2. Literature Review

2.1. Introduction

The literature review chapter plays a pivotal role in any research study as it aims to explore and synthesise existing scholarly works and research findings related to theme of the study. This study explored the scholarly works related to the assessment of HP in various systems, providing a comprehensive understanding of the themes, methodologies and trends associated with assessing Human Performance (HP) across different domains. HP can be analysed from internal and external perspectives, encompassing psychological, physiological, technological and social factors. Proper classification of these factors is crucial for unjustifiably ascribing human error to incidents besides effectively managing their impacts.

In the realm of Human Performance (HP), the goals of previous studies were centred on reducing errors, improving efficiency and enhancing safety. Approaches like Human Reliability Analysis (HRA) are integral, especially during the design phase of a system, to streamline efforts in bolstering safety and efficiency. HRA methods, whether qualitative or quantitative, play a pivotal role in identifying, assessing and managing the factors contributing to undesirable outcomes. These approaches extend beyond the physiological and psychological dimensions, encompassing technological and social factors. Concurrently, the psychological dimension emerges as a critical component in understanding cognitive processes, emotions and motivation, synergising with physiological, technological and social factors to comprehensively optimise human performance across diverse settings.

In this chapter, the researcher delved into the assessment of HP and human reliability (HR) literature to evaluate HP in any system. Through a thematic, methodological and chronological review of the literature, this study gained insights into common themes, research methodologies and the evolution of research in this field. The review also highlighted issues, opinions, gaps and trends associated with the assessment of HP, guiding towards further research and exploration.

It is important to acknowledge that this literature review represents a synthesis of existing research and opinions expressed in the reviewed literature. While efforts have been made to provide a comprehensive overview, the interpretations and conclusions drawn are subject to the limitations inherent in the available literature. Nonetheless, this review serves as a valuable foundation for the subsequent chapters of the research study, providing advice on the hypotheses, research design and practical recommendations to enhance HP in various systems.

2.2. Review Methodology

A literature analysis is the indispensable initial task to introduce one to the accessible body of information in his/her area of curiosity [10]. For this study, the research methodology suggested by Kumar [10] has been followed. Four stages have been involved in the literature review, which include searching for the present literature (books, journals, internet etc.) in the area of study, reading the selected literature to pull together themes and associated issues, analysis and slotting of the information besides finding opinions and gaps in the area, developing a theoretical framework by setting parameters which can sort out information and evolving a conceptual framework by focusing on a specific section of the theoretical framework [10]. So, the steps followed are specified below.

Step 1: Searching ‘Web of Science’ (WOS) with the key word “HP”

Step 2: Analysis of the search results for highly cited researchers.

Step 3: Searching the internet for books authored by highly cited researchers about the topic.

Step 4: Choosing the recent book/books which will provide a basic understanding of the topic and reading it carefully for the terminology.

Step 5: Repeating steps 1-4 with the search topic "HR"

Step 6: Searching ‘Web of Science’ (WOS) with the key word “HP” and "assessment".

Step 7: Reading the most cited and recent articles published within the last five years. Reading the title and abstract before selecting the article for critical review.

Step 8: Repeating steps 6-7 with the search topic "HR" and "assessment"

Step 9: After critical review, classifying the themes and associated issues and making an endeavour to find opinions and gaps in the area.

Step 10: Construction of theoretical frameworks.

Step 11: Providing the suggestions for the possible conceptual frameworks to address the research gaps in the theoretical framework.

By following steps 1–5, three books were found, which were later reviewed for having the basic knowledge on the topics “HP” and “HR” [11] [12] [13]. By using steps 6–8, 851 articles were found from a WOS search on “HP” and “assessment”. Via a WOS search on “HR” and “assessment” 227 articles were found, with a total collection of 1078 articles. The abstracts of these articles were reviewed and 53 relevant articles were selected for critical review. Each of these 53 articles was analysed based on its theme (a unifying idea that is a recurrent element in the article), issues (an important topic or problem debated or discussed in the article), opinions (the researcher's view or judgement, not necessarily based on fact or knowledge) and gaps (the area that has not yet been explored or is under-explored in the article).

2.2.1. Some of the critically reviewed articles

Article author	Theme (A unifying idea that is a recurrent element in literary work)	Issues (an important topic or problem for debate or discussion)	Opinions (a view or judgement formed about something, not necessarily based on fact or knowledge)	Gaps (the area that has not yet been explored or is under-explored)
Nsimah J. Ekanem [14]	Developing a model-based methodology that works with flow charts, fault trees, failure modes, influencing factors and Bayesian belief network to analyse HR qualitatively	Many HRA approaches do not provide comprehensive analysis by taking into account larger factors that contribute to crew failure. Furthermore, not all of them are well-documented, thorough, consistent, traceable and reproducible procedures.	The suggested methodology is universal, compatible with a variety of HR measurement techniques and adaptable for usage in a variety of organisations.	The author has not addressed the dynamic nature of HP and influencing factors in this methodology.
Yuandan Li [15]	Introducing a new reasoning module for the ADS-IDAC DPRA architecture to forecast the operator's attention while detecting control room indicators as well as to mimic the operator's knowledge-based behaviour while analysing and diagnosing the cause of an accident.	It is necessary to improve the realism of the IDAC model and simulation methodologies in order to improve the prediction quality of HRA.	With a thorough understanding of human dynamics, the ADS-IDAC platform may be improved in a variety of ways. One of them is increasing simulation capabilities in order to imitate intention-driven attention and deliberative knowledge-based reasoning.	There is always a scope for updating and improving the ADS-IDAC software.
Joseph G. Allen [16]	Finding the effectiveness of higher-order decision making in office workers when exposed to carbon dioxide, ventilation and a volatile organic compound.	The energy-efficient building construction practices lead to poor indoor environmental quality, affecting individual's health and productivity.	Building's design should optimise energy usage and employee productivity by adopting energy-efficient technology and educated operating practices.	Similar effort is necessary in the design of houses, schools and airplanes, where cognitive impairment may have serious ramifications for

				productivity, learning and safety.
Luyuan Chen [17]	Developed a more accessible and efficient dependency assessment approach that employs analyst's judgement and confidence, the analytic hierarchy process and the dempster-shafer evidence theory to determine conditional human error probability (CHEP)	There is subjectivity in analysts' judgement and computational complexity in dependence assessment among human failure events. There are also concerns about any constructed model validity.	THERP method provides limited guidance on determining dependence level and lacks traceability and repeatability. Decision trees can reduce subjectivity and improve dependence assessment repeatability but lacks traceability. The fuzzy expert system technique is flexible and traceable, however throughout the fuzzification and defuzzification processes, information is gained or lost.	There is always the potential of acquiring a precise estimate of the human error probability from models that are solely focused on improving HRA convergence.
Roger M. Enoka [18]	This review presented a framework that includes a taxonomy that can cover a wide range of fatigue-related conditions (modulating factors) and a fundamental tactic to determine the impact of fatigue on HP.	Little is known about the varied effects of fatigue on HP. Also, there are very limited authenticated experimental models to recognise these effects.	For suggesting countermeasures that can moderate the impact of fatigue on HP, there is a need for an ecologically valid laboratory test to measure the modulating factor responsible.	There is a scope to advance effective experimental models which measure fatigue (perceived and performance fatigability) that affects HP.
Xinyang Deng [19]	Using an evidentiary network method extended by belief rules and uncertainty measures in dempster-shafer evidence theory, they developed a novel framework for assessing dependency.	There is a probabilistic uncertainty due to analysts' judgement on input factors and epistemic uncertainty due to limited expert's knowledge on associations between input factors.	Dependence assessment between human actions is a critical issue in HRA	There is a scope for the further improvement of the inference algorithm built in this study and its applicability to more practical applications.

Jie Zhao [20]	The authors presented a model to show the consequence of performers on conditional human error probability using the D numbers approach.	The influence of task performers is ignored in determining the dependence level between human tasks.	The study helps extend the THERP dependence model based on the linguistic assessment process.	There is a chance to consider different influential factors (such as age difference, operation time difference and training time difference) to get accurate results.
Rabiul Islam [21]	The authors presented an approach to building a monograph for human error likelihood assessment that can help prepare, prioritise and improve safety and reliability in work procedures.	There is a lack of valid and user-friendly methodology that can provide instant HEP and support the decision-making course in a short period.	A developed monograph for human error likelihood assessment can allow instant decision making and enhance the overall safety and consistency of activities.	The author should have considered using advanced HRA techniques for evaluating human error probability.
Mashrura Musharraf [22]	The authors tried to assess PIFs like morale, motivation and attitude using behavioural indicators, providing insight into the PIF state. This study developed a Bayesian network model and used self-assessment, a virtual environment for measuring behavioural indicators.	It is difficult to assess person-based influencing factors like bias, morale, motivation and attitude.	The observable and measurable behaviours. The unobservable PIFs manifest themselves in how they behave.	The limited sample size imposed constraints on the results obtained.
Esmaeil Zarei [23]	This research suggested a hybrid and dynamic HRA model based on the Human Factors Analysis and Classification framework, fuzzy set theory and expert elicitation, Fuzzy AHP and Bayesian network.	Human factors are the leading causes of accidents in different industries.	The model can thoroughly identify operators to top-level management failures and handle uncertainty in accident investigation. It also uses dynamic and flexible modelling to provide a reliable measurement of failures in accident manifestation.	Further testing and rigorous validation of the suggested model is required.

Salzitsa Anastasova [24]	The authors developed a non-invasive wireless electronic wearable sensor that can continuously measure sweat metabolites, electrolytes and temperature.	There is a lack of available technology that can help assess individual's physiological capacity and efficiency.	To measure HP, health and well-being, continuous, non-invasive biomarker monitoring is necessary.	Not only in sport and exercise science, similar studies should also be progressed to support the improvement of human efficiency in human cantered organisations.
Tyler R. Ray [25]	The authors explored progress in biophysical and biochemical sensors that can help quantify HP and provide important insights into overall health.	There is a need to develop wearable biosensing technologies to advance the character and efficiency of medical care and public health emergencies.	Biosensors can gather information about body electrical signals, motion, temperature, skin properties, vascular dynamics, sweat, tears and saliva.	The biosensors must be physically robust and durable to sustain long-term wear and numerous application/removal cycles and should work in highly dynamic environments. The outputs should be calibrated and reliable.
Mickaël Causse [26]	The authors examined the suitability of fNIRS to assess mental workload. They also used workload combined with HP to quantify cognitive efficiency.	There is a need for portable and field-deployable technologies that can assess mental workload precisely, continuously and reliably.	Despite the fact that EEG, fMRI and PET provide vital insights into the functioning of the human brain, they are not suitable for use in ecological situations.	This research needs to look at the effects of inter-individual differences (such as training and practice) in brain activity and output performance in a complex environment.
Pietro Aricò [27]	This study aimed to explore if neurophysiological measurements can be used to evaluate the effectiveness of human-machine interactions.	Subjective questionnaires and neurophysiological measures will show a significant correlation with workload.	EEG and other neurophysiological metrics are useful for comparing new technologies or solutions with the goal of improving the operator's experience and increasing safety.	The author has used only EEG among many neurophysiological devices adapted for the purpose.

Kilian Zwirglmaier [28]	To enhance traceability in HRA, this study employed Bayesian networks to introduce new, qualitative causal routes.	Existing HRA approaches lacked causal structure and quantitative traceability due to a lack of scientific foundation and simple modelling techniques.	We may improve the scientific underpinning and traceability of HRA by incorporating causal relationships revealed in cognitive literature in Bayesian network models.	It is feasible to construct a quantification framework for the generated structure that incorporates both expert's elicitations and observable data via Bayesian updating.
Emre Akyuz [29]	In this study, HR performance was evaluated using fuzzy set theory to enhance fire safety management on-board ship operational level.	Human technical interface studies during HRA that are addressed to the maritime application are minimal.	The author used a dominance factor to alter the influence level of expert's judgements by aggregating multiple expert opinions.	The adapted marine-specific human error assessment approach is simple and might lack causal structure. It can be updated using the latest available HRA techniques.
Kevin Mandrick [30]	The psychophysiological cost of maintaining optimal cognitive performance was measured using pupil response, cardiovascular and prefrontal oxygenation quantities.	Maintaining optimal cognitive performance is a continuous challenge in stressful environments like the Toulouse n-back task and aversive sounds.	Compensatory effort may safeguard performance effectiveness under stress, but only at the penalty of a cognitive cost known as cognitive efficiency.	Using the threat of unpleasant noises, it is possible to analyse observable changes in performance under stress.
Woocheol Kim [31]	This study tried to find the role of employee work engagement and its structural relationship with other factors in the organisation using a questionnaire survey.	The human or social aspect of organisational sustainability has gotten far less attention than the economic and environmental aspects.	Employee work engagement is critical for enhancing HP and ensuring the long-term viability of an organisation.	This study focused only on the relationships among four variables, but there is a scope to include additional prevailing concepts connected to organisational sustainability.
Vincenzo Muto [32]	This research aimed to uncover the processes that keep cognition intact throughout the day and deteriorate it under insufficient	Circadian rhythmicity and homeostatic sleep pressure influence HP.	A lack of sleep causes numerous areas of cognition to deteriorate as well as an increased chance of human mistakes and health risks.	The same study can be carried out on a fatigued individual to understand the concept better.

	sleep and circadian misalignment.			
Raphael Muto [33]	This article used the CREAM HRA technique to introduce a new multi-attribute technological accidents dataset for HP data collection.	The chain of events leading to a serious accident is complex and is linked to the alignment of certain situations at the workplace.	It is critical to learn from previous incidents and improve system design in order to reduce the likelihood of unfavourable occurrences occurring again.	The dataset created should have the facility to categorise different industries' accidents to find specific input to hazard control strategies.
P. Sotiralis [34]	To include human aspects into quantitative risk analysis, this article presented a collision risk Bayesian network model.	Risk models are difficult to model using fault and event trees because they are complicated and involve many relationships between technological systems and human aspects.	To avoid collision accidents, HP under normal, abnormal and critical operational settings can be analysed for performance errors.	Other technological faults that contributed to the collision of two ships have not been thoroughly investigated.
Fan Zhang [35]	This review looked at studies on the impact of temperature on cognitive function from a variety of disciplines.	The impact of the ambient temperature condition on productivity and performance.	The ambient temperature condition can have a negative influence on the cognitive performance of inhabitants.	The author should have also reviewed fatigue and cognitive load, behavioural and physiological adaptability.
Fabiana B Nerbass [36]	Review of the effects of occupational heat stress on the kidney, heat-stress measurement techniques, preventative and mitigation options and economic implications.	Many employees are subjected to high temperatures, strenuous physical activity and slack labour rules that do not allow for adequate rehydration breaks, all of which have an impact on the kidneys.	The validation and financing of more sensitive disease biomarkers would allow for early identification and the possibility of slowing disease progression.	Health researchers and industry must work together to discover work habits that cause heat-stress nephropathy as well as to test focused, effective preventative and mitigation solutions.

2.2.2. Disciplines (and sub□disciplines) involved in understanding, evaluating and managing human performance

- Behavioural science
- Psychology (Cognitive psychology, Engineering psychology and Experimental psychology)
- Neuroscience (Neuroergonomics)
- Physiology
- Engineering (Human factors engineering and Reliability engineering)

2.2.3. Organisations/systems that have an interest in this area

- Nuclear power plant
- Space industry
- Processing plant
- Healthcare
- Sports
- Transport (aviation, maritime, railways and road)
- Construction
- Mining

2.2.4. Thematic Review

Review of the books of highly cited authors in the "HP" and "HR" fields enabled the researcher to understand the context of the topic, facilitating in a critical review of the chosen articles on assessing HP and HR. Most of the articles described a human being as an information processing system since it "encodes input, processes it, stores and retrieves it from memory and creates output in the form of actions" [37]. For the specific tasks, information-processing models have explained the flow of information through the various stages and predicted reaction times, mistake rates, error types and other elements of HP. These variables have been then evaluated in order to establish and determine their relation with HP or HR.

The researcher developed a generic information processing system (Figure 2.1) by incorporating most of the available models in the HP assessment literature [12], [38]–[44]. Along with this, a generic information processing context for representing human error has also been developed. Finally, the chronological development of different HP assessment techniques and HR assessment techniques were developed.

Theme 1. Information processing system on human performance

As shown in Figure 2.1, when an individual encounters a particular environment, he/she gathers information on the task environment or the surroundings through senses, which is called sensory processing [45]. The amount of information he/she gathers (through selective attention) depends on the goal/expectancy-driven or stimulus-driven behaviour [42]. Afterwards, he/she organises and interprets sensory information to understand it [45]. This is perceptual process (or perception) and one's memory (long-term memory) supports this process [44]. Memory retrieval depends on technological and social conditions and affective levels [40]. Now, he/she stores what he/she understood from the environment in his/her working memory [38], [39]. Using this working memory and long-term memory, he/she generates new knowledge, which has been called cognition [44]. In cognition, based on the level of conscious (or subconscious) mind and one's conditions and affective levels, he/she makes a decision (decision making) [43]. With a decision in mind, the person acts. The performance of all the above sub-processes depends on the level of attention [38], [44]. Based on his/her actions, his/her performance can be evaluated. While acting, monitoring the task goals is an effort-based regulation because it necessitates a high level of awareness. On the other hand, comparing the task goals with the completed action is effortless and is a routinely regulated process shown as feedback in HP information processing models [41].

The other concepts which have not been represented in the framework (Figure 2.1) but have shown a good effect on HP are situational awareness, workload and fatigue [46]–[49]. These three parameters have a strong correlation with working memory [44]. Much research in HP has considered human cognitive performance as an essential parameter. The main flow of the framework is same in all the studies and the research to date does not support consistent changes in cognitive processes [38].

From a naturalistic decision-making (NDM) [50] point of view, cognition and decision-making in real-world settings depend on the individual's expertise and stress may affect decision-making and lead to human error. Perceptual, cognitive and physiological stress reactions are the three basic attributes that have an impact on performance [51][52]. When under stress, the flight-or-fight reaction distorts the body's senses, resulting in perceptual impairments [51]. Individuals' perception of the environment (situational awareness) can be impacted by perceptual impairments; for example, a person may focus just on one particular feature, missing out on other important cues like sounds and sights. Memory deficits, such as a person's capacity to encode, store and recall information from memory, are among the cognitive impairments. This can alter how people reason, including their capacity to recall previously learnt knowledge, like training methods and tactics [53]. Finally, physiological issues have an impact on fine motor abilities because they interfere with the body's adrenaline-driven flight-or-fight reaction to stress. Running, punching and other gross motor abilities can be improved by this stress reaction, but coordination and accuracy can be negatively impacted by the rise in heart rate and respiration [53],

[54]. These three impairments (Perceptual, cognitive and physiological stress reactions) may result in unintentional or unwanted behaviour as well as potentially dangerous situations that increase the risk of personal injury or property damage. The impact of decision-making impairments can be minimised by identifying them and helping education and training procedures to regulate or prevent them from happening [55].

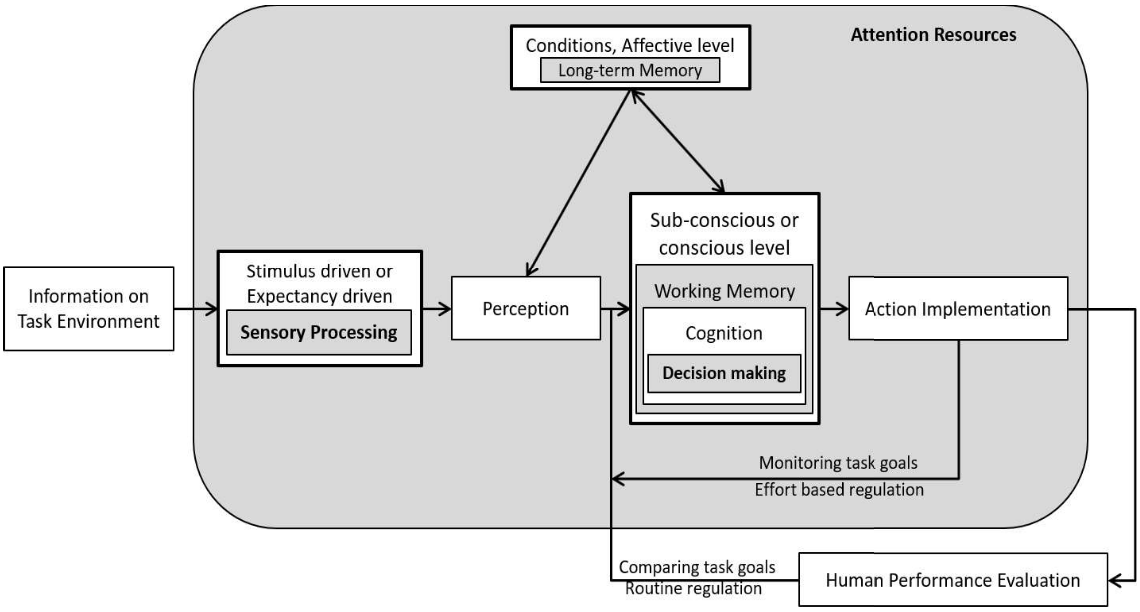

Figure 2.1. An information-processing system on Human Performance

Theme 2. Information processing context for representing human error

Figure 2.2 shows a developed model of human errors' evolution from the information processing system context. With the stimulus from the environment, the human beings perceive the information (perception) and as explained in the overview of Figure 2.1, cognition (decision-making) and action implementation occur. In this top-down model, technological and social conditions along with the affective state affect the conscious or sub-conscious mind that in turn affects perception, cognition and action implementation processes [56]. Reason [57] classified human failures into four types (i.e., slips, lapses, mistakes and violations) which can be used to fuse with the above processes. Mistakes and violations evolve from the conscious mind, where misjudgements and deliberate wrong actions happen [58]. Memory lapses and slips happen due to the subconscious mind, where memory recall and execution errors occur due to lower attention [44], [58], [59].

Human error may be classified into omission error, commission error and intentional mistake. The omission error occurs when an action is not completed due to a lapse or misconception. A commission error occurs when an action is completed improperly due to an insufficient quantity or quality of action or a mistake in selecting or following a sequence. The intentional mistake occurs when operations are performed incorrectly with knowledge of the consequences [60]. Human errors can also be designed at a different level of abstraction based on the model it follows. There is no generalised model to represent errors, but human errors are designed based on resource availability, work context and organisations.

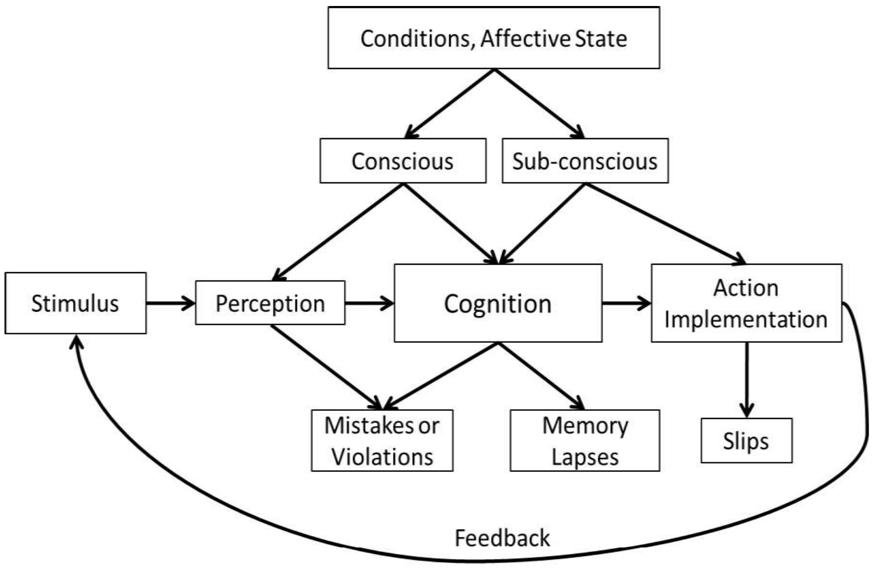

Figure 2.2. Information processing context for representing human error

Theme 3. Human reliability analysis (HRA)

Figure 2.3 shows the overall HRA process [11], [61]. Depending on the problem at hand (event selection), task analysis identifies human errors (error identification). To better understand the causes, susceptibilities, recoveries and likely risk mitigation methods, errors are represented in models (modelling). After modelling, it is easy to find the error (or performance) influencing factors (PIFs) responsible for specific HP. Now, it is possible to assess HR qualitatively or quantitatively. Later, managerial decisions are made to improve system safety after an impact assessment (error management).

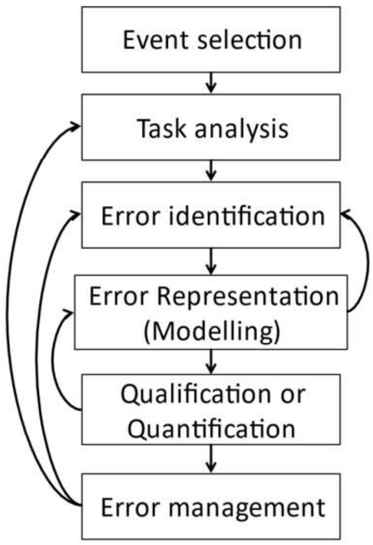

Figure 2.3. HR analysis process [11], [61]

2.2.5. Chronological Review

As an interdisciplinary field, HRA started to assess system safety from human context as well as to address safety measures concerning it [62]. Figure 2.4 shows the chronological development of the methods for evaluating HP in engineering psychology and HRA fields. First-generation HRA methods, without much taught about the complexity of human behaviour, assessed HP using laboratory experiments of error probabilities and PIFs multipliers [63]. Second-generation HRA methods used cognitive processes and PIFs responsible for human behaviour and field studies (i.e., observational, case study and questionnaire survey) [33], [64]. These methods are static assessment techniques in which the causes, susceptibilities, recoveries and likely risk mitigation methods are little understood. Even though second-generation HRA methods used advanced assessment methodology, there is much inconsistency in the HRA results obtained by different experts for the same problem. Due to its minimal time and resource-consuming nature compared to third-generation HRA methods, it is popular among many fields and researchers are trying sophisticated mathematical tools to reduce the inconsistency in results and improve validity [28], [34], [65], [66].

The latest trend in evaluating HP is to use non-invasive bio-signal monitoring sensors in human-in-the-loop simulations [25]. The third generation HRA methods use cognitive architecture to simulate the human cognition process by cognitive modelling (computer simulations) [15]. The evolution process of an event and errors, the dynamic nature of PIFs, dependencies between errors and interactions between PIFs are incorporated into the simulation for explicitly quantifying HP probabilities. Researchers primarily depend on the Bayesian network techniques to tackle this intricate work at hand [22], [23]. Third-generation practices are a well-constructed explicit method for assessing HR, but they are time and resource-intensive. Moreover, they analyse HR without much emphasis on individual deference [67]. The cognitive architecture used in third-generation HRA methods is constructed based on numerous facts derived from psychology experiments which have concerns about trivial sample sizes, individual differences, inadequate baseline practice, unreliable procedures and test sensitivity [38].

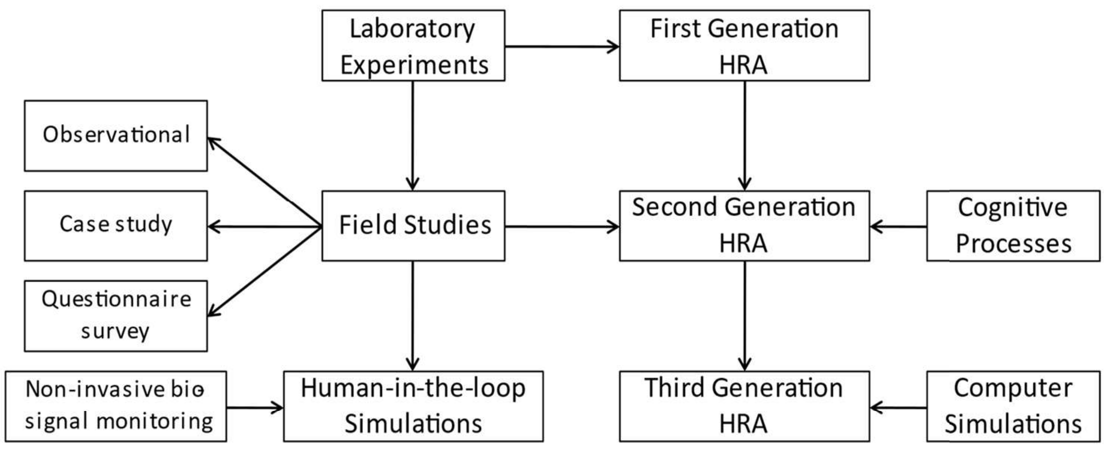

Figure 2.4. Chronological development in Engineering Psychology and HRA

2.2.6. Methodological Review

Methodologies and associated issues:

HP assessment typically comprises quantifying specific characteristics associated with HP. The evaluation of these characteristics might measure brain, body parts or other functioning. Although this assessment is extensively used in evaluating clinical patients, it is also significant to evaluate job-related actions. The most used characteristics for assessing HP are cognition [16], sustained cognitive performance [32], visual working memory, workload [26], attention, vigilance, fatigue [18], mental effort, emotional state, thermal stress [35] and psychophysiological functions [49]. There are over 500 specific measures of HP to evaluate functionality of these characteristics. These techniques mainly use questionnaire surveys, test batteries, bio-signal monitoring (electrical activity, temperature, skin conductivity, vascular dynamics and so on), eye measures, heart measures and neurophysiological measures [24], [27]. Some of the latest devices used to measure these characteristics for assessing HP are non-invasive, wearable, ergonomic and reliable and can work in real-time [68]–[71].

The main issue with the questionnaire survey is human subjectivity. This subjectivity needs complex mathematical modelling to deal with it. In assessing HP using test batteries, the time and resource consumption increase with abstraction at each block in the information processing system. Using bio-signal monitoring for objective measurement of HP is reliable, but there is a lack of ergonomic devices to do the task.

In HRA, most of the works recently used the Bayesian network technique to find dependencies between errors, performance influencing factors, individuals etc.[72]. There are also works on using the Bayesian technique to improve cognitive or error traceability in dynamic HR model development and dealing with expert judgment uncertainty [19]. Many research works used simulators or simulation data to improve HRA techniques. From 2010 to 2019, the research was mainly based on using fault tree analysis, analytical hierarchy process, fuzzy set theory etc. for finding human error probabilities [66]. Other works in this field include updating PIFs, constructing and updating HP database, developing dynamic simulation models for HRA, developing hybrid HRA approaches and developing working mathematical models of psychological concepts like fatigue and situational awareness to find HR and improve system safety [23], [67], [73]–[75].

Even though the methods used for HRA were adopted from engineering psychology (human factors engineering or ergonomics), there are issues in updating it fast enough. First- and second-generation HRA used laboratory and field studies. However, third-generation HRA methods have not fully adapted to the engineering psychology field trend, i.e., human-in-the-loop simulations. Even though present third-generation HRA methods have shown computer simulation for dynamic modelling, human-in-the-loop simulations are rare. In human-in-the-loop simulations, non-invasive bio-signal monitoring for HP assessment in HRA is remote.

2.3. Opinions, Research Gaps and Trends

- Cognitive efficiency is mainly associated with the attention, working memory and observed HP.
- Many fields highly support the search and development of biophysical and biochemical sensors for HP assessment.
- Many researchers are trying to assess psychological concepts (i.e., workload, emotional states, fatigue, stress, working memory and situational assessment) using fast-developing non-invasive bio-signal monitoring devices and cognitive batteries, which record human response accuracy and response time.
- Being dynamic and requiring much-advanced data analysis tools to achieve some level of accuracy for immediate results, the non-invasive bio-signal activity monitoring depends on real-time field studies.
- Recent research studies found that physiological measures unintentionally reveal an individual's internal status. Some of the frequently employed physiological indicators include electroencephalogram (EEG), electrocardiogram (ECG), electrooculogram (EOG) and electrodermal activity (EDA). A more widely used and reliable method for assessing workload and fatigue is the quantitative analysis of EEG (the brain's electrical activity) signals.
- In almost all HRA techniques, authors have used subjective data. So, there is a need for techniques to use objective data for HR assessment.
- Recent HRA studies have used sophisticated mathematical tools to model HP as well as to produce the human error probabilities (HEP) from expert judgments or questionnaires.

- Some approaches include finding dependencies between human errors, interactions between performance influencing factors using the fuzzy set theory and the Bayesian network.
- In HRA, there is also a new advancement that simulates HP. HRA approaches based on simulation can provide a dynamical modelling system based on a virtual task environment and even with virtual operators.

2.4. Conclusion

2.4.1. Key Findings:

1. Non-invasive bio-signal monitoring devices, such as EEG and EOG, have shown promise in predicting HP. These devices provide valuable insights into cognitive status and can be used to assess the cognitive processes that influence performance. By monitoring bio-signals in real-time, researchers can identify patterns and indicators that can predict an individual's performance in challenging tasks or situations.

2. Cognitive performance tests, which measure response accuracy and response time, have also been effective in predicting HP. These tests provide objective metrics that can capture the effectiveness of cognitive processes. By evaluating an individual's performance on these tests, researchers can gain insights into their cognitive capabilities and predict their performance in future tasks.

3. The use of advanced technologies, such as computer-based programmes, can aid in evaluating and predicting cognitive performance. By developing customised programmes that assess specific cognitive processes, researchers can gather data and insights that contribute to predicting HP. These technologies enable the collection of objective data in a controlled environment, allowing for accurate prediction of performance outcomes.

2.4.2. Research Contribution:

This research aims to contribute to the existing literature by focusing on the prediction of HP. By leveraging non-invasive bio-signal monitoring devices, cognitive performance tests and advanced technologies, the study seeks to develop a comprehensive framework for predicting HP in various settings.

The research seeks to explore the relationships between bio-signals, cognitive processes and performance outcomes. By analysing the data collected from bio-signal monitoring devices and cognitive performance tests, the study aims to identify indicators that can accurately predict HP.

Furthermore, the research intends to investigate the feasibility of utilising computer-based programmes to evaluate cognitive performance and predict future performance outcomes. By developing and validating these programmes, the study aims to enhance the accuracy and reliability of performance prediction.

Overall, this research is expected to contribute to the literature by providing insights into the prediction of HP. By focusing on the integration of non-invasive bio-signal monitoring, cognitive performance tests and advanced technologies, the study aims to fill gaps in existing research and provide practical recommendations for predicting HP in various domains.