Research Ambition
An International Multidisciplinary e-Journal
(Peer Reviewed, Open Access & Indexed)
Web: www.researchambition.com, Email: publish2017@gmail.com
Impact Factor: 3.071 (IIJIF)
ISSN: 2456-0146
Vol. 1, Issue-IV
Feb. 2017
e-ISJN: A4372-3068

Critiques on Vigilance Taxonomy

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Abstract

The vigilance tasks require prolonged monitoring of repeated stimulus events for infrequently and unpredictably occurring critical signals. Vigilance decrement, which is the main problem of sustained attention study, depended on tasks properties and individuals' abilities and environmental stressors. In this review only task components which affect vigilance performances are discussed. Sensory modality, signal conspicuity, event rate, knowledge of results and spatial and temporal uncertainty are the main components of vigilance task. In sum, it is important to know the taxonomy of task which determines vigil performance.

Key words: Taxonomy, Vigilance.

A scientific classification of task into groups based on similarities of structure or origin etc is called taxonomy. Taxonomic system had been developed by biological scientist. This system has been recognized for psychology and particularly in the general area of human performance for many years[1]. Attention refers to a complex set of physiological and behavioural responses to environmental stimuli[2]. The purpose of attention is to direct cognitive resources to events or situations with the intention of gathering information about the event[2]. Moreover, sustained attention or vigilance may be defined as ability to direct attention to the environment for prolonged periods of time. Mackworth[3], who was the pioneer of vigilance area research, described that sustained attention as "a state of readiness to detect and respond to creating specified small changes occurring at random time intervals in the environment"[4]. In general, mental tasks lasting longer than 30-min which involves the identification of infrequently occurring events is considered vigilance tasks.

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Most of the vigilance studies reported impairment in detection efficiency as time increases[5]. This impairment in vigilance performance is called 'vigilance decrement'[4]. The vigilance decrement usually appears within 20-35 minutes[6]. The vigilance decrement may be mediated by various task conditions which can moderate overall performance level and the appearance of a decrement. Moreover, theories of sustained attention are devoted exclusively to an explanation of vigilance decrement. Different theories advocated by different experimenter appear, at least in part, to depend on the type of task they have employed[4]. Thus, it is important to know that what level of generality different theories of vigilance can be applied. It can be defined easily, if a taxonomic framework were available within which characteristics of different tasks could be listed, with particular emphasis upon those most obviously associated with changes in performance[4]. Furthermore, Freeman, Mikulka, Scerbo and Scott[7] suggested that performance on a vigilance task is primarily affected by three major factors: event rate, the type of stimuli (cognitive or sensory), and discrimination type i.e., simultaneous versus successive. [8, 15, 21]

Vigilance task and its component

Vigilance task should have the following characteristics: Firstly, it should be boring or monotonous, second, signals should appear or display randomly and third, task should last longer time like 30-min or more. In other words, vigilance tasks require prolonged monitoring of repeated stimulus events for infrequently and unpredictably occurring critical signals (target). By virtue of repetitiveness and simplicity nature, vigilance task seems tedious and cognitively undemanding. McGrath[9] suggested the following four criteria of vigilance task:

1. The task should require detection, i.e. perceiving and reporting a change in the operating environment.
2. The intensity of the signal should be close to the observer's detection threshold, but the signal should be clearly perceivable when the observer is alerted or directed to it.
3. Signals should occur irregularly, if nonsignal stimuli are present, the ratio of nonsignal to signals should be high.
4. The task should be prolonged and continuous.

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Performance efficiency in vigilance task is closely tied to the nature of the stimuli that demand attention. The study of vigilance like that other perceptual phenomena, has profited from the precise determination of the stimulus conditions that influence performance. Jerison[10] developed a functional equation for task component, which was modified by Warm and Berch[11]. This equation is as fallows:

$$P = f(M, S, U, B, C)$$

According to this relation, performance (P) is a function of the sensory modality of signal (M), the salience of signals (S), stimulus uncertainty (U), the characteristics of the background of non signal events in which critical signals for detection are embedded (B), and task complexity (C). It is necessary to define these factors for the vigilance research and also for developing taxonomy.

Dember and Warm [12] further divided these components as two order factors. First order factors should involve immediate physical properties of the stimulus and the second order factors refer to characteristic of a signal inferred by the observer on the basis of experience with the task. Event rate, signal conspicuity, complexity and sensory modality are considered as first order factors and temporal and spatial uncertainty are taken as second order factors.

Taxonomy

Taxonomy is an approach to careful description of the development of a comprehensive system of classification, in which entities are ordered into groups or sets on the basis of their relationship[1]. Fleishman[13] proposed some advantages of taxonomic analysis: (1) It offers increasing efficiency in organizing empirical information. (2) It enhances our capability to compare different experiments. (3) It leads to more dependable generalizations of research result from one situation to another.

Perceptual speed and Flexibility of closure

In 1970s it was clear that whether performance decrements were dependent in part on task characteristics. However, it was unclear what task properties were important determinants. Fleishman[13] generated a taxonomic frame work for describing performance tasks which was relevant for the study of vigilance. Their work was related to the “ability requirements” in which tasks are

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categorized according to the abilities needed to perform them effectively. Levine et al.[14] conducted an extensive analysis of 58 vigilance experiments and determined that the tasks used in these investigations could be dichotomized into two ability categories. One of these was called "perceptual speed" refers to the ability to compare sensory patterns or configuration rapidly for identity or degree of similarity. The other category was "flexibility of closure," which involved the ability to detect a specified stimulus in a complex field. Levine et al.[14] found in his analysis that vigilance decrement seemed to be closely related to these ability categories. If predominant ability was perceptual speed, the decrement occurred primarily within the first hour of a vigilance and performance leveled off thereafter. Contrarily, the tasks requiring flexibility of closure, the decrement appeared during the first hour of watch and then performance improved spontaneously as the vigilance continued. They conclude that closure tasks resulted in less performance variability than did speed task.

Successive and Simultaneous Vigilance Task

Parasuraman and Davies[15,4] named 'successive' and 'simultaneous' discrimination type tasks instead of 'perceptual speed' and 'flexibility of closure' task. This taxonomy of vigilance task is the most widely used classification system[16, 17]. They emphasized the importance of the relationship between classification categories and specific information-processing transactions involved in vigilance tasks. This was based on intercorrelations between tasks that make similar information processing demands and which therefore facilitate generalization[19]. Before evaluating this taxonomy, it is necessary to define successive and simultaneous discrimination tasks. In successive discrimination task, the signal and non signal are not available at the same time and therefore the signal is distinguished from a non-signal through reference to a representation in the observer's memory. On the other hand, in simultaneous discrimination task the signal and non signal are presented in the same time and both are available for comparison[19]. The discrimination can be made on the basis of mental effort, attentional capacity and working memory, which are more required for the successive task than simultaneous task. Due to difference on information-processing, Donald [20] used the terms 'redundant' and 'orthogonal' interchangeably with simultaneous and successive, respectively.

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Furthermore, Parasuraman and Davies[15] noted that although the correlations among performance and task types were low, but they were not zero. They derived a taxonomic scheme for classifying vigilance tasks in categories according to sensory modality, number of sources to be monitored (source complexity), the rate of stimulus events (event rate), and memory load. For the last category Parasuraman and Davies[15] distinguished between tasks that required observers to compare a stimulus to a standard held in memory (successive tasks requiring absolute judgment) from those tasks in which the standard and the test stimulus were both presented (simultaneous tasks requiring comparative judgment). In an extensive review of the literature they observed that the vigilance decrement only occurred for certain categories of task. Specifically, they found that performance decrements were most likely to occur with successive tasks at high event rate (event rates> 24 events per minute) with multiple sources to be monitored. Parasuraman[21] further examined the effect of event rate (5 and 30 event per minute) on two auditory vigilance tasks, a successive-discrimination task and a simultaneous discrimination task performance. Result showed decrement on perceptual sensitivity performance measure in high event rate successive - discrimination task condition. Parasuraman and Davies[22] also found significant correlation between two successive vigilance tasks or two simultaneous vigilance tasks, but not between successive and simultaneous vigilance tasks.

Cognitive and sensory vigilance task

Differentiating between cognitive and sensory vigilance is also relevant to efforts to develop theory based taxonomies of monitoring tasks[23]. A lot of studies have been conducted with sensory and cognitive vigilance task. Cognitive vigilance differed from sensory vigilance[24]. It can be discriminated on the basis of stimulus type. In sensory tasks, of which critical signals for detection are specified changes in the physical attributes of stimuli[1]. It has signals that involve sensory and perceptual discrimination i.e., size, shape and pitch.[23] While in cognitive tasks, critical signals for detection are more symbolic than sensory tasks[1]. Cognitive signals that involve numerical, linguistic or semantic discrimination, [23] for example, name, number, semantic category etc. A major difference between sensory and cognitive tasks is that the signals are presented near threshold levels in sensory tasks, whereas in cognitive tasks, all events are presented for inspection at levels well above

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threshold[4]. The best known cognitive vigilance task is the Bakan task[25]. Other studies have confirmed that cognitive vigilance tasks showed less decrement than sensory task[18]. Several possible explanations for the finding that sensory vigilance tasks showed decrement over time, whereas cognitive vigilance tasks showed an increment or stable performance[23].

On the whole, sensory and cognitive vigilance were found to be differentiated as a function of time on task, event rate, age and subjective workload. These obtained results supported the view that the sensory and cognitive dimension should be included in taxonomy of vigilance tasks. Deaton and Parasuraman[23] emphasized that the sensory and cognitive dimension should be based on the type of signal discrimination, not simply on stimulus type.

Situation awareness: a new dimension of vigilance categorization

Although researches provided general experimental support for these taxonomy, a review of literature indicates that it has seldom been applied to the real world jobs. However, in operational contexts, vigilance tasks may be classified as being simultaneous or successive and event rates may be high, low, or continuous[17], including other task dimensions. Donald[20] evaluated the classification of vigilance tasks in the real world on the basis of close circuit television surveillance operators and air traffic controllers. He concluded that simultaneous task have been used in some situations, they do not capture all the conditions of the situations, and they do not capture all the conditions of the real work environment. It was also suggested that situation awareness is another thing on which basis the existing taxonomy can be more applicable in real world jobs.

Conclusion

Previous researches on vigilance task had identified six dimension of vigilance task, which leave their own effect on vigilance performance. The summary of vigilance taxonomy is presented in table 1. First dimension is based on situation awareness. In this dimension signals are either homogeneous or heterogeneous in nature. The successive discrimination type, sensory vigilance task type and single source complexity, vigilance task are mostly homogeneous whereas simultaneous discrimination, cognitive vigilance task type and multiple source complexity are generally heterogeneous by the nature of the signal[20]. The event rate is another dimension of vigilance

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taxonomy. The event rate has divided into three categories i.e. low, medium and continuous. The continuous event rate is actually high event rate but due to apply in multiple task condition it reflect specific performance state. The continuous event rate is multiplication of multiple object, speeds and direction[20]. Sensory modality has two major category named visual and auditory[21].

Mostly vigilance task categorizations included behavioral or performance measure. The researchers showed the differences between these categories on performance based measures but not on other measures. Physiological performance provides information about the different state of the vigilance operator. So, it remains to prove the taxonomy of vigil task on physiological performances. Operator's perception of the task is another important thing to consider in vigilance categorization.

Future research aimed at specifying different levels of complexity and examining their effect on vigilance performance would assist in bridging the gap between much of the research in operational environments. Another aim would be to develop taxonomy which has been representative for whole population. Further, inspite of a well-developed literature on vigilance in adults, relatively little is known about attentional processes in children, so the future research will have to be more focus on children. Finally, it is necessary to understand the taxonomy of vigilance for future research because performance is based on stimulus properties, which are related to vigilance task.

Table 1. *Vigilance taxonomy*

Dimension	**Category**		
Signal/target characteristic Propose by Donald [20]	**Homogenous**		**Heterogeneous**
Signal discrimination type	Successive or perceptual speed or Redundant		Simultaneous or flexibility of closure or orthogonal
Vigilance task type	Sensory		Cognitive
Source complexity	Single		Multiple
Sensory modality	Visual		Auditory
Event rate	Low	Medium	Continuous

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Acknowledgement

Part of this paper was presented in the 94th session of the Indian Science Congress Association held at Annamalai University, Annamalai nagar, Tamilnadu from 3-7 January, 2007.

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