Human Reliability Analysis

Lecturer

Lesson IV 3_7.1

Workshop Information

IAEA Workshop

City , Country
XX - XX Month, Year

Human Reliability

HUMAN RELIABILITY

The probability of successful performance of only those human activities necessary to make a system reliable or available.

HUMAN ERROR

Human Error is simply some human output which is outside the tolerances established by the system requirements in which the person operates.

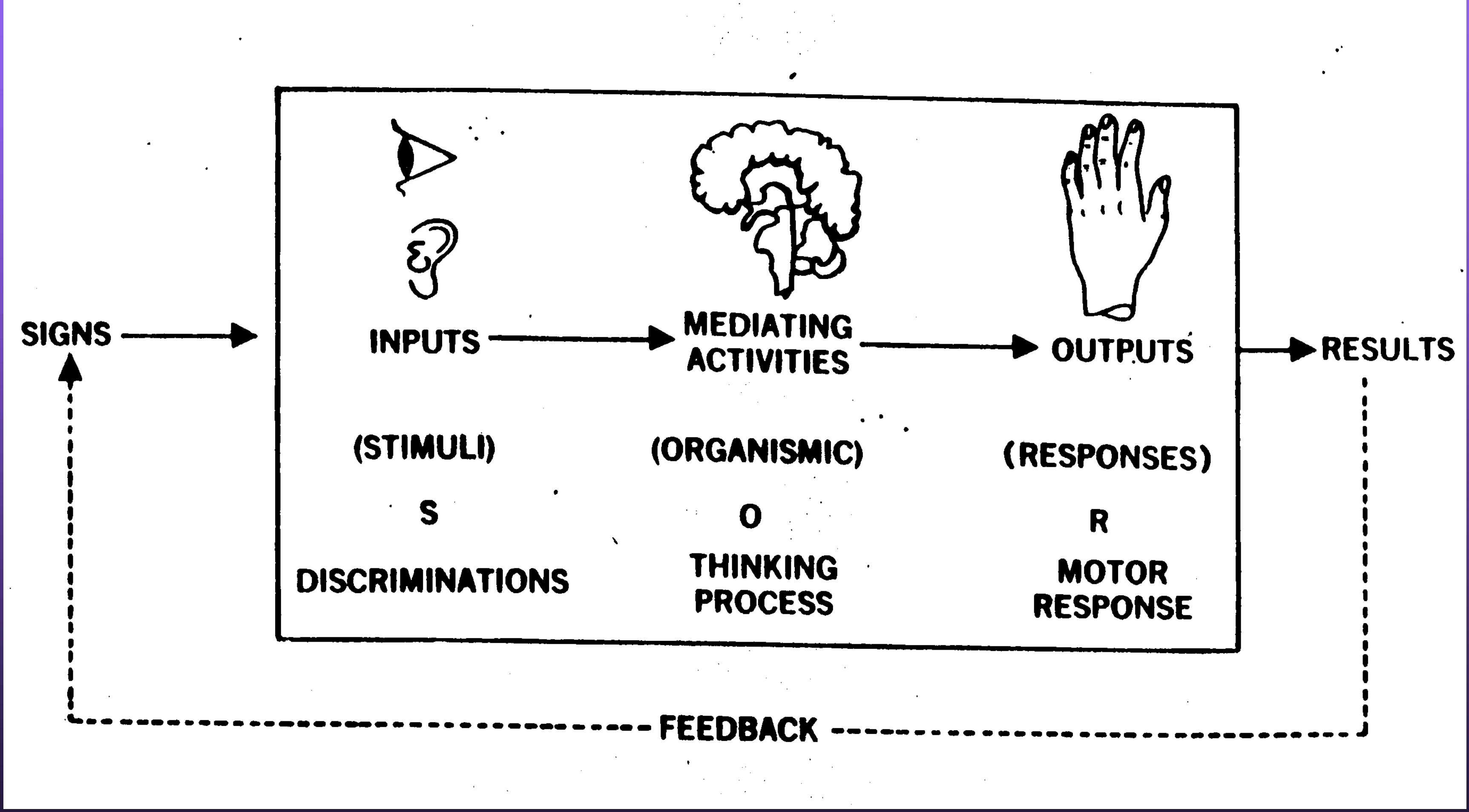
Human Reliability Analysis

- What can happen, i.e., what can go wrong?.
- How likely is it that this will happen?.
- If it does happen, which are the consequenses?.

Goal of Modeling the Human Performance for PSA

- To develop descriptive models to predict how well people will perform what they are supposed to do in normal and abnormal situations.
- It is not to understand human behavior and all the motivations behind it.
- A model of a system is an abstraction which reproduces (*simulates*) symbolically the way in which the system functions.

Human HRA Model



Human Error Categorisation

- **ERRORS OF OMISSION**
  - Omits entite task.
  - Omits a step in a task.
- **ERRORS OF COMMISSION**
  - Selection error
    - Selects wrong control.
    - Misposition of controls.
    - Issue wrong command on information.
  - Errors of Sequence
  - Timing Errors
    - Too Early.
    - Too Late.
  - Qualitative Errors
    - Too Little.
    - Too Much.

Human Action Categories

RUTINE

Human actions explicitly included in documents (*Procedures, Specification, etc*…).

COGNOSCITIVE

Human actuations that require a cognitive process of understanding and decision making, previous to do an action.

Performance Shaping Factors (PSF)

- Any factor that shapes (*Influences*) human performance.
- Less than adequate PSF - Higher human error probabilities.

Categories of PSF's

- External.
- Stressor.
- Internal.

Some PSF's in Man-Machine System

EXTERNAL PSFs		STRESSOR PSFs	INTERNAL PSFs
SITUATIONAL CHARACTERISTICS THOSE PSFs GENERAL TO ONE OR MORE JOBS IN A WORK SITUATION	**TASK AND EQUIPMENT CHARACTERISTICS** THOSE PSFs SPECIFIC TO TASKS IN A JOB	**PSYCHOLOGICAL STRESSORS:** PSFs WHICH DIRECTLY AFFECT MENTAL STRESS	**ORGANISMIC FACTORS:** CHARACTERISTICS OF PEOPLE RESULTING FROM INTERNAL & EXTERNAL INFLUENCES
ARCHITECTURAL FEATURES QUALITY OF ENVIRONMENT TEMPERATURE, HUMIDITY, AIR QUALITY, AND RADIATION LIGHTING NOISE AND VIBRATION DEGREE OF GENERAL CLEANLINESS WORK HOURS/WORK BREAKS SHIFT ROTATION AVAILABILITY/ADEQUACY OF SPECIAL EQUIPMENT, TOOLS AND SUPPLIES MANNING PARAMETERS ORGANIZATIONAL STRUCTURE (e.g., AUTHORITY, RESPONSIBILITY, COMMUNICATION CHANNELS) ACTIONS BY SUPERVISORS, CO-WORKERS, UNION REPRESENTATIVES, AND REGULATORY PERSONNEL REWARDS, RECOGNITION, BENEFITS	PERCEPTUAL REQUIREMENTS MOTOR REQUIREMENTS (SPEED, STRENGTH, PRECISION) CONTROL-DISPLAY RELATIONSHIPS ANTICIPATORY REQUIREMENTS INTERPRETATION DECISION-MAKING COMPLEXITY (INFORMATION LOAD) NARROWNESS OF TASK FREQUENCY AND REPETITIVENESS TASK CRITICALITY LONG- AND SHORT-TERM MEMORY CALCULATIONAL REQUIREMENTS FEEDBACK (KNOWLEDGE OF RESULTS) DYNAMIC vs. STEP-BY-STEP ACTIVITIES TEAM STRUCTURE AND COMMUNICATION MAN-MACHINE INTERFACE FACTORS DESIGN OF PRIME EQUIPMENT, TEST EQUIPMENT, MANUFACTURING EQUIPMENT, JOB AIDS, TOOLS, FIXTURES	SUDDENNESS OF ONSET DURATION OF STRESS TASK SPEED TASK LOAD HIGH JEOPARDY RISK THREATS (OF FAILURE, LOSS OF JOB) MONOTONOUS, DEGRADING, OR MEANINGLESS WORK LONG, UNEVENTFUL VIGILANCE PERIODS CONFLICTS OF MOTIVES ABOUT JOB PERFORMANCE REINFORCEMENT ABSENT OR NEGATIVE SENSORY DEPRIVATION DISTRACTIONS (NOISE, GLARE, MOVEMENT, FLICKER, COLOR) INCONSISTENT CUEING	PREVIOUS TRAINING/EXPERIENCE STATE OF CURRENT PRACTICE OR SKILL PERSONALITY AND INTELLIGENCE VARIABLES MOTIVATION AND ATTITUDES EMOTIONAL STATE STRESS (MENTAL OR BODILY TENSION) KNOWLEDGE OF REQUIRED PERFORMANCE STANDARDS SEX DIFFERENCES PHYSICAL CONDITION ATTITUDES BASED ON INFLUENCE OF FAMILY AND OTHER OUTSIDE PERSONS OR AGENCIES GROUP IDENTIFICATIONS
JOB AND TASK INSTRUCTIONS: SINGLE MOST IMPORTANT TOOL FOR MOST TASKS		**PHYSIOLOGICAL STRESSORS:** PSFs WHICH DIRECTLY AFFECT PHYSICAL STRESS	
PROCEDURES REQUIRED (WRITTEN OR NOT WRITTEN) WRITTEN OR ORAL COMMUNICATIONS CAUTIONS AND WARNINGS WORK METHODS PLANT POLICIES (SHOP PRACTICES)		DURATION OF STRESS FATIGUE PAIN OR DISCOMFORT HUNGER OR THIRST TEMPERATURE EXTREMES RADIATION G-FORCE EXTREMES ATMOSPHERIC PRESSURE EXTREMES OXYGEN INSUFFICIENCY VIBRATION MOVEMENT CONSTRICTION LACK OF PHYSICAL EXERCISE DISRUPTION OF CIRCADIAN RHYTHM	

Behaviour Types

- **Skill** based behaviour.
- **Rule** based behaviour.
- **Knowledge** based behaviour.

Definitions of Skill-Based, Rule-Based, and Knowledge-Based Behaviour

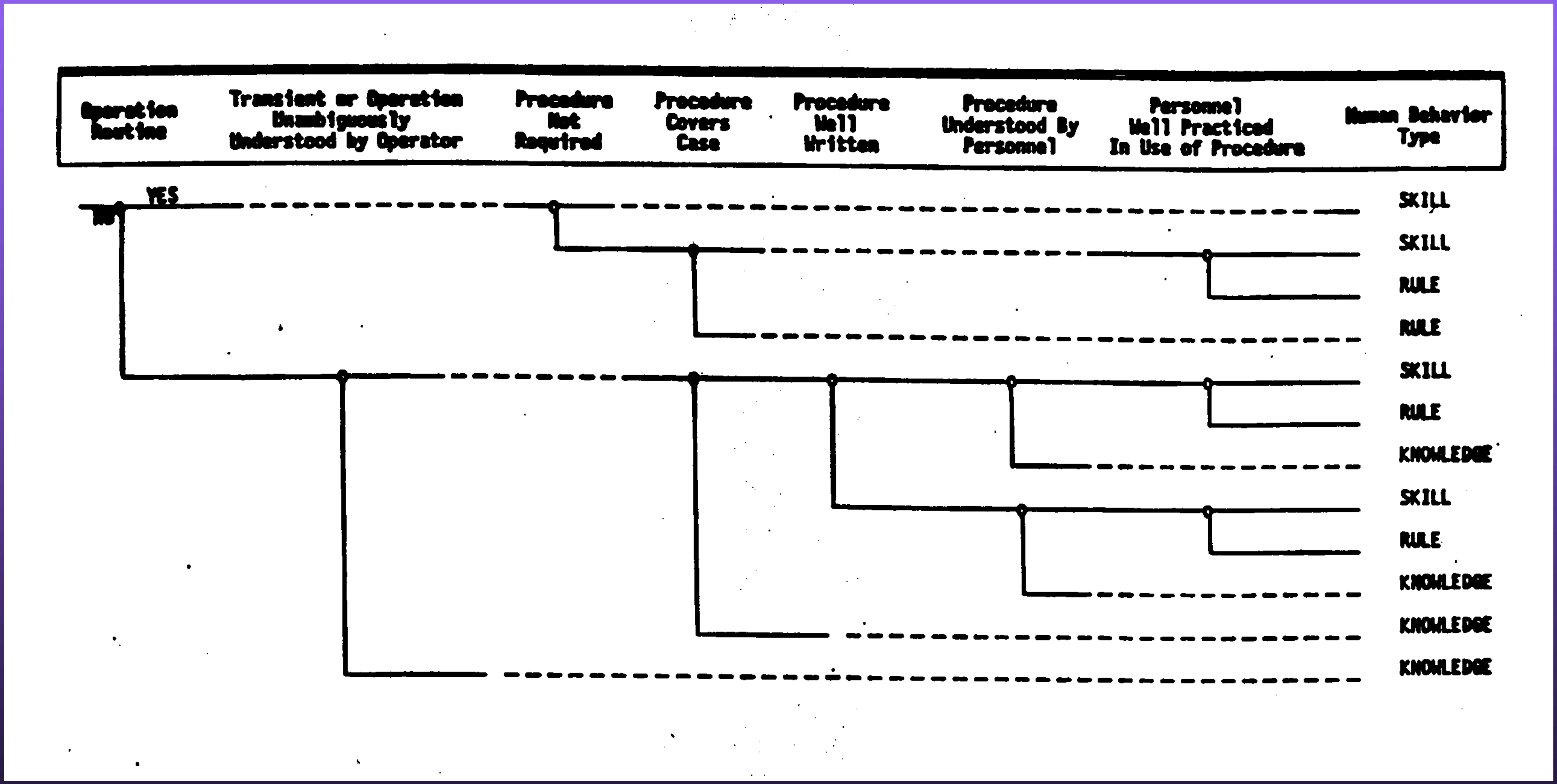
Skill-Based Behavior: "In skill-based behavior there is a very close coupling between the sensory input and the response action. Skill-based behavior does not directly depend on the complexity of the task, but rather on the level of training and the degree of practice in performing the task. While different factors may influence the specific behavior of a particular individual, a group of highly trained operators would be expected to perform skill-based tasks expeditiously or even mechanistically with a minimum of mistakes. For rule- and knowledge-based behavior, the connection between sensory inputs and output actions is not as direct as in skill-based behavior." One primary characteristic of skill-based behavior is that no interpretation of the meaning of a display is required; the display must be completely unambiguous with regard to the required action to take. Rasmussen (1981)# notes that skill-based behavior consists of the performance of more or less stored patterns of behavior (e.g., manual control of fuel rod insertion and withdrawal, or operating a crane.

Rule-Based Behavior: "Rule-based behavior is governed by a set of rules or associations, which are known and followed. A major difference between the rule-based and the skill-based behaviors stems fronm the degree of practice. If the rules are not well practiced, the human being has to consciously recall or check each rule to be followed. Under these conditions the human response is expected to be less timely and more prone to mistakes, since additional cognitive processes must be called upon. The potential for error results from problems with memory, the lack of willingness to check each step in a procedure, and failure to perform each and every step in the procedure in the proper sequence." Rasmussen (1981)# uses the term rule-based behavior to denote behavior that requires a more conscious effort (than is the case for skill-based behavior) in following stored (or written) rules, e.g., calibrating an instrument.

Knowledge-Based Behavior: "When symptoms are ambiguous or complex, the state of the plant is complicated by multiple failures or unusual events, or the instruments given only an indirect reading of the state of the plant, the operator has to rely on his knowledge, and his behavior is determined by more complex cognitive processes. Rasmussen calls this knowledge-based behavior. The performance of the human being in this type of behavior depends on his knowledge of the plant and his ability to use that knowledge. This type of behavior is expected to be more prone to mistakes or misjudgments and require more time for the appropriate action to be taken." Rasmussen (1981)# applies the term knowledge-based behavior to cases in which the situation is, to some extent, unfamiliar--that is, where considerably more cognition is involved in one's deciding what to do.

Rasmussen, J., Human Errors. A Taxonomy for Describing Human Malfunction in Industrial Installations, Riso-M-2304, Riso National laboratory, Roskilde, Denmark, August 1981.

Logic Tree to Aid in Selection of Expected Behaviour Types



Human Action Classification

TYPE 1

Before an initiating event, plant personnel can affect availability and safety either by inadvertantly disabling equipment, during testing or maintenance, or they can improve the availability of systems by restoring failed equipment through testing and maintenance.

TYPE 2

By committing some error, plant personnel can initiate an accident.

TYPE 3

By following procedures during the course of an accident, plant personnel can operate standby equipment that will terminate the accident.

TYPE 4

Plant personnel, attempting to follow procedures, can make a mistake that aggravates the situation or fails to terminate the accident.

TYPE 5

By improvising, plant personnel can restore and operate initial unavailable equipment to terminate an accident.

Procedures

<u>SHARP</u> (*SYSTEMATIC HUMAN ACTION RELIABILITY PROCEDURE*):

EPRI-NP-3583

- The SHARP methodology can be employed by the analyst as guidance to make assessments of human reliability, suitable for use in a PSA,
- Different techniques can be used within the SHARP framework,
- Innovation can be employed when current techniques are deemed insufficient for adequately addressing the case under study.

SHARP Steps (1/2)

1. **Definition**

   To ensure that all human interactions are adequately considered in the study.

2. **Screening**

   To identify the human interactions that are significant to the operation and safety of the plant.

3. **Breakdown**

   To develop a detailed description of important human interactions by defining the key influence factors necessary to complete the modelling. The human interaction modelling consists of a representation (e.g., qualitative model), impact assessments and quantification.

SHARP Steps (2/2)

4. **Representation**

   To select and apply techniques for modelling important human interactions in logic structures. Such methods help to identify additional significant human actions that might impact the system logic trees.

5. **Impact Assessment**

   To explore the impact of significant human actions identified in the preceding Step on the system logic trees.

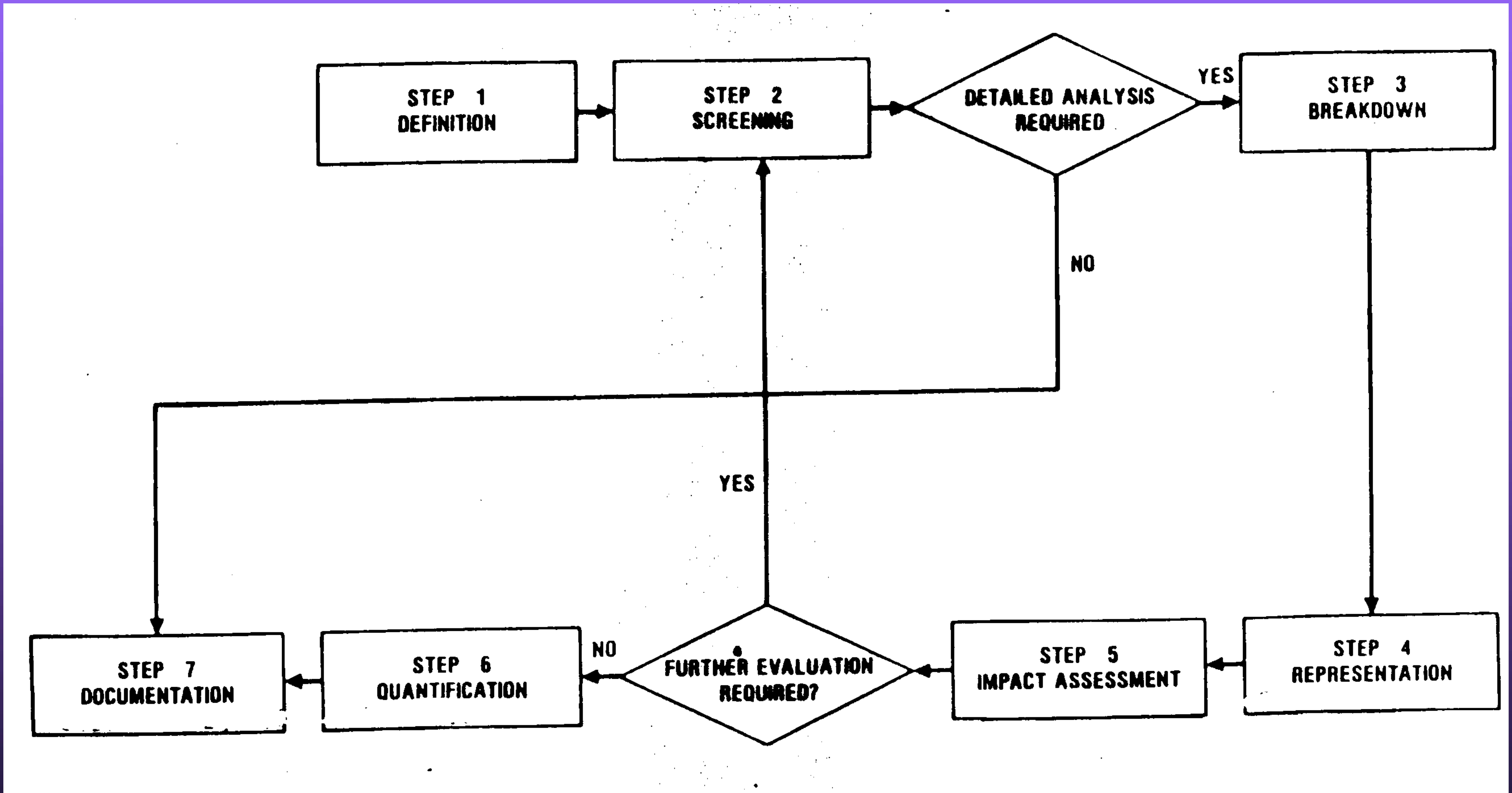
6. **Quantification**

   To apply appropriate data or other quantification methods to assign probabilities for the various interactions examined, determine sensitivities and establish uncertainty ranges.

7. **Documentation**

   To include all necessary information for getting a traceable, understandable, and reproducible assessment.

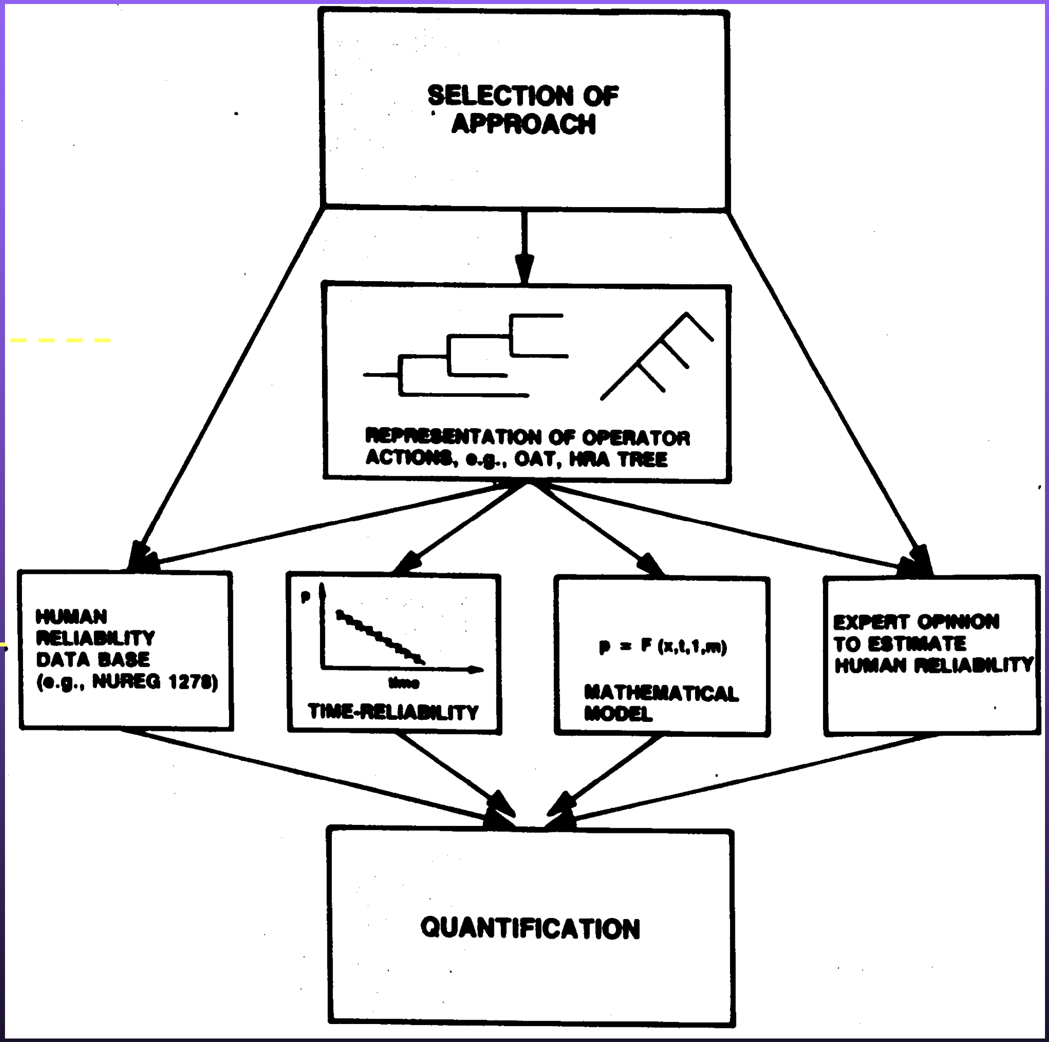
SHARP Flow Diagram



Pathways for Quantification of Human Errror Probabilities

REPRESENTATION

MODEL/DATA

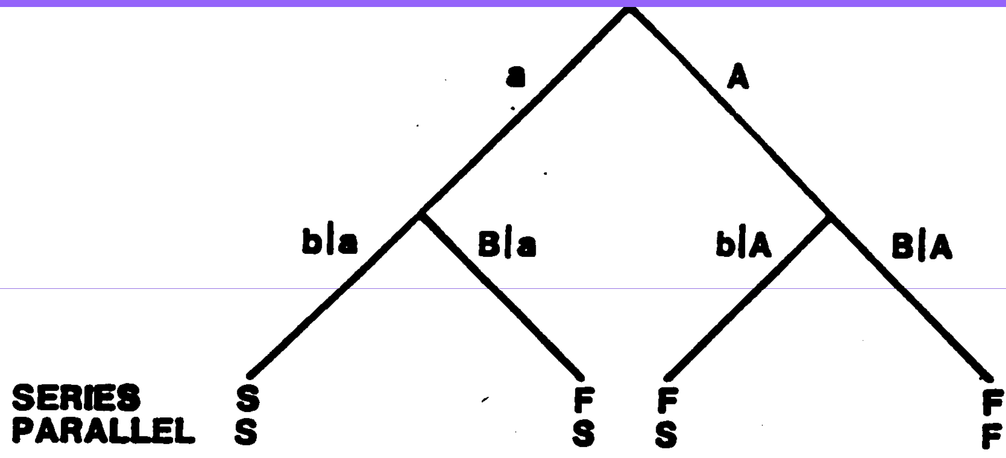


Human Action Representation

A Human Action Representation is a Logic Structure Used to Explain the Different Activities (*Decision and/or Actuation*) that the Operators Could do when they have to Respond to a Concrete Situation :

- HRA Event Tree.
- Operator Action Tree, OAT.
- Expanded Operator Action Tree, EXOAT.
- Confusion Matrix.

HRA Event Tree



TASK "A" = THE FIRST TASK

TASK "B" = THE SECOND TASK

a = PROBABILITY OF SUCCESSFUL PERFORMANCE OF TASK "A"

A = PROBABILITY OF UNSUCCESSFUL PERFORMANCE OF TASK "A"

b|a = PROBABILITY OF SUCCESSFUL PERFORMANCE OF TASK "B" GIVEN a

B|a = PROBABILITY OF UNSUCCESSFUL PERFORMANCE OF TASK "B" GIVEN a

b|A = PROBABILITY OF SUCCESSFUL PERFORMANCE OF TASK "B" GIVEN A

B|A = PROBABILITY OF UNSUCCESSFUL PERFORMANCE OF TASK "B" GIVEN A

FOR THE SERIES SYSTEM:

$Pr[S] = a(b|a)$

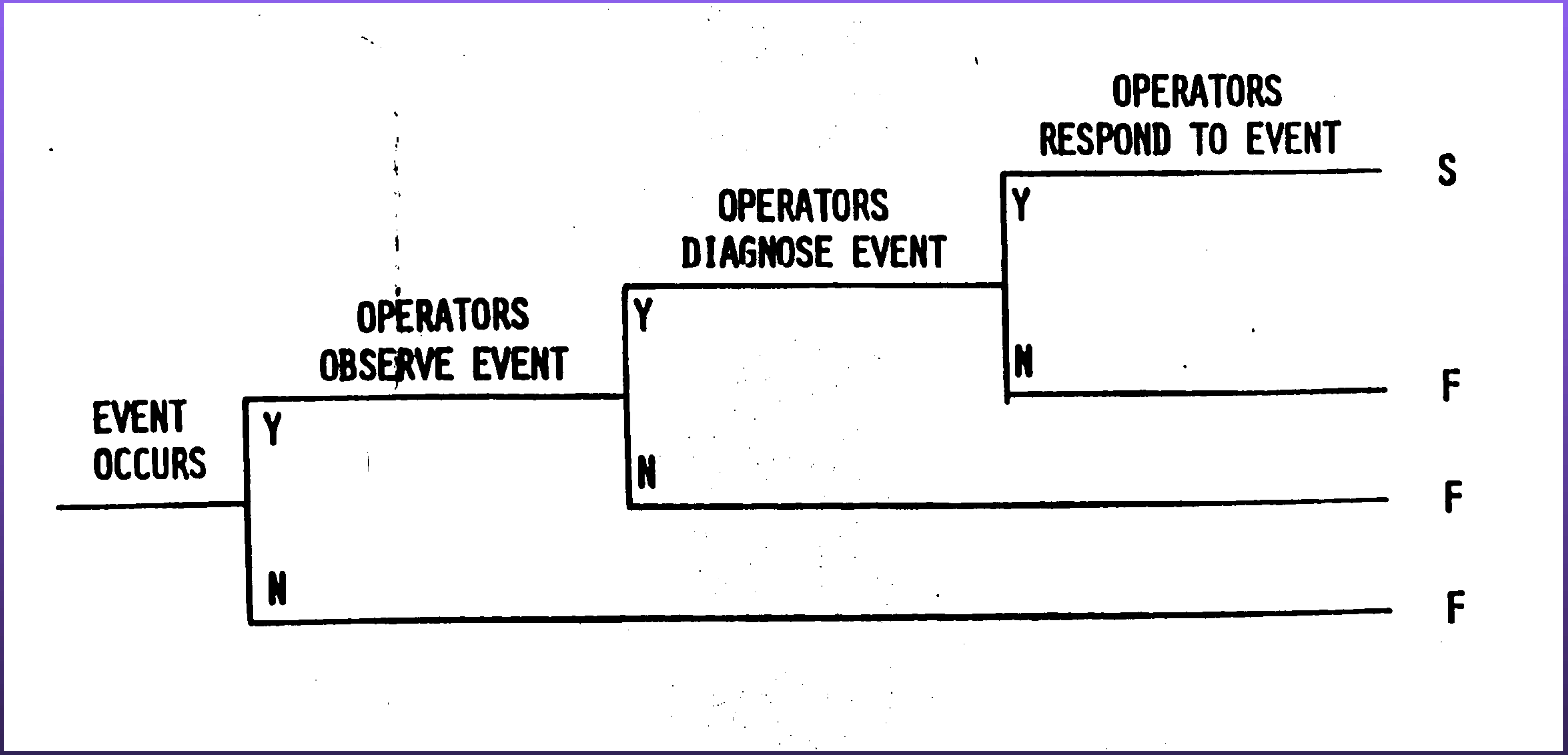
$Pr[F] = 1 - a(b|a) = a(B|a) + A(b|A) + A(B|A)$

FOR THE PARALLEL SYSTEM:

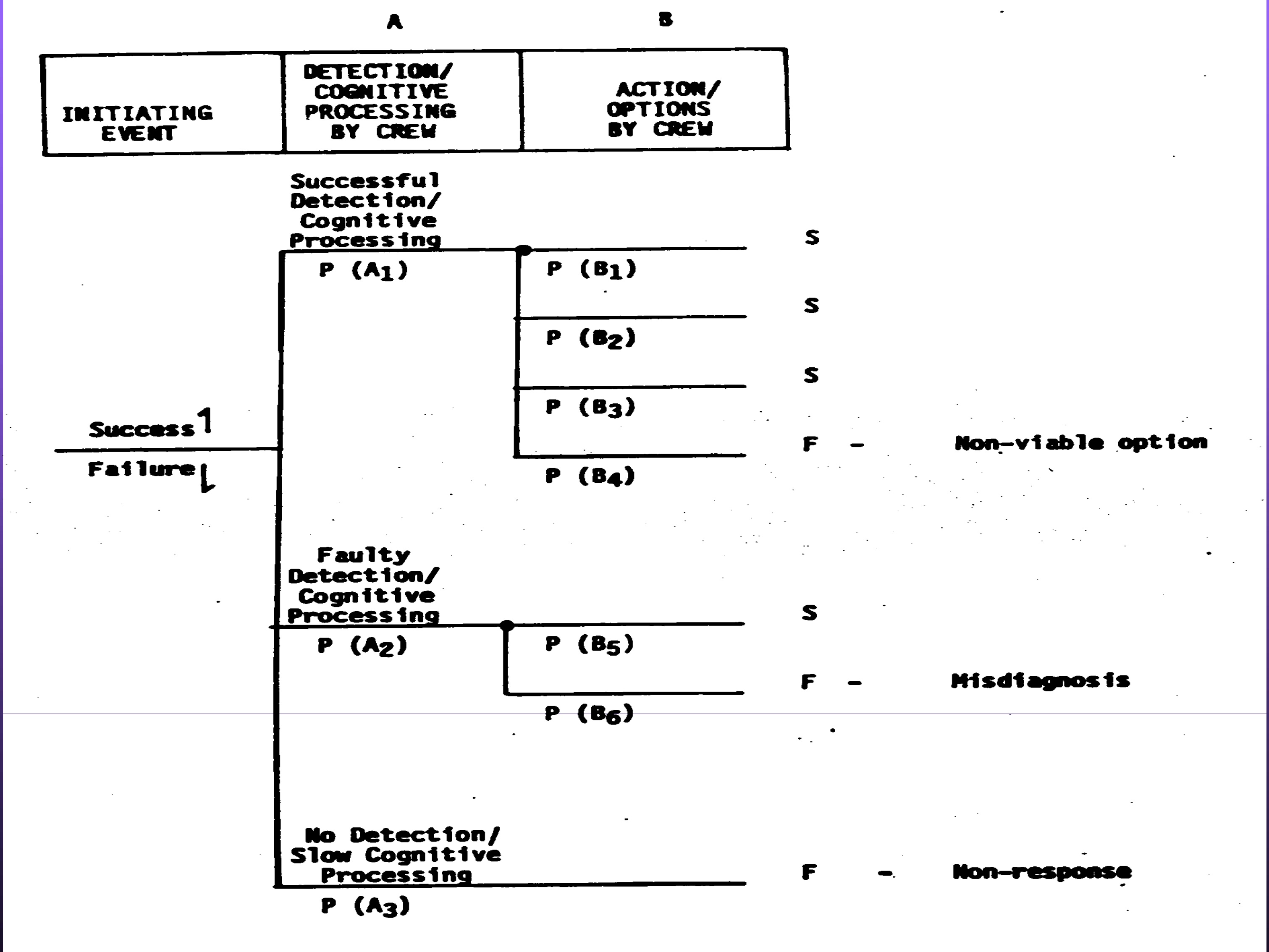
$Pr[S] = 1 - A(B|A) = a(b|a) + a(B|a) + A(b|A)$

$Pr[F] = A(B|A)$

Operator Action Tree



Expanded Operator Action Tree Representation



Example of Confusion Matrix for Misdiagnosis of an Event

ASSESSED EVENTS / POSSIBLE MISDIAGNOSIS	1 SMALL LOCA	2 LARGE LOCA	3 STEAM GEN. TUBE RUPTURE	4 STEAM LINE BREAKS: SMALL INSIDE CONTAINMENT	5 STEAM LINE BREAKS: LARGE INSIDE CONTAINMENT	6 STEAM LINE BREAKS: LARGE OUTSIDE CONTAINMENT	7 EXCESSIVE FEEDWATER FLOW	8 LOW FEEDWATER FLOW
1 SMALL LOCA	********		P3,1	P4,1				
2 LARGE LOCA		********	P3,2	P4,2	P5,2	P6,2	P7,2	
3 STEAM GEN. TUBE RUPTURE	P1,3	P2,3	*********				P7,3	
4 SMALL STM. LINE BRK. INSIDE CON.	P1,4	P2,4	P3,4	*******				
5 LARGE STM. LINE BRK. INSIDE CON.		P2,5		P4,5	********			
6 LARGE STM. LINE BRK. OUTSIDE CON.				P4,6		**********	P7,6	
7 EXCESSIVE FEEDWATER FLOW	P1,7	P2,7	P3,7	P4,7	P5,7	P6,8	*********	
8 LOW FEED-WATER FLOW				P4,8				***********
9 LOSS OF OFF-SITE POWER								
10 NO DIAGNOSIS IS MADE	P1,10	P2,10	P3,10	P4,10	P5,10	P6,10	P7,10	P8,10

P(α,β)= POSSIBLE MISDIAGNOSIS EVENTS TO BE ANALYZED
α ASSESSED EVENTS
β MISDIAGNOSIS EVENTS

Human Quantification Techniques

- Handbook of human reliability analysis (*THERP*) NUREG/CR-1278.
- Post event human decision errors, operator action tree/time reliability correlation. NUREG/CR-3010.
- Application of SLIM-MAUD.
- Human congnitive reliability model for PRA analysis EPRI Project RP 2170-3.

Comparison of Quantification Techniques

QUANTIFICATION APPROACH	HUMAN ERROR PROBABILITIES			
	DIAGNOSIS		ACTION	
	PROBABILISTIC	TIME-DEPENDENT	PROBABILISTIC	TIME-DEPENDENT
NUREG/CR-1278 HANDBOOK: DIAGNOSIS CURVE	YES	YES	YES	REDUCES THINKING TIME
NUREG/CR-3010 TRC	YES	YES	NO	(SAME AS ABOVE)
NUREG/CR-4016 SLIM-MAUD	REQUIRES ANCHOR POINTS	INDIRECTLY	REQUIRES ANCHOR POINTS	INDIRECTLY
NUS-4531 HCR	YES	YES	INDIRECTLY	REDUCE EFFECTIVE TIME WINDOW

Error of Commission

It is the consequence of a human action that is carried out inappropriately and causes that the situation will be worse than if the human action were not carried out.

INTENT

"A Method for estimating human error probabilities for decision based errors".

ATHEANA

"Technical basis and implementation guidelines for a technique for human event analysis".

CREAM

"Cognitive reliability and error analysis method".

HITLINE

"Human interaction time line".

Conclusions

- Human actions are always important in the final results.
- Studying human behaviour and assign error probabilities is not easy but it is possible.
- There always will be human failures and errors but their amount and consequences may be limited by a good job.