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Changing the World's Energy Future

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The HUNTER Dynamic Human Reliability Analysis Tool: Development of a Module for Performance Shaping Factors

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Abstract: The Human Unimodel for Nuclear Technology to Enhance Reliability (HUNTER) is a framework to support dynamic human reliability analysis (HRA) in communication with a variety of methods and tools. This paper explores how we developed one of the HUNTER modules: namely, the Individual module for evaluating performance shaping factors (PSFs). A PSF is any factor that influences human performance (e.g., workload or complexity). In the existing HRA, they are used to highlight human errors and adjust error probabilities. We consider the eight PSFs suggested in the Standardized Plant Analysis Risk-HRA (SPAR-H) method, a representative HRA method widely used in the nuclear field. To support our dynamic modeling using the eight SPAR-H PSFs, we reviewed the human performance literature and developed data-based mathematical models to rate and quantify PSFs in the context of dynamic HRA. We also designed the Individual module to consist of two functions: (1) the PSF qualification function for automatically or manually evaluating PSF levels, and (2) the PSF quantification function for dynamically or statically determining PSF multiplier values and integrating them to adjust human error probabilities (HEPs). How each function works in regard to the SPAR-H PSFs, and how the PSFs serve to adjust the HEPs, were investigated via literature review and are discussed in this paper.

1. INTRODUCTION

The Human Unimodel for Nuclear Technology to Enhance Reliability (HUNTER) is a framework to support dynamic human reliability analysis (HRA) in communication with a variety of methods and tools [1]. The HRA research team at Idaho National Laboratory developed the HUNTER framework to meet industry HRA needs by supporting the Risk-Informed System Analysis (RISA) pathway of the U.S. Department of Energy's Light Water Reactor Sustainability (LWRS) Program. The existing HUNTER (i.e., HUNTER 1.0) [2] conceptually proposed how dynamic HRA could be performed using information obtained from thermal-hydraulics codes, cognitive models, HRA methods, and procedures, while the latest HUNTER project (i.e., HUNTER 2.0) aims to systematically design the HUNTER modules and their functions, then develop a standalone HUNTER software to implement the dynamic HRA calculation [1][3].

Treating performance shaping factors (PSFs) within a dynamic context (i.e., dynamic PSFs) is an important issue in the field of dynamic HRA. The characteristics of dynamic HRA (e.g., time-dependent effects) may require novel approaches for adapting PSFs dynamically. In a dynamic context, triggered events (e.g., the burden of starting new tasks) could cause the effects of some PSFs (e.g., stress) to directly vary over time, whereas other PSFs could be indirectly influenced or determined by time-dependent information (e.g., parameters over time). To date, a couple of previous efforts have been made to operationalize PSFs for dynamic HRA. Representatively speaking, the earlier efforts to make Standardized Plant Analysis Risk-HRA (SPAR-H) PSFs dynamic within HUNTER 1.0 focused on so-called external PSFs [4]. External PSFs use contextual factors such as plant parameters to build functions linking PSFs to the plant. In this earlier work, the level of the complexity PSF was auto-calculated via a multiple regression equation, with core temperature and power level as independent variables [2].

This paper explores how we developed one of the HUNTER modules—namely, the Individual module for evaluating PSFs—as a follow-up study to the effort mentioned above. The Individual module qualitatively and quantitatively evaluates PSFs, then modifies the basic HEPs of tasks assigned by GOMS-HRA primitives [5] in the Task module. The basic strategy of the Individual module is to use the theoretical part of the existing static HRA method as it stands, but suggest the option of a relatively new way to account for PSF effects in a dynamic context. In other words, human reliability analysts can choose between either the static HRA or the dynamic approach suggested in this section when rating and quantifying PSFs. This strategy aims to reduce the confusion caused by the transition from static to dynamic HRA, and to give human reliability analysts the opportunity to select their preferred approach, based on the intended use. In this study, we consider the eight PSFs suggested in the SPAR-H method [6]. To support our dynamic modeling using the eight SPAR-H PSFs, we reviewed the human performance literature and developed data-based mathematical models to rate and quantify PSFs in the context of dynamic HRA. We also designed the Individual module to consist of two functions: (1) the PSF qualification function for automatically or manually evaluating PSF levels, and (2) the PSF quantification function for dynamically or statically determining PSF multiplier values and integrating them to adjust human error probabilities (HEPs). How each function works in regard to the SPAR-H PSFs, and how the PSFs serve to adjust the HEPs, were investigated via literature review and are discussed in this paper.

2. CONCEPTUAL DESIGN OF THE HUNTER INDIVIDUAL MODULE

The Individual module in the HUNTER software was designed to represent dynamics, meaning human risks over time. Regarding PSFs, it is important to understand how their effects change over time and how they interact with PSFs that relate to other human actions. The existing static HRA does consider dynamics, which are often the basis of dependence. Dependence in HRA refers to adjusting the failure probability of a given action by considering the impact of the preceding action [7]. However, static dependence only considers the linkage between human actions in regard to certain factors (e.g., same crew, work performed closely in time, overlapping cues, and a location shared by multiple actions) [6]. This conventional treatment of dependence does not specifically attempt to recognize the quantitative influence over time that exists in relationships between PSFs. Dependence is treated as a correction factor for dynamics, not as a true model of PSF changes over time.

Representatively speaking, PSFs such as stress or fitness for duty are highly sensitive to the effects of time. For example, assume that operators perform many tasks that create an extremely high stress level. If they perform additional tasks right after finishing those stressful tasks, their stress levels for the additional work will be higher by virtue of carryover stress from the previous tasks. On the other hand, if they wait a couple of hours before performing the additional tasks, their stress levels will likely have dissipated and therefore be unaffected by the previous stressful tasks. Thus, we have observed evidence of time's effect on PSFs. Nevertheless, it has not been specifically researched and treated in HRA.

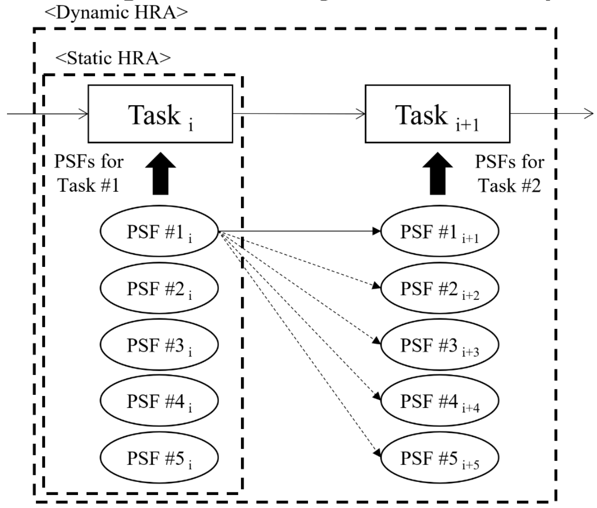
To consider the effects over time on PSFs in the HUNTER Individual module, this paper extends the PSF concept from static to dynamic HRA, as shown in Figure 1. In static HRA, PSFs are primarily used for quantifying at the level of tasks or human failure events. In other words, human reliability analysts evaluate the PSFs for each task independently, with relationships between PSFs across different tasks rarely being considered in the analysis. In the extended PSF concept for dynamic HRA (also shown in Figure 1), PSFs in a task are assumed to also affect those in subsequent tasks. Three influences are suggested in this concept:

- Intra-PSF influence of a PSF on the same PSF for subsequent tasks
- Inter-PSF influence of a PSF on different PSFs for subsequent tasks
- Inter-PSF influence of a PSF on different PSFs during the same task.

An example of intra-PSF influence is when the stress PSF in Task 1 affects the stress PSF in Task 2. An example of inter-PSF influence is when the complexity PSF in Task 1 influences the available-time PSF in Task 2. This report mainly focuses on intra- rather than inter-PSF influence. In this conceptualization of PSF influences, it is also assumed that dynamic modeling encompasses the dependency effects between human actions.

The third influence—inter-PSF influence during the same task—is primarily an artifact of the lack of independence between PSF definitions [8], and does not constitute a specific area of interest for dynamic HRA.

Figure 1. Extending the PSF concept from static to dynamic HRA.



3. TREATMENT OF SPAR-H PSFs IN THE HUNTER INDIVIDUAL MODULE

Table 1 summarizes how to treat the SPAR-H PSFs in the Individual module, which consists of two functions: PSF qualification and PSF quantification.

Table 1: Categorization of the PSF qualification and quantification functions.

		Qualification Function	
		Manually Assigned	**Automatically Assigned**
Quantification Function	**Static**	The level of the PSF and its multiplier are manually assigned in the model, equivalent to static HRA.	The PSF level is automatically assigned, and static (i.e., predefined) multipliers are applied for each level.
	Dynamic	The PSF level is manually assigned but the multiplier is automatically calculated (e.g., adjusted for lag/linger effects).	The PSF level is automatically assigned, and the PSF multiplier is auto-calculated.

The *PSF qualification function* is responsible for manually assigning PSF levels, similarly to how this is performed in the existing static SPAR-H method. Alternately, PSF levels may be assigned automatically based on information such as procedure instructions or plant response data from thermal-hydraulic codes or mathematical models. The PSF qualification function includes two categories: "Manually Assigned" and "Automatically Assigned."

In the *PSF quantification function*, HUNTER uses the selected PSF levels to estimate final HEPs, based on the PSF multiplier values suggested in the SPAR-H method; otherwise, it automatically quantifies the values, based on mathematical models. This function has two options: "Static" and "Dynamic." Static refers to using the multiplier values suggested in the existing static SPAR-H method in order to allocate the multiplier value to the selected PSF level determined in the PSF qualification function. Dynamic refers to estimating a PSF multiplier value, based on experimental-data-based mathematical models. All the options afforded by the PSF qualification and quantification functions can be selected via the HUNTER interface.

As mentioned at the beginning of this section, the HUNTER Individual module basically offers a method of applying the existing static SPAR-H to the Manually Assigned and Static options. Some

PSFs (e.g., stress/stressor, fitness for duty, and available time) have an Automatically Assigned option in the PSF qualification function, or a Dynamic option in the PSF quantification function. In the current version, these dynamic approaches are only available for stress/stressor, fitness-for-duty, and available-time PSFs. However, this does not mean that other PSFs cannot be automatically or dynamically assigned in future implementations. If adequate mathematical models or experimental data exist for implementing dynamic approaches to other PSFs, they will be updated in the future. Table 2 cross-walks the different static/dynamic options for PSF qualification and quantification functions.

Table 2: Summary of how to treat SPAR-H PSFs in the Individual module.

SPAR-H PSFs	PSF Qualification Function	PSF Quantification Function
Stress/stressors	"Manually Assigned" only	"Static" or "Dynamic"
Fitness for duty	"Manually Assigned" "Automatically Assigned" (if "Dynamic" is selected in the PSF quantification function)	"Static" or "Dynamic"
Available time	"Manually Assigned" "Automatically Assigned" (if "Dynamic" is selected in the PSF quantification function)	"Static" or "Dynamic"
Work processes	"Manually Assigned" only	"Static" only
Experience/ training	"Manually Assigned" only	"Static" only
Complexity	"Manually Assigned" only	"Static" only
Ergonomics/human system interface	"Manually Assigned" only	"Static" only
Procedures	"Manually Assigned" only	"Static" only

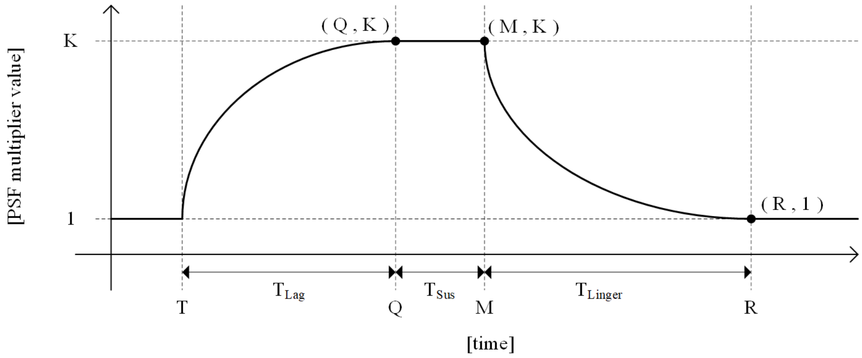
3.1. Stress/Stressors

The stress PSF includes the Dynamic option in the quantification function. We use PSF lag and linger models [9][10] to implement the Dynamic option for stress in the HUNTER Individual module. PSF lag indicates that the PSF's psychological or physical effect on performance is not immediately apparent, while PSF linger means the PSF's influence on human actions carries over to subsequent actions, resulting in residual effects on those actions. The authors' previous research [9, 10] conceptually suggested PSF lag and linger effects as an option for treating the dependence between operator actions within a dynamic context, and then developed mathematical models for PSF lag and linger effects.

The lag and linger effects of the stress PSF are technically based on experimental research in the field of biology. Several studies have demonstrated that secretion of hormones such as cortisol [11] and corticosterone [12] affects stress levels. Based on the results of these studies, we developed mathematical models for PSF lag and linger effects. First, for modeling the PSF lag effect, we focused on the stress-increasing trend (i.e., how stress reaches a maximum level, and the time it takes to do so). In a relevant biological study, Dorin et al. [11] tried to estimate maximum cortisol secretion rates. Cortisol is a hormone that increases dramatically during adaptation to physiological stress. The results of their study revealed a trend in which cortisol concentrations reach the maximum level (i.e., natural log function), and the time that it takes to reach the maximum value (i.e., 60 min). Next, we reviewed Vitousek et al. [12] in order to model the lingering impact of stress. Their study experimentally investigated decreases of corticosterone hormones, representing decreases in stress over time. The result of their study was that the concentration of corticosterone (i.e., stress) exponentially decreased, reaching a normal state after 180 minutes.

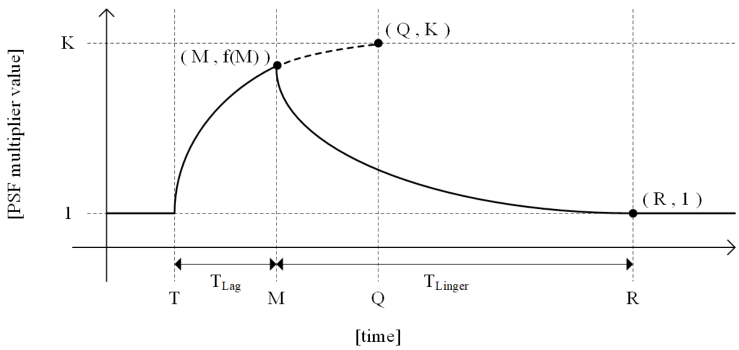
Figure 2 and Figure **3** show mathematical models of the PSF lag and linger effects for a task, when the task performance time is over and under 60 minutes, respectively. Explanations of the parameters in these figures are given in Table 3. The biggest difference between the two models concerns the PSF lag time. For the first model, the time to perform a task exceeds 60 minutes, so the effect of the PSF is sustained at the end of the task. For the second model, the time to perform a task is under 60 minutes, meaning that the task is finished before the PSF value reaches its maximum level. In addition, this report only adopts PSF lag and linger effects for negative PSF multiplier values (e.g., ×2 or ×5), and does not consider positive PSF multiplier values (i.e., values that enhance performance).

Figure 2. Mathematical model of the PSF lag and linger effects for a task, when the task performance time is over 60 minutes.



$$\begin{cases} y = 1 & [x < T] \\ y = \dfrac{K-1}{\ln(Q-T+1)}\ln(x-T+1)+1 & [T \le x < Q] \\ y = K & [Q \le x < M] \\ y = exp\left(-\dfrac{\ln K}{R-M}(x-R)\right) & [M \le x < R] \\ y = 1 & [R \le x] \end{cases}$$

Figure 3. Mathematical model of the PSF lag and linger effects for a task, when the task performance time is under 60 minutes.



$$\begin{cases} y = 1 & [x < T] \\ y = \dfrac{K-1}{\ln(Q-T+1)}\ln(x-T+1)+1 & [T \le x < M] \\ y = exp\left(-\dfrac{\ln(f(M))}{R-M}(x-R)\right) & [M \le x < R] \\ y = 1 & [R \le x] \end{cases}$$

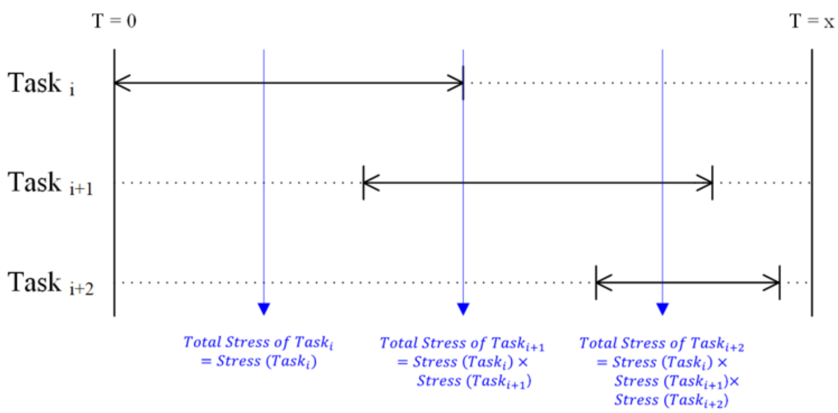
Table 3: Definition of parameters used in the mathematical models in Figure 2 and Figure 3.

Parameter	Definition
T	Starting time for a task
Q	Time it takes to reach the maximum PSF value in a task
M	Time to finish a task
R	Time to return to the nominal PSF level (i.e., time for the PSF effect on a task to totally finish)
K	A PSF value
f(M)	A PSF value limited by the lag effect when the time to perform a task is under 60 minutes
T_{Lag}	Delayed time to arrive at a PSF value, due to the lag effect (maximum 60 minutes)
T_{Sus}	Time that the effect of PSFs is sustained by end of the task
T_{Linger}	Delayed time to return to the nominal PSF level, due to the linger effect (i.e., 180 minutes)

In the field of biology, it is an established fact that stress is cumulative [13]. Accordingly, our research assumes that stressors resulting from different tasks can temporarily accumulate. After the mathematical model is applied to each stress PSF in each task, we must incorporate the stress effects into a value that represents the stress level of each task in consideration of the cumulative effect. Figure 4 shows how the stress value in each task is integrated. The solid line in each timeline represents the task duration from start to finish. As seen in the figure, the total stress (i.e., cumulative stress) is calculated as the product of the stress values of all tasks up to that point. For example, the stress of Task $_{i+2}$ is calculated as the product of the stress values of Task $_{i}$, Task $_{i+1}$, and Task $_{i+2}$. For Task $_{i}$ in this case, the stress-inducing action is already finished, but there is a lingering stress effect from the mathematical model.

Figure 4. Example of stress effect integration.

$$Total\ Stress\ of\ Task\ i = \prod_{n=1}^{i} Stress\ (Task\ n)$$



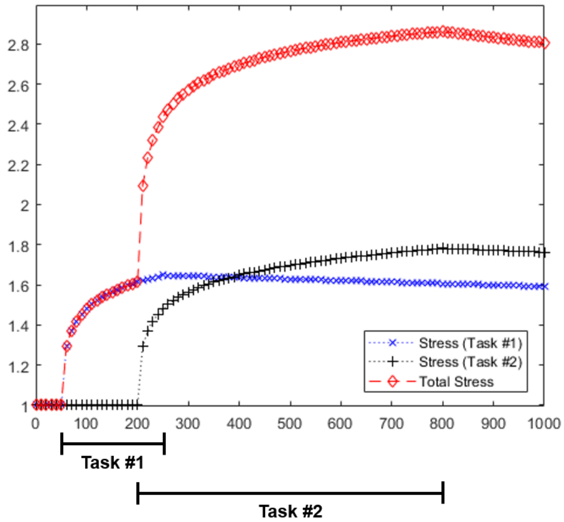
The necessary input data for running PSF lag and linger models are task starting time, time required, and PSF multiplier value. The starting time of a task can be obtained from thermal-hydraulic codes or simulator models interfaced to HUNTER. The time required comes from GOMS-HRA. The PSF multiplier value is manually obtained from the HUNTER interface by human reliability analysts. Other PSFs are automatically calculated by equations assumed in the PSF lag and linger models.

Table 4 shows the input data needed to dynamically calculate the stress PSF, and Figure 5 shows plots representing the result of this calculation. In the example, two tasks are assumed. The first is performed between 50 seconds and 250 seconds with 200 seconds time required, while the second task is started at 200 seconds and finished at 800 seconds with 600 seconds time required. In Figure 5 are three plots representing the individual stress effects of Tasks 1 and 2, along with the total stress (i.e., cumulative stress). The total stress accumulated over the duration of Tasks 1 and 2 represents the final stress multiplier value over time with the cumulative effect.

Table 4: Example of input data for dynamically calculating the stress PSF.

Task No.	Parameter						
	Time re quired [sec]	**T [sec] (Starting t ime of a ta sk)**	**M [sec] (Time to finish a t ask)**	**Q [sec] (Time to rea ch the maxi mum PSF v alue)**	**R [sec] (Time to return to nominal PSF level)**	**K [sec] (A PSF v alue for a task)**	**f(M) [sec] (A PSF valu e limited by lag effect)**
#1	200	50	250	3,650	11,050	2	1.648
#2	600	200	800	3,800	11,600	2	1.781

Figure 5. Example of plots representing dynamic calculation of the stress PSF.



3.2. Fitness for Duty

The SPAR-H method [6] defines fitness for duty as being an individual's physical and mental fitness for performing a specific task at a given time. Factors that may affect fitness for duty include fatigue, sickness, drug use, overconfidence, personal problems, and distractions. To develop a mathematical model for the fitness-for-duty PSF, more time was spent reviewing the literature on fatigue than that on all the other factors previously mentioned. Fatigue is a representative fitness factor that has been extensively researched in the field of cognitive engineering [14]. However, few studies have been performed that specifically focus on other subfactors.

The Health and Safety Executive, Britain's national regulator for workplace health and safety, developed an approach for estimating fatigue indexes by considering six fatigue factors: (1) duty length, (2) rest length, (3) average duty per day, (4) the cumulative component, (5) the duty timing component, and (6) the job type/breaks component [15]. The fatigue index trend has been researched in light of different shift lengths [16]. Specifically, the fatigue index values were calculated based on the four datasets shown in Table 5, while the relative fatigue values were estimated by dividing hourly fatigue values into the mean value for the first 8 hours, then compared with each other to verify that the trends from different datasets were consistent. Through a repeated-measures analysis of variance based on relative fatigue values for the four datasets, this study revealed a highly significant primary effect caused by time on shift ($p < 0.001$).

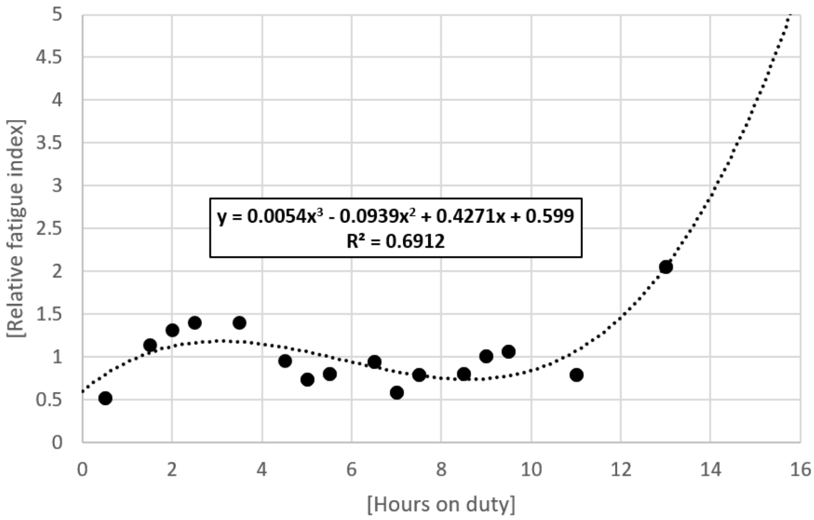
To account for fitness for duty in HUNTER, we developed an equation representing the relative fatigue values from the dataset included in the research discussed above [16]. Figure 6 shows the relative fatigue index over hours on duty. In the figure, the curve-fitted equation is shown as a cubic equation. The R-square value of the equation (i.e., 0.69) shows a statistically adequate level. In the HUNTER Individual module, the equation is used to determine the fitness-for-duty PSF level and to quantify its multiplier value over time. If a shift is changed, the multiplier value resets to 0, while the maximum value is assumed to be 5, as per the existing SPAR-H method. This equation is automatically applied when the human reliability analyst selects the Dynamic option in the HUNTER interface.

Interestingly, the figure shows some fatigue levels between the second and fifth hours to be slightly higher. Regarding this phenomenon, [17] suggested that this fleeting peak in fatigue may be due to the individuals' circadian rhythms—meaning physical, mental, and behavioral changes that follow a 24-hour cycle. In fact, this type of phenomenon has never been treated in HRA, apart from one exception (i.e., determining cumulative sleep deprivation effects as a PSF) [18]. Nevertheless, using the data-driven model over time may afford an opportunity to include a multimodal curve and thus realistically reflect the fitness-for-duty PSF's effect in HRA.

Table 5: Summary of the studies across hours on duty [16].

Authors	Data	Measure	Total Number
[19]	Sweden (1990/1991)	Lost time injuries (1+ days)	160,000
[17]	Various Transport Operations	Accidents or signals pa ssed at danger	N/A
[20]	Germany (1994)	Lost time injuries (>3 days)	1,200,000+
[21]	Germany (1994–1997)	Fatal injuries	2,000+

Figure 6. Relative fatigue index over hours on duty.



3.3. Available Time

Available time refers to the amount of time in which an operator or crew must diagnose a situation and execute a task. To design a function that automatically evaluates the level of the available-time PSF, we first classify the GOMS-HRA task-level primitive types into diagnosis- or action-related tasks, as shown in Table 6.

Next, we modify the existing time windows to make them applicable to the HUNTER framework for dynamic HEP calculations. Figure 7 shows the HUNTER timeline, which includes the system time window (T_{SW}), time it takes to perform a task (T_{Task}), time to start a task (T_{Start}), and time available ($T_{Available}$). First, in the HUNTER software, the system time window (T_{SW}) value is automatically provided by the connected thermal-hydraulic model. Second, the time it takes to perform a task (T_{Task}) is used on behalf of the time required to diagnose and execute in the existing SPAR-H method. Third, the time to start a task (T_{Start}) is used instead of the delay time. Delay time refers to the amount of time required for an operator to acknowledge the cue generated at the start of an initiating event. It has generally been estimated by interviewing experts such as operators or instructors greatly experienced in NPP systems. However, in the dynamic context, delay time may include delays provided by thermal-hydraulic codes or time values estimated from the GOMS-HRA task-level primitive time distributions. Therefore, rather than using the delay time concept, it may be preferable to instead use time to start a task (T_{Start}), which can be obtained from the HUNTER scheduler. Lastly, the definition of time available ($T_{Available}$) is similar to the existing definition. It is calculated via: $T_{Available}$ minus T_{Start}.

Finally, this report suggests the logic to determine a multiplier value for the available-time PSF featuring the modified timeline and existing logic. Table 7 shows the logic to determine a multiplier value for the available-time PSF, while Table 8 shows an example of the available-time PSF calculation. This logic is automatically applied when human reliability analysts select the Dynamic option in the HUNTER interface.

Table 6: Classification of GOMS-HRA task-level primitive types.

Task Level Primitive	Description	Task Type
A_C	Performing required physical actions on the control boards	Action
A_F	Performing required physical actions in the field	Action
C_C	Looking for required information on the control boards	Action
C_F	Looking for required information in the field	Action
R_C	Obtaining required information on the control boards	Action
R_F	Obtaining required information in the field	Action
I_P	Producing verbal or written instructions	Action
I_R	Receiving verbal or written instructions	Action
S_C	Selecting or setting a value on the control boards	Action
S_F	Selecting or setting a value in the field	Action
D_P	Making a decision based on procedures	Diagnosis
D_W	Making a decision without available procedures	Diagnosis

Figure 7. HUNTER timeline.

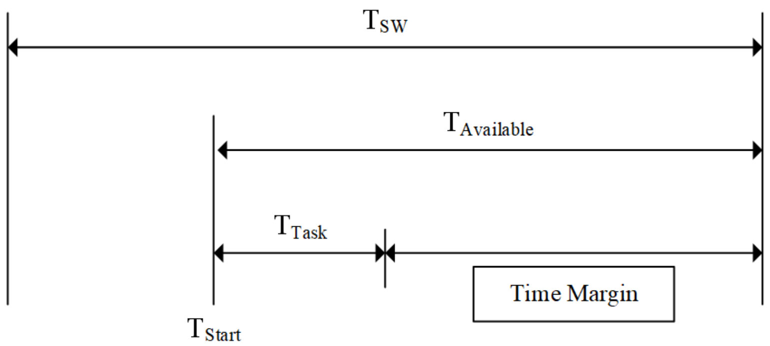


Table 7: Logic to determine a multiplier value of the available-time PSF.

GOMS-HRA Primitive Type	Evaluation Logic	Multiplier Value
Diagnosis-based primitive	($T_{Available}$ > 30 mins) & ($T_{Available}$ / T_{Task} > 2)	0.01
	($T_{Available}$ > 30 mins) & ($T_{Available}$ / T_{Task} <=2)	0.1
	($T_{Available}$ <=30 mins)	1
	($T_{Available}$ < T_{Task})	Task Failed
Action-based primitive	($T_{Available}$ / T_{Task} >=50)	0.01
	(50 > $T_{Available}$ / T_{Task} >=5)	0.1
	(5 > $T_{Available}$ / T_{Task} >=1)	1
	($T_{Available}$ < T_{Task})	Task Failed

Table 8: Example of the available-time PSF calculation.

T_{Start} [sec]	T_{SW} [sec]	T_{Task} [sec]	$T_{Available}$ [sec]	Multiplier value for diagnosis-based primitives	Multiplier value for execution-based primitives

0	3000	50	3000	0.01	0.01
100	3000	50	2900	0.01	0.01
200	3000	50	2800	0.01	0.01
300	3000	50	2700	0.01	0.01
400	3000	50	2600	0.01	0.01
500	3000	50	2500	0.01	0.01
600	3000	50	2400	0.01	0.1
700	3000	50	2300	0.01	0.1
800	3000	50	2200	0.01	0.1
900	3000	50	2100	0.01	0.1
1000	3000	50	2000	0.01	0.1
1100	3000	50	1900	0.01	0.1
1200	3000	50	1800	1	0.1
1300	3000	50	1700	1	0.1
1400	3000	50	1600	1	0.1
1500	3000	50	1500	1	0.1
1600	3000	50	1400	1	0.1
1700	3000	50	1300	1	0.1
1800	3000	50	1200	1	0.1
1900	3000	50	1100	1	0.1
2000	3000	50	1000	1	0.1
2100	3000	50	900	1	0.1
2200	3000	50	800	1	0.1
2300	3000	50	700	1	0.1
2400	3000	50	600	1	0.1
2500	3000	50	500	1	0.1
2600	3000	50	400	1	0.1
2700	3000	50	300	1	0.1
2800	3000	50	200	1	1
2900	3000	50	100	1	1
3000	3000	50	0	Task Failed	Task Failed

Note that the available-time PSF is unique and requires inputs from the Task, Individual, and Environment modules in HUNTER. A particularly unique aspect of the available-time PSF is the run-ahead function required of the Environment module, in which the system time window (T_{SW}) must be calculated without operator intervention.

3.4. Other SPAR-H PSFs

As shown in Table 2, the current version of the HUNTER Individual module only offers static evaluations of the other SPAR-H PSFs (e.g., work processes, experience or training, complexity, ergonomics / human-system interface, and procedures). In the current HUNTER software, most input information for the dynamic HRA relies on parameters from thermal-hydraulic codes and procedures. Accordingly, HUNTER may be unable to treat all the PSFs when using these parameters. For this reason, the current version of HUNTER opted to employ static options for evaluating these PSFs, but it is too early to conclude that this is a limiting factor for the versatility of dynamic PSFs. We found some literature and methods that may be useful for dynamicizing the PSFs, though they require modification for application within HUNTER. Representatively speaking, research related to the complexity PSF suggests an equation for quantifying complexity [1], or an approach to quantify task complexity based on procedures [22].

4. CONCLUSION

This paper explored our development of the HUNTER Individual module. To support our dynamic modeling using the eight SPAR-H PSFs, we reviewed the human performance literature and developed data-based mathematical models to rate and quantify PSFs in the context of dynamic HRA.

We also designed the Individual module to consist of two functions: (1) the PSF qualification function for automatically or manually evaluating PSF levels, and (2) the PSF quantification function for dynamically or statically determining PSF multiplier values and integrating them to adjust human error probabilities (HEPs). How each function works in regard to the SPAR-H PSFs, and how the PSFs serve to adjust the HEPs, were investigated via literature review and are discussed in this paper. This study represents ongoing research to discover additional mathematical models, collect the necessary data to develop models applicable to NPPs, and validate that the models are meaningful within HRA. The more realistic and reasonable dynamic PSF models will be investigated and included in future versions of the HUNTER software.

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