The Significance of Verbal and Spatial Attentional Resources on Mental Workload and Performance

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Abstract— **For decades, scientists have been studying the impact of task workload on individual performance. The purpose of this study was to examine and validate the difficulty levels of two visual tasks (verbal and spatial) to be used in a later experiment studying the interaction of physical and mental workload on attentional resources and performance. Additionally, the study was conducted to determine if a significance difference exists between how men and women perform these types of tasks. The verbal and spatial task workloads satisfied the difficulties levels.**

Keywords-mental; workload; attentional resources; verbal; spatial

I. INTRODUCTION

Workload has been identified as one of the main variables that impacts human performance [1][2]. Task workload can be divided into two types, i.e., mental demands and physical demands [2][3]. In fact, mental workload has increased more than physical workload in many jobs due to the rapid increase in technology in recent years [4]. However, most tasks still include physical and mental demands on the operators [1][2][5][6].

The mental workload concept does not have a conventional definition; however, mental workload can be defined as the resources (i.e., human capacity and skills) that are needed to complete the demanded tasks [2][7]. On the other hand, the concept of physical demand can be defined as the demand associated with tasks that require physical work from the operators, thereby utilizing the musculoskeletal system, the cardiorespiratory system, and the nervous system of the human body [8].

The description of the interference of multi-task demands in terms of shrinkage of some energy for information processing is the goal of resource theory [9]. The attentional resources model includes three orthogonal components. These components are: processing stage (perception, working memory, and response), processing codes (spatial and verbal), and processing modalities (visual and auditory) [9].

The purpose of this study was to examine and validate the difficulty levels of two tasks visually resource (verbal and spatial) that will be used in a subsequent series of studies. Also, it aimed to identify whether there is a difference between male and female performance in both tasks. The gender factor is important since the second part of the future research programme will be the investigation of the effect of verbal and spatial through auditory resources on attentional resources and performance for both males and females. Therefore, the gender difference is necessary for both studies (visual and auditory tasks) to determine if any significant differences occur in completing the tasks before this study is implemented in the real domain. In addition, the last part of this programme of research will be conducted in the industrial field and will include tasks performed by male operators.

II. MENTAL AND PHYSICAL WORKLOAD AGAINST PERFORMANCE

In terms of the effects of workload, reference [10] reported that workload can affect and reduce the ability level of the user. In addition, an unexpected rise in the task demand level may lead to a decrease in performance accuracy and an increase in response time of the operator and the operating system [10]. In addition, most researchers agree that the optimum levels of mental load produce acceptable job performance and response; in other words, the job demands should not be too low or too high [1][2][11][12]. Moreover, mental workload includes two major parts; these parts are “stress (task demand) and strain (the resulting impact upon individual)” [7]. Furthermore, a balance must be reached between the physical load of the assigned tasks and user’s physical functional capacity in order to produce acceptable performance and reduce injuries and errors [13]. Accordingly, the interaction between the impacts from physical and mental workload on performance is not uniform.

III. VERBAL AND SPATIAL TASKS AGAINST GENDER DIFFERENCES

Variations in the ability of males and females to perform verbal or spatial tasks have been reported by researchers in several studies [14][15][16]. Research indicates that gender could affect operator performance in tasks that require spatial ability, such as the mental rotation test [15][16]. Researchers report that males do better than females in spatial ability tasks. According to [14], the differences between males and females in their ability to perform mathematical tasks are small and decreased in severity over the course of a year-long study. Furthermore, the difference in the ability of males and females to perform well in the spatial ability task is dependent upon the type of spatial task [17]. Other researchers reported that women participants received a lower score than men when performing several tests of spatial ability, including Money's Road Map Test, the Geometric Forms test, and the Mental Rotation Test [17]. However, in some types of cognitive tasks, females have faster response rates than males [17]. Therefore, differences of males and females in ability to perform cognitive tasks or tests are related with the type of the job.

IV. Workload Measurements Techniques

Various techniques are used to measure mental workload, including performance measures, subjective assessment tools e.g., "NASA-TLX, SWAT" and physiological incidents [2][4][7][18]. Furthermore, subjective tools have been frequently implemented for measuring mental and physical workload in separate situations [18]. Although all of these techniques have advantages and disadvantages and have been widely examined in numerous studies [2][7], many researchers believe that physiological indicators, such as heart rate (HR), heart rate variability (HRV), blood pressure and eye blink, are more sensitive to mental demand and thus more reliable [2][4]. Reference [19], found that when the HRV of individuals was high the appropriate responses increased and errors declined, whereas when the HRV was low the inappropriate responses increased. Furthermore, they believed that there is a relationship between HRV and mental task performance.

V. Methods

A. Design

This experiment was conducted to evaluate and validate the impact of three levels of mental workload for two tasks upon attentional resource performance of operators: an arithmetic task (verbal) and a spatial figures task (spatial); the experiment was a full factorial repeated measures design. Each study was implemented separately with a separate group of participants, so the counterbalancing between the types of tasks was not necessary in this research study. The arithmetic mental task included the following three different levels:

1- The low level involves addition/subtraction problems with numbers between 1 and 10.
2- The intermediate level involves addition/subtraction problems with two numbers between 3 and 35 for the subtraction operation and two numbers between 6 and 35 for the addition operation.
3- In the difficult level, participants are asked to complete high level addition/subtraction problems with two numbers between 20 and 150 for the subtraction operation and between 20 and 105 for the addition operation.

The second task, i.e., the spatial figures task, also included the following three various levels:

1- For the low level, participants are asked to compare three figures with an original figure.
2- In the intermediate level, participants are asked to select two identical figures from six figures.
3- In the difficult level, participants are presented with nine figures and are asked to choose two identical figures from the group.

These types of tasks were chosen to represent the effect of typical workload levels upon the attentional resources performance of users [20]. The arithmetic task was used on three different levels to emulate the demand of a verbal task, according to some [21], who used the mathematical mental task as a verbal task that placed a load on attentional resource capacity and information processing. In addition, the arithmetic mental task is considered to be a verbal task that places a load on working memory capacity since individuals memorize the numbers as words in short-term memory [17]. Also, according to reference [17], mental rotation is considered to be a spatial task that relies on spatial resources; numerous studies have measured the spatial reasoning abilities of individuals. Moreover, several studies have employed mental rotation tasks (the figures were published by [22], in order to evaluate the load on the spatial ability resources of individuals (see, [16][23][24])).

Overall, this research included two independent variables: the types of tasks (an arithmetic task and a spatial figures task), and the difficulty of each task. Furthermore, it contained three different dependent variables: performance (number of correct responses and time of correct responses); physiological indices (obtained by measuring the heart rate and heart rate variability); and subjective assessments of mental workload (observed by using the NASA-TLX scores) [25].

B. Materials

All performance trials were conducted using an Acer-compatible PC with a Pentium II 300 processor operating at 266 MHz and a Tangent 17-inch monitor; it involved the MathsNet Mental Tests 1.5 Software [26], "see Figure 1", and the Mental Rotation Test Software [27], "see Figure 2". All participants were comfortable with and clearly understood how to present the task on the PC screen.

Figure 1. Screenshot of the mental math software.

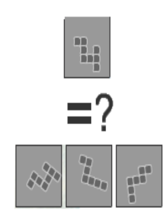

Figure 2. Screenshot of the spatial figures program.

The testing was conducted using Web-based software for two reasons: first, the programs met the experimental requirements in terms of recording the correct responses and trial time. Secondly, there is other software (i.e., E-prime) that can do these same tasks, but it is expensive, whereas the software chosen is available online and is easy to use. Also, Polar CS600 chest-electrode was used in order to measure heart rate (HR) and heart rate variability (HRV). Polar ProTrainer 5 software (5.35.164) was used to analyze the heart rate and heart rate variability. In addition, the NASA-TLX [25] was used to evaluate the mental workload of each task.

C. Participants

Twelve participants (ages 25–35) were selected randomly from Brunel University. This sample size included 6 males and 6 females who were chosen in order to find one standard deviation for the independent variables as well as normality. Also, the same sample was utilized for both studies. The task procedures were explained to all participants. Participants were invited by an announcement that was issued through the university Web site. In addition, the experiments met the ethical rules of the School of Engineering and Design at Brunel University.

D. Procedures

At the beginning, participants were given a brief introduction about the experiment in order to familiarize them with the steps. Also, the participants were provided instructions and advice on how to perform an arithmetic mental task and a spatial figures task. Then, the participants were asked to affix the chest electrodes for the heart rate monitor on their chest such that we could record the HR and the HRV for each participant as they completed the assigned tasks. In addition, the height, weight, age, and gender of each participant was recorded and used to set-up the heart rate monitor tool.

Subsequently, the first experiment began with the presentation of the arithmetic mental tasks. In addition, the participants were presented the levels of difficulty randomly in order to reduce the potential carryover effects and fatigue. Each volunteer completed 25 questions within each level as accurately and quickly as possible in the allotted 5 minutes. The number of correct responses and the actual time required to complete the correct responses and the section were recorded directly by the software. The HR and HRV were recorded at rest level and continuously throughout the completion of each condition using chest electrodes made by Polar. Also, immediately after completing each trial, the participants were asked to complete the NASA-TLX scale in the 2 to 3 minute interim between each level. After completing the first experiment, i.e., three levels of arithmetic problems, the subjects were given 5 minutes to complete the NASA-TLX and rest.

Then, the second experiment (i.e., the spatial figures test) began. The participants were asked to continue wearing the chest electrodes for the HR monitor such that we could continue measuring HR and HRV. The Mental Rotation program generated different figures with various angles of rotation at three different levels (i.e., low, intermediate, and high). The program also recorded the number of correct choices and the time required to complete the task. Each condition level included 25 problems, and participants were given 5 minutes to complete each level. In addition, they took 2 to 3 minutes to rest and complete the NASA-TLX between each condition.

VI. DATA ANALYSIS

Analysis of variance (ANOVA) was used to investigate the impact of the independent factors (i.e., the arithmetic and spatial figures mental tasks) on the dependent variables (i.e., performance, mental workload, and physiological arousal). Also, repeated contrast comparisons were used to determine whether or not homogeneous levels of arithmetic tasks were significantly different from that of the spatial figures tasks. Furthermore, independent t-tests were implemented in order to examine the significance of the mean differences of each type of task and their interaction. A 95 % confidence level (i.e., $\alpha = 0.05$) was applied in these studies.

VII. RESULTS

A. Performance

The descriptive statistics for the participants are illustrated in Table I. The participants' performance was measured by recording the number of correct responses for the arithmetic tasks and the spatial figures tasks (i.e., the mental rotation test). In addition, the responses were related to the task workload levels for each task arithmetic and spatial figures tasks; "see Figure 3" and "see Figure 4", respectively.

TABLE I. DESCRIPTIVE STATISTICS FOR SAMPLE SIZE

	Male(n=6)		**Female (n=6)**	
Variable	*Mean*	*SD*	*Mean*	*SD*
Age	28	2.7	27.8	2.9
Height (cm)	165.7	8.8	161.7	7.6
Weight (kg)	65.2	11.3	58.2	4.4

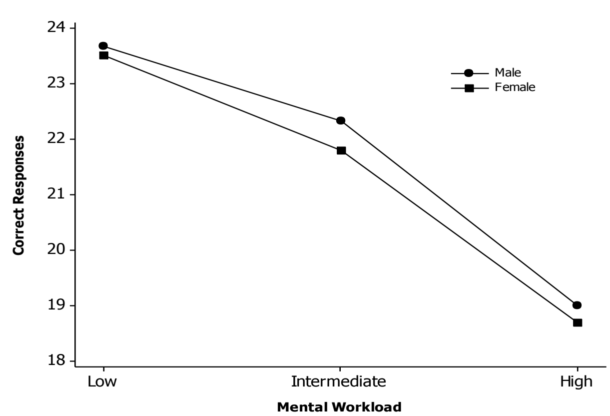

Figure 3. Arithmetic mental workload levels against correct responsesforboth male and female.

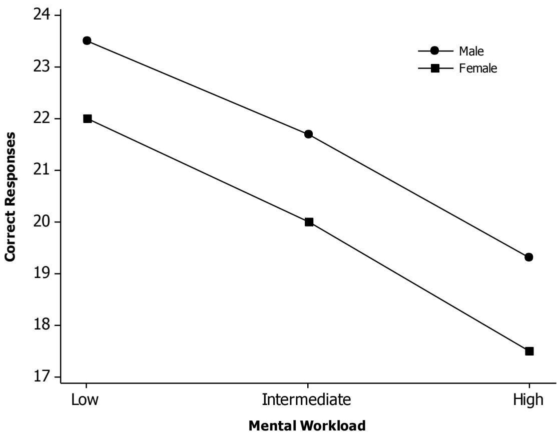

Figure 4. Spatial mental workload against correct responses for both male and female

The ANOVA technique showed that the level of difficulty of the arithmetic mental task significantly influenced the participants' ability to provide correct responses ($F(2,20) = 23.50$, $p=0.000$). The ANOVA findings revealed that the effect of the interaction between gender and arithmetic difficulty level on the number of correct responses was not significant ($F(2,20) = 0.118$, $p=0.889$). Moreover, a significant difference was observed between the intermediate level and the high level of the arithmetic test ($p<0.001$), whereas the difference between the low and intermediate levels was not significant ($p=0.136$). According to an independent t-test, no significant differences were observed between the performance of the male and female participants at all levels (i.e., low, intermediate, and high) ($p>0.05$). Table II illustrated the descriptive statistics of participants' correct responses at all tasks levels.

TABLE II. CORRECT RESPONSES MEAN AND STANDARD DEVIATIONS ACROSS ALL PARTICIPANTS IN ARITHMETIC AND SPATIAL FIGURES TASKS.

Task	**Low level**		**Intermediate level**		**High level**	
Arithmetic Task	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Male	23.7	1.40	22.3	1.80	19.0	2.80
Female	23.5	1.52	21.8	2.86	18.7	2.50
Spatial Figures Task	Mean	SD	Mean	SD	Mean	SD
Male	23.5	1.5	21.7	1.6	19.3	2.4
Female	22.0	0.9	20.0	2.4	17.5	2.4

On the other hand, the ANOVA analysis illustrated that the impact of spatial figures mental task conditions was significant ($F(2,20) = 15.85$, $p= 0.001$). In contrast, no significant effect of the interaction between gender and spatial figures levels on the participants' performance ($F(2,20) = 0.023$, $p=0.946$). However, according to contrast tests, there was a significant difference between the low and intermediate levels and between the intermediate and high levels ($p= 0.016$ and $p= 0.034$, respectively).

B. Participants' Accuracy and Time of Correct Responses

The percentage of correct responses (accuracy) of participants and the average time of correct responses for both tasks (arithmetic and spatial figures tasks) were generally related with the task difficulty levels.

The ANOVA showed that the levels of difficulty of the arithmetic mental task and spatial task significantly impacted the participants' accuracy ($F(2,20) = 40.909$, $p=0.000$). The ANOVA findings revealed that the effect of the interaction between gender and task type on response accuracy was not significant ($F(2,20) = 0.70$, $p=0.480$). Moreover, a significant difference was observed between the intermediate level and the high level of the arithmetic test ($p=0.001$), as well as the difference between the low and intermediate levels ($p=0.005$). In addition, when the task level (arithmetic and spatial) increased the accuracy decreased "see Figure 5".

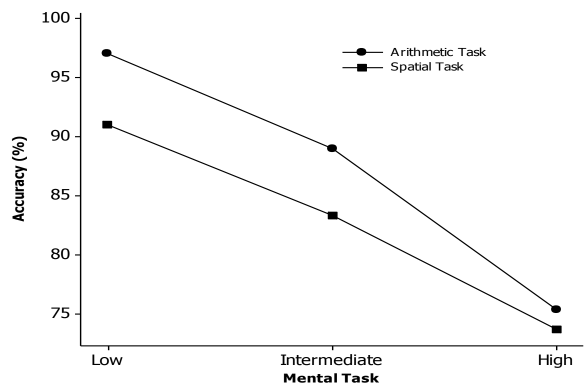

Figure 5. Response accuracy associated with the three levels of mental workload for both arithmetic and spatial figures tasks.

In terms of response time, the repeated-measures ANOVA indicated that a significant impact was made by the task levels on participants' average correct responses ($F(2,20) = 606.46$, $p<0.001$), and when the task difficulty increased, the speed significantly decreased as shown in "see Figure 6". On the other hand, the ANOVA findings revealed that the effect of the interaction between gender and tasks types on response accuracy was not significant ($F(2,20) = 0.25$, $p=0.778$).. Moreover, a significant difference was observed between the intermediate level and the high level of the arithmetic test ($p<0.001$), also the difference between the low and intermediate levels was significant ($p<0.001$).

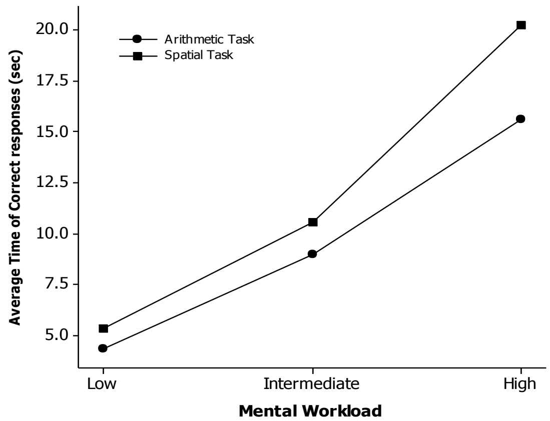

Figure 6. Average of correct response time (time in sec) associated with the three levels of mental workload for both arithmetic and spatial figures tasks.

C. Physiological Parameters

- Heart Rate (HR)

The HR and HRV parameters were measured in order to determine the impact of the mental workload on the arousal level of the participants. As in previous research, a correlation was observed between these parameters and the difficulty level of the task. Table III presents the mean HR for participants as they completed the low level, intermediate level, and high level mental workload (i.e., both the arithmetic and spatial figures tasks). The table reveals that on average, the participants' HRs raised as the mental workload increased. However, the ANOVA indicated a significant effect of task type (i.e., arithmetic and spatial figures) on HR, ($F(1,11) = 30.28$, $p<0.001$). Also, the data analysis indicated that a significant impact was made by the task levels on participants' HRs ($F(2,22) = 50.07$, $p<0.001$), and when the task difficulty increased, the HR significantly increased as shown in "see Figure 7".

TABLE III. HAERT RATE OBSERVATION(BEATS/MIN) MEAN AND STANDARD DEVIATION ACROSS ALL PARTICIPANTS

	Low level		**Intermediate level**		**High level**	
Task	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Arithmetic Task	72.8	8.6	78.3	9.6	86.2	9.6
Spatial Figures Task	81.8	8.7	88.6	10	95.8	12

On the other hand, no significant impact from task type interaction and their levels on HR was observed ($F(2,22) = 0.224$, $p=0.775$). According to the ANOVA analysis, there was a significant difference between the tasks ($p<0.001$). The ANOVA results for the arithmetic task demonstrated that no significant influence was observed by gender and arithmetic levels interaction on participants' HRs ($F(2,20) = 0.531$, $p=0.596$) "see Figure 8".

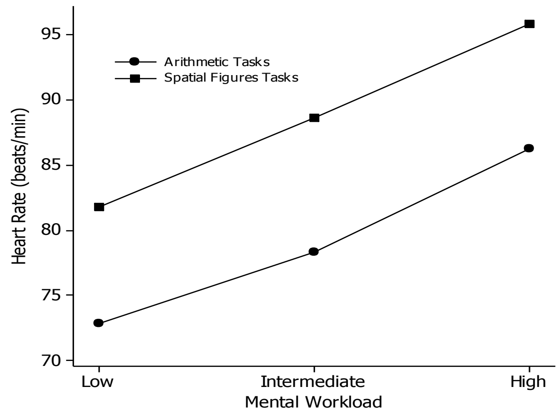

Figure 7. Heart rate (HR) variable associated with the three levels of mental workload for both arithmetic and spatial figures mental tasks.

In contrast, the difficulty level of the arithmetic task significantly affected the HRs of the participants ($F(2,20) = 31.15$, $p<0.001$). According to repeated contrast comparisons, the mean HR increased significantly during the participants' completion of the high level arithmetic task ($p= 0.001$) as compared to that of the intermediate level. Also, the HRs of participants rose significantly ($p= 0.007$) during their completion of the intermediate level arithmetic task versus that of the low level arithmetic task. The independent t-test showed that no significant difference was observed between the mean HRs of both genders during completion of the low, intermediate, and high level task ($p>0.05$).

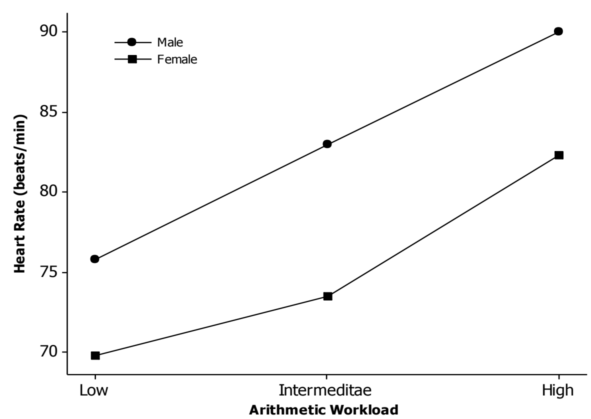

Figure 8. Heart rate (HR) variable associated with the three levels of mental workload of arithmetic mental task for male and female.

Additionally, repeated-measures ANOVA results reported that the the spatial figures task workload affected the HRs of the subjects ($F(2,10) = 28.54$, $p<0.001$). Conversely, the difference of the impact of gender and spatial task level interaction on the participants' HR was not significant ($F(2,20) = 2.51$, $p=0.107$) "see Figure 9". According to repeated contrast comparisons, the HR significantly increased when participants completed the high level spatial figures tasks as compared to that of the intermediate and low levels ($p< 0.05$). Also, the HR of participants rose significantly ($p< 0.05$) when participants completed intermediate level spatial figures tasks versus low level spatial figures tasks. An independent t-test indicated that no significant difference was observed between the mean HRs for both genders when completing the low, intermediate, and high levels ($p>0.05$) of spatial figures tasks.

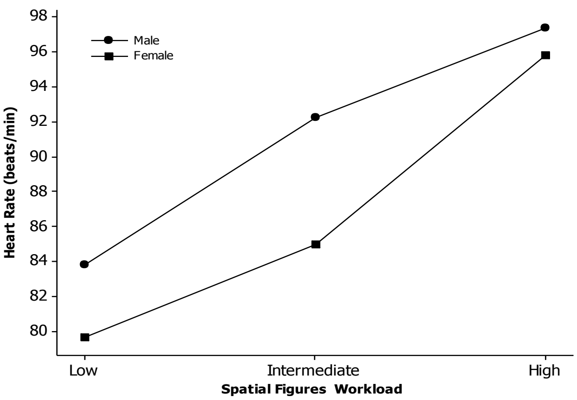

Figure 9. Heart rate (HR) variable associated with the three levels of mental workload of spatial figures task for male and female.

- Heart Rate Variability (HRV)

ANOVA analysis indicated that task type (i.e., arithmetic versus spatial figures tasks) significantly affected the mean HRV ($F(1,11) = 8.93$, $p=0.012$). Also, the data analysis indicated that the task level significantly impacted the participants' HRV ($F(2,22) = 38.14$, $p<0.001$); i.e., when the arithmetic and spatial figures task difficulty level increased, the HRV significantly decreased as shown in "see Figure 10". Contrast comparisons were used to explore the differences that occurred in HRV when participants completed tasks in different difficulty levels. The HRV during completion of the difficult level was lower than that of the intermediate level ($p<0.001$), and the mean HRV was lower during completion of the intermediate level than that of the low level condition ($p< 0.001$).

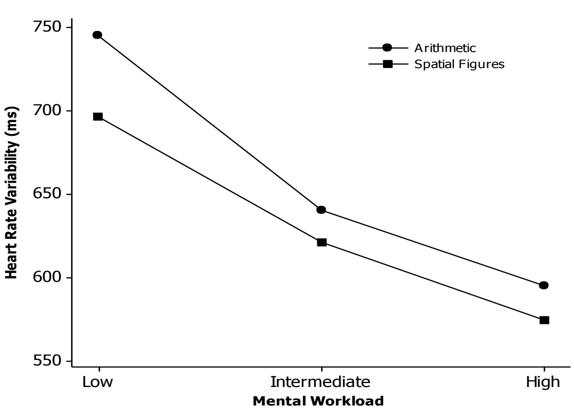

Figure 10. Heart rate variability (HRV) variable associated with the three levels of mental workload for both arithmetic and spatial figures mental tasks.

In contrast, no significant difference was observed between the interaction of both tasks and their levels ($F(2,22) = 0.884$, $p=0.386$). According to the ANOVA analysis, there was a significant difference between the tasks ($p = 0.002$).

However, according to the ANOVA analysis, the difficulty level of the arithmetic tasks significantly influenced the mean HRV ($F(2,20) =20.13$, $p<0.001$). In contrast, the effect of the interaction between gender and arithmetic levels on the HRV of participants was not significant ($F(2,20) =3.85$, $p=0.065$) "see Figure 11". A significant difference was observed between the low and intermediate levels ($p=0.003$), as well as between the intermediate and high levels ($p=0.004$). An independent t-test analysis indicated that a significant difference was observed between the HRV of males and that of female during the completion of low, intermediate, and high level of arithmetic tasks ($p<0.05$).

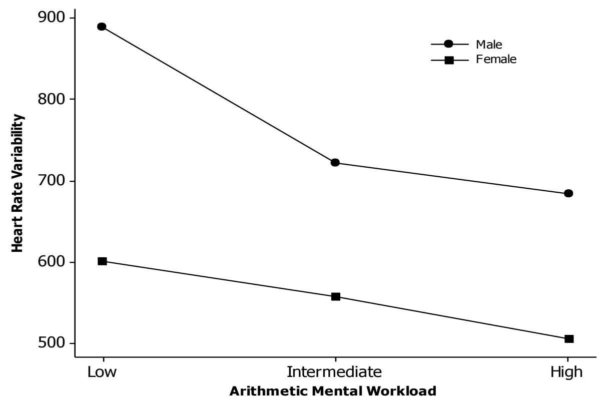

Figure 11. Heart rate variability (HRV) variable associated with the three levels of mental workload of arithmetic mental task for male and female.

Additionally, the analysis findings remarked that the level of difficulty for the spatial figures tasks significantly impacted the participants' HRV (i.e., both male and female) ($F(2,20) = 122.79$, $p<0.001$). However, the interaction between gender and spatial figures task level did not impact the participants' HRV ($F(2,20) = 3.45$, $p=0.082$) "see Figure 12". Contrast comparisons indicated that the HRV decreased significantly when participants completed the high level spatial figures task as compared to that of the intermediate level ($p<0.001$). Also, the mean HRV dropped significantly ($p<0.001$) when participants completed the intermediate level spatial figures task versus that of the low level spatial figures task. Furthermore, the independent t-test presented that a significant difference was observed between the HRV of males and females when completing low, intermediate, and high level spatial figures tasks ($p=0.008$, $p=0.01$ and $p=0.01$, respectively).

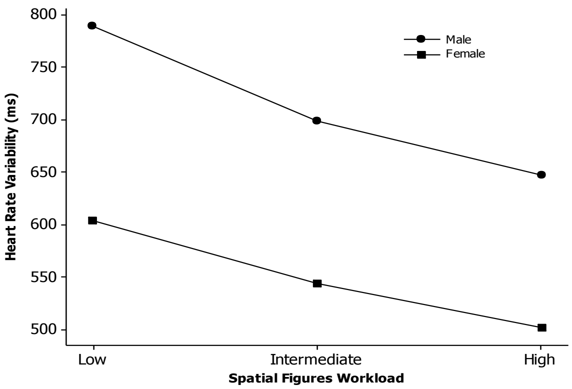

Figure 12. Heart rate variability (HRV) variable associated with the three levels of mental workload of spatial figures task for male and female.

- NASA-TLX Assessment Tool

The impact of the arithmetic task levels on overall NASA-TLX ratings was significant for both male and female participants ($F(2,20) = 182.79$, $p<0.001$). As arithmetic task difficulty increased, the overall NASA-TLX scores also increased ($p<0.001$ from low to intermediate; $p<0.001$ from intermediate to high). According to the independent t-test results, no significant difference was observed between the male and female overall workload scores for intermediate and high level arithmetic tasks ($p>0.05$), whereas a difference in means was observed for the low level arithmetic tasks ($p= 0.026$) "see Figure 13". However, the ANOVA results indicated that the impact from the interaction between gender and arithmetic levels on the NASA-TLX scores was not significant ($F(2,20) = 0.320$, $p=0.730$).

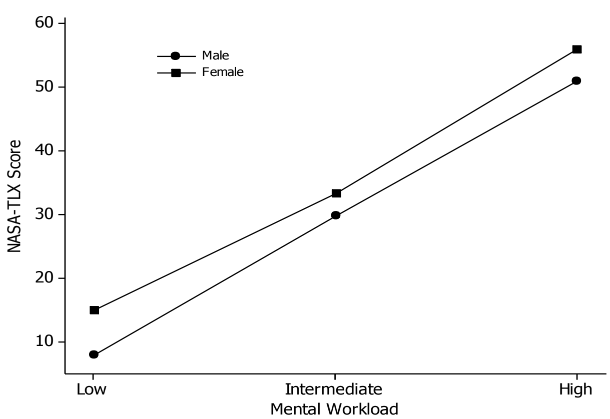

Figure 13. Mean NASA-TLX ratings assessment tool associated with three levels of arithmetic task for both gender

Statistically significant differences were observed in the overall NASA-TLX ratings for the spatial figures tasks ($F(2,20) = 379.85$, $p<0.001$). In addition, the overall workload from the NASA-TLX increased when the task level became more difficult (low to intermediate, $p<0.001$; intermediate to high, $p<0.001$). On the other hand, the ANOVA results did not reveal any significant effect from the interaction between gender and spatial mental task levels on overall NASA-TLX scores ($F(1,5) = 3.21$, $p>0.05$) "see Figure14". The independent t-test indicated that no significant difference was observed between the mean scores on the NASA-TLX for both genders in the intermediate and high levels ($p>0.05$), whereas a significant difference was observed between the mean scores on the NASA-TLX males and that of females when completing the low level task ($p= 0.017$). However, the overall NASA-TLX scores were significantly related to the scores on the mental demand dimension for both the arithmetic and spatial figures tasks ($r= 0.99$, $p<0.001$ and $r=0.99$, $p<0.001$, respectively).

In addition, all dimensions of the NASA-TLX increased except the physical dimension, which was not affected, since no physical effort was expended with either of these tasks.

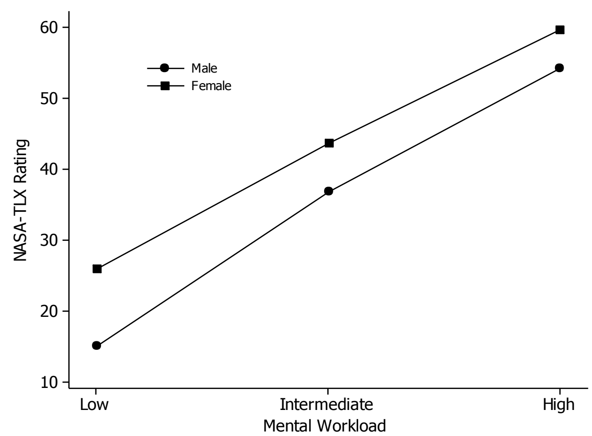

Figure 14. Mean NASA-TLX ratings assessment tool associated with three levels of spatial figures task for both gender

VIII. DISCUSSION

The number of correct responses indicated that the arithmetic and spatial figures tasks levels were varied in difficulty. In addition, it presents that the compatibility of mental workload of the tasks was satisfied from low level to high workload level. Moreover, the participants' responses decreased in sequence as the mental demand from the arithmetic and spatial figures tasks increased. These findings are similar to that of previous research studies. Reference [18], found that performance decreased with increasing mathematical operation load. Regarding mental workload (i.e., monitoring and arithmetic tasks), Reference [2], pointed out that an increase in the monitoring and arithmetic process demand led to a degradation in the individual performance. Generally, the results showed that no significant difference has been observed between the genders when completing arithmetic task, whereas a considerable difference has been observed between the genders in terms of spatial ability. These findings are supported by [28], who reported no significant difference between the performance of men and women in arithmetic and language tasks. Furthermore, the findings revealed that a significant difference was observed between the HRV of each gender in terms of both tasks.

Also, the NASA-TLX analysis showed a significant gender difference in the mathematics and spatial tasks at low level, whereas there was no difference at intermediate or high levels in either task.

In addition, a significant difference in gender performance appeared only in the spatial ability task. This may be because the female participants took more time than the male participants in order to be as accurate as possible on the arithmetic task, which leads to more performance stress and perception of strain. This resulted in significant differences in the NASA-TLX ratings and the HRV variable between genders, yet resulted in no significance difference in their performances. References [15][16], mentioned that many previous studies determined the differences between males and females in terms of spatial capability on the mental rotation test; i.e., men tend to outperform women on spatial tasks. These results support the finding from this study; i.e., males provided more correct responses on the spatial figures task than females. Furthermore, the present results indicate that the interaction between gender and task levels did not significantly impact the participants' ability to provide correct responses. Finally, the participants' performance analysis of the arithmetic task showed that there was no significant correct response difference between the low and intermediate level, whereas there was a significant performance difference between intermediate and high level. This may create a potential problem for subsequent research, but it might be related to the sample size (in other words, a more significant effect may be found with a larger group of participants). However, the physiological and NASA-TLX scores analyses revealed a significant performance difference between the low vs. intermediate and intermediate vs. high levels of arithmetic tasks.

Physiological indices in this study were affected by the mental demand levels of the tasks (i.e., both arithmetic and spatial figures tasks). The physiological data analysis found a significant difference between the tasks, which appears to indicate that participants found the spatial task to be more difficult than the arithmetic task. That difference may be reduced by increasing the difficulty level of the arithmetic task, but this would produce a potential problem in the validation of these levels by pilot study. However, both tasks had a significant impact on physiological parameters, and these effects were parallel; therefore, this will not affect the study. However, the participants' (male and female) HR parameter was positively related to the arithmetic and spatial task difficulty levels. Specifically, as the arithmetic task level increased, the HR also increased, and the HR increased as the complexity of the spatial figures task increased. This was consistent with previous experimental studies [2][4] who found that the HR of subjects was affected by the complexity levels of the mental workload in the form of arithmetic and monitoring tasks. Their results indicated that when the difficulty level of the mathematical and monitoring tasks increased, the HR of the participants also increased. On the contrary, this study presented that HRV declined as the difficulty level of the arithmetic and spatial figures tasks increased. Reference [2], found that HRV declined as the monitoring workload level increased. In addition, the findings showed that a significant difference was observed between the HRV of participants completing arithmetic tasks and the HRV of participants completing spatial figures tasks, whereas no significant difference was observed between the HR of subjects completing either task. According to [19], the increase in HRV leads to an increase in the acceptable responses; however, the decrease of HRV produces a decrease in the correct responses.

The study results indicate that a significant relationship exists between the subjective mental assessment tool (i.e., the NASA-TLX) ratings and the arithmetic and spatial figures task levels. Specifically, the NASA-TLX score increased with the increase in task level for both types of tasks. In general, the experimental data analysis indicated that the NASA-TLX scores were sensitive to changes in mental demand levels. This finding is similar to that of numerous papers. For example, [2][18], concluded that increases in NASA-TLX ratings were related to an increase in mental workload. For most participants, the highest NASA-TLX rating was recorded after completing the most complex arithmetic and spatial figures tasks. On the other hand, the lowest score was recorded after completing the simplest level of both tasks. However, the interaction between gender and task levels did not significantly impact the NASA-TLX scores. Furthermore, the study analysis indicated that no significant differences were observed between the male and female performance on intermediate and difficult levels for both tasks. In contrast, a significant difference was observed between the genders on the low level for both the arithmetic and spatial figures tasks.

IX. CONCLUSION AND FUTURE WORK

In conclusion, the level of difficulty for arithmetic and spatial figures tasks were validated, which was the target of this experiment. Indeed, all of the variables (i.e., performance, physiological variables, and NASA-TLX scores) that were measured in this study indicated that the design of both tasks achieved three intensity levels (i.e., low, intermediate, and high) of mental effort. Furthermore, the participants' correct answers, HR, and NASA-TLX ratings increased when the arithmetic and spatial figures levels increased. In contrast, the HRV of the participants correlated negatively with the complexity level for both tasks; in other words, the HRV declined when the arithmetic and spatial task levels increased. Based on the findings of this study, each of these tasks appears to include three cognitive load conditions that are demanding enough to produce reliable differences between participants. Therefore, both tasks are seemingly suitable to use in the subsequent research programme. That future study aims to examine the effects of the combination of physical and mental demands on human attentional resources performance in dual occupations in a laboratory setting. The study will include visual resources (verbal and spatial resources), and the second study will include auditory resources (verbal and spatial), while future work is planned to investigate the overlaps between physical and mental workload in a real domain such as factory production lines.

In summary, this paper studied the impact of mental workload on verbal and spatial attentional resources in order to validate levels of difficulties of two mental tasks. The first task was an arithmetic mental task used to show verbal resource. The second task used spatial figures to reflect spatial resource. In addition, gender difference was considered as a factor in this study because it will be looked at in a second, future experiment. Three parameters were used as dependent variables (performance, physiological parameters, and NASA-TLX score). The participants' responses decreased in sequence as the mental demand from the arithmetic and spatial figures tasks increased. Physiological indices in this study were affected by the mental demand levels of the tasks. The HR parameter of the participants (male and female) was positively related to the arithmetic and spatial task difficulty levels. On the other hand, this study showed that HRV declined as the difficulty level of the arithmetic and spatial figures tasks increased. In addition, the NASA-TLX score increased with the increase in task level for both types of tasks. The three difficult levels of arithmetic and spatial figure tasks were validated according to the results of the study.

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