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That's easy! The effects of objective and subjective task difficulty when multitasking

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Abstract

As systems grow in complexity, there are more tasks that people want to complete simultaneously. Prior research has shown that receiving interruptions hurts people's performance. A few studies have found that interruptions can negatively impact performance during a hard task, but can help in an easy task. Our research intends to better understand the performance implications of users multitasking during simple and complex tasks by examining task difficulty both objectively and subjectively. We created a web-based word search puzzle as the primary task with an objectively easy and hard version. 726 were randomized into one of four conditions. In the first two conditions, participants received the objectively easy or hard version of the primary task and did not receive any interruptions. In the latter two conditions participants received the easy and hard versions with interruptions. Subjective difficulty was measured based on the participants' opinions of the primary task. While we did not find any significant differences in conditions with the objective or subjective divisions, however, when participants perceived the interrupting task as difficult receiving interruptions during both the easy and hard conditions helped participants perform better. This was only true for the subjective breakdown. These findings suggest that the difficulty level of the interrupting task may impact users' performance outcome when receiving interruptions. We also found that while there was no significant correlation between participants' propensity to multitask and performance in the interrupting conditions, when examining those who did not receive interruptions, participants' performance significantly positively correlated with their propensity to multitask. This implies that multitasking users perform better than non-multitasking users when mono-tasking.

Keywords: Multitasking; Performance; Interruptions; Objective; Subjective

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1.Introduction

Today many people multitask, whether at home or at work. We know that multitasking is often inefficient, yet it is not easy to stop. As systems grow in complexity and accessibility, information workers deal with a higher workload [1]. A lot of multitasking occurs when people switch between tabs on the web. Often there are more tasks that people want to complete and more activities are being done simultaneously to save time.

Our research intends to better understand the performance implications of people multitasking during simple and complex tasks. Task complexity can be classified into two different groups, objective and subjective [2]. Subjective task complexity is based on the mental experience of the user, while objective task complexity is based upon the characteristics of the task itself [2]. Having these two measures of task complexity can help researchers inspect, both objectively and subjectively, the impacts of multitasking and task complexity during easy and hard tasks.

Multitasking occurs when individuals work on two or more tasks simultaneously, like talking on the phone while typing emails or eating food while working on an assignment. Previous research has discussed different questions such as whether interruptions help or hinders people's performance and efficiency.

Understanding the implication and effects of user multitasking is important since people use computers and switch between applications very often in school, in the workplace, and at home. By analyzing the performance effects of multitasking on the tasks performed, system designers can learn to build systems to reduce the negative effects of multitasking.

2.Background Literature

2.1.Effects of Interruptions on Multitasking Performance

Many researchers have observed the effects of interruptions on human behavior. Interruptions effect people's performance negatively and can cause them to make mistakes and reduce their efficiency [3,4]. Interruptions can be classified into two categories: internal and external interruptions. Internal interruptions are the effects of internally backgrounded activities, while external interruptions are the effects of activities that people perform outside the focus of their conscious attention [5]. One example of an internal interruption can be that, while working on a specific project, we remember we need to pay a phone bill. An external interruption could be someone physically interrupting another at the work place while s/he is working on a project.

Zijlstra et al. [6] similarly hypothesized that interruptions hurt task performance. However, contrary to their hypothesis, they found that interruptions helped people perform primary tasks faster, though the performance remained the same.

Interruptions take time away from working on an ongoing work activity, potentially resulting in a feeling of time pressure and ultimately, information overload. Furthermore, an interruption breaks a decision maker's attention on a primary task which forces the decision maker to turn his or her attention towards the interruption [7].

An experiment was done to determine the effects of multitasking in the classroom [8]. Two groups of students heard the same lecture and were tested immediately after. One group of students was allowed to use their laptops and to engage in browsing, searching, and/or social computing behaviors during the lecture. Students in the second condition were not allowed to use their laptops. The results showed that the students who used laptops suffered decrements on traditional measures of memory for lecture content.

McFarlane [9] examined four categories of interruptions: immediate, negotiated, mediated, and scheduled. In immediate interruptions, the user has to respond immediately. In negotiated interruptions, the user can choose when or whether to be interrupted. In mediated interruptions, a middle agent would determine when the interruption would occur. Lastly, in scheduled interruptions, the user gets interrupted in intervals. The results indicate that negotiated interruption is the best solution.

Many studies on the effects of interruptions have shown that interruptions can be disruptive to the performance of the primary task [10,11]. Specifically, examining the context of the primary task and how different types of tasks, or the difficulty level of the primary task, are affected by interruptions can be beneficial in understanding the performance implications of multitasking.

2.2. Task Complexity and the Effects of Interruptions

When examining performance research, task complexity has become an important factor [2]. Gillie and Broadbent [3] found that the type of the interruption (i.e., the similarity of the primary task) and the difficulty level of the interruption are factors which determine whether interruptions negatively affect the performance on the primary task. Different and dissimilar interruptions are less disruptive than when the primary task and the interrupting tasks were similar [3].

Speier et al. [12] found that interruptions improved performance on simple tasks and hurt performance on complicated tasks. If the primary task is complex, it might be more difficult for the user to resume the primary task. For example, if a primary task is simple like shredding papers, and the user is interrupted, s/he might easily figure out where s/he left of by checking the papers which are not shredded. However, if the primary task is difficult, such as solving calculus problems, it would be difficult for the user to resume the task as simply since the user will need to spend time recalling the previous calculation and formulas he applied to that calculation in order to resume solving the problem.

Adler and Benbunan-Fich [13] examined subjective task difficulty, where participants were asked whether they found the task difficult, and found that when that receiving interruptions during a task that was considered difficult it hurt performance, but helped performance when the task was perceived as simple.

3. Hypotheses

Speier et al. [12] found that interruptions helped performance on simple tasks and hurt performance on complicated tasks. However, task performance depends not only on objective task complexity but also on subjective observations of task difficulty as well [2]. Subjective task difficulty has received much less attention than objective. It provides an estimate of mental load experienced by participants and provides theoretical descriptions for the different effects on performance [2]. Subjective task difficulty refers to the observation that some tasks seem harder due to an instinctive sense of difficulty [13]. A task that is hard for one individual may be easier for another. Adler and Benbunan-Fich [13] found that receiving interruptions during a task that was considered difficult can hurt performance, but helps performance when the task is perceived as simple. This research examines both objective and subjective task difficulty in a single study. Therefore, we hypothesize:

Objective Hypotheses:

H1. Participants who complete a difficult task without an interruption will perform better than those who receive interruptions.

H2. Participants who complete an easier version of the task and receive interruptions will perform better than those without interruptions.

Subjective Hypotheses:

H3. Participants who complete a task they consider difficult without an interruption will perform better than those who receive interruptions.

H4. Participants who complete a task they consider easier and receive interruptions will perform better than those without interruptions.

4.Methodology

4.1.Participants

Seven hundred and twenty six participants (336 female and 390 male) completed our experiment. Participants were recruited via Amazon.com's Mechanical Turk and received $1 for completing the task. The effectiveness of this method of subject recruitment has been demonstrated in several studies that find MTurk samples to be generally reliable and comparable to more expensive methods [14-18]. This new platform opens up the possibility of recruiting this larger number of subjects with relative ease and at low cost. One participant was removed because his experiment had frozen on him in the middle, and he wrote that he did not complete it accurately. The remaining 725 participants' results were analyzed.

4.2.Objective Conditions

We developed a website with two different tasks. Our primary task was a word search puzzle and our interrupting task was the game, Snake. We created two versions of the word search puzzle, easy and hard. Participants were randomly assigned into one of the four conditions of the experiment. These conditions were based on objectively difficult and easy versions of the primary task:

1. *Easy with No Interruptions (ENoI):* This control condition received an easy version of the word search puzzle. The objectively easy version had a 20X20 grid of words and the answers could appear top to bottom (downwards) and left to right (forward). They did not receive interruptions.
2. *Hard with No Interruptions (HNoI):* This control condition received a hard version of the word search puzzle. The objectively hard version had a 30X30 grid of words and the answer could appear top to bottom (downwards), bottom to top (upwards), left to right (forward), right to left (backwards), and all four diagonal (top left to bottom right, bottom left to top right, top right to bottom left, bottom right to top left). They did not receive interruptions in this condition.
3. *Easy with Interruptions (EI):* Participants in this condition received an easy version of the word search puzzle and received interruptions of the snake game.
4. *Hard with Interruptions (HI):* Participants in this condition received a hard version of the word search puzzle and received interruptions of the snake game.

In all four conditions, participants had eight minutes to complete the puzzle. See Figures 1 and 2 for screenshots of the hard and easy versions of the puzzle. In both versions, there were 40 words on the right-hand side of the puzzle for participants to find. Forty words was chosen based on pilot testing since we did not want participants to be able to find all the words before the time ran out. Those in the interrupting easy and hard conditions had four interruptions during the eight minutes allotted for the word search puzzle. The clock stopped when the snake game appeared and resumed once the snake game ended. A word search puzzle was chosen as the primary task, since it was a good task to form objectively easy and hard versions of. We chose Snake as our secondary task. The goal of the snake game is for the snake to eat as many spiders as it can while growing longer. The game ends if the snake's head touches the wall or itself. This was chosen as our secondary task due to it being a fun game similar to what people often play while multitasking.

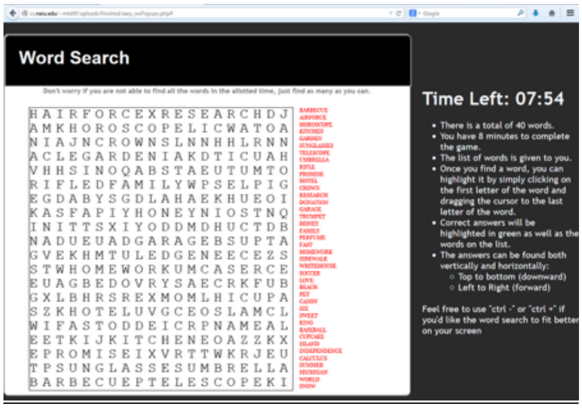

Figure 1. Easy Version of the Word Search Puzzle

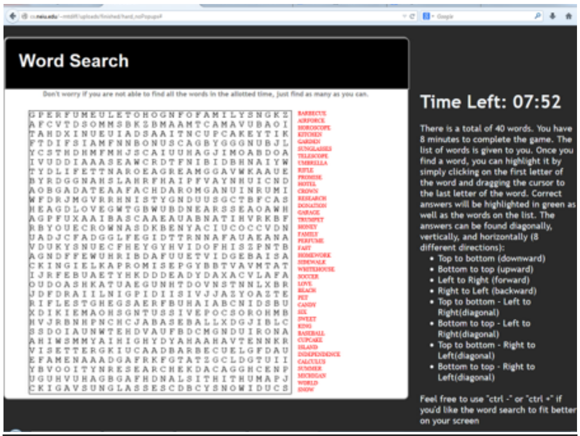

Figure 2. Hard version of the Word Search Puzzle

4.3.Subjective Conditions

We used Maynard and Hakel's [2] subjective scale to break down the user conditions into a subjective categories. In the post-test we asked participants to rank their agreement with the below statements based on a 7-point Likert Scale.

1. *I found this to be a complex task.*
2. *This task was mentally demanding.*
3. *This task required a lot of thought and problem solving.*
4. *I found this to be a challenging task.*

The four questions loaded as one factor with all items .89 or higher. The raw and standardized Cronbach Alpha was .92. We averaged the four subjective difficulty questions together and considered participants in the easy category if their average subjective difficulty was less than 4. Those with greater than 4 were considered as having a subjective difficulty level of hard. Those who averaged exactly 4 were removed from the subjective category.

4.4.Measures

Performance – Performance was calculated as the number of words found in the puzzle.

Interrupting Task Difficulty – Participants were asked to rank the difficulty of the interrupting task from 1-5.

Multitasking Propensity – Using a modified scale from Bluedorn et al. [19] we asked participants questions pertaining to whether they multitasked in general. One question was reversed. These loaded as one factor with items all greater than .76. The raw and standardized Cronbach Alpha was .88.

4.5.Process

After agreeing to the consent form, participants filled out a pre-task questionnaire for their demographic information as well as information pertaining to their experience with word search puzzles, the snake game, and multitasking in general. Next, participants were directed to a practice tutorial of the word search puzzle. Those in the interrupting conditions received a practice version of the snake game. All participants were then directed to the instructions and the actual experiment.

Once the allotted time had passed, participants were brought to a post-test questionnaire. Those in the interrupting condition were given an additional questionnaire asking them specific questions about the interruptions.

5.Results

We did not find any significant differences in conditions with the objective or subjective divisions. Therefore, our hypotheses were not supported. However, when we took into account the difficulty level of the interrupting task and only examined those who found the interrupting task difficult, interruptions helped for the subjective category. When participants perceived the interrupting task as difficult receiving interruptions during both the easy and hard conditions helped participants perform better (EI_{Mean} = 31.27; $ENoI_{Mean}$=28.03; HI_{Mean} =18.76; $HNoI_{Mean}$=16.18; $F(3, 566)=67.78$, $p<.0001$). See Figure 3. Those in the Easy with Interruptions condition performed significantly better than Easy without Interruptions, and those in the Hard with Interruptions performed significantly better than those in the Hard with No Interruptions. This was only true for the subjective breakdown.

Figure 3. Performance across subjective conditions when the interrupting task was perceived as difficult.

Furthermore, we ran a linear regression which showed a significant and positive relationship between performance and the difficulty level of the interrupting task ($F(1, 321)=12.26$, $p=0.0005$, see Figure 4). The more difficult one found the interruptions the better the performance.

Figure 4. Linear Model between Performance and Interrupting Task Difficulty

5.1.Multitaskers

This study also examined participants' multitasking habits and asked users to indicate whether they liked to multitask in general. We found that while there was no significant correlation between participants' propensity to multitask and performance in the interrupting conditions, when examining those who did not receive interruptions, participants' performance significantly positively correlated with their propensity to multitask ($\rho=0.16$, $p=0.002$). Figure 5 shows a linear regression between performance and multitasking propensity in the mono-tasking (no interruptions) and multitasking (interruptions) conditions. Only the mono-tasking conditions was significant (Mono-tasking Conditions: $F(1, 384)=9.64$, $p=0.002$). This implies that multitasking users perform better than non-multitasking users when mono-tasking.

Figure 5. Linear Model between Performance and Multitasking Propensity

6.Discussion

Our results differ than previous research as we did not find that interruptions hurt performance on the primary task, but appeared to help performance. In fact, as mentioned by Cades et al. [10], while difficult interruptions may not lead to greater disruptions, however, other factors within the interruption should be examined.

In Adler and Benbunan-Fich [13], receiving interruptions hurt performance during difficult tasks, however the primary task was a Sudoku puzzle and Sudoku is a primary task where the entirety of the task is all dependent on each other. In the word search puzzle, each word can be more similar to a sub-task, where receiving interruptions may not have made as much of a negative impact. Furthermore, our findings indicate that overall most people found the word search hard. In the subjective breakdown 460 participants found the task hard, while 231 found it to be easy. Perhaps since the puzzle was viewed as difficult by the majority of the participants, the interruptions actually produced a necessary break.

7.Conclusion

These findings suggest that subjective rather than objective may be a better measure to use in terms of studying task difficulty and that the difficulty level of the interrupting task may impact users' performance outcome when receiving interruptions. Difficult interruptions may be helpful rather than harmful to performance. Future research can explore different levels of objective difficulty for the interrupting task.

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References

[1] V.M. Gonzalez and G. Mark: 'Constant, Constant, Multi-Tasking Craziness': Managing Multiple Working Spheres. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '04) (2004) 113-120.

[2] D.C. Maynard and M.D. Hakel: Effects of Objective and Subjective Task Complexity on Performance. Human

Performance 10 (1997) 303-330.
[3] T. Gillie and D. Broadbent: What Makes Interruptions Disruptive? A Study of Length, Similarity, and Complexity. Psychological Research 50 (1989) 243-250.
[4] B.P. Bailey and J.A. Konstan: On the Need for Attention-Aware Systems: Measuring Effects of Interruption on Task Performance, Error Rate and Affective State. Computers in Human Behavior 22 (2006) 658-708.
[5] D.C. McFarlane and K.A. Latorella: The Scope and Importance of Human Interruption in Human-Computer Interaction Design. Human-Computer Interaction 17 (2002) 1-61.
[6] F.R.H. Zijlstra, R.A. Roe, A.B. Leonora and I. Krediet: Temporal Factors in Mental Work: Effects of Interrupted Activities. Journal of Occupational and Organizational Psychology 72 (1999) 163-185.
[7] C. Speier, J.S. Valacich and I. Vessey: The Influence of Task Interruption on Individual Decision Making: An Information Overload Perspective. Decision Sciences 30 (1999) 337–360.
[8] H. Hembrooke and G. Gay: The Laptop and the Lecture: The Effects of Multitasking in Learning Environments. Journal of Computing in Higher Education 15 (2003) 46-64.
[9] D.C. McFarlane: Comparison of Four Primary Methods for Coordinating the Interruption of People in Human-Computer Interaction. Human-Computer Interaction 17 (2002) 63-139.
[10] D.M. Cades, D.a.B. Davis, J.G. Trafton and C.A. Monk: Does the Difficulty of an Interruption Affect Our Ability to Resume? In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, (2007) 234-238.
[11] Y. Miyata and D.A. Norman. "Psychological Issues in Support of Multiple Activities," in User Centered System Design, D. A. Norman and S. W. Draper (Eds.) Lawrence Erlbaum, Hillsdale, N.J., USA, 1986 pp. 265-284.
[12] C. Speier, I. Vessey and J.S. Valacich: The Effects of Interruptions, Task Complexity, and Information Presentation on Computer-Supported Decision-Making Performance. Decision Sciences 34 (2003) 771-797.
[13] R.F. Adler and R. Benbunan-Fich: The Effects of Task Difficulty and Multitasking on Performance. Interacting with Computers (2014).
[14] M. Buhrmester, T. Kwang and S.D. Gosling: Amazon's Mechanical Turk a New Source of Inexpensive, yet High-Quality, Data? Perspectives on Psychological Science 6 (2011) 3-5.
[15] J. Chandler, P. Mueller and G. Paolacci: Nonnaivete among Amazon Mechanical Turk Workers: Consequences and Solutions for Behavioral Researchers. Behavior Research Methods 46 (2014) 112-130.
[16] J.J. Horton, D.G. Rand and R.J. Zeckhauser: The Online Laboratory: Conducting Experiments in a Real Labor Market. Experimental Economics 14 (2011) 399-425.
[17] W. Mason and S. Suri: Conducting Behavioral Research on Amazon’s Mechanical Turk. Behavior Research Methods 44 (2012) 1-23.
[18] D.N. Shapiro, J. Chandler and P.A. Mueller: Using Mechanical Turk to Study Clinical Populations. Clinical Psychological Science 1 (2013) 213-220.
[19] A.C. Bluedorn, C.F. Kaufman and P.M. Lane: How Many Things Do You Like to Do at Once? An Introduction to Monochronic and Polychronic Time. Academy of Management Executive 6 (1992) 17-26.