ORIGINAL ARTICLE

A Deeper Dive into Mental Workload Implications Amidst Digital Design Tasks Among Designers Afflicted with Carpal Tunnel Syndrome Symptoms

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Abstract: Carpal tunnel syndrome (CTS) is a common occupational condition affecting designers and other professionals who work long hours working with computers. The aim of this study is to assess the risk of CTS for mental workload in designers who have been diagnosed with the symptoms of CTS. In this experimental study on image editing for Mood Board, the risk of mental workload was measured using NASA Task Load Index (TLX) instruments.

A total of 17 designers from different design disciplines participated in this study and ranked "Effort" first in both pre- and post-assessment of NASA TLX in the Image Processing for Mood Board task. This study found that designers who scored more than 60 MWL points on this NASA TLX assessment were significantly associated with mental distress with a P-value of 0.029. The high MWL score on the NASA TLX assessment was strongly associated with mental workload. Significant correlations were observed between higher MWL scores and mental distress, spotlighting the necessity for ergonomic interventions and workload management strategies to alleviate the CTS symptoms' detrimental effects.

Keywords: Carpal Tunnel Syndrome, NASA Task Load Index (TLX), Mental Workload, Designers

1.0 INTRODUCTION

Carpal Tunnel Syndrome (CTS) is the most commonly reported Musculoskeletal Disease (MSD) at the workplace reported by International Labour Organisation [1], [2]. CTS, characterized by pressure on the median nerve within the wrist [3], is a prevalent occupational ailment especially among professionals involved in extensive computer usage [4]–[6]. Designers, given their substantial computer interaction, are among the most susceptible groups to CTS, which manifests through various musculoskeletal symptoms in hands and fingers [3]. The study endeavoured to dissect the mental workload implications on designers already diagnosed with CTS symptoms during their digital design tasks.

The majority of designers, including those working in graphic, multimedia, industrial, automotive, architectural and CAD design, spend at least 50% of their working time at the computer [7]. While handwritten sketches are still used to establish initial design concepts, the computer has become an indispensable tool in the design process. In order to keep up with design deadlines, designers have been identified to easily be immersed in their work for hours, especially among graphic designers [8]. This habit of working long hours with computers has been identified by many scholars as a risk factor for CTS [4]–[6]. Working long hours with computers requires designers to sit for the same duration. Designers' workstations need to offer comfort and ergonomic sitting positions to prevent musculoskeletal injuries. This study examined the risk of mental workload (MWL) among designers who had CTS symptoms. To assess the likelihood, NASA TLX was used to measure mental workload.

2.0 POPULATION & SAMPLE

An initial screening identified 45 designers with positive CTS symptoms, out of which 17 voluntarily participated in the experiment conducted in real work environments across four diverse

locations [7]. This cohort represented a mix of design professionals including graphic designers, industrial designers, automotive designers, and design engineers.

3.0 METHODOLOGY

NASA Task Load Index (TLX) was established more than 20 years ago originally to measure workload in the aviation sector [9]. 300 studies used NASA TLX as an instrument in various sectors, mainly in air traffic control and civilian or military aviation [9]. NASA TLX is now widely accepted in different industries, such as the healthcare industry, to evaluate the workload of nurses in the intensive care unit (ICU) [10]. A multidimensional instrument, NASA TLX has six subscales, namely; Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Frustration (FR), Effort (EF), and Performance (PE) [9]. In this instrument, twenty-step bipolar scales were used with a score between 0 and 100. The six elements combined below represented the workload engagement by the designers [10]. The psychological risk of designers with CTS symptoms while performing digital design activities was assessed in this study with NASA-TLX. The measure was used to collect data related to the aim of the study, which was to assess the likelihood that designers with CTS symptoms experience psychological distress.

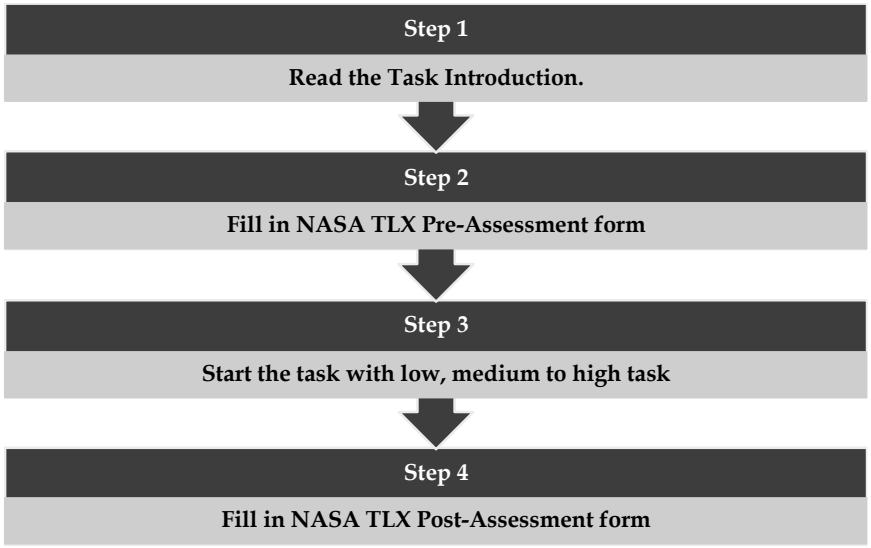

Figure 1: Step by step task to complete NASA TLX

The methodology employed the NASA Task Load Index (NASA TLX) as the primary instrument to measure the mental workload during the image processing task for Mood Board creation. The study was structured into four meticulous steps, from briefing participants about the task to a post-task NASA TLX assessment as shown in Figure 1. The task entailed a systematic approach to image editing, requiring participants to adhere to a specific theme while ensuring a balance of creativity and deadline adherence.

Step 1: At this stage, the assignment for the participant's task, which involved image processing for a mood board, was provided. A common first step in the design process is the mood board. A mood board is a visual collage of photos on a specific theme. To generate ideas for the design, the designers put together each image that embodies the theme. For this task, the designers had three concepts at their disposal: a maritime concept, a Scandinavian concept, and a futuristic concept. The designers' goal was to find photos that relate to the theme. The designers were allowed to edit, trace and crop the photos using any editing programme, e.g. Adobe Photoshop. The work consists of three main tasks, as found in Figure 2. The tasks are divided into three steps, from low to high subtasks. The task and the given time frame were explained to the designer by the researcher, as listed in Figure 3.

Step 2: Participants were asked to complete the NASA TLX pre-assessment for the task after receiving a briefing on the task. The pre-and post-assessment for the task was completed by each participant in this study using the mobile application running on an iPhone 13 Pro. NASA TLX iOS Version 1.0 was used for this study. Used NASA technology number ARC -15150-1A. NASA created this version primarily for educational reasons for students. The pairwise comparison (questions 1-15) and rating scale are two sets of activities for study participants to complete (questions 16-21). The form proposed by NASA also contained the same set of assessments. Subjects were shown a series of pairs of rating scale components, with each pair displayed on

a different screen. For each pair, participants selected the aspect they considered more important for the upcoming activity than the workload. Participants are presented with a set of rating scales. They have to rate each of the six scales by tapping on the phone screen or marking the point on the scale that they think best reflects their experience of the activity. Two endpoints on each line describe the scale. In order to distinguish between the different task situations and consider each scale independently, participants need to carefully analyse their responses.

IMAGE SEARCHING (LOW) 20 Minutes	IMAGE EDITING (MEDIUM) 30 Minutes	IMAGE TRACING & CROPPING (HIGH) 40 Minutes
There will be 3 sub-task in this stage as below: 1. Choose one of below themes: • Nautical • Scandinavian • Futuristic 2. Find 5 images online/images bank/ stock images. Two of the images must be in organic form l; and 3. Save all images in jpeg format.	There will be 5 sub-task in this stage as below: 1. Images resize; 2. Exposure adjustment; 3. Brightness adjustment; 4. Contra adjustment; and 5. Colour level adjustment.	There will be 7 sub-tasks in this stage as below: 1. Images resolution; 2. Setting crop edges; 3. Tracing image with pen tool; 4. Crop and clear background; 5. Resize image with transparent background; 6. Image affects; 7. Prepare image with transparent background format.

Figure 2: Task and sub-tasks with timing

Step 3: The designer started working on the low, medium, and high difficulty tasks. The time span was set taking into account the difficulty of each task, as can be seen in Figure 2.

Step 4: After completing the task, participants were asked to fill in a post-assessment form. The method was the same as described in Step 2.

4.0 RESULT & DISCUSSION

In this study, 17 designers took part, including design engineers, automotive designers, industrial designers, and graphic designers (5). Men made up 64.7% of the participants in this study, who had an average age of 30 to 60 years. In this study, 58.8% of participants reported using a computer for 5-8 hours per day, while 29.4% (5) reported using a computer for more than 8 hours per day. Mainly, male industrial designers and design engineers participated in this study. The majority of the designers were older (>60 years old), and the more time they spent on the computer, the higher the risk for CTS. This can be explained by the fact that 70.6 % of those who participated in the survey had more than eight years of professional experience.

Table 1: M±SD Rating Score of Pre and Post NASA-TLX Subscales (n=17)

NASA-TLX SUBSCALE	PRE M±SD	PRE RANKING	POST M±SD	POST RANKING
Mental demand	13.82±4.05	3	13.71±4.66	3
Physical demand	8.71±3.75	6	9.00±5.10	5
Temporal demand	14.18±3.73	2	14.94±3.42	2
Performance	10.00±4.54	5	8.76±6.03	6
Effort	14.94±3.70	**1**	15.47±4.40	**1**
Frustration level	8.71±3.75	4	10.76±4.80	4
NASA-TLX total	**56.82±15.6**	**-**	**63.48±12.5**	**-**

Note: TLX= Task Load Index

Pre-Assessment Image Processing for Mood Board Task

NASA-TLX pre-assessment was given to the designers to gauge their expectations of the mental effort of the task at hand. The cumulative mean score for NASA-TLX during the pre-assessment was 56.82 out of 100 as shown in Table 1. Tasks were ranked effort at position 1, followed by temporal demand, mental demand, frustration, effort, and the least expected task, physical demand, which was ranked 6th. Designers with CTS symptoms participated in this assessment, and the tasks had to be completed in the allotted time and required effort The time frame that was strung out created stress that explained why the task was ranked temporal demand at second. The pursuit of deadlines was an integral part of designers' working lives and triggered many emotions

that increased the energy to get the job done. Image processing for the mood board required designers to take three main steps. The first step was to find the images to match their chosen theme. This possible factor causes stress to the designers as they have to select only five images that best represent the selected theme within the given time. The stress was associated with mental demand, which was ranked 3rd in this assessment. This task, where designers have to consider subtasks and deadlines, reflects the actual working environment of most designers. Juggling tasks and coordinating tasks by priority is essential for designers. Once designers go beyond the given time frame, the work can become invaluable. This sometimes leads to restlessness among designers, and this is evident in this task, where frustration was second only to mental demand. Physical demand was ranked last because the task does not consume too much physical energy.

Post-Assessment Image Processing for Mood Board Task

The mental strain predicted by the task creator for image editing for mood boards was to be expected. The imposed time constraints made time demands, and the pre-assessment levels of mental strain and anger were maintained. An increase in work deadline pressure was identified as one of the stress variables in a study on stress among designers and architects in Malaysia [11]. However, from a different perspective, designers have also been associated with stress arising from deadline pressure as a motivating element to complete the task [12]. Selye (1976) distinguished between distress and eustress as two types of stress [12]. Unpleasant, unwanted, and uncontrollable stress is the result of a stressful event that is more than a person can handle. Eustress, on the other hand, is a stressful situation that promotes growth, development, and motivation. According to Janipha et al. (2012), stress at work is the physical and emotional reaction to unfavourable work circumstances, e.g., when work demands exceed an employee's abilities and resources [11].

A theoretical exploration of the creative perspective was conducted using the pressure-creativity model developed by Gutnick et al. (2012) (see Figure 3), which assesses the impact of work pressure and performance [13]. The assessment of hazards and challenges is triggered by pressure, which then affects workers' cognitive flexibility and stamina, which in turn affects creativity [13].

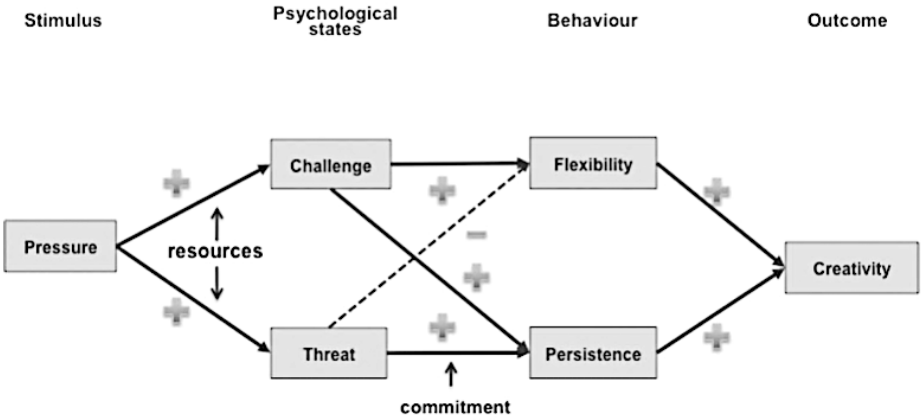

Figure 3: The Pressure-Creativity Model (Gutnick et.al., 2012)

Ranks 5 and 6 of the post-assessment ranking differed, whereas in post-assessment, ranking number 5 was the physical demands. In the reality of the task, the designers noted that the task required both quickness of hand and dexterity to complete the task within the allotted time. As participants suffered from CTS symptoms, the classification changed to the task requiring physical demands rather than performance. A study on RSI among designers in Nigeria found that 33% of designers experienced RSI symptoms during work, and 37% suffered from RSI symptoms after work [8]. This might be a similar situation found in this study, where the physical demands of the task were assessed as low, but the classification was changed during post-assessment after performing the task while having CTS symptoms. In a study comparing the work of CAD designers with that of regular computer office workers, Sahu et al. found that CAD designers who worked with CAD software increased wrist, shoulder and back pain [14]. Shoulder pain from using the computer mouse was triggered by the flexors and extensors of the wrist suggesting that this could be the result of excessive use of the mouse on the output device [15].

Through the temporal and mental demands, the repetitive stress of intensive mouse use may indirectly affect MWL. Similar results were obtained in the study by Roquelaure et al. which found that biomechanical stress had a direct effect on CTS, while organisational and psychological factors

had an indirect effect on a cohort of workers representative of the workforce in an area. The mental workload required for performance was little in this experimental exercise. To do the assignment within the allotted time is the designer's main objective. The stress of having to fulfil deadlines spurs inventiveness, which then results in performance. Designers did not consider the task to be a performance burden as a result. The assessment of performance on a secondary job can be used to monitor attention and exertion on a primary activity, according to a study by Young et al. (2015) [16]. In a true dual-task scenario where one activity takes precedence over the other, performance on the secondary task (in terms of errors and time) is closely connected to the spare capacity left unused by the primary task.

Figure 4: Pictures of respondents working on NASA TLX task at their workstation

Association of MWL Factors & Mental Workload Score

The post-assessment study of the relationship between the paired components of mental workload and the NASA task load index score is shown in Table 2. The table shows the results of 15 pairs of workload factors associated with NASA TLX that had scores greater than or less than 60.

Scores between 0 and 10 on the NASA TLX rating scale were classified as low and between 10 and 29 as medium. High scores were defined as scores between 30 and 79 and extremely high scores were scores above that. The manual NASA TLX, which is not used in Malaysia, served as the basis for these scales.

Table 2: Fisher's Exact Test of Pairwise Comparison with Post-Assessment NASA TLX Score (n=17)

Pairwise Factor	Factor Pair	Total	SCORE		Fisher's Exact Test
			<60	>60	P
Pairwise 1	Physical Demand	2	2	0	0.206
	Temporal Demand	15	6	9	
Pairwise 2	Effort	8	4	4	1.000
	Performance	9	4	5	
Pairwise 3	Mental Demand	13	5	8	0.294
	Temporal Demand	4	3	1	
Pairwise 4	Effort	8	4	4	1.000
	Mental Demand	9	4	5	
Pairwise 5	Effort	11	4	7	0.335
	Temporal Demand	6	4	2	
Pairwise 6	Mental Demand	13	4	9	**0.029***
	Physical Demand	4	4	0	
Pairwise 7	Mental Demand	14	6	8	0.576
	Performance	3	2	1	
Pairwise 8	Performance	13	6	7	1.000
	Physical Demand	4	2	2	
Pairwise 9	Effort	16	7	9	0.471
	Physical Demand	1	1	0	
Pairwise 10	Frustration	2	1	1	1.000
	Temporal Demand	15	7	8	
Pairwise 11	Frustration	2	0	2	0.471
	Performance	15	8	7	
Pairwise 12	Frustration	9	2	7	0.057
	Physical Demand	8	6	2	
Pairwise 13	Effort	13	6	7	1.000
	Frustration	4	2	2	
Pairwise 14	Performance	12	6	6	1.000
	Temporal Demand	5	2	3	
Pairwise 15	Frustration	2	1	1	1.000
	Mental Demand	15	7	8	

*Significant P<0.05

This study discovered a strong relationship between mental strain and designers who scored more than 60 MWL points in the NASA TLX assessment, with a P-value of 0.029. According to NASA

TLX, the task requires designers to engage in mental and perceptual tasks (Noyes and Bruneau 2007). For the NASA TLX total score, this scale item was statistically linked, with a total of 9 designers scoring more than 60 points and 4 scoring less than 60 points. The pre- and post-assessment of the task assigned to the designers verified the result. Both the pre- and post-task assessments gave the highest ratings to efforts that were a combination of physical and mental workload.

The findings revealed a noteworthy underestimation of the task's mental workload with a post-task NASA TLX score of 63.48 compared to the pre-task score of 56.82. A significant correlation between higher MWL scores and mental distress was observed, underscoring the adverse psychological impact on designers afflicted with CTS symptoms.

Furthermore, the study illuminated the real-world implications of CTS on designers' mental workload, especially under deadline pressures. It was discerned that the temporal and mental demands escalated with intensive mouse use, indirectly affecting the MWL. This aligns with other studies indicating a direct biomechanical stress effect on CTS, with organizational and psychological factors playing an indirect role.

The study also delved into the pressure-creativity model, assessing the impact of work pressure on performance. The exploration posited that pressure triggers a chain reaction affecting workers' cognitive flexibility and stamina, thereby influencing creativity.

5.0 CONCLUSION

In this study, an average score of 56.82 was obtained in the pre-assessment, and a higher average score of 63.48 was reported after the completion of the task. A total score of more than 30 points on the scale NASA TLX is considered high in relation to MWL. The higher number of total scores after NASA TLX indicates that the MWL requirements of the task were higher than its perceived value, which is reflected in the higher post-task scores.

Effort came first in both pre- and post-assessment. The guidance for mobile applications NASA TLX defines "effort" as the level of mental and physical effort required of designers to achieve the desired level of performance. The evaluation shows that the MWL that the designers expected during the pre-assessment of the task did not match the MWL that emerged after the task was completed. The high MWL score on the NASA TLX assessment was strongly associated with mental strain by the Fisher's Exact Test. This could indicate that the mental workload of the designers during the experiment was significantly influenced by CTS symptoms. This suggests that the mental workload of the designers during the task was significantly affected by the CTS symptoms. The NASA-TLX mean is moderately influenced by the use of a computer at the designers' real workplace and the stress caused by the deadline. Working on a computer in a real design environment and the stress of a deadline have a moderate effect on mental effort established on NASA-TLX mean score.

The study underscored the exigent need for ergonomic interventions and workload management strategies to mitigate the adverse effects of CTS symptoms on designers. The moderate impact of computer-centric work environments and deadline-induced stress on mental workload necessitates a holistic approach to foster a conducive work environment for designers.

5.0 FUTURE IMPLICATIONS

The study paves the way for subsequent research focused on ergonomic solutions and workload management strategies to alleviate the detrimental effects of CTS on designers. Furthermore, a broader study encompassing a larger and more diverse sample could unravel additional facets of MWL dynamics among designers with CTS symptoms.

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