Are Heavy Media Multitaskers More Adept at Managing Simultaneous Tasks?

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ABSTRACT
There are people who are good at juggling simultaneous tasks. In everyday life, someone might listen to music or read a book while cooking. At work, someone might write documents or chat with colleagues while answering a telephone call. How do they handle these tasks so effectively? Is it a capability based on repeated experiences of these tasks? Or is it an ability based on their behaviour with media usage more generally? Or is it simply an innate ability? This dissertation assumes that heavy media multitasking is the ability to handle these various tasks well. This paper identified 20 participants as either a Heavy Media Multitasker (HMM) or as a Light Media Multitasker (LMM), using the Media Multitasking Index (MMI), to see if they differed in their ability to optimize the performance trade-offs in a task-switching experiment. This experiment consisted of typing tasks (entering numbers) and tracking tasks (controlling a cursor to prevent it from leaving a circle). There were payoff functions that show the performance of both tasks in a single score. Participants had to change their strategies to achieve high scores and adapt to the changed payoff functions. There was little difference between the two groups in tasks involving sufficient practice, but there was a significant difference in the task of adapting to a changing environment. This suggests HMMs optimize their performance faster than LMMs in a new environment. Implications and limitations are discussed.

Author Keywords
Media; multitasking; MMI; task-switching; trade-off

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1. INTRODUCTION

Since the advent of Weiser's Ubicomp concept, a great many studies have been conducted on multitasking [20,24,28,32]. Nonetheless, the rapid development of mobile technologies and the increase in media usage has called for further study into media multitasking [17]. Engaging in multiple tasks simultaneously, such as using a social networking service and listening to music while following the directions of a mobile mapping program, is not unfamiliar in today's society, especially for the younger generations [1,7]. In some more extreme examples, accidents have occurred while users have been playing *Pokémon Go* while driving or walking [30]. From this, we now have a new word "Smombie", a portmanteau of smartphones and zombies, that describes people walking slowly while using smartphones [15]. There is ample evidence of ever-increasing multitasking behaviours in the 21st century. These behaviours have sparked interest among researchers, and various studies have reached a wide variety of conclusions. These disparate results make it difficult to produce a clear determination about multitasking behaviours today and the trends for these behaviours going forward.

People often think of multitasking as doing more than one thing at the same time [8,10,16]. However, studies of such behaviour have found that it is more akin to rapid transitions between multiple tasks [10,16,23]. In fact, it is very challenging to perform two tasks at the same time [10]. Therefore, in this paper, task-switching, a behaviour that occurs more frequently in real life, is defined as multitasking. There are obviously people in the real world who excel at handling multiple tasks simultaneously. How can we objectively identify such people?

There is a long tradition of conducting experiments to examine multitasking performance. The Media Multitasking Index (MMI) devised by Ophir et al. has been used to assess the level of multitasking in daily life and how this may affect people's ability to perform certain tasks [2,17,18,21–23,26,29,33]. The questionnaire in their study consisted of 144 questions in total. Primarily, respondents were asked about their weekly usage of 12 different media types. Second, when asked about concurrent use between one media type and one of the 11 others, they were to select an answer from among the following: ‘most of the time’, ‘some of the time’, 'a little of the time', or ‘never’. The answers were scored and divided into the HMM and LMM groups. Ophir et al. [22] found that the group of people who scored highly on this performed worse on the task-switching experiment. The task in the experiment was to classify a given alphabetical character as a vowel or consonant, or a given number as even or odd according to the given signals.

Other studies investigating the relationship between MMI and task-switching ability have reported ambiguous results, showing that HMMs were better [2], equivocal [2,21], or worse [22,26,33] than LMMs. Lin & Parsons [17] argue that the cause of these conflicting results may be a lack ecological relevance because they focused solely on one thing, such as cognitive work.

There have been recent studies measuring the trade-offs of task-switching behaviour, overcoming problems where existing experiments did not reflect ecological relevance, such as maximum compensation in a given period of time, which is the main motivation for switching tasks in real life. Farmer et al. [12] and Janssen et al. [14] developed a multitasking experiment that gave people a score to check their performance when they were dividing their attention and performing two tasks. These are methods for identifying optimal multitasking ability, to see whether people were good or bad at multitasking. Participants had to infer payoff functions to determine the number of switches between two tasks and the length of time they stayed on each task. They also had to come up with an optimal strategy in response to the changing payoff functions. These experiments showed relatively good results, with people adapting effectively in responding to changes in the payoff functions.

The aim of this paper is to make sure that people's trade-off ability is related to media multitasking behaviour. To this end, firstly, this paper will define the concept of multitasking in its various forms. Secondly, this paper will review the criticisms and suggestions of the existing MMI to find a suitable alternative to fit in this era. Thirdly, this paper will consider various experiments that have been conducted to verify multitasking abilities. Then, the paper analyses the participants' MMI scores and their associations with the results of the task-switching experiment. The results suggest the relationship between the MMI score and the ability to achieve optimum performance in multitasking environments. These studies can also be used to assess how good people are at multitasking, generally.

The structure of this paper is as follows; Section 2 consists of a literature review and will describe the main points and criticisms of existing papers related to the background of this study. Section 3 covers the methods that are employed in this investigation and will be include a questionnaire to assess people's multitasking index and a specific method of testing to ensure that the optimal trade-off strategy is achieved. Next, conclusions will be presented on the questionnaire and its link to the results of the experiment. Section 4 contains the discussion, with the implications and impacts based on the results and an overview of what needs to be supplemented in future research. Finally, Section 5 contains the conclusion.

2. LITERATURE REVIEW

Definition of Multitasking

People often think of multitasking as the performance of two or more activities at the same time [8,10,16]. However, a review of existing studies show that the commonly accepted definition of multitasking is the ability to rapidly switch between two or more tasks [10,16,23]. Completing multiple tasks at the same time is complex and difficult, but sequentially performing both tasks is closer to the definition of multitasking to be addressed in this paper [10]. Rigby et al. [23] subdivide the latter form of multitasking into concurrent multitasking, wherein the individual very frequently switches tasks such as talking while driving a car, and sequential multitasking, wherein the individual actively performs only one task at a time such as using a mobile device while watching TV (typically a program to which the viewer has not fully committed their attention, for example, the news).

The multitasking to be addressed in this paper is similar to concurrent multitasking. Salvucci et al. [25] studied the time taken for one task before switching to another in a useful way to distinguish multitasking. For example, talking while driving involves frequent switching, but cooking while reading may require a relatively long time between the two tasks. Given this, the multitasking to be addressed in this paper hews more closely to tasks requiring frequent transitions of attention, such as the driving and talking example. In addition, Brasel & Gips [5] studied the differences in multimedia behaviour between students and faculty members through experiments with Television and Computer Usage. Students responded that they multitask more than their faculty members, and they spend less time on a particular medium; the number of switches was also high in students. These results may be the reason why this paper should focus on more frequent switching, or concurrent multitasking.

Media Multitasking Index

There has been an interest in measuring the extent to which people multitask in daily life. Some people seem to do it more and some do it less. To assess this, Ophir et al. [22] developed the MMI questionnaire. This is a 144 item questionnaire which addressed 12 different media forms: print media, television, computer-based video (such as YouTube or online streaming services), music, non-music audio, video or computer games, telephone and mobile phone voice calls, instant messaging, SMS (text messaging), email, web surfing, and other computer-based applications (such as word processing). Respondents were required to record the total weekly usage time for each medium and at the same time choose how often different media were used simultaneously, from 'Most of the time (= 1)', 'Some of the time (= 0.67)', 'A little of the time (= 0.33)', or 'Never (= 0)'.

What is important about this index is that it has been widely used to digitize people's multitasking levels, and to prove their association with certain experimental results. For example, Ophir et al. [22] identified people with high MMI scores as HMMs and those with low MMI scores as LMMs, indicating that HMMs performed worse in filtering experiments and task-switching experiments.

However, there have been claims that the MMI might encounter difficulties in representing the current media environment. Wiradhany & Nieuwenstein [33] cited the need for a new calculation, because the existing calculation measures the percentage of time that someone uses two media types simultaneously. This means that a person who uses a laptop while watching TV for only one hour a day can have the same MMI as a person who does it 16 hours a day. Baumgartner et al. [3] argued that the existing MMI, which requires a focus on one of the 12 media types to record the remaining 11 media activities, or a total of 132 combinations, is very precise, but could result in low response quality because there are so many combinations that the respondents may lose concentration and not answer all of the questions thoroughly. They also said that these problems can take a lot more time because teenagers can be less attentive than adults and are often slower readers than adults. These findings could lead to similar problems for this study's participants, many of whom were international students in their early twenties. Baumgartner et al. [3] developed Media Multitasking Measure - Long Version (MMM-L) and Short Version (MMM-S). Firstly, the 132 items in the original MMI was reduced to 72 items by combining instant messaging and SMS and adding social media, excluding audio, to become MMM-L. Second, considering the frequency of responses to MMM-L, MMM-S was developed by reducing it to nine items. MMI-L and MMI-S showed similar results to the conventional MMI, indicating the potential to be a reliable and useful tool for measuring media multitasking among teenagers.

Edwards [11] developed the Abbreviated Media Multitasking Index (AMMI) and the weighted AMMI (wAMMI) because of how long the original MMI takes to use and because researchers are more interested in how much multitasking a respondent engages in, generally, than in the results of each item. Of the 12 items in the MMI, social networking and other mobile applications were added, SMS was excluded, resulting in 13 items. Participants were questioned using the MMI method asking about activity associated with the remaining 12 media types for each of these 13 items (156 questions); they were required to record their total weekly usage time for each medium (13 questions). On the other hand, the AMMI method asked participants one question on how much the other 12 media types were used at the same time (total of 13 questions). The wAMMI had a combination of the MMI and the AMMI. It mixed the total weekly usage time for each medium from the MMI method (13 questions) with questions about concurrent usage with other media from the AMMI method (13 questions). The MMI scores, AMMI scores, and wAMMI scores showed similar standard deviations and distributions, demonstrating that AMMI and wAMMI are capable of measuring media multitasking compared to the original MMI [22].

The MMI was first developed a decade ago [22]. In that time, new issues have arisen that make the MMI no longer representative of the current media environment. Another problem was that it took a lot of time to obtain measurements. Studies on simplified and improved MMIs that addressed these problems have been conducted. Nevertheless, the MMI is a very useful tool as it can quantify people's multitasking capabilities, and for this reason has been widely used in many experiments.

The Relationship Between MMI and People’s Abilities

There are several papers that have studied the association between MMI scores and specific task performance. In the Ophir et al. study [22], participants were required to perform the rectangle filtering task to indicate whether the target rectangle had changed direction while ignoring distractor rectangles. In that experiment, HMMs performed worse than LMMs. In addition, in the character filtering tasks, where a response of ‘No’ is required when the given alphabetical character was not an ‘A’, HMMs were slower in the environment where there were distractors although there was no significant performance difference between the two groups in the environment without distractors. In the two- and three-back tasks, which examined the monitoring and updating of multiple representations in working memory, HMMs showed a significantly greater decrease in performance. This indicated that HMMs were more vulnerable in terms of distractibility.

However, a study by Wiradhany & Nieuwenstein [33], which duplicated the Ophir et al. study twice by making the participating groups different [22], did not show that heavy multitaskers were affected by distractions. They also meta-analysed about 40 relevant studies that existed, raising questions about presenting consistent results because there were 11 studies showing greater distractibility in LMMs, three studies showing no difference between LMMs and HMMs, and 25 studies showing greater distractibility in HMMs.

Uncapher et al. [29] studied the relationship between multitasking and memory. Similar to the filtering test in the Ophir et al. study [22], participants had to remember a screen with four squares or objects in red and blue and respond to any change in the objects’ orientation after a certain time. HMMs had low working memory regardless of external interference. Long-term memory was also low due to working memory degradation. The participants' wide range of interests was found to be the cause of these results. This is because HMMs showed relatively advanced multisensory integration compared to LMMs [18]. Participants were asked about whether one of the 48 red and blue lines was vertical or horizontal, which changed at a certain time. In two of the four rounds, a short auditory tone was provided when changes were made. HMMs performed substantially worse than LMMs in a tone-absent condition, but there was no difference in a tone-present condition.

Studies investigating the relationship between MMI and task-switching ability have reported ambiguous results, showing that HMMs were worse [22,26,33], equivocal [2,21], or better [2] than LMMs. In the Ophir et al. study's task-switching experiment, HMMs had a slower response speed relative to LMMs [22]. Participants were tested to classify given alphabetical characters and as vowels or consonants, and given numbers as even or odd. Ophir et al. [22] had argued that HMMs were more severely affected by distractors and had lower performance. Sanbonmatsu et al. [26] asked participants to respond to a maths question, asking whether mathematical statements were true or false; they also conducted tests to determine the recall of suggested characters, such as 'a' and 'b', in order between the questions. Here, HMMs performed worse than LMMs. Another study by Wiradhany & Nieuwenstein [33], which duplicated the Ophir et al. study [22], produced same results, showing that HMMs were slower than LMMs on switch trials.

Minear et al. [21] used the switching task exactly as described by Ophir et al. [22]. They failed to get the same results as Ophir et al. [22] despite three attempts, and they did not find any significant difference between the two groups, HMMs and LMMs. The reasons behind these results were estimated to be: (1) the difference in HMM and LMM definitions, (2) the difference in activity of cognitive processes and loads, and (3) the difference in participants.

However, Alzahabi & Becker [2] in their study assumed that media multitasking was more akin to parallel processing than to task-switching. The task-switching block of tests they conducted was the same as in the Ophir et al. study [22], but they changed the nature of the dual-task block of tests such that the participant had to classify the alphabetical characters and numbers at the same time. Compared to Ophir et al.'s results [22], they found no relationship between MMI and dual-tasking performance. . However, HMMs did show better results in task-switching performance than LMMs. They assumed that these results were caused by recent drastic changes in the media environment and because of differences in gender distribution amongst the participants in the studies; Ophir et al. [22] did not reveal the gender of the participants in their study so there could have been many more male participants than in Alzahabi & Becker's study [2]. Additionally, they concluded that HMMs had acquired a wealth of practice going back and forth between tasks, rather than being efficient parallel processors, and that these practices allowed them to refine their task-switching skills. While the practices of task-switching have little impact on the ability to perform concurrent tasks, it does reduce the cost of task-switching by quickly reconfiguring them with new tasks or via complete suppression of existing tasks.

Because of these unclear consequences, Lin & Parsons [17] argue that the cause of these conflicting results may be the lack of ecological relevance because they focused on one aspect, such as cognitive work. For example, a heavy multitasker may not be a person that pays attention to one task at a time. Lin & Parsons [17] mentioned the need for a multi-tasking assessment that reflects the daily activities found in an ecologically valid functional capability assessment. Scott et al. [27] used an ecological approach to investigate multitasking behaviour, which required participants to properly allocate and use four interconnected performance-based functional tasks. The multitasking capabilities investigated here meant that participants had to plan and execute separate tasks within a specific time frame. Burgess et al. [6] stated that multitasking is a number of cognitive processes that must be performed to ensure successful execution. In other words, it includes information about the maintenance of these relationships and the immediate presentation of environmental stimuli, goals, and sub-objectives in an individual's working memory, as well as the associated strategy for carrying out these actions. Zhang & Hornof argued that the differences between the upper and lower performers did not come from inherent perceptual, cognitive, and athletic abilities, but from the skill of orchestrating complex symphonies of micro strategy selection, coordination, and execution [13,34].

There have been many studies to identify the relationship between MMI scores and people's specific abilities, but there has not yet been a consensus on the conclusion. The nature of these results suggests that there may be a reason for the current experimental composition, which lacks the ecological feasibility that people consider in the real world. This suggests that a new approach is needed to create an experiment that measures people's multitasking capabilities.

The Performance Trade-offs at Stake

There are obviously people who are good at task-switching in the real world. There have been recent studies of trade-offs in which people achieve greater performance by optimizing between different tasks. Farmer et al. [12] reported the results of experiments in which participants had to perform two independent tasks. Each of these tasks was rewarded based on how well the task was performed. The participants could not perform both tasks at the same time, so they had to decide how to divide their efforts between each task. Further, the researchers reviewed whether the participants were able to derive an optimal strategy by modelling the maximum possible rewards.

The experiments by Farmer et al. were organised as follows [12]: Participants were required to enter numbers with one hand and not to let a randomly-moving cursor out of a circle by operating a joystick with the other hand. Entering a number enabled them to obtain a score, and if the cursor went out of the circle, they then lost part of that score accordingly. However, since the experiment was set up so that they could not see or perform both tasks at the same time, they had to map out strategies for how long they would stay on which task. Three different payoff functions were applied under the same conditions. There are three loss conditions, which occur when the cursor moves outside the perimeter of the circle: one, where the participant loses all points that they had earned; two, where the participant loses 50 per cent of their points; and three, where they lose a fixed amount of points, a minus 500 penalty. People did not achieve the maximum rewards predicted by the modelling, but showed the use of appropriate interleaving strategies for each condition. These results suggested that participants were hedging risks. The results of this particular experiment did not predict long-term effects, so additional experiments were carried out. Two groups were tested the minus 500 points and minus 50 per cent penalty conditions, respectively, with sufficient practice opportunities, and they were tested the minus 200 per cent condition without any practice opportunities. The experiment also showed that in general, people can change their strategies in response to changes in the environment. Overall, people have been shown to adapt effectively while achieving a moderately good score by reducing risk, if not achieving the best performance. That is, there was an important implication that in human multitasking there is a strategic choice made about their goals.

Janssen et al. [14] conducted an experiment wherein two of three payoff functions were applied differently for each group. These payoff functions are: the reward is constant, the reward increases, or the reward decreases. This is meant to map to real-life situations. Editing a document, for example, comes with a high-reward, but over time, most of the errors have already been corrected, so the return decreases. In the Janssen et al. experiment [14], participants were able to score points when entering the exact location of the mole on the screen. Between the two screens, each with different payoff functions, participants had to devise an optimal strategy to achieve the best performance. Similar to the experimental results of a study by Farmer et al. [12], the participants in the Janssen et al. study demonstrated that people can use time efficiently in limited conditions, providing an ideal test bed for theoretical research on task interleaving efficiency [14]. Thus, how can we identify HMMs can achieve better results when interleaving multiple tasks?

Current Study

The aim of this dissertation is to determine whether HMMs do indeed have better capabilities to achieve optimum performance in multitasking environments. An experiment is conducted in which, to achieve high performance, time should be properly distributed between the two tasks to establish an optimal strategy. Participants are categorised into two groups, HMMs and LMMs, with improved MMIs that are simplified and reflect the current media environment. In order to measure their multitasking abilities, the task-switching experiment in the Farmer et al. study [12] is replicated. The experiment centres on inputting correct numbers in one task and controlling the position of a cursor in the other. It is a simple experiment, but they cannot manipulate both screens at the same time, so participants must create a strategy in which they should distribute their attention. This can be seen as very similar to their choices and focus on achieving efficient performance in a limited amount of time in their daily lives. There are two payoff functions in this experiment. The first payoff function is being given sufficient practice, which verifies the ability to perform simple multitasking repeatedly in real life. The second payoff function is being given no practice, confirming multitasking capabilities in environments that have not been experienced or environments which change frequently.

This dissertation has two predictions. The first is that HMMs and LMMs will not show different multitasking capabilities in familiar environments when they are given ample time to adapt. This will be determined by the average of the scores for each group shown in the first payoff function. The second is that HMMs will be more adaptable in unfamiliar and variable environments than LMMs. This will be confirmed by the average visit time and the average score between the two groups in the round with the second payoff function applied.

3. METHOD

Participants

Twenty students took part in this experiment voluntarily. There were 14 women and 6 men. Participants were aged between 22 and 34, with a median age of 24. They were paid £9 in compensation for responding to the MMI questionnaire and to participate in one set of experiments. In order to motivate active participation in a series of simple and repeated experiments, an additional £20 in prize money was paid to the one who achieved the highest score.

Materials

A questionnaire containing a total of 26 questions was printed and used for the MMI measurements. There were several additional demographics questions on this questionnaire.

This experimental environment was shown on a 21-inch monitor (Samsung S23B300H) with a resolution of 1,920 × 1,080 pixels, and each task was shown in a box that was 450 by 450 pixels. On the left, the typing task was placed on the right with the tracking task and there was a 127 pixels gap between the two tasks. However, participants had to manipulate the joystick's trigger to switch between them (see Figure 1). They were provided with a standard QWERTY keyboard (Logitech K270) with which to enter the numbers on the screen and a Logitech Extreme 3D Pro joystick to operate the cursors. The task-switching experiment in the Farmer et al. study [12] was replicated.

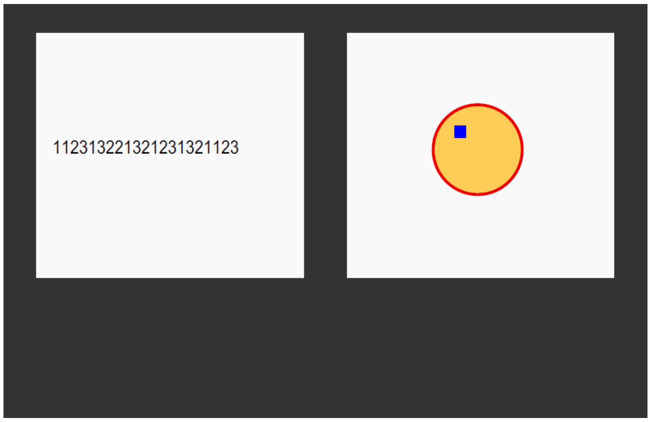

Figure 1. The two tasks, shown here side by side. In the experiment itself, only one task at a time was visible to the participants. Participants had to manipulate the joystick's trigger to switch between the two tasks (see text for details).

MMI Questionnaire

The MMI questionnaire in this study used the same items as in Edwards' study [11]: Print media, Television, Computer-based video, Music, Non-music audio, Video games, Voice calls, Instant messaging, Email, Web surfing, Other computer-based applications, Social networking service, and Other mobile applications. To secure a more accurate set of responses from participants, examples were provided for different items (such as Netflix and Instagram to denote Computer-based video and Social networking service) taking into account the current media environment to ensure that the young participants who were not native English speakers understood what was being described [3]. Plus, since the majority of participants were currently in the dissertation project period, a guide was given to respond in consideration of their usage in general conditions. Participants were asked to respond primarily to questions about the usage time per week of 13 media types. Then, when using each media type, they were required to choose between four options to how many different media types they used at the same time. Each item was coded 'Most of the time (= 1)', 'Some of the time (= 0.67)', 'A little of the time (= 0.33)', or 'Never (= 0)' and was quantified using the formula below.

$$wAMMI = 12 \times \sum_{i=1}^{13} \frac{am_i \times h_i}{h_{total}}$$

Where am_i is the simultaneous usage frequency of other media types for each media usage in which participants responded the second time, and h_i is the total weekly usage time for each media that was first answered. h_{total} is the weekly usage time of all media, or the sum of usage time for each media. The factor of 12 was used to calibrate the score size with the MMI used in existing papers.

Typing Task

Participants were required to use the numeric keypad to enter the 27 digits given on the screen sequentially, starting with the number on the left. When a correct digit was entered, it disappeared and the number sequence moved one space to the left, while a new number was added to the last position. The numbers were randomly generated, were between 1 and 3, with the same number set to not appear more than 3 consecutive times. The exact number input gave four points, and the wrong number input was imposed with a penalty of minus one point. The scores were not provided in real-time, and no screen effects were provided with incorrect input.

Tracking Task

Participants had to control the free-moving square cursor so that it would not exit the circle-shaped boundary. The size of the cursor was 10 × 10 pixels and the area of the circle was 120 pixels. The cursor moved a distance in pixels equal to the sampled value of a Gaussian distribution every 23 ms; a standard deviation cursor noise of four pixels was used. If the joystick was moved with the trigger held, the cursor moved with it. If the trigger was disengaged, the screen would switch to the typing task, meaning that participants could not see the current status of the cursor. Due to the characteristics of the free-moving cursor, there could be cases where the cursor moved out of the circle and back into the circle while participants were engaged in the typing task. In this case, the colour of the cursor changed to red. The red cursor did not change back to the original colour blue in real-time, even if the participants moved the cursor back into the circle. The same colour would persist for as long as the participant remained on the tracking task screen. The colour would return to blue if, on the next 'visit' to the tracking task, the cursor is kept within the circle. Similarly, the cursor would remain blue even if participants were unable to keep the cursor within the circle. In short, the colour change is solely to indicate if the cursor has left the boundary when the participant is on the other screen (typing task).

Payoff Function

The payoff function was given of four points for multiple numbers that had been inputted correctly during the typing task visit, a penalty of minus one point for multiple incorrectly entered numbers, and if the cursor went out of the circle in each the tracking task visit, an additional penalty of minus 50 per cent (round 2: minus 200 per cent) of the total points acquired the latest typing task visit.

Task-switching task round 1: exploitation

Both tasks were set such that they could not be viewed at the same time; participants were only able to see and control one task at a time. When the experiment started, the typing task was shown by default, and the tracking task was hidden. In order to manipulate the tracking task, participants had to press and hold the trigger on the joystick. When the trigger was released, the screen returned to the default state where only the typing task was visible. The participants' scores, average typing task visit times, and a number of transitions between two tasks were automatically recorded.

Participants were given a total of 20 trials and had to do their best to achieve high scores in each trial, which lasted 30 seconds. The main decision-making element that participants had to contend with was the balance between the typing task and the tracking task. They had to decide whether to spend a long time on typing task, the only way to score points, or how much to neglect the movement of the cursor, a major factor that would cause them to lose points. In other words, the weight of attack and defence had to be properly adjusted to derive the best strategy. After each attempt, the participants were able to check their obtained scores or performance. At the end of each set of five attempts, the average score of the last five rounds was provided; participants could rest for as long as desired. After all 20 attempts were completed, the total cumulative score was shown to the participants.

Task-switching task round 2: transfer

In round 2, most of the conditions were the same as in round 1, the only difference being the penalty given when the cursor was out of the circle, which was changed from minus 50 per cent to minus 200 per cent. A total of 10 attempts were given to the participants.

Design

Based on the MMI score, participants were divided into HMM and LMM groups to compare their performance in task-switching tasks. The Heavy group and the Light group were divided based on the median MMI scores.

Each participant was able to think about all the ways to maximize the score in 20 trials of the exploration stage (minus 50 per cent). Then in the 20 trials of the exploitation stage, a condition that was completely consistent with the exploration phase, they tried to achieve a high score based on the strategy they had developed. Finally, in the transfer stage (minus 200 per cent), they had to correct or maintain their strategies immediately without any practice. These steps were designed to confirm the difference in task-switching behaviour between the two groups and how quickly they adapt to the new environment and derive an optimal strategy. Other conditions, except for the penalty when the cursor was out of the circle, were kept the same across all stages. This minimised the complexity of modifying or maintaining their strategies based on the scores presented.

Procedure

The participants agreed to use their personal information in the consent form after reading the information sheet which provided details about the experiment. The experimenter gave the participants the MMI questionnaire and asked them to respond. At the end of the questionnaire, there were some brief demographic questions. The survey took about five to ten minutes in total.

Prior to the experimental test, participants were guided on how to press numbers on the keyboard, how to use the joystick, and were told that the participant who achieved the highest total score would receive an additional £20 as a prize. Participants were able to experience two 20-second typing tasks and two 10-second tracking tasks, before performing the two task-switching tasks to determine whether they had understood the experimenter's guidance. At this stage, participants were told that accurate typing would result in scores, but that they would receive penalty scores if they entered any numbers incorrectly or if the cursor went out of the circle. However, the complete method used to calculate scores was not disclosed.

The experiment consisted of a total of 50 task-switching trials; 20 trials in the exploration stage, 20 trials in the exploitation stage, and 10 trials in the transfer stage. In the exploration phase, the participants were given an additional chance to test each of the two typing and tracking tasks. Then 20 task-switching trials were carried out. Participants were instructed to explore and try different ways because their scores at this stage would not be reflected in the final score. After each trial, the participants were able to check their scores and modify their strategies based on those scores. A break was given every five trials, when the average scores for the last five trials could be checked. Participants were able to press the space bar to move on to the next trial if they thought they had rested enough. The exploitation phase was perfectly consistent with the exploration phase. In this step, however, participants were informed that these scores would be included in their final score. Finally, the transfer stage changed the penalty from minus 50 per cent to minus 200 per cent when the cursor moved out of the circle, with practice opportunities provided. Participants were required to infer and adapt to the changed conditions by observing their scores. All other conditions were all the same across each stage. The experiment took about 40 to 50 minutes in total.

Results

MMI

The MMI results of the 20 participants were: AMMI method ($M = 6.32$, $SD = 1.79$) and wAMMI method ($M = 7.21$, $SD = 2.03$). The two methods showed a positive correlation ($R2 = .63$), $F(1,18) = 29.96$, $p < .001$. This is in line with Edward's results [11] (See Figure 2).

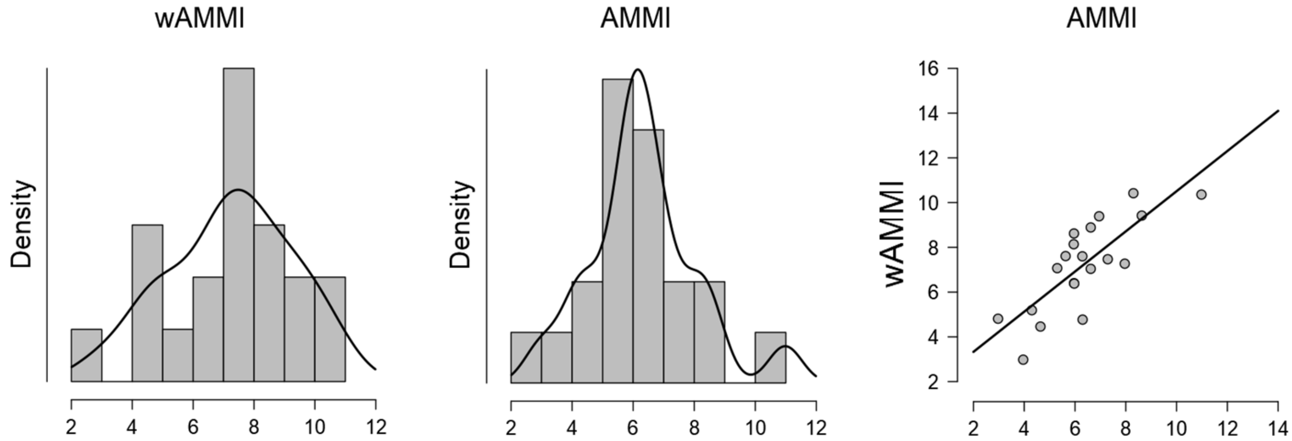

Figure 2. Pearson's correlation plot between wAMMI and AMMI.

Either AMMI or wAMMI had to be chosen to assess correlation with the task-switching task results. Similar to the MMI in the Ophir et al. study [22], which has been widely used so far, wAMMI, which has more general distribution, was chosen for use in this experiment. Participants were grouped into LMMs and HMMs based on a value of 7.37, the median of the wAMMI results; each group consisted of 10 participants.

Task-switching Task

The results of three participants with significantly lower numerical input accuracy were excluded [18,26]. The average of 17 accuracy (excluding the aforementioned three), was 96 per cent. The average of the excluded three was 59 per cent. This was because they were too faithful to the experiment's direction to achieve high scores. They capitalised on a limitation in the experiment itself where, rather than entering the given numbers in order, their total score was higher when they simply attempted to enter the numbers at random (even after penalties were applied). This allowed them to focus more of their attention on the tracking task. The average scores of the three participants in the combined first and second rounds were 20629.5, while the average scores for the rest were 4309.9. Two of these three were HMMs and one was an LMM. Therefore, there were eight HMMs and nine LMMs, excluding the three just discussed.

Exploitation Round

The performance of both HMMs and LMMs at this stage was not significantly different, although HMMs had a higher average score (HMMs = 4567, LMMs = 3819) and had a lower average visiting time to typing tasks (HMMs = 3.55 s, LMMs = 6.78 s) than LMMs. The results of Independent Samples t-test are as follows (See Table 1). This indicates that there is no difference between the two groups in an environment where sufficient exploration opportunities are given and there is no change in that environment.

Objects	t	df	p
Score (R1)	1.128	15.00	0.277
AvrTime (R1)	-1.918	15.00	0.074
AvrSwitching (R1)	1.694	15.00	0.111

Table 1. Student's t-test in the exploitation stage.

In the table, Score refers to the total points obtained in the Exploitation phase, AvrTime is the average time the participant stayed in the typing task, and AvrSwitching represents the average number of transitions between the typing task and the tracking task in each round.

Transfer Round

The performance of both HMMs and LMMs at this stage changed markedly (See Table 2). Except for the average number of transitions (where there was no change), the performance of the two groups differed significantly in the following areas: scores (HMMs = 1168, LMMs = -774.9) and average visiting seconds (HMMs = 2.43 s, LMMs = 3.14 s). HMMs are judged to be better able to adapt to the changed environment by modifying the strategy immediately compared to LMMs.

Objects	t	df	p
Score (R2)	2.502	15.00	0.024
AvrTime (R2)	-2.142	15.00	0.049
AvrSwitching (R2)	1.715	15.00	0.107a

[a] Levene's test is significant ($p < .05$), suggesting a violation of the equal variance assumption

Table 2. Student's t-test in the transfer stage.

4. DISCUSSION

In the context of multitasking, task-switching is not the ability to make faster and more frequent transitions, but the ability to perform more productive and accurate activities between transitions in pursuit of the overall goal [6,13,17,27,34]. Under this definition, the results of the exploitation round show that HMMs and LMMs' basic capabilities were similar. The two groups showed no particular difference when they were given ample practice and the opportunity to explore. These results do not diverge from the first of our hypotheses that multitasking abilities which are repeated daily or which function with sufficient practice do not differ significantly between the two groups. In other words, this means that, that LMMs can perform similar to HMMs if they are given sufficient practice.

However, in the transfer round, where no exercise opportunities were given, significant differences were observed in the scores and the average visiting times of both groups. This could suggest that HMMs had a higher innate task-switching capability to consider trade-offs in unfamiliar media environments, compared to LMMs. However, there was no difference in the number of times HMMs switched tasks compared to LMMs, suggesting that the HMMs keyed in the numbers more efficiently than the LMMs during each 'visit'. Furthermore, HMMs spent more time than LMMs on the cursor, ensuring that it did not leave the circle. This means that the task-switching ability in the multitasking context is not the ability to switch more quickly and frequently, but instead the precision when carrying out a specific task. These results suggest that HMMs are more likely to show superior multitasking capabilities in new environments or rapidly changing works than LMMs. This is consistent with the second hypothesis of this paper and with previous studies showing that there are indeed excellent multitaskers in the real world [31].

Implications

Multitasking ability has been defined with various terms, using various measures, such as memorisation, concentration, and task-switching ability [2,18,21,22,26,29]. This experiment indicates that, at a minimum, ability at media multi-tasking produces differences in the ability to task-switch. This has implications in that the multitaskers of today's era, where the mobile environment has developed and matured, are likely to have better task-switching ability and are better able to explore optimal rewards in concurrent multitasking environments than in sequential multitasking environments. This could further deepen in the future, considering the current media environment in which different media types and formats are used simultaneously, both at work and in daily life [17]. In addition, this study has shown that task-switching ability may not simply be the number of frequent transitions, but the ability to perform more efficiently on a given 'visit' to a particular task [6,17,27]. This means that future experimental designs seeking to investigate media multitasking may require more detailed performance measurement methods [17]. Findings may lead to further confirmation that HMMs are able to adapt quickly to newer or more complex environments in the current era of work or daily life. Executives or managers may get better results when HMMs are deployed to work in a new environment.

Limitations

Though improved Edwards [11] questionnaires were used to produce an MMI, it still does not adequately represent the current media environment. Some respondents said that compared to questions about other media, questions about the mobile environment were relatively small and unsegmented. This is because it was tied to item 13, 'other mobile environments'. This suggests that the current media environment has become more mobile-based than it was in 2017, just two years ago [17]. For example, even though there are various mobile-based media platforms and applications such as LinkedIn, Google Docs, and mobile scheduler, they were not fully reflected in the questions. The need for MMI questionnaires with better coverage of enhanced mobile usage behaviour has emerged. Alternatively, it may be possible to ask the same questions about mobile and PC usage times and give different weights after considering the participant's usage behaviour.

The limitations of laboratory testing and the number of participants make it difficult to determine the performance of each group in a real environment. Wiradhany & Nieuwenstein [33] indicated that at least 428 participants per group (of HMMs and LMMs) are needed to detect the exact effects based on the results of the meta-analysis for studies that followed Ophir et al. [22].

Plus, while this test means HMMs adapt quickly to the new environment, it cannot be concluded that they will perform better. Although the limitations of this experimental design may conclude that HMMs will perform more quickly on an adaptive basis, there may not be sufficient evidence that HMMs will perform better on any long-term events in real life. Of course, it may be assumed that HMMs can perform better in terms of their higher scores on the exploitation task, but given the various factors taking place in the real world, field tests are necessary in a long-term study.

Carrier et al. [7] and Rigby et al. [23] mention that there may be generational differences in media multitasking, giving rise to the need to investigate this matter with respect to age. This is because these results are based solely on students in their early twenties and does not account for older individuals who did not grow up with modern digital technology.

There are a few studies investigating the relationship between personality and multitasking [4,9,19,29]. Participants' personality differences may affect media usage behaviour. HMMs may be more interested and immersed in new environments than LMMs, while LMMs' interest in simpler, more repetitive tasks may affect their media usage behaviour. This means that a study may be needed on the nature of the participants and the correlation between MMI scores. Such research could in the future make important discoveries that give easier access to media multitasking's capabilities in the real world.

Finally, the scores of three participants were excluded from the test. This was because there was a small problem with the experimental design in that the penalty of mistyping was relatively low, allowing those participants to exploit that and adopt a strategy for obtaining a higher score (randomly typing numbers and focusing instead on the tracking task) but one which ran counter to the aims of this study, as they were no longer multitasking. Therefore, subsequent studies may be able to respond to this problem either by increasing the penalty of mistyping or by increasing the range of numbers to be entered.

5. CONCLUSION

The results of this experiment show significant differences between people's media multitasking and task-switching abilities. In other words, HMMs have demonstrated that that they can develop a faster and better strategy in changing environments than LMMs. The results of this study show that media multitasking activities affect people's adaptations to new environments.

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REFERENCES

1. Mariek M.P. Vanden Abeele. 2016. Mobile youth culture: A conceptual development. Mob. Media Commun. (2016). DOI:https://doi.org/10.1177/2050157915601455
2. Reem Alzahabi and Mark W. Becker. 2013. The association between media multitasking, task-switching, and dual-task performance. J. Exp. Psychol. Hum. Percept. Perform. (2013). DOI:https://doi.org/10.1037/a0031208
3. Susanne E. Baumgartner, Jeroen S. Lemmens, Wouter D. Weeda, and Mariette Huizinga. 2017. Measuring Media Multitasking. J. Media Psychol. (2017). DOI:https://doi.org/10.1027/1864-1105/a000167
4. Mark W. Becker, Reem Alzahabi, and Christopher J. Hopwood. 2013. Media Multitasking Is Associated with Symptoms of Depression and Social Anxiety. Cyberpsychology, Behav. Soc. Netw. (2013). DOI:https://doi.org/10.1089/cyber.2012.0291
5. S. Adam Brasel and James Gips. 2011. Media Multitasking Behavior: Concurrent Television and Computer Usage. Cyberpsychology, Behav. Soc. Netw. 14, 9 (2011), 527–534. DOI:https://doi.org/10.1089/cyber.2010.0350
6. Paul W. Burgess, Nick Alderman, Catrin Forbes, Angela Costello, Laure M.A. Coates, Deirdre R. Dawson, Nicole D. Anderson, Sam J. Gilbert, Iroise Dumontheil, and Shelley Channon. 2006. The case for the development and use of "ecologically valid" measures of executive function in experimental and clinical neuropsychology. J. Int. Neuropsychol. Soc. (2006). DOI:https://doi.org/10.1017/S1355617706060310
7. L. Mark Carrier, Nancy A. Cheever, Larry D. Rosen, Sandra Benitez, and Jennifer Chang. 2009. Multitasking across generations: Multitasking choices and difficulty ratings in three generations of Americans. Comput. Human Behav. (2009). DOI:https://doi.org/10.1016/j.chb.2008.10.012
8. Quan Chen and Zheng Yan. 2016. Does multitasking with mobile phones affect learning? A review. Computers in Human Behavior. DOI:https://doi.org/10.1016/j.chb.2015.07.047
9. Brittany R.-L. Duff, Gunwoo Yoon, Zongyuan (Glenn) Wang, and George Anghelcev. 2014. Doing It All: An Exploratory Study of Predictors of Media Multitasking. J. Interact. Advert. (2014). DOI:https://doi.org/10.1080/15252019.2014.884480
10. Cora M. Dzubak. 1989. Multitasking: The good, the bad, and the unknown. J. Chem. Inf. Model. (1989). DOI:https://doi.org/10.1017/CBO9781107415324.004
11. Justin Edwards. 2017. A New Index to Measure Media Multitasking. Undergrad. Res. J. Psychol. UCLA 4, May 2017 (2017), 38–45. Retrieved from https://urjp.psych.ucla.edu/publications/
12. George D. Farmer, Christian P. Janssen, Anh T. Nguyen, and Duncan P. Brumby. 2018. Dividing Attention Between Tasks: Testing Whether Explicit Payoff Functions Elicit Optimal Dual-Task Performance. Cogn. Sci. 42, 3 (2018), 820–849. DOI:https://doi.org/10.1111/cogs.12513
13. Anthony J. Hornof, Yunfeng Zhang, and Tim Halverson. 2010. Knowing where and when to look in a time-critical multimodal dual task. (2010), 2103. DOI:https://doi.org/10.1145/1753326.1753647
14. Christian P. Janssen, Emma Everaert, Heleen M.A. Hendriksen, Ghislaine L. Mensing, Laura J. Tigchelaar, and Hendrik Nunner. 2019. The influence of rewards on (sub-)optimal interleaving. PLoS One 14, 3 (2019), 1–25. DOI:https://doi.org/10.1371/journal.pone.0214027
15. Donghee Kim, Kyungsik Han, Jeong Seop Sim, and Youngtae Noh. 2018. Smombie guardian: We watch for potential obstacles while you are walking and conducting smartphone activities. PLoS One (2018). DOI:https://doi.org/10.1371/journal.pone.0197050

16. Annie Lang and Jasmin Chrzan. 2016. Media Multitasking: Good, Bad, or Ugly? Ann. Int. Commun. Assoc. 39, 1 (2016), 99–128. DOI:https://doi.org/10.1080/23808985.2015.11679173
17. Lin Lin and Thomas D. Parsons. 2018. Ecologically Valid Assessments of Attention and Learning Engagement in Media Multitaskers. TechTrends (2018). DOI:https://doi.org/10.1007/s11528-018-0311-8
18. Kelvin F.H. Lui and Alan C.N. Wong. 2012. Does media multitasking always hurt? A positive correlation between multitasking and multisensory integration. Psychon. Bull. Rev. (2012). DOI:https://doi.org/10.3758/s13423-012-0245-7
19. Gloria Mark, Shamsi T Iqbal, Mary Czerwinski, Paul Johns, and Akane Sano. 2016. Neurotics can't focus : An in situ study of online multitasking in the workplace. Proc. SIGCHI Conf. Hum. Factors Comput. Syst. (2016). DOI:https://doi.org/10.1145/2858036.2858202
20. Gloria Mark and Norman Makoto Su. 2010. Making infrastructure visible for nomadic work. Pervasive Mob. Comput. 6, 3 (2010), 312–323. DOI:https://doi.org/10.1016/j.pmcj.2009.12.004
21. Meredith Minear, Faith Brasher, Mark McCurdy, Jack Lewis, and Andrea Younggren. 2013. Working memory, fluid intelligence, and impulsiveness in heavy media multitaskers. Psychon. Bull. Rev. (2013). DOI:https://doi.org/10.3758/s13423-013-0456-6
22. Eyal Ophir, Clifford Nass, and Anthony D. Wagner. 2009. Cognitive control in media multitaskers. Proc. Natl. Acad. Sci. (2009). DOI:https://doi.org/10.1073/pnas.0903620106
23. Jacob M. Rigby, Duncan P. Brumby, Sandy J.J. Gould, and Anna L. Cox. 2017. Media Multitasking at Home. DOI:https://doi.org/10.1145/3077548.3077560
24. Yvonne Rogers. 2006. Moving on from Weiser's Vision of Calm Computing: Engaging UbiComp Experiences. DOI:https://doi.org/10.1007/11853565_24
25. Dario D Salvucci, Niels A Taatgen, and Jelmer P Borst. 2009. Toward a unified theory of the multitasking continuum: From concurrent performance to task switching, interruption, and resumption. Proc. SIGCHI Conf. Hum. Factors Comput. Syst. (CHI '09) (2009), 1819–1828. DOI:https://doi.org/10.1145/1518701.1518981
26. David M. Sanbonmatsu, David L. Strayer, Nathan Medeiros-Ward, and Jason M. Watson. 2013. Who Multi-Tasks and Why? Multi-Tasking Ability, Perceived Multi-Tasking Ability, Impulsivity, and Sensation Seeking. PLoS One 8, 1 (2013). DOI:https://doi.org/10.1371/journal.pone.0054402
27. J. Cobb Scott, Steven Paul Woods, Ofilio Vigil, Robert K. Heaton, Brian C. Schweinsburg, Ronald J. Ellis, Igor Grant, Thomas D. Marcotte, and The San Diego HIV Neurobehavioral Research Center (HNRC) Group. 2011. A Neuropsychological Investigation of Multitasking in HIV Infection: Implications for Everyday Functioning. Neuropsychology (2011). DOI:https://doi.org/10.1037/a0022491
28. John C Tang and San Jose. 1991. Ubiquitous computing : Individual productivity at the expense of social good ? (1991), 1–5.
29. Melina R. Uncapher, Monica K. Thieu, and Anthony D. Wagner. 2016. Media multitasking and memory: Differences in working memory and long-term memory. Psychon. Bull. Rev. (2016). DOI:https://doi.org/10.3758/s13423-015-0907-3
30. Victoria R. Wagner-Greene, Amy J. Wotring, Thomas Castor, Jessica Kruger, Joseph A. Dake, and Sarah Mortemore. 2017. Pokémon GO: Healthy or harmful? American Journal of Public Health. DOI:https://doi.org/10.2105/AJPH.2016.303548
31. Jason M. Watson and David L. Strayer. 2010. Supertaskers: Profiles in extraordinary multitasking ability. Psychon. Bull. Rev. 17, 4 (2010), 479–485. DOI:https://doi.org/10.3758/PBR.17.4.479
32. Mark Weiser. 1991. the Computer of 21Th Century - Wieser. Sci. Am. 265, 3 (1991), 94–104.
33. Wisnu Wiradhany and Mark R. Nieuwenstein. 2017. Cognitive control in media multitaskers: Two replication studies and a meta-Analysis. Attention, Perception, Psychophys. (2017). DOI:https://doi.org/10.3758/s13414-017-1408-4
34. Yunfeng Zhang and Anthony J. Hornof. 2014. Understanding multitasking through parallelized strategy exploration and individualized cognitive modeling. (2014), 3885–3894. DOI:https://doi.org/10.1145/2556288.2557351