use, exercise), and biochemical changes (e.g., cholesterol). Research concerning these mechanisms is limited, but there is some support for explanations based on dietary differences and increased smoking in shift workers (Boggild & Knutsson, 1999; Kivimaki et al., 2001). Costa (1996) suggests that the association between shift work and increased risk of cardiovascular disease may arise from both a direct mechanism (disruption of hormonal,

neurovegetative and biochemical homeostasis) and indirect effects from the more stressful working and living conditions associated with shift work.

Mental health. As well as being linked to problems of physical health, shift work has also been linked to mental health problems (see Cole, Loving, & Kripke, 1990; Costa, 1996; Koller, Haider, & Kundi, 1981). Studies have found increased acute psychological and somatic symptoms such as job strain and irritability among shift workers. Shift workers may also be at greater risk for a number of chronic psychological problems including chronic fatigue, persistent anxiety, neurotic disorders, and depression. Indeed, it has been observed that poor adaptation to shift work and depression share a number of core complaints, possibly because they have circadian disturbance in common (Healy, Minors, & Waterhouse, 1993). Long work hours have also been associated with poor psychological health and depression (White & Beswick, 2003), but there is little research on chronic effects.

Research on adaptation to shift work indicates that these, and other, negative consequences of shift work may be mediated by the environmental and individual differences discussed above.

Definitions for SEM Terminology

Constructs are abstract or general ideas inferred or derived from specific instances. These constructs frequently have labels that are also used in informal language. When constructs are used to explain behavior, they must be measured. When several measures are made of a single construct they can be combined in a number of different ways.

Factors are one variety of these mathematical entities. Factors are constructed from the shared variance of the measured variables. The objective of deriving factors is to have a 'pure' measure of the construct.

Path Analysis (PA) is a statistical tool that allows several multiple regression equations to be estimated simultaneously. This allows regression weights, here called path coefficients, to be estimated in the context of these complex relationships. An important assumption of PA is that the measures selected have very little measurement error. That is, the measures are assumed to be almost perfect measures of the constructs of interest. In contrast, structural equation modeling (SEM) uses multiple measures for each construct of interest. The assumption here is that the construct is best represented by the shared variance of these measures.

In Confirmatory Factor Analysis (CFA), we select measures that are believed to measure the (psychological) constructs of interest. Factors are then mathematically derived from those measures. Associations among the variables, and therefore between the variables and factors, are made *a priori*.

Additionally, when the participants belong to different groups, a sequence of tests can determine if the pattern of relationships among the factors is the same for all groups. These tests have three levels of invariance: complete metric invariance; pattern invariance; factor invariance. Complete metric invariance involves all relationships among the factors being the same for all groups and the strengths of those relationships being equal. Pattern invariance releases the equality of strength constraint, but the relative strength of the relationships must be the same for all the groups. Factor invariance requires that the relationships between the factors are the same for all groups

but releases the relative strengths constraint. It is also possible that the groups are different enough that the factors are not related in the same way for all groups (Kline, 2005).

Previous Shift Work Structural Models

When examining adaptation to shift work by employees, internal and external factors may be assessed. Internal factors are those characteristics of the employee which may affect adjustment to shift work. External factors are environmental variables, some of which are job-related and others involve social or domestic circumstances. The categorization of these variables as either predicting adjustment or as measures of adjustment is largely dependent on the researcher and the research question.

Given the recursive nature of the relationships among the constructs typically examined in shift work studies, structural modeling and path analysis are commonly chosen tools. C. Smith et al. (1999) examined the relationships among individual variables [age, morningness/eveningness, flexibility of sleep habits, ability to overcome drowsiness], mediator variables [sleep disturbances, social disruption, domestic disruption, engagement coping, disengagement coping], and outcome variables [emotional problems, job satisfaction, digestive symptoms, cardiovascular symptoms] using path analysis. The model that best fit the data varied by group, such that those nurses working permanent night shifts had a different pattern of relationships among the variables than nurses working rotating shifts, and both of these groups had different patterns than the industrial shift workers.

It is well established that shift work in the service and manufacturing industries results in higher levels of sleep disruption, domestic disturbances, and illness

(Bourdouxhe et al. 1999). However, the effect of shift work on air traffic employees in the United States had not been examined until the 1999 survey.

Methods

Participants

Approximately 21,000 air traffic control specialists, designated as series 2152s (trainees, certified professional controllers, air traffic control specialists, staff specialists, supervisors, and managers), received the questionnaire in December 1999. Responses were received from approximately 29% of those surveyed (n = 6,712).

Measures

The 1999 FAA Shift Work Survey was modeled after C. Smith et al. (1999) Shift work survey. The FAA survey comprises 169 questions concerning several topics. These topics are listed in Table 1. See Hackworth et al. (2xxx) for details of the survey.

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Overview of Statistical Procedures

Path Analyses (PA)

Using LISREL 8.54 (Joreskog & Sorbom, 2003), several PA models were fit to the data. C. Smith and colleagues had used a similar set of questions to assess the impact of shift work on health in three populations, nurses who worked only nights, nurses who worked rotating shifts, and industrial workers who worked rotating shifts. These industrial jobs included air traffic controllers, police officers, postal workers, and chemical, steel, and power plant workers.

We attempted to replicate the model C. Smith et al. (1999) fit to their industrial sample (model 3). We chose this group's model to replicate because this group most closely matched our largely male sample of CPCs and FSSs. In this model, C. Smith and

colleagues used age, morningness/eveningness, subjective workload, flexibility, and languidity to predict quality of sleep, social and domestic disturbances, coping style, chronic fatigue, job satisfaction, emotional problems, and finally, cardiovascular and digestive complaints (see Figure 1).

The C. Smith et al. model was fit to the CPC and FSS samples simultaneously. The three levels of metric invariance were tested; the best fitting model was the completely invariant model, in which the CPC and FSS groups have identical relationships among the factors. However, this model, seen in Figure 2, did not fit sufficiently well to meet minimum criteria: $\chi 2$ (175) = 16212.25; RMSEA= .145 (95% CI= 0.143; 0.147). Thus, the pattern of relationships among the constructs that predicted health complaints of industrial workers does not predict those complaints among air traffic personnel. This might occur for a number of reasons, not all of which imply that the constructs are not valuable predictors. For example, it might be the case that the constructs are important, but that they stand in a different relationship than was the case for C. Smith et al. This led to a search for theory driven alternatives. Many personality theorists in the U.S. (e.g. McCrae, Costa, & Ostendorf, 2000) regard personality as genetically determined. If this is so, then a better fitting model should emerge if the personality variables (disengagement coping, engagement coping, and emotional problems) are used as predictors. That is, if we treat them as if they characteristics of people, like age, morningness/eveningness, etc.

Using the same data set and modeling techniques, we fit a model in which personality variables joined the other predictors. These antecedents were then used to predict the remaining outcome variables. Again, a completely invariant model fit the data

best, and exceeded minimum fit requirements: $\chi 2$ (159) = 6243.85; RMSEA= .094 (95% CI = 0.092; 0.096). The completely invariant model suggests that there is no difference between CPCs and FSSs when it comes to predicting the consequences of shift work.

Factors that were considered inherent in the respondents, that is, characteristics that are not easily influenced, if at all, by external forces were used only as predictors. These factors were age category, morningness/eveningness, flexibility of sleep habits, and ability to overcome drowsiness (labeled 'languidity'). In addition to these C. Smith et al. predictors, we added the two coping style variables (engagement coping, disengagement coping) and the emotional problems variable. These inherent factors were allowed to correlate with each other, but no causal relationships were hypothesized.

The model replicated several well know relationships, as well as giving us new information about the causes and effects of shift work. It is well supported that as age increases, sleep quality decreases as we see in this model. Engagement coping style, not surprisingly, reduced the level of domestic and social disruptions. Also well known is the positive influence of the ability to sleep whenever and wherever (sleep flexibility) on the quality of sleep of those who must sleep at odd times of day. Interestingly, sleep flexibility also resulted in greater social and domestic disruptions. This may be due to those who can't sleep during the day being able to participate in activities when they should be sleeping. Sleep quality, in turn, had a modest effect on chronic fatigue, with better sleep quality resulting in less fatigue.

Job satisfaction resulted from a number of influences. Emotional problems and disengagement coping caused lower job satisfaction, while engagement coping style produced higher job satisfaction.

Chronic fatigue was modestly ameliorated by sleep quality, but disengagement coping style and emotional problems had much stronger effects on chronic fatigue. Higher levels of disengagement coping and emotional problems resulted in higher levels of chronic fatigue.

Somatic anxiety was also an outcome of disengagement coping and emotional problems. People with low levels of job satisfaction and low levels of engagement coping were more likely to experience somatic anxiety. It is also interesting to note that the only direct influence on cardiovascular and gastrointestinal complaints was from somatic anxiety. This suggests that the negative influences shift work can result in somatic anxiety, which in turn causes the negative health outcomes.

Given the superior fit of this new model, we became curious about its applicability to the original C. Smith data set. We fit the personality-as-predictor model to the C. Smith et al. (1999) data for the industrial sample. The resulting model fit well: $\chi 2$ (154) = 616.57; RMSEA= .088 (95% CI = 0.082; 0.094). If those same constructs are used but configured with personality as an outcome variable, the fit is $\chi 2$ (170) = 1176.98; RMSEA= .108 (95% CI = 0.103; 0.114). We should note that in the original C. Smith et al. dataset, a measure of workload was available and used by C. Smith et al. as a predictor. With workload added C. Smith et al. report that model as fitting better: $\chi 2$ (156) = 503.94; RMSEA= .044.

Structural Models

Because we have many measures of each of the constructs of interest we were able to perform a CFA to produce measures of the constructs that are freer from error than those used in the path analyses.

Prior to performing structural analyses, confirmatory models were fit to the data using LISREL 8.54 (Joreskog & Sorbom, 2003). Confirmatory models are developed based on a priori hypotheses about the relationships of the measured variables to the constructs of interest. The constructs are correlated, but no causal relationships are represented at this stage. Once this measurement model is constructed, causal relationships among the constructs are tested. We randomly selected one-half of the CPC respondents to fit the initial models. We fit both the C. Smith et al., model and the personality-as-predictor model to the data. Measured variables related to the constructs represented in the path analyses were chosen. Measured variables were eliminated for either of two reasons: 1. they were not clearly related to the constructs of interest; 2. they failed statistical tests of relationship to the constructs of interest.

The models were first fit to a subset of the CPC respondents. The relationships of the measured variables to their factors were, for the most part, unremarkable, providing no new insights into the adaptation to shift work. However, sleep quality was dominated by the questions pertaining to strategies for sleeping in the daytime. This suggests that those who are most effective at using these strategies (unplugging the phone, using a sleep mask, etc.) experienced the best sleep.

After the initial models were well fit to the first CPC subset, we then fit these models to the remaining CPC respondents and the FSS respondents simultaneously (see Figures 3 and 4). The C. Smith et al. model once again fit fairly poorly: $\chi 2$ (1494) = 16212.25; RMSEA= .157 (95% CI= 0.148; 0.162). The personality as predictor model fit well: $\chi 2$ (1461) = 6243.85; RMSEA= .077 (95% CI = 0.072; 0.087).

Discussion

Both the PA models and SEM models produced similar results. That is, individual differences in age, morningness/eveningness, sleep flexibility, laguidity, emotional problems, and coping styles predicted the environmental factors of social/domestic disruptions, sleep quality, and job satisfaction. These environmental factors in turn predicted somatic anxiety and chronic fatigue. Emotional problems and coping styles also had direct effects on somatic anxiety and chronic fatigue. Finally, somatic anxiety predicted cardiovascular and digestive complaints.

These analyses suggest that the C. Smith et al., (1999) model does not characterize these data very well. The size of the sample and the modeling of the survey instrument from the C. Smith et al., shift work survey precludes methodological error as the explanation for these results. Therefore, it seems likely that the personality as predictor model is the better model for shift workers employed by the FAA.

The negative effects of shift work on mental and physical well-being are pervasive, but it is clear that some shift workers adapt better than others. These workers have fewer negative consequences from working irregular hours. These findings suggest that there may be a few key points at which to focus remediation or intervention. In order to reduce the negative consequences of shift work, shift working employees could be given help in developing active coping mechanisms and/or training in how to direct their anxiety through other channels, rather than internalizing it. Also, the structural models allow us to see that behaviors that result in better sleep quality (e.g. unplugging the phone, wearing a sleep mask) are important to greater adaptation to shift work. So as long

as shift workers are needed there will be a need for well-targeted interventions that can reduce these negative effects.

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C. Smith et al. (1999) model for the industrial sample.

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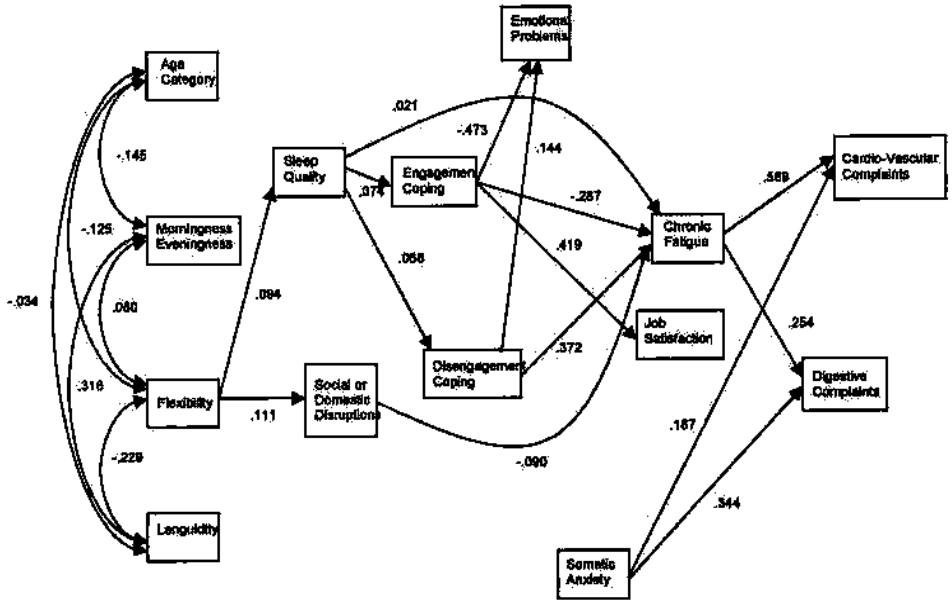
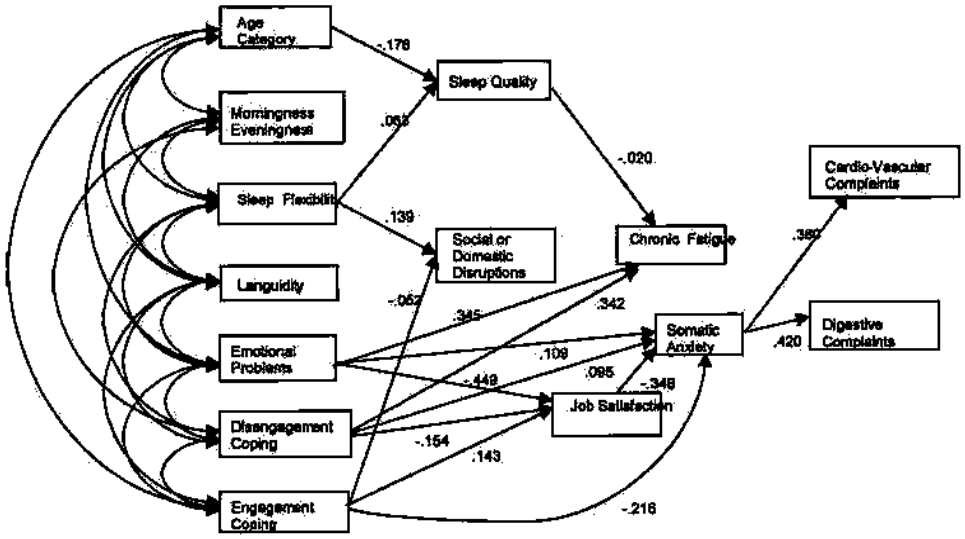
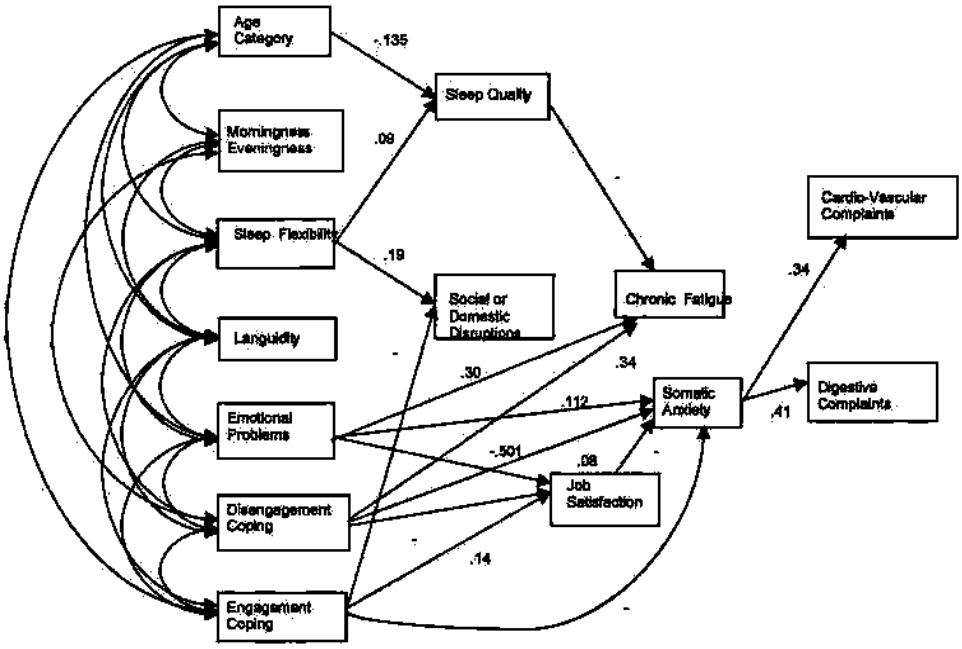
Figure 2. Replication of C. Smith et al. 1999 model using CPC and FSS samples



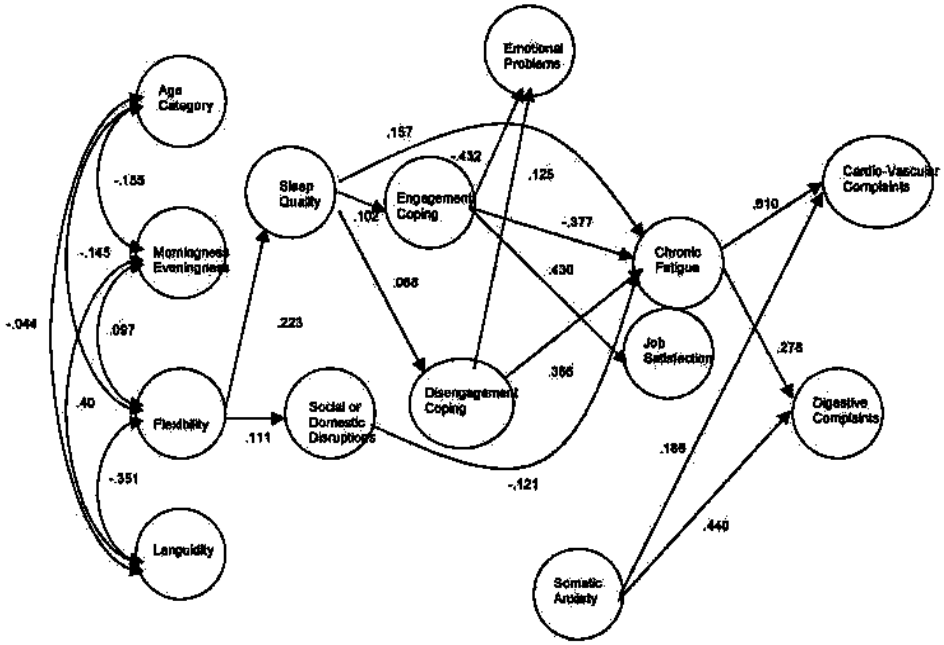
Path analysis of personality-as-predictor model



Application of the personality-as-predictor model to the C. Smith et al. industrial sample



Structural model replication of C. Smith et al., 1999



Structural model of the personality-as-predictor model