IMPROVING LEARNING DESIGN AND EDUCATION OUTCOMES THROUGH COGNITIVE PSYCHOLOGY: THE EFFECTS OF CONTROL OPPORTUNITIES ON INFORMATION PROCESSING AND MENTAL FATIGUE

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Abstract

Persistent mental fatigue induced by sustained task performance and mental workload has been shown to have serious cognitive effects such as lowered discrimination capacity, circumscribed range of attention, and increased distractibility, all reducing the ability to absorb information and leading to impaired learning. Studies show that having greater autonomy in choosing how to complete given cognitive tasks is associated with lower levels of strain and better educational outcomes. The present study investigated the effects of control opportunities over a series of information processing tasks on mental fatigue and learning. Adapting a yoked - subject experimental design, it was assumed that provision of varying degrees of personal control over the method and timing on a series of information processing tasks would determine the degree of participants' mental fatigue. The overall pattern of results was consistent with our expectations as indicated by subjective measures of affective state prior to and after the information processing tasks. Enhanced opportunities for personal control over the timing and methods of action were associated with lower levels of mental fatigue. The results have significant implications for educational purposes. In terms of learning design, it is vital to reduce the time spent on exerting high effort. One way of doing this is by the provision of opportunities for performing information processing tasks in different ways and with different pace. This will enhance personal control over a given cognitive activity and result in low levels of fatigue, since more effort can be applied in parts of the task that are more interesting (tasks can be carried out in a preferable order and pace), while more boring parts can be dealt with by the application of less effort. A general conclusion can be drawn from the findings: Given mental tasks or activities that impose greater limitations on personal control are associated with less favourable results.

Keywords: Learning Design, Education, Cognitive Psychology, Information Processing, Mental Fatigue, Personal Control

1. INTRODUCTION

Research that has investigated the effects of personal control over a given activity in an educational context, has focused more directly on stress and less directly on information processing and states such as mental workload and mental (or cognitive) fatigue (Sutton & Kahn, 1987). This may be partly due to the difficulties that arise when one attempts to define and measure mental fatigue, and partly due to the lack of a theoretical framework which would conceptually integrate personal control, information processing and mental fatigue. Adopting an experimental approach, the present study hypothesized that enhanced opportunities for control over the scheduling of a series of information processing tasks and over the choice of how to carry out those tasks would result in lower levels of cognitive fatigue, as indicated by subjective measures of affective state prior to and after the information processing tasks.

2. THEORETICAL FRAMEWORK

2.1. Timing and Method Control

The concept of control has been increasingly recognised as a topic of major importance in the context of education and its impact on information processing, mental workload, and learning (Earle et al, 2015). Control is the individual's perception that he can execute some action that changes aversive stimuli. It is often hypothesised that individuals will react less negatively to mentally demanding, learning-related tasks, if they have control over them, adopt more difficult goals if given a choice and that they will be more satisfied and motivated in tasks that give them autonomy (Van Mierlo et.al., 2001). In their influential study Glass et al. (1971) found that subjects who had no control suffered higher levels of tension and showed relatively impaired performance on a proof-reading task. Frese (1987) emphasised the goal-related nature of control, saying that without a goal there is no issue of control. In his research, he examined workers whose tasks changed because of the introduction of computer technology and found that those who had the highest control over the technological changes also reported the greatest motivation, improved information processing, and suffered from the least anxiety and somatic complaints. Being given control facility is an important factor in ameliorating a boring or stressful effect (Jimmieson, 2000; Kurzban et al., 2013).

Personal control over a given activity can be enhanced by allowing more opportunities for participating in activity scheduling and decision making. Furthermore, control opportunities have favourable effects on perceptions of control, on learning and performance (Kubicek, et al., 2017). Those who are required to maintain precise schedules, while exposed to conditions which constrain their freedom to do so, experience both time pressure and lack of control (Schaubroeck et al., 2001). Having flexible activity schedules produced positive benefits, including reductions in psychological stress symptoms. Thus, a large body of research suggests that those who participate on externally paced activities suffer higher levels of subjective stress and associated mental and physiological symptoms than those who participate on self-paced activities.

Frese (1987), referred to different aspects of control and among others included control over the sequencing and timeframe. Control regarding sequence may for example mean that people are able to determine which cognitive activity they do first and which one second, and in which sequence plans are being formed and executed. Timeframe refers to two sets of decision possibilities: First, the decision, when a certain activity is tackled or a certain plan is performed; second, deciding on how long it will take to stay on a task or on a plan. Timing control refers to the individual's opportunity to determine the scheduling of his or her task behaviour, and method control refers to individual choice in how to carry out given activities (Hockey & Earle, 2006).

2.2. Mental Workload and Fatigue

As early as 1911 Max Offner published his research monograph entitled "Mental Fatigue". There he described the nature of the impairment in the ability to absorb information and he emphasised such cognitive effects as lowered discrimination capacity, circumscribed range of attention, and increased distractibility, all reducing the efficacy of learning. More recent studies have shown that workload is an important factor in inducing mental fatigue (Healy et al., 2004). It seems that there is a limit to the amount of information a human operator can process. One can view fatigue not only as the experience of symptoms associated with continuous work but also as the individual's experience of his or her own ability to cope with the demands that are responsible for the symptoms. Brown (1994) supported this view and related the subjective experience of fatigue to the fact that human behaviour is both adaptive and purposeful. Given sufficient motivation, people can respond with greater effort to the demand for continuous mental processing, and they may maintain it over long periods.

Mental fatigue is inferred from detriments in performance on given tasks requiring alertness and the manipulation and retrieval of information stored in memory. It is often associated with lack of motivation, lack of interest, low reserve mental capacity and could be caused by factors such as monotony, boredom, and tiredness (Van der Linden et al., 2003). Mental fatigue has repeatedly been associated with decline in performance over a given task in controlled situations. Several markers derived from office related tasks, i.e., typewriting, are susceptible to changes in behaviour related to mental fatigue (de Jong, 2020). It is particularly important that the evaluation of cognitive fatigue should consider subjective feelings. A measurement of physical factors needs to be backed up by subjective feelings before it can be correctly assessed as indicating a state of cognitive fatigue. However, the findings of studies concerning reports of subjective fatigue have often been treated with suspicion on the grounds that fatigue both impairs the capacity for introspection and changes the tendency to report symptoms (Brown, 1994).

The development and use of systematic data collection techniques that constrain the frequency of reporting symptoms while simplifying the method of responding, have significantly reduced this problem. Such techniques include the checklist approach, in which individuals simply identify their symptoms from a verbalised list (for example, "energetic", "irritated", "relaxed", etc.) or indicate them on a Likert-type scale. Responses can be categorised into factors reflecting feelings of anxiety, tiredness, affect, and so on. Such brief measures of positive and negative affect (PA and NA) may be applied with different focal time periods and settings and may be used to indicate the extent to which each item describes peoples' feelings and mood. PA measures the degree of energy or enthusiasm versus lethargy, depression, while NA refers to the degree of anxiety and tension versus calm, relaxed feelings (Hockey, 1996).

3. METHODOLOGY

3.1. Experiment

Though the effects of personal control on stress and well-being have been extensively researched (Sutton & Kahn, 1987), the effects on mental workload and mental fatigue have not been the subject of a similar interest. Adopting an experimental design in a controlled environment, the present study hypothesized that enhanced opportunities for control over the scheduling of a series of information processing tasks (timing control) and over the choice of how to carry out those tasks (method control) would result in lower levels of cognitive fatigue, as indicated by subjective measures of affective state prior to and after the information processing tasks.

3.2. Tasks and Materials

3.2.1. Information Processing Tasks

Four different information processing, computer-based, tasks were used: (a) data entry, (b) formatting, (c) table completion, and (d) proof-reading.

- *Data entry*. This consisted of four tables of three-digit numbers printed on paper. Participants were required to transfer the data from the paper to the corresponding tables on the computer screen.

- *Formatting*. This consisted of many typed documents selected from a range of scientific and non-scientific documents. These contained bold, underlined, and different font sentences, in addition to documents with double spaces between the lines and different paragraph positions. The same documents were also shown on the computer screen, but without the variety of formations already mentioned. Participants were required to format the documents on the computer screen, so that they were made the same as the ones on paper.

- *Table completion*. This comprised of several tables on the computer screen with spaces provided at the end of each row and each column. Participants had to add up the columns and rows respectively and type the results in the spaces provided (subjects were supplied with calculators for their convenience).

- *Proof-reading.* This consisted of a lengthy number of documents drawn from a variety of fields, which were shown on the computer screen, and which contained several spelling errors (i.e., misspelled words, capital letters in place of small letters, etc.). The mean number of errors per document was 9 with a range from 6 to 12. Participants were required to read the documents, find the spelling errors, and correct them. The use of spell-checker was not allowed.

For each computer task a large stuck of materials was supplied so that it was obvious that no single task could be completed in the time allowed for each subject.

3.2.2. Subjective Measure

A Mood Scale was administered, aimed at assessing participants' mood (Affective State) prior to and after the information processing tasks (Hockey and Earle, 2006). It contained 16 mood-relevant adjectives, eight items (1, 2, 3, 5, 9, 12, 13, 15) were associated with feelings of negative affect, four items (4, 6, 8, 11) with feelings of positive affect, and four items (7, 10, 14, 16) with energy (PAE). The NA dimension referred to the degree of anxiety and tension (versus calm, relaxed feelings), while PA measured the degree of enthusiasm (versus depression), and PAE measured the degree of energy (versus lethargy). The PAE dimension was reversed to reflect mental fatigue (versus alertness/energy). Each adjective was related to a 9-point scale, anchored with "not at all" (1) and "very much" (9).

3.3. Participants

Subjects were selected from a sample of volunteers who responded to a local advertisement. They were recruited for what was described as a study of the effects of different office environments. No mention of the

relationship with fatigue was made at the time. The only prerequisite for participation was sufficient knowledge of Microsoft Word. The sample used in the study consisted of 40 subjects, including 22 male (mean age 27.3, age range 24-37) and 18 female participants (mean age 25.2, age range 20-36).

3.4. Procedure

To assess their affective state, participants were asked to rate their current subjective state on the Mood Scale, prior to and after the information processing session. Two levels, or experimental variations, of timing and method control were designed: A high control condition and a low control condition. In the high-control condition subjects were given complete discretion in scheduling their activities. Specifically, they were told to begin with the task of their preference, to spent as much time as they wanted and to switch to another task whenever they wanted. Participants in the low control condition had no discretion in the order of carrying out the tasks and the time they spent on them. In fact, each subject in the low control condition was yoked to a participant in the high control condition in terms of the order of executing the tasks and the time he or she spent on each one (time allocation). Subjects were randomly assigned to either the high control or low control condition. The yoking factor was a random factor because each participant in the high control condition could select a unique order and time allocation pattern.

4. RESULTS

Participants were treated as pairs (high and low control condition). Thus, using the SPSS 20 software, paired t-tests for dependent samples were implemented to statistically analyse the results. Measures of their negative affect (NA), positive affect (PA), and energy level (PAE), were collectively considered to be a measure of subjective fatigue. Data were submitted to a two-tailed t-test analysis (Table 1).

Table 1. Affective state measures (Prior to and after information processing session)

	HC condition	LC condition	Difference of Means	t. value	2-tail p
NA 1	3.50	3.07	0.43	1.00	0.329
PA 1	5.91	6.94	-1.02	-3.30	0.004
PAE 1	5.34	5.52	-0.19	-0.39	0.701
NA 2	3.38	3.24	0.14	0.31	0.761
PA 2	6.31	6.41	-0.10	-0.21	0.833
PAE 2	5.01	4.46	0.55	1.11	0.282

* NA=anxiety, PA=enthusiasm/depression, PAE=energy.

* l=prior to session, 2=after session

* Significant results are shown in bold.

To investigate the effects of control on subjective state, three variables were created to provide a measure of the change over the session. This was done by subtracting the state prior to the information processing session from the state after the session. The change in affective state (NAc, PAc & PAEc) was submitted to a two-tailed t-test analysis (Table 2).

Table 2. Affective state measures

(Change between measures prior to and after the information processing session)

	HC condition	LC condition	Difference of Means	t. value	2-tail p
NA change	-0.12	0.17	-0.29	-0.59	0.559

PA change	0.40	-0.52	0.92	2.54	**0.020**
PAE change	-0.32	-1.06	0.74	1.97	0.064

* NA=anxiety, PA=enthusiasm/depression, PAE=energy

* Change= state after the session- state prior to the session

* Significant results are shown in bold.

The difference between the change in NA (anxiety) for the HC and LC groups was not found to be significant. However, the slight changes in NA are in the direction predicted, namely, an increase in NA in the LC condition. A significant difference was revealed between the change in PA (enthusiasm) in the LC group and the change in PA in the HC group ($t = 2.54$, $df = 19$, $p < 0.05$). There was a decrease in the PA in the LC group and an increase in PA for the HC group, indicating the former were less enthusiastic (or more depressed) at the end of the information processing session. Although the analysis did not reveal a significant difference in change in PAE of the two groups, the difference was almost significant ($t = 1.97$, $df = 19$, $p = 0.064$) and in the direction predicted. Participants in both conditions showed a decrease in energy, which was much larger for the LC group (-1.06). The overall pattern of the results from the Mood Scale indicates that after the information processing session, participants in the LC condition experienced more mental fatigue than those in the HC condition.

5. CONCLUSIONS

The present study attempted to evaluate the effects of personal control over the timing and method of carrying out several cognitive tasks, on information processing and mental fatigue. It was predicted that higher levels of control would be associated with low mental fatigue as indicated by subjective measures. The results are in favour of the positive effects of control opportunities, since measures of the affective state, taken prior to and after the information processing session, show a significant reduction in energy and a significant increase in depression and fatigue for participants in the LC group.

Mental fatigue may be considered primarily as the result of an extended period of high effort, resulting in an aversion to further effort which impairs learning. Persistent mental fatigue has been shown to lead to increased distractibility, and poor information processing. Operating at higher levels of effort for any length of time is known to be uncomfortable and avoided whenever possible. Such conditions are regarded as a major source of fatigue associated with cognitive work and mental workload. Thus, in terms of learning design, it is vital to reduce the time spent exerting high effort. One way of doing this is by the provision of opportunities for doing mental activities in different ways and with different pace (timing and method control). It is assumed that this will enhance personal control over a given mental task and result in low levels of fatigue, since more effort can be applied in parts of the task that are more interesting (activities can be carried out in a preferable order and pace), while more boring parts can be dealt with by the application of less effort. Having greater autonomy in choosing how to complete given cognitive activities is associated with lower levels of strain. A general conclusion can be drawn from the findings: Given mental tasks or activities that impose greater limitations on personal control are associated with less favourable responses and results.

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