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ORIGINAL ARTICLE

Validity and Reliability of Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale in Iran

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ABSTRACT

Mental workload is an important issue in occupational health. This study aimed to determine the validity and reliability of the Rating Scale Mental Effort (RSME), Integrated Workload Scale (IWS), and Overall Workload Scale (OW) in Iran. This study was conducted on 100 male students of Iran University of Medical Sciences. The forward-backward translation method was used to evaluate the linguistic validity of the scales. Then the scales were presented to six ergonomics and occupational health experts to assess the content validity of the scales. Internal validity of the scales was assessed by correlating mental workload scale scores with reaction times on a criterion task. Finally, multiple sessions of a hybrid memory-search task were performed to determine the reliability of the scales. There was prefect agreement among the experts regarding of all three scales. Content Validity Index and Content Validity Ratio were 1 for each three scales. About the reliability of the scales, the Pearson correlation coefficients between the scale scores in the test and retest phases were 96, 88, and 84 for RSME, IWS, and OW, respectively. Finally, Validity and reliability of the scales were approved and It seems that these scales can be used for measuring self-reported mental workload.

KEYWORDS: *Mental workload, Unidimensional scales, Hybrid Memory Search Task, Validity, Reliability*

INTRODUCTION

High workloads (long hours) are some of the most important factors leading to fatigue [1]. Low efficiency, reduced memory capacity, errors in thinking, irritability and petulance, and reduced capacity to learn may all result from fatigue. Tired people are also more likely to choose risky behaviors, such taking shortcuts to perform their tasks [2]. Cantin et al. stated that errors are often the result of high mental workload [3]. De Waard maintains that a simple definition of workload is a requirement that is imposed on people. He states that this definition makes workload subject to an external factor; therefore, workload can be better defined through the experienced load. In this regard, workload is not only

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related to tasks but it is also related to specific characteristics of individuals [4, 5]. More specifically, workload refers to the determination of the degree of information processing capacity that is used for the conduct of tasks [4]. In fact, it can be claimed that workload strongly depends on the Demand identification that is imposed on the limited resources of human mind by tasks [6, 7].

The existence of some relationship between task demand and task performance has been stated by Meister[8, 9]. Meister has specified three zones of A, B, and C. Zone A has been described as the low workload of the operator with high performance level. In this zone, a slight increase in demand does not necessarily lead to reduced performance. In zone B, the performance level is reduced as a result of increased demand. In fact, performance level is reduced with the increase of demand and workload in this zone. In zone C, the high levels of workload reduce performance to a minimum level up to the point that performance is maintained at the minimum level with the increase of task demand and no declining trend will be at play any longer [8, 9].

Various behavioral, mental, and physiological measurements have been studied in order to measure mental workload successfully. Majority of studies have attempted to evaluate the performance, physiological, and self-reported (subjective) methods for measurement of mental workload [4, 10, 11]. One of the requirements of self-reported measurements of workload is that individuals report higher levels of mental workload with the increase of tasks demand. Higher ratings can be interpreted as difficulty in performing a task or as difficulty in expressing the task demand[10]. Self-reported methods include unidimensional and multidimensional methods. Unidimensional methods are simple and easy to use and generally take less time to complete than multidimensional methods. Multidimensional methods, which are composed of subscales, require more time is needed to complete but can be more accurate in some cases [4].

The Rating Scale Mental Effort (RSME; ref) is one of the scales that is used for the measurement of mental workload. This scale is a unidimensional index that was introduced in the Netherlands by Zijlstra [12]. Ratings of mental effort are made by marking a point on a line 150 mm in length with markings each 10 mm. Nine “anchor points” label the effort associated with (perhaps give the numerical values of the anchor points). Mental effort is determined by measuring the distance from the zero point to the point marked by the individual [4, 13]. The Integrated Workload Scale (IWS) is another methods of assessing mental workload. It was introduced in 2005 by Pickup et al[14]. This is also a unidimensional scale with a description of 9 different levels of mental workload. Each of its levels has a title and a short explanation and is differentiated from the other levels by a specific color. This scale was first evaluated in train signaling units and is used more in the measurement of the maximum and minimum of the mental workload experienced by an individual in a period of time and in a particular set of scenarios [14]. Overall Workload (OW) is another unidimensional mental workload scale that is used to measure mental workload. This scale is rated between zero and 100 where the number zero represents very low workload and the number 100 denotes very high workload. It is also notable that all the five degrees in this scale are marked by one line [15]. Studies have shown that OW scale is a reliable great method to measure mental workload on a unidimensional scale and its sensitivity is also comparable with that of multidimensional scales [15, 16]. Given the importance of mental workload in different occupations, it seems that the decision on the use of a suitable instrument in measuring mental workload is one of the notable tasks in this domain. In the present study, the researchers focused on unidimensional scales. Thus, the aim of this study was to determine the validity and reliability of Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale in Iran.

MATERIALS AND METHODS

This cross-sectional study was conducted on 100 male students of Iran University of Medical Sciences where these participants had been randomly selected. The inclusion criteria were: being healthy male, having visual acuity of 8/10 or higher, having adequate sleep in the night before the test. The exclusion criteria were: tendency to exit the study for any reason, answering the trials uniform and without precision. In terms of age, the mean value of 21.8 years (with range of 19-25) was obtained for these participants. In terms of marital status, 85 percent of the participants were single and 15 percent of them

were married. It is also notable that 45 percent of them were bachelor's students, 30 percent of them were students at general practitioner, and 25 percent of them were master's students. This study entailed two phases, namely determination of the validity and the reliability of the scales. These phases were as follows:

Validity of the scales:

The linguistic validity of scales was first examined. To this end, Forward-Backward translation method was used. The English version of the scales was independently translated into Persian by 10 PhD candidates who had sufficient proficiency in English. Then, the translations were presented to two faculty members of the Faculty of public health and two occupational health experts who had lived in an English speaking country and were fluent in English. These experts were asked to choose more appropriate equivalents and translations for each scale, as required. In the next step, the Persian versions of the scales were translated back into English by two other university professors. Finally, these English versions were compared with the original versions and any differences or discrepancies were resolved by two other professors.

Thereafter, the content validity, face validity, and construct validity of the scales were investigated. In this step, six occupational health and ergonomics specialists were asked to comment on the Persian scales. Content validity ratio (CVR) and content validity index (CVI) were used to specify the content validity of the scales. In terms of CVR, experts were asked to evaluate the necessity of each of the scales based on a three-point scale, including "necessary", "useful but not necessary", and "not necessary". In addition, the experts were asked to determine the CVI of the scales by evaluating the simplicity, relevance, and clarity of Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale on a four-point scale (for example, in terms of relevance: irrelevant, fairly relevant but needs serious reconsideration, relevant but needs reconsideration, and fully relevant). Item impact score was used to determine the face validity of the scales. To this end, Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale were presented to 6 Occupational Health and Ergonomics specialists and 20 workers of a metal industry. They were requested to judge the importance, simplicity, and appropriateness of the scales based on a 5-point Likert scale.

Furthermore, internal validity was used to assess the construct validity of Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale. For this purpose, the correlation of the scales' scores was measured with the respondents' reaction time. As it was mentioned above, one of the measurement methods of mental workload is performance method wherein one of the representations is the respondents' reaction time [4].

Reliability of the scales:

A test-retest method in which the scales were filled out under load conditions at two points in time was used to calculate the reliability of the scales. A hybrid visual/memory search task was used to create mental workload. This tool is a computer-based tool to evaluate working memory and reaction time and is used in some of studies to impose mental workload [10]. This task consisted of 80 trials and the respondents were to respond in each trial within 2 seconds. Respondents were to sit behind the computer and announce their readiness for the initiation of the study after receiving the necessary explanations on part of the researchers. At the outset, two letters (the memory set) appeared at random in English and in black bold Courier New 22-point font in the center of the display monitor and the respondents were to memorize these two letters. There was no time limit for memorizing the letters. Then, the 80 testing trials would commence by pressing the space key. On each trial, four English letters appeared randomly in the center of the monitor and the respondents were required to determine whether any of these letters had been presented in the memory set. It was explained to the respondents that they should immediately press the “1” key if they saw one or two of that two letters of the memory set and that they should press the “2” key with left hand fingers (middle finger, fore finger) otherwise. It is noteworthy that the next step would begin in case of the receipt of no response on part of the respondents and the non-responsiveness of the respondents was recorded by the software. The interval between appearance of the four letters and pressing the key 1 or 2 was recorded as reaction time. At the end of the block, the percentage of correct and wrong answers

as well as the unanswered items and reaction time of the respondents were recorded by the software. The respondents were to express their mental workload perceived from Hybrid Memory Search Task on each of the scales. Rating Scale Mental Effort was graded between zero and 150 millimeters, each 10 millimeters of this line has been labeled by specified lines, and contains nine anchor points[4]. The respondents were to express the level of their mental effort or mental workload by showing a point on the scale. Integrated Workload Scale contains 9 points that represent different levels of mental workload, and each level has a distinct color [14]. For example, the first level is blue and means that work is not demanding at all and the ninth level is red and represents that the work is too demanding. Overall Workload Scale is also simple and is comprised of two ends, one of which is representative of very low workload and the other one represents very high workload. There is a 100-part rating from zero to 100 between these two ends [15] and the respondents were required to specify their mental workload by demonstrating a point on this line.

In the next stage of this study, the same respondents conducted the same task once again within a 20-day interval and expressed the level of their mental workload on these scales. Then, the correlation coefficient of the scale scores was examined in two states.

For data analysis, the R software version 3.2.3 was used. The normality of the data was checked via the Kolmogorov-Smirnov test (K.S) and the Pearson correlation coefficient was used according to the confirmation of the normality of the data. In addition, the confidence level of 95% was considered for the conduct of the tests.

RESULTS

The linguistic validity of the three scales used in the study (Rating Scale Mental Effort (Appendix 1), Integrated Workload Scale (Appendix 2), and Overall Workload Scale (Appendix 3)) was confirmed and the scales' versions were translated into Farsi. The content validity of these scales was examined and approved by six occupational health and ergonomics specialists. The necessity of the scales was confirmed by these experts and the content validity ratio (CVR) was obtained equal to 1. Similarly, the parameters pertaining to content validity index (CVI) were confirmed. These parameters included relevance, simplicity, and clarity. Indeed, the value of content validity index was obtained equal to 1 for the three scales, namely Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale. In terms of the face validity, the impact score was calculated according to experts and industry workers' opinions, which was obtained equal to 4.2, 4.1, and 3.8 for Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale, respectively. Therefore, the face validity of all the three scales was also earned.

The analysis of the responses given by the subjects to Hybrid Memory Search Task revealed that they provided correct answers to 89.2 percent of the 80-trials process of the test on average. This is so while the mean value of the correct answers given by the same individuals in the retest phase equaled 90.1 percent. It is noteworthy that all the participants in this study responded to the trials of Hybrid Memory Search Task and non-responsiveness to the stages was not observed. It is noteworthy to reiterate that the reaction time of the respondents was also recorded as the performance measurement of mental workload in this study. The average reaction time of participants in the test phase equaled 1509 milliseconds with the standard deviation of 195 milliseconds. Moreover, the average reaction time of these participants was obtained equal to 1532 milliseconds with the standard deviation of 190 milliseconds in the retest phase. In the same way, the normality of the data in Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale was evaluated through Kolmogorov-Smirnov test and was earned. In this regard, the P-values of 0.12, 0.18, and 0.26 were obtained for Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale, respectively. Hence, Pearson correlation coefficient was used to analyze the data and measure their correlation.

In Table 1, one can observe the participants' estimates of the rate of mental workload of Hybrid Memory Search Task in the test and retest phases for Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale. In addition, the Pearson coefficient values of the correlation between the scales in the test and retest phases have been shown in order to determine their reliability.

Table 1. Summarized results for Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale along with the Pearson correlation coefficient between scale scores in the test and retest phases

Scale Name	Test phase	Retest Phase	Pearson correlation coefficient between scale scores in test & retest phases	`
	Mean (±SD)	Mean (±SD)		
RSME	74.2 (±12.7)	70 (±11.5)	96	<0.001
IWS	5.7 (±1.8)	5.1 (±1.8)	88	<0.001
OW	48.6 (±8.9)	41.3 (±9.2)	84	<0.001

As can be observed in Table 1, all the correlations are significant and the correlation coefficients are larger than .7. The highest correlation coefficient (.96) between the values of Rating Scale Mental Effort, which was representative of the reliability of this scale. Similarly, the reliability of Integrated Workload Scale, and Overall Workload Scale was also desirable and acceptable.

Finally, in Table 2, the Pearson correlation coefficients of the scale values with each other and with reaction time in the test and retest phases can be observed.

Table 2. The correlation between Reaction time, Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale in the test and retest phases

Variables	Test phase		Retest phase	
	Pearson Correlation coefficient	P-Value	Pearson Correlation coefficient	P-Value
RSME & IWS	0.84	<0.001	0.82	<0.001
RSME & OW	0.85	<0.001	0.82	<0.001
IWS & OW	0.74	<0.001	0.77	<0.001
RSME & Reaction time	0.87	<0.001	0.87	<0.001
IWS & Reaction time	0.8	<0.001	0.81	<0.001
OW & Reaction time	0.8	<0.001	0.82	<0.001

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As can be observed in Table 2, all the correlation coefficient are significant and above 0.7. From among the scales under study, the highest Pearson correlation coefficient was between Rating Scale Mental Effort and Integrated Workload Scale as well as between Rating Scale Mental Effort and Overall Workload Scale. In addition, all these three scales were significantly correlated with reaction time (coefficient above 0.8) and, in this way, the internal validity of Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale was confirmed in this study. It should be also noted that Rating Scale Mental Effort took up the highest correlation with reaction time from among the scales under study. This is indicative of the higher internal validity of this scale than the other two scales in this study.

DISCUSSION

This study was an attempt to determine the validity and reliability of Rating Scale Mental Effort, Integrated Workload Scale, and Overall Workload Scale. As was observed in the results section of this study, all these aspects were analyzed and set; and the linguistic, content, face, and construct validity as well as the reliability of these scales were confirmed.

To date, Rating Scale Mental Effort has been used in many studies around the world to evaluate mental workload[4, 10, 17, 18]. The sensitivity of this scale to different levels of mental workload has been established[19] and appropriation scale has been shown to be more sensitive to changes in the level of mental workload than such well-known scales as the NASA-TLX[4]. Johnson and Widyanti (2011) evaluated the sensitivity of Rating Scale Mental Effort in the Netherlands and Indonesia. The results of their study showed that the Dutch version of this scale was more sensitive than the Indonesian version[10]; therefore, they decided to modify the Indonesian version of this scale in accordance with the national culture of Indonesia. In a second study, they found that the new Indonesian version of Rating Scale Mental Effort was far more sensitive and valid than the first version[17]. In the present study, Rating Scale Mental Effort took up the highest reliability among the scales used here. In addition, the high correlation of this scale with reaction time in this study was representative of the fact that this scale can sometimes lead to a proper estimate of the level of mental workload of tasks for individuals even as well as performance measurements. In Iran, NASA-TLX has been used in most studies to assess self-reported mental workload [20, 21]. In addition to the inclusion of 6 dimensions and the more time-consuming completion of NASA-TLX, the calculation of its total score is also another important issue. Unidimensional scales have this advantage that are easier to use and give a way to get only one unit score[4].

The other scale investigated in this study was Integrated Workload Scale. So far, the number of the studies done on this scale has not outnumbered the number of the studies conducted on Rating Scale Mental Effort. However, some experimental and field studies have been carried out to explore the validation of this study [14, 22, 23]. For example, Pickup et al. confirmed the validity of this technique in an experimental environment. In another study, Wilms et al. also confirmed the validity of this scale [22]. The findings of this study also confirm the linguistic, content, face, and construct validity of this scale as well as its reliability. This scale was significantly correlated with reaction time and the two other scales under study. In other studies, a significant correlation was observed between this scale and other measurement performance methods of workload [14, 22].

In terms of Overall Workload Scale, it is noteworthy that the validity of this scale has been confirmed in studies conducted in different countries of the world; for example, Vidulich et al. conducted a study to compare AHP and NASA-TLX and confirmed the validity of this scale [24]. This scale has been used in other studies, as well [25]. Hill et al. argued that this scale is as sensitive as other multidimensional scales, enjoys even higher popularity, its usage is easier, and it takes less time for training and data mining [15, 26]. In the present study, Pearson correlation coefficient between the test and retest phases for this scale was above 0.80, which indicated the desired reliability of Overall Workload Scale. This scale was more simple compared to Rating Scale Mental Effort, Integrated Workload Scale; and it has been composed of two poles and there is a 100-unit rating between the two poles [15]. Of course, it should not be ignored that many occupations contain different levels of workload and one may not be able to specify mental

workload with a total number. This limitation is at play for all the unidimensional scales pertaining to the measurement of mental workload.

CONCLUSION

The validity and Reliability of the studied scales were approved and these establishments of the linguistic, content, face and internal validity of these scales, as well as their reliability, showed that they can be used in measuring mental workload of tasks. The non-use of physiological measurement equipment of mental workload, such as electroencephalography device was one of the restrictions of this study. Another restriction was in the study design and non-use of real employees.

In terms of suggestions, unidimensional scales of mental workload assessment, such as the ones used in this study are recommended to be used for various occupations and different tasks in future studies so that the validity of these scales can be evaluated in other occupations, such as driving and in industries. Another suggestion for the researchers interested in this area is to use these scales together with multi-dimensional scales, such as NASA-TLX and to compare the obtained results. Another further suggestion for future studies can be the comparison of the results of performance, self-reported, and physiological measurements of mental workload.

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DECLARATION OF INTEREST STATEMENT

The authors declare that they have no competing interests.

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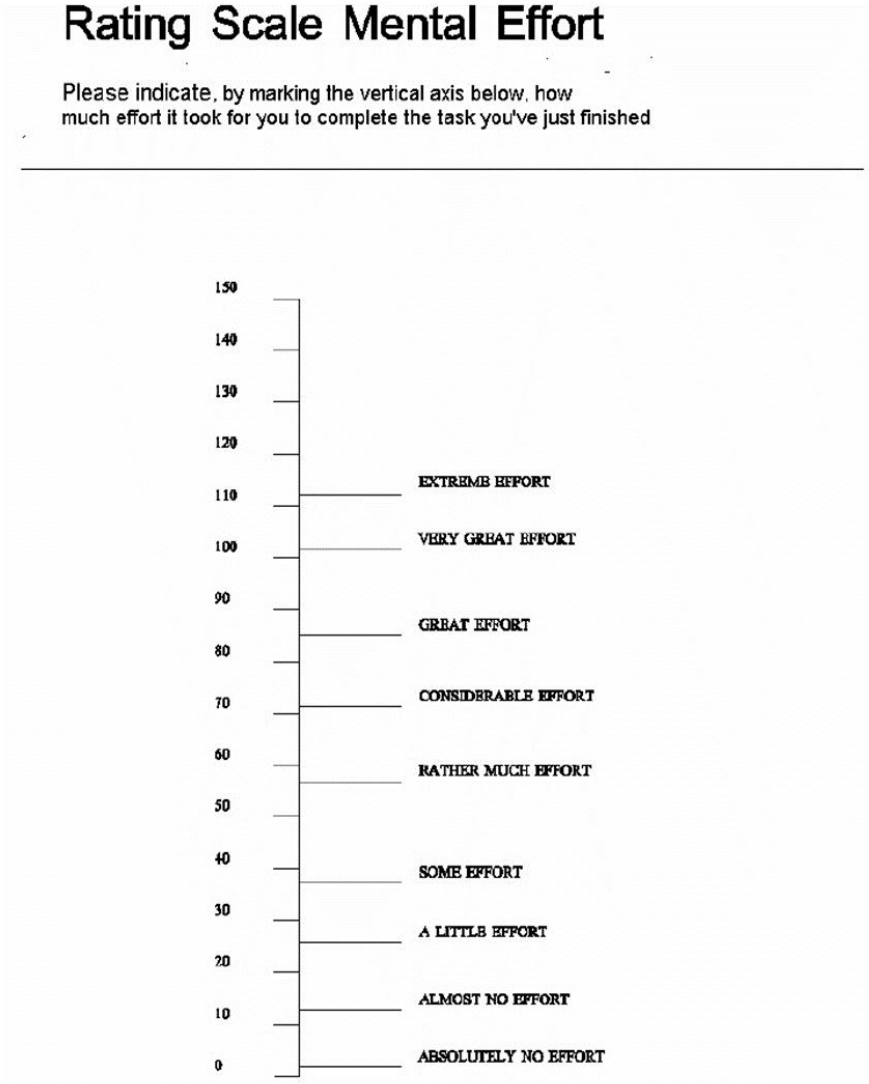
INTEREST

Appendix1. Rating Scale Mental Effort in English and Persian version



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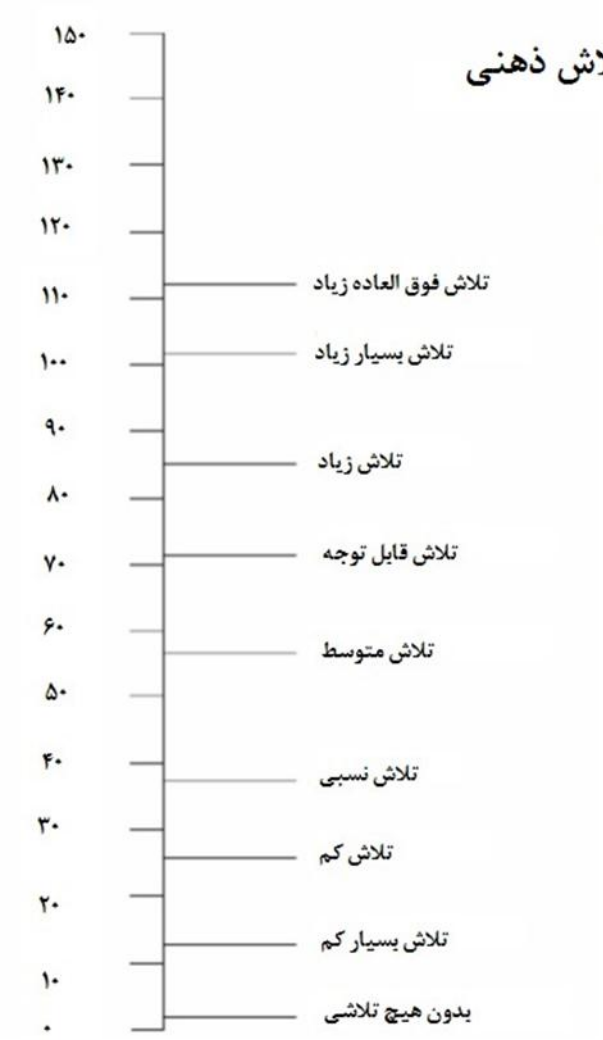
مقیاس درجه تلاش ذهنی
لطفا سطح متناظر با تلاش ذهنی مرتبط با وظیفه را با علامت ضربدر بر روی مقیاس نشان دهید
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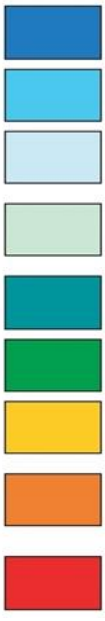
تلاش فوق العاده زیاد
تلاش بسیار زیاد
تلاش زیاد
تلاش قابل توجه
تلاش متوسط
تلاش نسبی
تلاش کم
تلاش بسیار کم
بدون هیچ تلاشی

Appendix 2: Integrated Workload Scale (IWS)



Not Demanding	Work is not demanding at all
Minimal Effort	Minimal effort required to keep on top of situation
Some Spare Time	Active with some spare time to complete less essential jobs
Moderate Effort	Work demanding but manageable with moderate effort..
Moderate Pressure	Moderate pressure, work is manageable
Very busy	Very busy but still able to do job
Extreme Effort	Extreme effort and concentration necessary to ensure everything gets done
Struggling to keep up	Very high level of effort and demand, struggling to keep up with everything
Work too Demanding	Work too demanding – complex or multiple problems to deal with and even with very high levels of effort it is unmanageable.

	۱	سخت نیست	کار به هیچ عنوان سخت نیست
	۲	تلاش حداقل	تلاش بسیار کمی برای حفظ وضعیت مناسب لازم است
	۳	مقداری زمان آزاد	وضعیت فعال است همراه با مقداری زمان آزاد و اضافه
	۴	تلاش متوسط	کار سخت است اما با تلاش معمولی قابل مدیریت است
	۵	فشار متوسط	فشار متوسطی وجود دارد و کار قابل مدیریت است
	۶	بسیار مشغول	بسیار مشغول اما هنوز توانایی انجام کار وجود دارد
	۷	تلاش فوق العاده زیاد	تلاش و تمرکز فوق العاده زیادی برای اطمینان از اینکه همه چیز انجام می شود مورد نیاز است
	۸	تقلا کردن برای ادامه دادن	سطح بسیار بالایی از سختی و تلاش وجود دارد. برای ادامه دادن نیاز به تقلا کردن و کوشش بسیار زیادی است
	۹	کار بسیار طاقت فرسا است	کار بسیار طاقت فرسا است. مشکلات عدیده یا پیچیده ای برای کنار آمدن با کار وجود دارد حتی با سطوح بسیار بالایی از تلاش باز هم کار غیر قابل مدیریت است

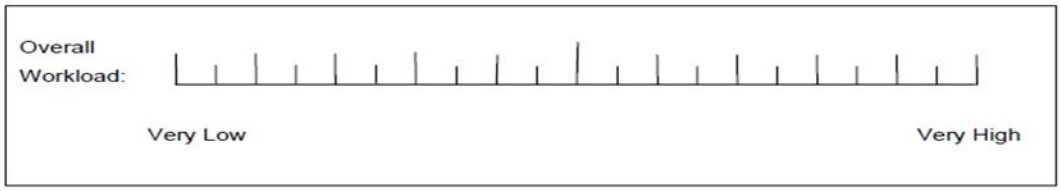
مقیاس بار کاری یکپارچه (IWS)

Appendix3. Overall Workload scale in English and Persian version

Appendix 3 Overall Workload (OW)

Task or Mission Segment:_____

Please mark an "X" on the line which best corresponds to how you rate your Overall Workload.



مقیاس بار کاری کل

نام وظیفه یا کار:

لطفا بر روی مقیاس زیر نقطه ای که معادل با بار کاری ذهنی شماست را با علامت ضربدر مشخص کنید