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Review Article

The Impacts of Mental and Physical Fatigue of Employees on the Perception Level and the Risk of Accident

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Abstract

The sources of work accidents identified in the root cause analysis are dangerous behaviors and dangerous occurrences. Despite the studies, improvements, and arrangements made on this subject in recent years, the status of the matter has not been improved until today, and the rates of occurrences have almost remained the same. In the accident root cause studies conducted, the findings suggest that the human factor is the leading cause of accidents in the workplace. However, pointing out that the human factor alone is not enough to correctly examine the causes of these accidents. In the assessments performed, the physical and mental fatigue and psychological conditions of the workers are generally excluded from the studies. Despite this, the perceptual deficit that arises from fatigue and insomnia plays a significant role in the occurrence of accidents or near-miss incidents. These fluctuating changes in the mental and physical well-being of the worker overtime often go unnoticed by both the employee and the employer. By regularly monitoring the components of this state of well-being, within the scope of occupational health and safety, it must be aimed at proactive and preventive protection of the health and safety of employees in the workplace concerning the environment, equipment, and individual/team. In this study, a roadmap developed for the prevention of near-miss incidents or accidents that may occur due to changes in decision-making skills, risk-taking behaviors, and reaction time of employees due to deterioration in the perception levels of them, and a matching matrix regarding the Occupational Health and Safety (OHS) processes are presented.

Keywords: The root cause of the accident, mental fatigue, fatigue, insomnia, perception

Çalışanın Zihinsel ve Fiziksel Yorgunluğunun Algı Üzerindeki Etkisi ve Kaza Riski

Öz

İş kazalarında kaza kök analizinde oluşum kaynağının tehlikeli davranışlar ve tehlikeli durumlar olduğu bilinmektedir. Geçen yıllar boyunca yapılan araştırma, çalışma, iyileştirme ve düzenlemelere rağmen bu oranlarda iyileşmeler yeterince olmamış ve neredeyse aynı şekilde günümüze kadar gelmiştir. Kaza kök neden çalışmalarında en büyük etki olarak insan faktörüne ulaşılmaktadır. Ancak insan faktörünü işaret ederek kök nedenin burada bitmesi doğru değildir. Ramak kala veya kaza oluşumunda çalışanın fiziksel ve zihinsel yorgunluğu ve psikolojik durumu genellikle incelenme dışı bırakılmaktadır. Oysa ki yorgunluk, uykusuzluk sonucu oluşan algı sapması; olayın gerçekleşmesinde önemli bir rol oynamakta, ancak dönemsel meydana gelen bu değişiklik, çoğu zaman hem çalışan hem de iş veren tarafından göz ardı edilmektedir. Bu durumun düzenli takip edilerek, bileşenlerin, çalışanların iş yerinde çevre, ortam, ekipman ve birey/takım kapsamında proaktif ve önleyici olarak korunmalarını hedeflenmelidir. Bu makalede çalışanın algısında oluşan sapmaların karar verme, risk alma ve reaksiyon süresindeki değişimlerin sonucunda oluşacak ramak kala veya kaza riskinin önlenmesine yönelik geliştirilmiş olan bir yol haritası ve İş Sağlığı ve Güvenliği (İSG) süreçleri ile eşleşme matrisi sunulmaktadır.

Anahtar Kelimeler: Kaza kök nedeni, zihinsel yorgunluk, yorgunluk, uykusuzluk, algı

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1. Introduction

Consumption needs to rise with the growing population and the increase in production. Thus it becomes inevitable to meet up with this demand. Technology is advancing rapidly nowadays. This advancing technology makes change inevitable, and it brings along the circumstances, such as the development of new practices, transformation of the machines, increase of efficiency and shortening of the duration of processes. The increase in the rate of production and the pace of daily life is causing a growing pressure and stress on the employee. With escalating production, the risk of accidents or incidents increases. Despite this negative picture, developing technology and science offer new options and means for the prevention of possible dangers and accidents. Therefore, the importance of occupational health and safety is increasing day by day.

Occupational accidents or occupational diseases are significant social phenomena that should also be evaluated within their social dimensions, as well as with their economic effects and thus impact the development of the country in several ways. According to the International Labor Organization (ILO), approximately 2.3 million people die each year from occupational diseases and accidents. Besides, 860.000 occupational accidents are happening each day around the world, and many injuries and deaths occur as a consequence. The direct or indirect costs of occupational diseases and occupational accidents are estimated at USD 2.8 trillion worldwide [1].

In our country, progress has been made thanks to many actions taken related to OHS, but despite these duties performed, the desired level of improvement in the rate of accidents and deaths could not be achieved. This situation shows us that it should be questioned whether the problem is being considered from the right angle. In Figure 1, it is seen that the number of employees who died due to occupational accidents and diseases in 1997-2017 continued at the same levels, without a decrease. When we look at the number of accidents, there has been an increase of 282.1% in the five years between 2012 and 2017 (Figure 2) [2].

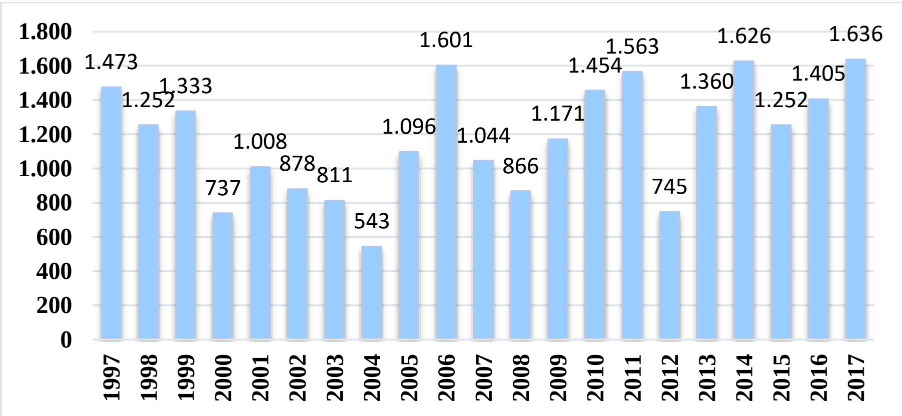

Figure 1. Deceased employees due to occupational accidents or diseases in Turkey (1997-2017)

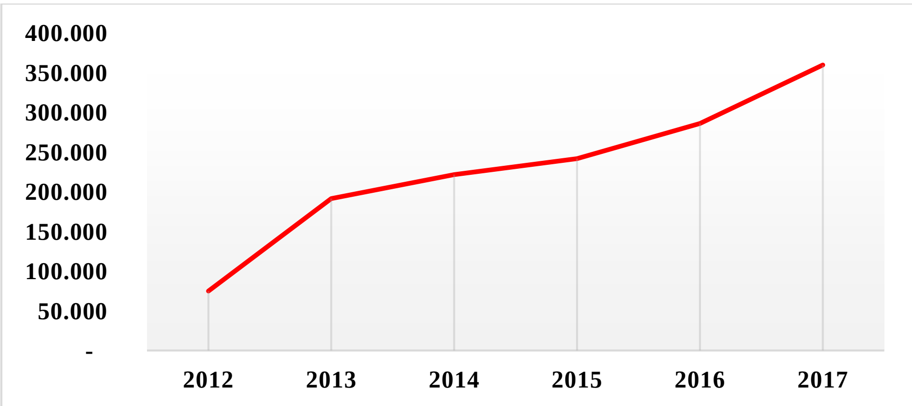

Figure 2. Number of Occupational Accidents Occurred in Turkey (2012-2017)

When the 28 member states of the European Community are taken together, it is seen that the average rate of occupational accidents resulting in death is 1.65 accidents per 100,000 employees. However, this ratio is higher about three times in Turkey, and 4.7 fatal occupational accidents occur per 100,000 workers each year (Figure 3) [3].

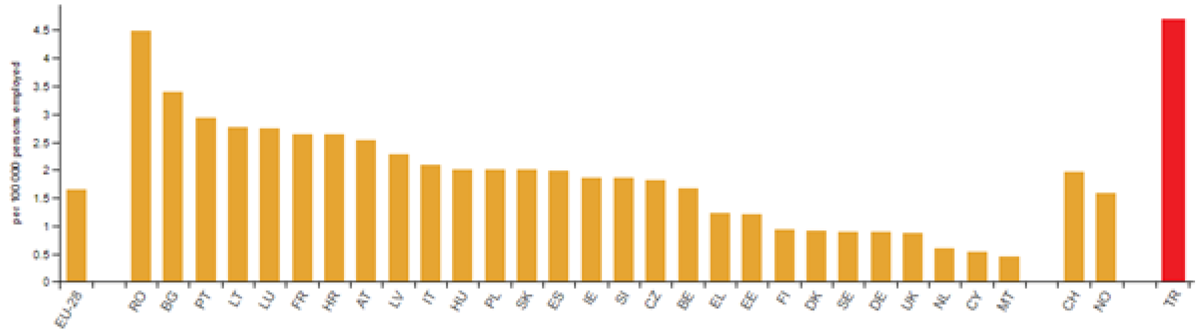

Figure 3. Fatal Occupational Accidents Occurred in Europe vs. Turkey in 2017 (per 100.000 workers)

According to the assessments performed, it is accepted that 88% of occupational accidents arise from dangerous behaviors, 10% from dangerous occurrences, and 2% from unavoidable causes [4]. It has been determined that human or human-related, or both factors are the main causes of most occupational accidents in various industries. Many studies quantitatively put forward the critical role of the human factor in this regard [5].

- 90% of nuclear accidents,
- 80% of chemical processing accidents,
- 75-96% of marine accidents,
- 70% of aviation accidents in the European Union [6],
- 75% to 96% of occupational accidents in Europe,
- More than 94% of the accidents at oil and gas refineries in countries such as the United States [7] and Iran occur due to human-related factors.

Therefore, the prevention of human-related factors plays an important role in reducing accidents and ensuring workplace safety. Managing human error is increasingly important to reduce the risks associated with loss of production, asset damage, environmental pollution, and death in various industries.

Given that human-related factors cause most accidents, it is an absolute necessity to review these errors in accident investigations to prevent similar accidents in the future. In this respect, it is a necessity to include human-related factors in accident analysis models for the effective prevention of accidents [7]. There are various methods commonly used to evaluate human-related factors in occupational accidents. The Swiss Cheese Model, System-Theoretic Accident Model and Process (STAMP), Classification of Socio-Technical Systems [7], [11], System Dynamics, AcciMap, Human Factors Analysis and Classification System are examples of these models. Among the models developed, “Human Factors Analysis and Classification System” is the most widely used model, specially designed to investigate human-related and organizational factors' contribution to an accident.

Accidents that arise from human-related factors are grouped under five behavioral topics following. The cause of an accident may be related to more than one of these topics [4]:

- Distraction
- Involuntary misconduct (lack of training, experience or the inability, or both to assess the presence of critical situations when necessary)
- Desire to take the easy way
- Violation of the rules
- Being affected by the environment (neglect, disorder, insufficiency of the system and machines)

In preventing accidents, it is critical to distinguish the components of human-related factors and reveal their effects. It is seen that detecting these effects before an accident occurs will play a warning role in preventing many accidents from happening and will make it possible to prevent accidents.

Heinrich emphasized that traditions and the social environment may lead to errors, thus causes unsafe behaviors or situations or both, resulting in accidents, injury, or damage. He explained this course leading to accidents by comparing it to dominoes, with the following five main effect factors operating in this process [1].

- ***Traditions, lineage and social environment***

  Bad environment (high temperature, polluted air, noise), irregular working environment, open-ended unplanned work, the behavior of the team, managers not showing an exemplary behavior

- ***Employee error***

  Personal problems, bad habits, physical and mental condition, lack of knowledge, lack of skills, pressure, excessive willingness or overconfidence

- ***Unsafe behaviors or situations, or both***

  Unsafe behaviors: Using the machinery without proper authorization, working or using at an unsafe speed, removing or disabling protective equipment, working with a malfunctioning or inappropriate tools, making repairs or adjustments while the machine is running, working in an unsafe posture, not using personal protective equipment

  Unsafe situations: Inappropriateness of protective equipment, such as lack of protection in works requiring protective equipment, unsafely designed machinery or tools, insufficient lighting or glare sources, sources of polluted air and inadequate ventilation

- ***Accident***
- ***Injury***

Every accident occurs due to these five leading causes lined up in a row. Unless one of the conditions is fulfilled, the next one does not happen, and the accident conditions do not emerge unless the sequence is completed.

Simple linear models assume that accidents are the result of a sequence of occurrences. Accordingly, it is possible to prevent the accident by eliminating one of the events, situations, or reasons that interact with each other linearly. However, complex linear models are based on the assumption of a combination-based cause-effect relationship of accidents. According to this approach, combinations of unsafe behaviors and hidden dangerous situations in the system bring about the accident (Figure 4).

According to the new generation's views on accident modeling, it is usually accepted that accident models should not be linear. In this context, accidents are considered to result from the complex relationships of combinations of collectively interacting variables. Today, it is better understood that accidents occur due to the mixture and interaction of multiple factors in real-world environments [12].

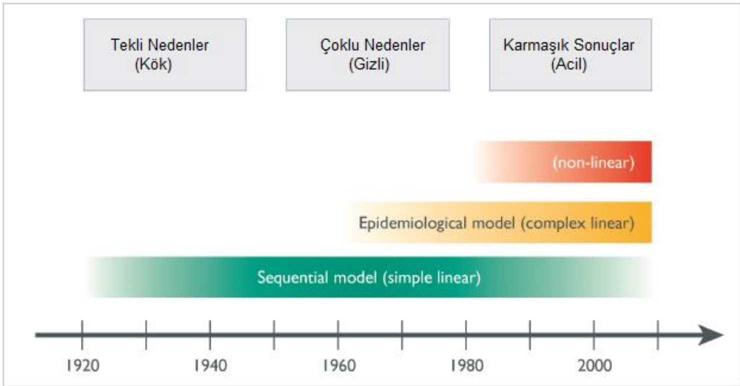

Figure 4. Summary of the history of accident modeling [12]

In this context, there is a 98% wide band that can be intervened to prevent accidents. It is foremost significant to focus on human behaviors in actions carried out on the factors included in this intervenable band. Thus, it will be possible to proactively prevent near-miss incidents or accidents by determining persons' accident risk potentials.

2. Material and Method

In order to prevent occupational accidents, the ecosystem that Industry 4.0 started to create can be defined as OHS 4.0[†] in the field of occupational safety. With OHS 4.0, the effect of human-oriented factors on the occurrence of accidents will be measured, and the results obtained will be used to prevent accidents.

2.1. The role of Perception in the Occupational Accident

[†] The use of computers, wearable technologies, remote monitoring systems, camera recognition systems, the internet of things (IoT), and artificial intelligence (AI) in the workplace to prevent accidents has led to the emergence of the concept of OHS 4.0.

The root causes of many accidents are directly or indirectly linked to the human factor. However, it is not usually assessed which components make of this "human factor", and why an employee actually might have caused this accident. When the processes before the accident are examined, it is seen that it is possible to recognize the factors causing the accident before the accident occurs. Accidents caused by human factors may have many reasons. It is observed that accidents can become inevitable due to the decrease in perception, prolonged reaction time, and taking high risks for the desire to finish the job as soon as possible due to one or a combination of reasons, such as mental and physical fatigue, diabetes, psychological reasons, and malnutrition.

Perception can be defined as the cognitive process that enables an individual to understand, feel, interpret, and react to what is happening around using sensory organs. The mental processing of what is perceived and the comparison of these perceptions with past experiences play a significant role in determining the reactions of individuals in daily life. Perception is a developing cognitive process, and its level can be increased due to exercise/experience. Perception enables us to predict not only the current situation but also the possible and future situations and reacts accordingly. The level of perception can change in both negative and positive directions depending on the physical and mental state of the person. If the person's psychological or physical condition is better than usual, there will be a positive change, and if it is worse, a negative change will occur on the perception level.

Studies show that approximately 80% of industrial accidents are entirely or partially caused by human actions [13]. When the events that occur due to human error and that have proportionately larger consequences are examined in a study, it is seen that

- 20-53% of the malfunctions of the US Air Force missile systems,
- more than 90% of air traffic control system errors,
- 82% of the production errors,
- 50-70% of malfunctions of electrical appliances,
- 25.8% of maintenance malfunctions,
- 16% of all critical incidents of the US Strategic Air Command

arise from human-induced factors.

One of the most compelling results obtained in this study on large-scale accidents is that 20% of the errors in the accidents have been overlooked in the evaluations carried out. In a study examining 135 ship failures around the world between 1926 and 1988, the findings showed that 24.5% of the malfunctions that occurred were directly caused by human error. Similarly, it has been determined that 47.4% of failures in boiling water reactors and 45.7% of failures in pressurized water reactors, resulting in accidents in nuclear power plants, were caused by human error [15].

2.1.1. Factors Affecting the Perception

The first studies to reduce occupational accidents were conducted in the 1800s on the sectors where injuries and deaths were more frequent, and the first measures were taken against them. These early studies were performed primarily in the mining sector, and later studies were conducted in the transportation sector, especially in trains and later in the nuclear power plants. Increasing technological developments and multidisciplinary studies on the subject have begun to be utilized to reduce accidents.

The study, which was presented at the International Conference on Fatigue Management in Transport Operations held in Boston in 2009, regarding the search for new ways of detecting disorders in human behavior in the workplace, is considered a significant step in understanding the necessity of monitoring the perception state of employees [16].

The perception level of employees may change due to many reasons, and it is possible to classify them into two groups as individual and environmental factors. Each subtitle in this classification is a complex and deep topic in itself, and each of them has a relative effect that varies from person to person. The perceptual factors table prepared by the Australian State of Victoria, Department of Health and Human has been improved and rearranged (Table 1 and Table 2) [17].

Table 1. Individual Factors Affecting the Perception Level

Individual Factors		
Biological Factors	***Psychological Factors***	***Lifestyle***
Genetics	Personality characteristics	Nutrition
Gender	Cognition	Sleep environment
Age	Behavior patterns	Recreational activities
Temperament	Reactions to stressors	Second job
Health	Stress management	Habits
Medication	Traumas	Substance use
Disease	Weather condition	

Table 2. Environmental Factors Affecting the Perception Level

Environmental Factors	
Job	Social environment
Duty	Family
Time and duration	Marriage or
Shift and Rotation	Ethnic status
Prediction	Economic status
Time	Culture
Environment	Religion
Co-workers	
Time pressure	
Accidents and incidents	

According to the tables prepared by the Australian State of Victoria, Department of Health and People (Table 3) [17], fatigue symptoms are categorized as physical, mental, and emotional symptoms.

Table 3. Symptoms of Fatigue

Physical Symptoms	Mental Symptoms	Emotional Symptoms
Slowed reaction time	Difficulty	Social withdrawal
Lack of energy	Attention deficiency	Lack of motivation
Staggering while	Slow reactions	Irritability
Eyelids feeling heavy	Problems	Low morale
Drowsing off	Making mistakes	Emotional sensitivity
Small nap was taken	Weak decision making	Unwillingness
	Difficulty	

The employee can experience at least one or more of these symptoms periodically or during the day. In this case, although the symptoms may appear to be the employee's characteristics, it is also possible for the individual to show them only depending on the current conditions and conditions.

While many reasons play a role in the emergence of mental and physical fatigue, mostly encountered factors from the perspective of the employee are:

- Prolonged or intense mental or physical activity
- Sleep deprivation or sleep disturbances
- Travel
- Organizational change
- Irregular work scheduling or excessively long shifts
  - Strenuous activities
  - Long journeys to and from work
  - Extremely hot or cold working environments

According to the review written by Anne-M. N. in 2004, the employees with the highest risk of fatigue are [18]:

- Shift workers
- Night workers
- Seasonal workers
- Employees on call
- Emergency service workers
- Medical specialists and other healthcare professionals

Many factors may affect perception. Sometimes, this is a single factor, and sometimes, it can be a group of multiple-factors with a considerable effect of synergy. These factors may lead to several problems in the body and cause the perception to be negatively affected.

2.1.2. Fatigue, Sleep, and Perception

Fatigue is a multi-faceted factor addressed by different research areas and specialties, such as exercise physiology, cognitive psychology, human factors, engineering, and medicine. Different disciplines working on this issue have not reached a consensus on the definition of fatigue. Thus, the concept of fatigue can encompass an experiment term, a symptom, a risk, a cause (e.g., decreased performance), or a consequence (e.g., sleep deprivation) without a precise context.

Fatigue is typically defined as "excessive and persistent tiredness, weakness" or "exhaustion, including mental, physical, or both" [19].

Psychology investigates fatigue concerning subjective perception, well-being, cognitive performance, and the sleep-wake relationship of the neurophysiological conditions underlying them. In the field of exercise physiology, fatigue has traditionally been defined as "an acute disturbance of exercise performance that results in the inability to produce maximum power output due to possible metabolite accumulation or substrate depletion at the peripheral level" [20]. According to the Turkish Neurological Society, "sleep is an active period that covers one-third of our lives and is important for us to renew our mental and physical health every day" [21]. Similarly, according to the Turkish Thoracic Society, sleep is “a state of rest where the consciousness does not perceive some or all of external stimuli, the reaction power is weakened and the activity of many organs in our body is greatly reduced” [22]. In summary, we can define sleep as a naturally recurring state of mind and body with changes in consciousness, relatively suppressed sensory activity, reduction or prevention of muscle activity, and reduced interactions with the environment.

Our body utilizes the circadian rhythm to regulate its sleeping time. The circadian rhythm is a 24-hour internal clock cycle that works at the background of consciousness and provides regular alternation between sleepiness and wakefulness. It can also be defined as the repetition of our body's biochemical, physiological, and behavioral mechanisms in a routine. In summary, it is also considered as our sleep/wake cycle.

For most adults, the greatest decline in bodily energy occurs in the middle of the night (usually between 2:00 and 4:00 during REM sleep), and right after lunch (between 13:00 and 15:00, people tend to take a nap after lunch). However, the drops in the energy of an individual who sits up late or wakes up in the morning before the sun or with the sun may occur at different times.

Part of the hypothalamus controls the circadian rhythm. However, external factors, such as light and dark, may also affect the circadian rhythm. When it is dark at night, our eyes send a signal to the hypothalamus that it is time to feel tired. Thereupon, the brain sends a signal to release melatonin, a hormone that causes the feeling of tiredness to the body. Thus, periods of wakefulness and sleep in the circadian rhythm tend to coincide with the cycle of day and night. This is why the difficulties in the life pattern in which shift workers sleep during the day and stay awake at night (Figure 5) [23].

Circadian rhythm gives the best performance results in the body when regular sleep habits, such as going to bed at night and waking up at the same time of the day (including weekends), are present. Situations such as jetlag and blue light exposure and activities, such as watching TV, surfing on the internet, doing strenuous exercise, may disrupt the circadian rhythm. This situation causes the person to feel bad during the day and makes it difficult to provide and maintain attention.

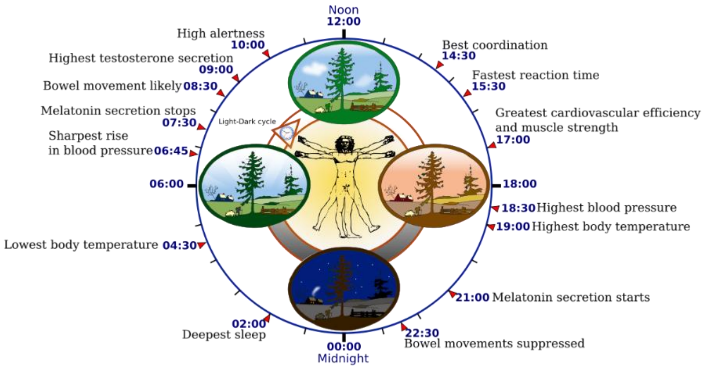

Figure 5. The Circadian Rythm [23]

It is observed that one or more of the following individual factors that are affected by the sleep deprivation directly affect the person's behavior:

- Mood/Communication
- Memory/Alertness
- Reaction Time
- Problem Solving Skills
- The tendency of Risk-Taking
- Operational Performance

Physical fatigue decreases by sleeping, but unfortunately, mental fatigue does not alleviate with sleep.

Generally, drowsiness increases as an individual staying awake. This circumstance is related to the accumulation of a chemical called adenosine in the brain. This accumulation acts as a signal telling that the sleep is needed in our brain. As adenosine levels increase throughout the day, a strong behavioral urge to sleep begins to emerge. Due to adenosine accumulation, it is normal for people to fall asleep while watching TV or reading just before going to bed. The adenosine level decreases as the person sleeps; thus, its effect on triggering the sleep decreases.

2.2. Perception Tests

Psychological and neurological conditions of people are checked by subjecting them to various tests. However, these tests are generally applied in work environments that are considered to be problematic or risky. Employees' situational behaviors are accepted as a natural part of daily life, not enough attention is paid, and therefore such tests are not applied regularly to them.

Cognitive ability assessments are a form of tests used to measure each cognitive skill. These tests evaluate how well the applied person uses a wide variety of mental processes, such as reading comprehension, working with numbers, finding solutions to problems, abstract thinking, and learning and applying new information. Generally, these types of cognitive tests can be categorized into three groups:

2.2.1. Verbal

Verbal tests evaluate reading comprehension and general understanding skills of the person. This type of evaluation is applied to determine how well the person to whom the test is administered can obtain/understand/recognize important details and express the relevant information. Typically, a text is given to the test taker, and then, true or false statements are presented in a multiple-choice form.

- Visual/Verbal Analogy: Finding the relationship between two concepts
- Sentence Completion
- Visual/Verbal Classification: Classification of a certain concept according to its relation to other concepts.

2.2.2. Quantitative

Quantitative tests are classified as numerical and logical tests in itself.

Numerical: The numerical assessment tests are designed to measure the person's ability to work with numbers correctly. In these tests, ratios, number strings, percentages, graphs, and statistical tables are given, and the test person must answer the questions using the numbers.

Logical: In logical tests, it is measured how well the test person can interpret the given patterns, number sequences and figures to evaluate to what extent the abstract concepts and ideas are handled. These tests measure critical thinking skills, risk management skills, and ability to manage complex tasks.

- Number Analogy: Finding the relationship between a given pair of mathematical concepts
- Number Series: Completing the sequence by finding the underlying link
- Visual/Verbal Classification: Categorization of given concepts according to the relationship between them

2.2.3. Non-Verbal

Spatial skills, learning agility, and especially perceptual speed and accuracy are essential topics to be evaluated in non-verbal tests. Particularly in recruitment or when a new assignment is given, it is crucial to determine an individual's suitability for the task at hand. Non-verbal tests are used in this context to predict how well a potential employee will follow instructions and how they will communicate with colleagues and to measure his/her cognitive abilities.

Spatial Ability: In spatial ability tests, three-dimensional objects are shown to the person who is tested, and they are asked to reconstruct these objects mentally. In this way, how the individual reacts in continually changing environments and adapting to the environment is measured.

Learning Agility: These tests are carried out to determine how well the person learns from their experiences and whether they apply this information correctly in the face of a new situation. In this way, how the individual reacts and adapts to the environment is continually changing environments is measured.

Perceptual Speed and Accuracy: With these tests, cognitive skills related to short-term memory are evaluated, and reasoning and decision-making abilities are measured. These tests assess how well an individual learns, processes, remembers and re-expresses information.

- Shape Categorization: Choosing the most appropriate shape or figure for a particular category
- Paper Folding: Determining the result of the shape of a hole-punched paper after folding it in a certain way

Many studies have been conducted on the skill of perceptual speed and accuracy. Products related to the advancement of these skills have been developed, and significant studies are also being conducted on developing these products. William L. Rankin (Boeing employee) conducted substantial studies on sleep habits for the US Federal Aviation Administration (FAA) between 1998-2000. In these studies, the sleeping habits of actively working aircraft technicians in the USA were evaluated. Due to the examination of approximately 50,000 hours, it was determined that the technicians were having an average of five hours and five minutes of sleep per day, although they had to sleep eight hours a day. [24]. After this study, Boeing Alertness Model (BAM) was developed by Jeppesen, one of the subsidiaries of the Boeing Company [25].

Military psychology is a specialized discipline in applied psychology. It is generally accepted that psychological sciences should be used for military operations, systems, and personnel. Thus, these methods are utilized in the armies of many countries. The first specialized institutions in this field were formally established in England and the USA during World War I. Since this period, psychological and neuropsychological trauma has been recognized as part of many early military concepts and interventions. In addition, the psychological assessment provided a basis for the selection of military personnel. During and after the Second World War, military psychology continued to contribute to aviation psychology, cognitive testing, rehabilitation psychology, and many psychotherapy models. Military psychology today consists of several sub-specialties, including clinical, research, and occupational psychology, and the equivalent of this specialization is called industrial/organizational psychology in the United States. In this context, the SAFTE (Sleep, Activity, Fatigue, and Task Effectiveness) model was developed for the American army in 2014 and is used today [26].

In the mobile Psychomotor Vigilance Test (m-PVT) study conducted by Michael Scott Evans in 2019, a mobile phone application was used to determine the fatigue levels of personnel working in critical environments, such as hospital staff, emergency service workers, aviation workers, and law enforcement officers. Moreover, a comparison was made between iPhone and Samsung users in this study (Evans et al. 2019).

In the study conducted by Maarten A. Hogervorst in the Netherlands in 2014, electroencephalogram (EEG), peripheral physiology, and eye-related measurements were combined and compared to evaluate the mental workload (Hogervorst et al., 2014). In this study, EEG, electrocardiography (ECG), skin temperature, respiratory rate, pupil size, and eye blinking frequency were recorded. They achieved the best accuracy of classification of just over 90% with a 2-minute EEG and eye-related variables to detect high and low workload. They also reached a similar and not significantly different finding of 86% accuracy using a single-electrode EEG.

In a study conducted by Rodrigo (2017) at the University of Chile, Neurociencia Department and Biomedical Neuroscience Institute, it is evaluated whether the attention performance can be predicted by measuring the finger temperature. Based on this study, several studies have previously demonstrated that increased psychological stress estimations performed by body temperature measurements increase the likelihood of unsafe behaviors during industrial work (Ramsey et al., 1983), cause cognitive dysfunction (Mazloumi et al., 2014) and reduce driving performance (Hancock, 1986). It has been observed that this phenomenon, called thermal stress, also causes a decrease in the mental attention performance of the employee (Vasmatzidis et al., 1994; Hancock and Vasmatzidis, 1998). Besides, it has been determined by other studies that thermal stress increases the possibility of unsafe behaviors due to a decrease in the mental and cognitive resources during the operating performance and driving performance.

3. Result and Discussion

It is accepted that 88% of occupational accidents arise from dangerous behaviors, 10% from dangerous occurrences, and 2% from unavoidable causes. All of the dangerous behaviors and most dangerous occurrences, which are the sources of the accidents that occur, are caused by the human factor. Thus, it is crucial to reduce the causes related to the human factor in preventing the occurrence of accidents.

This research is one of the pioneering studies conducted to prevent accidents by determining the accident probability before the accident has occurred, in a qualitative way, and a proactive approach. Objectively measuring and mathematically modeling the perception levels of employees who often have an essential role in the accident will have a significant effect on preventing accidents before they occur. It is critical to ensure that the perception level of the employees is high. Thus, possible accidents could be noticed in advance, correct and rapid response in the event of an accident can be provided, and undertaking unnecessary risks can be prevented.

In addition to qualitative measurements of perception, it will be possible to reach quantitative results with a model that will be created by following up the changes that may occur in the employee by monitoring the other factors affecting perception.

The next step of this study is to create software in which the perception levels will be calculated electronically by the inclusion of all factors. Thanks to the qualitative evaluation and monitoring to be performed using this computer program, the deviations in the employee's perception level would be instantly detected. In further studies, necessary warning mechanisms can be engineered, which will generate warnings depending on the level of these deviations, to prevent accidents in advance.

4. Conclusions and Recommendations

Human-related factors are considered as one of the most prominent elements in the occurrence of work accidents. Thus, it is critical to focus on studies on human behavior in preventing occupational accidents. In this study, a model with a proactive approach has been developed that aims to prevent accidents before they occur. In this model, the data have been gathered by continuously monitoring the perception levels and behaviors of the employees. Then, the data were analyzed accordingly.

The model developed in the present study will enable a large amount of data to be collected as a result of continuous measurement of the perception levels and behaviors of employees with a qualitative approach, which will also allow the activation of necessary warnings in the light of the gathered data to prevent occupational accidents. These warnings constitute a critical aspect of the accident prevention processes. We should note that the accuracy of the analyses and results to be produced by this process is strongly associated with the quality of the data obtained from the employees.

In the fieldwork to be conducted during future studies, the employees are expected to try to demonstrate behaviors different from their routine due to fear of losing their jobs and other possible reasons, as they will be aware that they are being monitored. In this direction, issues, such as the attempts by the employees to prevent the emergence of system-based warnings with manipulative behaviors, can be expected to be tackled in future studies. According to the designed model, employees will be monitored using mobile sensors. Therefore, personal data will be continuously recorded by monetarization of employees using cameras and other electronic systems. Thus, the systems to be engineered in line with this model must comply with the Personal Data Protection Law (PDPL).

The system to be engineered in the light of the model developed will provide valuable information about the employee's work efficiency, quality of life outside of the work, compliance at work, as outcomes of the measurements to be performed. The analysis of all these collected data will enable the employer to perform more accurate evaluations about the performance of the employees, and at the same time, it will allow early recognition of risk conditions, such as human-related factors.

The present study aims to protect human life by minimizing occupational accidents using the developed model. For this model to achieve its purpose in daily practice, it is essential that the employee and the employer support the functioning of the proposed model in this study. To gather qualitative data more accurately and to reach more accurate analysis results, this study should be replicated with wider participants and different sectors to provide new insights into the model discussed here.

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