**Understanding the impact of information richness and external online interruptions on task performance**

Abstract

This study examined the effect of information richness in the content of online interruptions and the frequency of such interruptions on the quality of cognitive performance. A total of 250 participants took part in a computerized game that simulated online external interruptions. A significant difference in the quality of cognitive performance was found between participants who experienced online interruptions with less frequency compared with those who experienced them with greater frequency. The richness of the information presented during the interruptions did not independently affect the quality of participants’ cognitive performance. However, the interaction between the richness of information and the interruption rate significantly affected the quality of cognitive performance.

Keywords: online interruption, information richness, simulation

**1. Introduction**

The concept of interruption has drawn a great deal of interest among researchers who study managerial work. Much emphasis has been placed on how a manager copes with interruption and multitasking—that is, switching between different tasks or the combination of shifting between a particular task and communicating with others (Iqbal & Horvitz 2007; Mark et al., 2012).

Empirical studies have attempted to identify the effect of interruption on task performance. Many studies have examined the effect of interruption on managers’ multitasking capacity in a technological environment in which they alternate between various tasks, independent work, and communication with others (Bailey & Konstan, 2006; Iqbal & Horvitz, 2007). For example, Ophir et al. (2009) found that people who engage in a high degree of multitasking within a communications technology environment perform more poorly than those who do not, and those who multitask are more likely to have a tendency toward distractibility.

### 1.1 Workplace interruptions and fragmented work

Fragmented work is defined as a break in continuous work activity (Mark et al., 2005). Studies of managers’ performance and fragmented work found that self-interruption frequently occurs among workers in an “open space” environment (Hudson et al., 2002). Self-interruptions prevent people from completing individual tasks as compared with tasks that involve other people. Studies that examine the extent of fragmented work have discovered that people interrupt themselves as often as they are interrupted by external sources (González & Mark, 2004). A study on how to support proper decision-making in response to interpersonal interruption management (Grandhi & Jones, 2010) examined decision-making in answering a phone call. The study found that within a social or cognitive context, 87% of participants relied on the caller’s identity as a factor in the decision to answer. The study further found that one-fourth of the participants needed to answer calls in the middle of a meeting. Another important finding of the study was that people preferred to receive even nonessential information to ensure that they did not miss important calls or information. The study was based on the interruption value evaluation paradigm, which addresses interruption as something beneficial (Grandhi et al., 2008) when assessed in a social or cognitive context and based on the benefit it provides.

Salvucci and Taatgen (2011) view interruption as a form of multitasking because the person interrupted must simultaneously cope with several tasks. In recent years, special attention has been paid to improving people’s ability to cope with multitasking and manage interruptions efficiently, such as by deciding whether to decline or answer a phone call (Grandhi & Jones, 2010). The effects of switching tasks and transitioning between activities can manifest as slow or sloppy performance, stress, or frustration. People tend to alter tasks if they feel they are not progressing sufficiently in an activity (Payne et al., 2007). Sometimes, switching tasks improves alertness when performing a monotonous task (Atchley & Chan, 2011). Gould et al. (2016) examined whether people who were interrupted by a request to pause while entering data checked their work once they resumed it before confirming the input. The findings indicated that if the interruption was too short, people did not check their input before confirming it. On the other hand, if the interruption was too long, they switched tasks.

Researchers have sought to quantify the cognitive cost of shifting attention between tasks (Janssen et al., 2011) and have examined the reduced effect of interruptions that are limited to subtasks. For example, Gould et al. (2016) examined whether people who were interrupted by a request to pause while entering data (fewer complex tasks) checked their input once they resumed working on the performance of the main task (Janssen & Brumby, 2010; Janssen et al., 2012). A long or demanding interruption in task performance makes it more difficult to resume and continue the original task (Monk et al., 2008). On the other hand, refocusing on the task is more comfortable if the subject matter of the interruption was related to the interrupted task (Czerwinski et al., 2000). In addition, restarting a task after an interruption may help reduce potential mistakes in the task (Brumby et al., 2013).

### 1.2 Types of online interruptions: Are interruptions beneficial or disruptive?

Most studies that have examined interruptions in the context of human–computer interactions and computer-based work addressed external interruptions (Adler & Benbunan-Fich, 2013; Dabbish et al., 2011).

Mark et al. (2005) found that an interruption effect can be beneficial or detrimental: interruptions outside of a task’s context were disruptive, whereas interruptions relating to the same context as the task were beneficial. An interruption harms work when it involves switching among tasks in different contexts and creates unnecessary work. Moreover, an interruption can cause one to forget the main task’s focus (Cutrell et al., 2001). Alternatively, an interruption can effectively help people to gain control over work when deciding whether to respond to others (Wajcman & Rose, 2011) or when gathering information (Mark et al., 2005).

### 1.3 Media Richness Theory

Media Richness Theory is one of the most controversial theories that have emerged from studies on computer-mediated communication (Robert & Dennis, 2005). The theory posits that there are differences among communication media regarding media richness and the transmission of different information types. According to the theory, task performance improves if the task’s needs correspond with the communication medium’s ability to transmit information. For example, face-to-face conversations (such as those involving several explanations for the information transmitted) are ranked as a communication medium that can transmit rich information suited to equivocal tasks. In contrast, communication media such as an informational brochure are ranked as less suited to tasks lacking information. According to the theory, information richness is an inherent element of the medium. Therefore, measurement of information richness is objective, and any communication medium has technical characteristics that necessarily attest to its richness. However, the conceptualization of richness as a given, measurable factor independent of the medium—that is, “the message is the richness”—raises important questions about whether it is possible to measure richness objectively.

Media Richness Theory has drawn a great deal of criticism, most of it focused on the predictive quality of ranking richness, which the theory identifies as inherent and “natural.” In various studies, a criticism of Media Richness Theory has been directed at its classification of different media as rich or lean and its lack of differentiation between a medium’s technological suitability and its information.

The Paradox of Richness model, proposed by Robert and Dennis (2005), identifies attention and motivation as mediating factors that affect a medium’s suitability for transmitting information. According to this model, a rich medium distracts a person’s attention from a task. Therefore, if a medium is rich and capable of conveying large amounts of information, the recipients must ignore distracting information and focus on the message. The paradox stems from the fact that processing a large amount of information can distract the recipient and impede the performance of a complicated task.

# 3. Research hypotheses

In a study on multitasking, Jeong and Hwang (2016) performed a meta-analysis of 49 articles. They found that on one hand, multitasking has adverse effects on cognitive outcomes, but on the other hand, it has a positive effect in terms of attitudes and persuasion. Their study found that user control, task relevance, task continuity, and user age constituted significant mediating variables that moderated the effects of multitasking on cognitive outcomes. However, task contiguity constituted the most significant mediating variable for moderating the effects of multitasking on attitudinal and persuasion-related outcomes. Another study, examining heavy multitasking in a digitized environment, found that performance was poor among participants, and some suffered from distraction (Ophir et al., 2009).

A study on the performance of 56 managers in the United States found that they performed an average of one activity every 48 seconds. A study by Mintzberg (2007) among 160 senior and midlevel managers found that on average, the managers only succeeded in working continuously and without interruption on a single issue for half an hour every two days. In contrast, Mark et al. (2012) found that task performance improved if multitasking was reduced among managers working without e-mail. Moreover, the time they invested in performing individual tasks also increased. Another study indicated that managers switched tasks at a rate of every three minutes, on average (González & Mark, 2004).

Based on this background knowledge, the first research hypothesis of this study was as follows:

**H1:** The quality of cognitive performance will be higher among participants exposed to interruptions at a slow rate (less frequent interruption) than among those exposed at a rapid rate (more frequent interruption).

A second hypothesis was that exposure to an online interruption consisting of rich information would be less disruptive to the quality of cognitive performance than would exposure to lean information. This hypothesis was based on the assumption that interruption composed of lean information, such as a written message, would require more attention to decipher (e.g., reading and comprehension of the written information) than an interruption composed of rich information (such as a picture), which transmits information rapidly because it is rich in cues.

The present study focused on differences in the quality of cognitive performance relative to the information richness of online interruptions. In computer-mediated communication, the prevalence of rich information, rather than lean information, is conducive to transmitting cues. Thus, the focus of this study was on the information transmitted rather than the medium by which it was transmitted. Accordingly, the second research hypothesis was as follows:

**H2:** The quality of cognitive performance will be higher among participants exposed to interruptions composed of rich information than among those exposed to interruptions composed of lean information.

An examination of the interaction between the study’s two independent variables, richness of information and rate of interruptions, aimed to show that in addition to each variable’s separate effect on performance quality, they would also have combined effects.

We hypothesized that the quality of the participants’ cognitive performance would be the lowest when the rate of interruptions was high and the type of information transmitted was lean, because lean information does not contain many of the cues needed to understand it quickly; therefore, people must shift attention to it to process and filter it. However, when interruptions consist of rich (visual) information, it is easier to ignore them even when they are frequent, because they do not demand full attention; the information transmitted is straightforward and does not require deciphering. According to our first two hypotheses, if the rate of interruptions is slow, the interruptions will be less disruptive, and therefore, cognitive performance will be greater; optimal outcomes for cognitive performance during interruptions will also occur when the information is rich.

Therefore, we posed the following question: Is there an interaction—and if so, to what degree—between richness of information (lean information versus rich information) and the rate of online interruptions (slow versus rapid) in terms of an effect on the quality of cognitive performance (eg, points scored in an online game)? The research hypothesis derived from this question was the following:

**H3:** The interaction between the degree of richness of information and the rate of interruptions will have an evident effect on cognitive performance quality. The quality will be highest when the rate of interruptions is slow and the information is rich.

## 4. Definition of variables

### 4.1 Quality of cognitive performance

In a study on how interruptions affect tasks, González and Mark (2004) examined performance quality following an interruption, but their findings were inconclusive. In this study, the quality of cognitive performance was defined as the degree of a participant’s success in a computer simulation test that included planning and decision-making processes. The degree of success was measured by the points a participant scored in the test through various actions performed in the simulation.

### 4.2 External online interruption

External online interruption was defined in this study as exposure of the participant to an external online event that could shift attention away from the main cognitive activity. This interruption was triggered in the study by advertisements appearing on the computer screen on which the simulation was performed.

### 4.3 Rate of interruption

The rate of interruption was defined as the frequency of interruptions that took place within a given range of time. This study used predefined slow-rate and rapid-rate interruptions.

### 4.4 Information richness

Following the distinctions used in Media Richness Theory, information transmitted as text (text banner) was defined as lean information, and information transmitted as a picture containing text (image banner) was defined as rich information. Participants were exposed to both types of information (text or picture with text) containing identical subject matter.

**5. Methodology**

5.1 The use of simulation games and the advantages of Internet gaming

This study used the online simulation game *Sea Trader* to simulate online interruptions among participants engaged in the experiment’s cognitive task. During the simulation, participants were sent two types of advertisements: (1) promotional messages composed of text and (2) promotional messages composed of a picture combined with text. Each advertisement had different subject matter in diverse areas such as consumer goods, food, leisure and entertainment, cosmetics and hygiene, technology and communication, public service announcements, and the like. In addition, the study used “push” messaging—that is, it “pushed” information at the participants, thereby creating external interruptions.

*Sea Trader* is a business-style game in which players compete as individuals and try to maximize their profits over seven days of playing. The game simulates an international trade system, with the players buying and selling various commodities to profit. The system is composed of six information units provided to the players at each stage of the game. Players can make decisions within a single trading day: buy, sell, sail, go to the bank, or rest until the following day. Using the data available at each stage, players can make a financial profit. The game does not require previous knowledge of business management or familiarity with marketing, accounting, or other areas. Although *Sea* *Trader* is constructed as a game for individual players, the present study’s design simulated a group game. The player who earned the most money within each assigned group of players received a reward.

The top left corner of the computer screen had a stopwatch visible to the participants throughout the game and to which they were instructed to pay attention. The stopwatch was programmed to produce a report and register every participant’s keystroke responses throughout the experiment. Participants were instructed to press the *Start* button to begin the game. They were further instructed to press the *I was interrupted* button on the stopwatch when they noticed an advertisement during the game and then to press the *Continue playing* button. The aim of asking participants to press the *I was interrupted* button was to measure whether they noticed the interruption.

The use of simulation games allows researchers to study the effects of variables. One of the unique characteristics of gaming is its high external validity for predicting real-life activity (Feinstein & Cannon, 2003; Jensen, 2003; Vissers et al., 2001).

5.2 Research design

The proposed research design was an “after-only” experimental design with a control group. It used a 2 × 2 factorial design of two independent variables that produced four configurations. The design was based on randomization and did not include previous measurements. The independent variables were the rate of interruptions and the richness of information. The dependent variable was the quality of cognitive performance in the game (measured by the score achieved). During the experiment, participants were informed that they would participate in a competitive Internet game in which they would score points. The participant with the highest score in each assigned group would receive a reward. In each of the four assigned groups, the participants received rich or lean information through the Internet as a medium for transmitting information. The fifth group, which served as a control group, was not interrupted during the experiment. In each trial, group participants were exposed to advertisements depending on their assigned group.

## 5.3 Process

In the present study, the placement in various trial groups was random and was not affected by interruptions’ timing. The study used a game in a computer laboratory, and each participant sat at an individual computer station connected to the Internet. The experiment was implemented under five sets of conditions. First, the interruption scenarios were similar for each group (the transmission of an interruption depended on the length of time each participant had been playing). Second, the information in all the messages across all of the interrupted groups was identical in content and of an advertising nature relating to various consumer areas. Third, the interruption rate varied (slow or rapid) for each assigned group interrupted during the study’s simulation game.

### 5.4 Participants

Participants in the experiment were male and female students from academic institutions who were completing a bachelor’s degree or already had a bachelor’s degree and were completing a master’s degree. The sample group was recruited by approaching students in academic institutions and inviting them to participate in an experiment for research purposes. Participants were informed that their participation in the experiment was voluntary, and every participant was entitled to leave the classroom during the experimental phase. Alternatively, several experimental groups were at academic institutions where students volunteered outside of the classroom, and these participants were financially compensated. The objective was to assemble a sample group that was as uniform as possible regarding age, status, and education. At least 50 participants were allocated to each of the experimental interruption conditions. The total number of participants screened was 302. After screening, the study had a total of 250 participants. The numbers of participants and their placement into groups are shown in Table 1. The experiment was implemented under five sets of conditions corresponding with five groups, with at least 50 participants in each group.

**Table 1**

*Experimental Conditions and the Number of Participants in Each Group*

|  |  |  |  |
| --- | --- | --- | --- |
| Number of participants (*N* = 250) | Rate of interruption | Type of interruption | Group |
| 50 | None | None | 1 |
| 50 | Slow (5 interruptions) | Text banner | 2 |
| 50 | Slow (5 interruptions) | Image banner | 3 |
| 50 | Rapid (20 interruptions) | Text banner | 4 |
| 50 | Rapid (20 interruptions) | Image banner | 5 |
|  | | | |

# 6. Results

After screening, the study included a total of 250 participants. These participants took part in one of five different experimental groups playing the simulation video game *Sea Trader*, which we manipulated to include interruptions. Each experimental group had 50 participants. The gender distribution of the full sample was 67% women and 33% men. Most participants (83%) were aged 18 to 29 years, and 8% were aged 30 to 41 years. Regarding educational level, most participants (87%) were students pursuing a bachelor’s degree in the social sciences. Hebrew was the native language of 72% of the participants.

6.1 Evaluation of the experimental manipulation

For this experiment, the video game was manipulated so that participants in each experimental group received interruptions while performing a cognitive task (excluding the control group, for which no manipulation was implemented). The mean number of interruptions experienced by the participants in the various groups and the percentage of participants who pressed the *I was interrupted* button are shown in Table 2.

*Number and Characteristics ofthes*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Group\* | Rate of interruption | Richness of information | Number of interruptions | Number of interruptions observed by participants, mean (SD) | Percentage of participants who pressed the *I was interrupted* button |
| 1 | None | None | 0 | 0 | 0 |
| 2 | Slow | Lean (text) | 5 | 3.46 (0.86) | 64 |
| 3 | Slow | Rich (banner) | 5 | 3.84 (1.33) | 20 |
| 4 | Rapid | lean (text) | 20 | 14.52 (3.88) | 44 |
| 5 | Rapid | Rich (banner) | 20 | 14.22 (4.42) | 22 |

\*Each group had 50 participants.

The participants in each of the experimental groups were instructed to perform two sequential tasks if they experienced an interruption: (1) press the *I was interrupted button*, then (2) press the *Continue playing* button. Pressing the *I was interrupted* button provided measurable evidence that the manipulation had occurred, although the active response of pressing the buttons was only one aspect of a participant’s actual interruption.

Participants in each manipulation group demonstrated an active response, but differences were evident in some trends. To analyze the differences, we conducted a one-way analysis of variance of the incidence participants’ pressing the *I was interrupted* button. A significant difference was found among the groups (F[3, 196] = 6.531, *p* < .001). Table 2 indicates that the percentage of times participants pressed the button in the groups for which manipulations used lean text was significantly higher than the percentage in groups for which manipulations used rich text. For example, in the group that experienced lean-text interruptions at a slow rate, 64% of participants pressed the *I was interrupted* button, compared with 44% of the group participants who experienced lean-text interruptions at a rapid rate. In contrast, only 22% of the participants in the group that experienced interruptions involving rich banners at a rapid rate and only 20% of the participants in the group that experienced interruptions involving rich banners at a slow rate pressed the *I was interrupted* button.

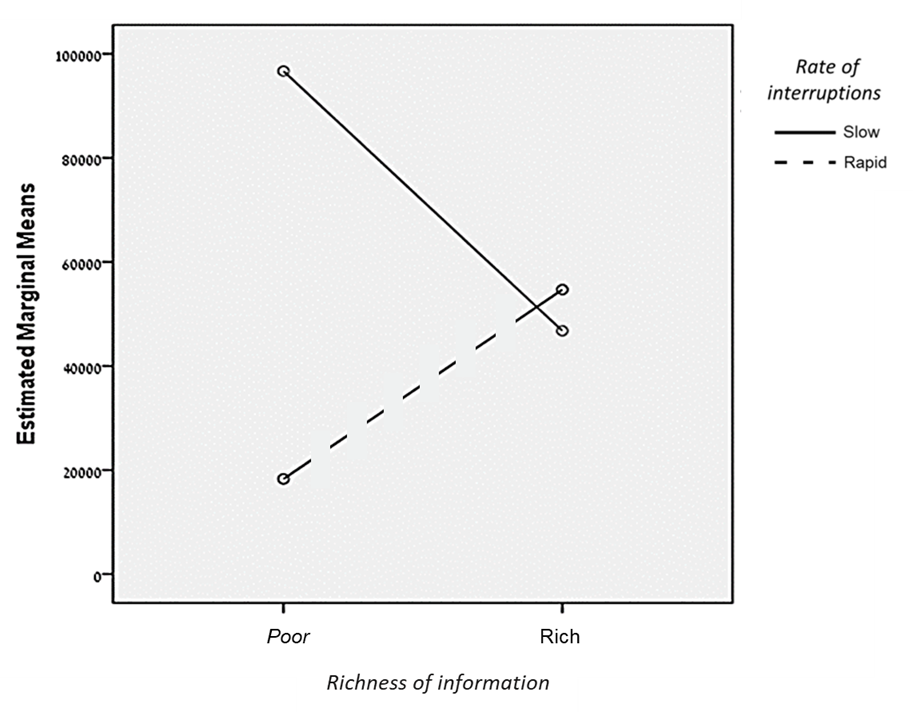
6.2 Testing the hypotheses

To test hypothesis 1, that a difference would be found in the quality of cognitive performance between participants exposed to online interruptions at a slow rate versus at a rapid rate, a *t* test was performed for independent samples. A significant difference was found in the quality of cognitive performance between participants who were exposed to online interruptions at a slow rate compared with those exposed at a rapid rate (t [df, 198] = –1.898, *p* < .05). However, the findings indicated that the situation was the opposite (and significantly so) of what we had posited. The mean (SD) quality of cognitive performance was higher when the interruption rate was rapid (717.21 [153.09]) than when it was slow (364.86 [104.94]).

The second research hypothesis was that there would be an evident difference in the quality of cognitive performance between participants exposed to interruptions composed of lean information versus rich information, such that the quality of the cognitive performance would be higher among those exposed to interruptions composed of rich information than among those exposed to interruptions composed of lean information. Thus, the dependent variable was the quality of cognitive performance, and the independent variable was the richness of information. To evaluate hypothesis 2, a *t* test was performed for independent samples. No significant difference was found (t [df, 198] =.361, *p* > .05), and therefore, the hypothesis was not confirmed.

The third research hypothesis was that the interaction between the degree of richness of information and the rate of interruptions would have an evident effect on the quality of cognitive performance. A two-way variance analysis was performed, and the findings indicated that there was a significant effect resulting from the interaction between the degree of richness and the interruption rate (F[3] = 3.1, *p* < .05). Nevertheless, the findings indicated that the quality of cognitive performance was not affected as we had hypothesized. An analysis of the findings revealed that the highest quality of cognitive performance occurred when the rate of interruptions was rapid and the information was lean. The next-highest level of cognitive performance occurred when the rate of interruptions was slow and the information was rich, as we had hypothesized. The effect of the interaction between the richness of information and the rate of interruptions on the quality of cognitive performance is shown in Figure 1.

*theRichness*





**7. Discussion**

7.1 Effect of the rate of online interruptions

This study found that the rate of online interruptions affected the quality of cognitive performance, which was higher when interruptions were rapid than when the rate of interruptions was slow. In the group with a rapid rate of interruption, participants were exposed to an interruption every minute; that is, a participant who used all the time available to play the game was exposed to 20 interruptions during the game. In contrast, a participant in the slow-interruption group was exposed to an interruption every 4 minutes; that is, a participant who used all the time available to play the game experienced only five online interruptions throughout the game. The findings indicated a significantly higher quality of cognitive performance when the rate of interruptions was rapid than when it is slow.

Our first research hypothesis, based on the findings of previous studies, was that a rapid rate of interruptions would reduce the quality of cognitive performance. For example, one study found a low quality of cognitive performance among participants who frequently multitasked in a computer-mediated communications environment (Ophir et al., 2009), and another study (Mark et al., 2012) found that managers who worked without e-mail focused more on performing an activity if the number of tasks decreased. An additional study examined performance quality after a task was interrupted and found that the performance speed did not affect the results, but it led to stress, overwork, frustration, and exertion (Mark et al., 2008). Therefore, alternative explanations for this study’s finding that the quality of participants’ cognitive performance was higher at a rapid interruption rate than a slow interruption rate might be attributable to the possibility that rapid interruptions lead to greater concentration. It is possible that when the exposure to interruptions increases, each interruption becomes less disruptive as one continues to engage in the activity. Alternatively, it is possible that multitasking while being exposed to rapid interruptions enabled participants to self-learn while performing the activity and to ignore repeated interruptions. These explanations are supported by the results of a study that examined workload and e-mail and found that the more participants engaged in processing e-mails, the better they could cope with the interruption (Barley et al., 2011).

7.2 Effect of the richness of online interruptions

This study did not find that the richness of information affected the quality of cognitive performance. We hypothesized that cognitive-performance quality would be highest when participants were exposed to rich information, because lean information lacks cues and must be processed and deciphered. Relying on Media Richness Theory (which ranks richness), we assumed that reading a passage of text would require more time to decipher (relative to an image, defined as rich information) and would reduce the quality of task performance. The classic theories of computer-mediated communication posit that there is a correlation between information’s effectiveness and its richness. According to the Media Richness Theory, for high-equivocality tasks in which the transmitted information is subject to various interpretations, performance quality is expected to be higher if the channels used can transmit rich information, whereas for tasks of an uncertain nature, for which information is lacking, performance quality is expected to be better if the channels used can transmit lean information such as computer-mediated communication (Daft et al., 1987).

An explanation for the fact that this study’s second hypothesis was not corroborated was the inability to address information richness separately without examining the interruption rate. Instead, these variables must be examined together. This explanation also supports the findings regarding the third hypothesis, which suggested an interaction between the independent variables.

A study by Kalman and Gergle (2014) supported the claim that text-based online communication (such as e-mail, chats, or Twitter), which traditional communications theories define as lean, nonetheless manages to convey many nonverbal messages. Their study found that people express themselves not only through speech but also through writing (such as e-mail)—for example, by repeating a letter in computer-mediated communication (e.g., “Yessssss”)—and that people also manage to imitate speech through nonverbal cues.

7.3 The effect of interaction between the variables

Consistent with the third hypothesis of this study, the interaction between the richness of information and the rate of interruptions affected the quality of cognitive performance. The study’s findings indicated that the independent variables’ effect was more substantial if they operated jointly rather than separately. We found that the interaction between the richness of information and the rate of interruptions had a significant effect on the quality of cognitive performance, as compared with the results of testing the second hypothesis, in which the richness of information was not found to affect the quality of cognitive performance. The effect of the richness of information was evident only if the independent variables operated jointly.

7.4 Limitations of the study

This study used an experimental simulation to examine the effect of external online interruptions on the quality of cognitive performance and work pace. Because the experiment was structured as a competitive game among multiple players, we encountered difficulty implementing it in large groups. Therefore, in classrooms that had large numbers of participants, the participants were placed in two classrooms for each experiment to control the conditions (maintaining quiet in the classroom, silencing mobile phones and placing them in participants’ bags, and keeping desktops clear during the experiment except for a personal computer, mouse, and keyboard).

In terms of the validity of the findings, the study’s external validity is a question that deserves special attention. By its nature, the experimental research design chosen undermined its external validity. In this experiment, one might specifically question the ecological validity of the research design.

7.5. Contributions of the study and proposals for further research

The findings of this study suggest a need to examine the various possible effects of online interruptions in combination with other explanatory variables such as the richness of information in the interruption. A significant contribution of this study to research in this field is the finding that examining only one characteristic of interruptions is not enough to provide a complete picture of the effects. This observation is particularly true of the natural environment in which individuals and organizations operate, where additional environmental interruptions (online or otherwise) have not been neutralized. Accordingly, integrated models such as those examined in this study and more sophisticated models that manage to control additional characteristics of interruptions might explain supplementary validity regarding the possible effects of online interruptions on cognitive performance or other dependent variables.

This study’s research tool implicitly indicated several ways to manipulate the variables by measuring them at more varied levels. Thus, follow-up studies could use a more differentiated scale of online interruption rates and more varied levels of information richness. Over time, various manipulation of the rates and richness of interruptions could provide clearer indicators of inflection points concerning the quality of cognitive performance.

At a practical level, today’s organizational environment makes it necessary to cope with impaired work productivity owing to massive information overload and multiple (online and other) interruptions during the course of performing tasks (Jones et al., 2004). This study focused on external interruptions, which are among the significant disruptive factors with which employees and managers alike must cope. The study’s findings imply that controlling the rate and richness of online interruptions might improve cognitive performance. Therefore, an accurate, customized assessment of the work environment and a simple manipulation of the frequency and content of interruptions could improve organizational capacity.

## References

Adler, R.F., & Benbunan-Fich, R. (2013). Self-interruptions in discretionary multitasking. *Computers in Human Behavior*,*294*, 1441–1449.‏ doi:10.1016/j.chb.2013.01.040

Atchley, P., & Chan, M. (2011). Potential benefits and costs of concurrent task engagement to maintain vigilance: A driving simulator investigation. *Human Factors, 531*, 3–12. doi:10.1177/0018720810391215

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Bailey, B. P., & Konstan, J. A. (2006). On the need for attention aware systems: Measuring the effects of interruption on task-performance, error rate, and affective state. *Computers in Human Behavior*, *224*, 685–708. doi:10.1016/j.chb.2005.12.009

Barley, S. R., Meyerson, D. E., & Grodal, S. (2011). E-mail as a source and symbol of stress. *Organization Science*, *224*, 887–906. doi:10.1287/orsc.1100.0573

Brumby, D. P., Cox, A. L., Back, J., & Gould, S. J. (2013). Recovering from an interruption: Investigating speed-accuracy trade-offs in task resumption behavior. *Journal of Experimental Psychology: Applied*, *192*, 95–107. doi:10.1037/a0032696

Cutrell E., Czerwinski, M., & Horvitz, E. (2001). Notification, disruption, and memory: Effects of messaging interruptions on memory and performance. In M. Hirose (Ed.), *Human-Computer Interaction—INTERACT 2001 Conference Proceedings* (pp. 263–269). IOS Press and IFIP Technical Committee.

Czerwinski M., Cutrell E., & Horvitz E. (2000). Instant messaging: Effects of relevance and timing. In S. Turner & P. Turner (Eds.), *People and Computers XIV:* *Proceedings of HCI 2000* (pp. 71–76). Springer. doi:10.1016/S1361-37230201112-0

Dabbish, L., Mark, G., & González, V. M. (2011, May). Why do I keep interrupting myself? Environment, habit and self-interruption. In*CHI‘11: Proceedings of the SIGCHI Conference on Human Factors in Computing System*s (pp. 3127–3130). doi:10.1145/1978942.1979405

Feinstein, A. H., & Cannon, H. M. (2003). A hermeneutical approach to external validation of simulation models. *Simulation and Gaming*, *342*, 186–197. doi:10.1177/1046878103034002002

González, V. M., & Mark, G. (2004, April). Constant, constant, multitasking craziness: Managing multiple working spheres. In *CHI‘04: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 113–120). doi:10.1145/985692.985707

Gould, S. J., Cox, A. L., Brumby, D. P., & Wickersham, A. (2016, May). Now check your input: Brief task lockouts encourage checking, longer lockouts encourage task switching. In*CHI‘16: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (pp. 3311–3323). doi:10.1145/2858036.2858067

Grandhi, S. A., Laws, N., Amento, B., & Jones, Q. (2008). The importance of “who” and “what” in interruption management: Empirical evidence from a cell phone use study. *AMCIS 2008 Proceedings*. http://aisel.aisnet.org/amcis2008/79.

Grandhi, S., & Jones, Q. (2010). Technology-mediated interruption management. *International Journal of Human-Computer Studies*, *685*, 288–306. doi:10.1016/j.ijhcs.2009.12.005

Hudson, J. M., Christensen, J., Kellogg, W. A., & Erickson, T. (2002, April). I’d be overwhelmed, but it’s just one more thing to do: Availability and interruption in research management. *CHI’02: SIGCHI Conference on Human Factors in Computing Systems* (pp. 97–104). doi:10.1145/503376.503394

Iqbal, S. T., & Horvitz, E. (2007). Conversations amidst computing: A study of interruptions and recovery of task activity. In *Proceedings of the 11th international conference on User Modeling UM '07* pp. 350-354. Berlin: Springer. doi:10.1007/978-3-540-73078-1\_43

Janssen, C. P., Brumby, D. P. (2010). Strategic adaptation to performance objectives in a dual-task setting. *Cognitive Science*, *348*, 1548–1560. doi:10.1111/j.1551-6709.2010. 01124.x

Janssen, C. P., Brumby, D. P., & Garnett, R. (2012). Natural break points: The influence of priorities, and cognitive and motor cues on dual-task interleaving. *Journal of Cognitive Engineering and Decision Making*, *61*, 5–29. doi:10.1177/1555343411432339

Janssen, C. P., Brumby, D. P., Dowell, J., Chater, N., & Howes, A. (2011). Identifying optimum performance trade-offs using a cognitively bounded rational analysis model of discretionary task interleaving. *Topics in Cognitive Science*, *31*, 123–139. doi:10.1111/j.1756-8765.2010. 01125.x

Jensen, K. O. (2003). Business games as strategic team-learning environments in telecommunications. *BT Technology Journal*, *212*, 133–144. doi:10.1023/A:1024407506021

Jeong, S. H., & Hwang, Y. (2016). Media multitasking effects on cognitive vs. attitudinal outcomes: A meta-analysis. *Human Communication Research*. doi:10.1111/hcre.12089

Kalman, Y. M., & Gergle, D. (2014). Letter repetitions in computer-mediated communication: A unique link between spoken and online language*. Computers in Human Behavior*, *34*, 187–193. doi:10.1016/j.chb.2014.01.047

Mark, G. J., Gudith, D., & Klocke, U. (2008, April). The cost of interrupted work: More speed and stress. In *CHI‘08: Proceedings of the SIGCHI Conference on Human factors in Computing Systems* (–). doi:10.1145/1357054.1357072

Mark, G., Czerwinski, M., Iqbal, S., & Johns, P. (2016, April). workplace indicators of mood: Behavioral and cognitive correlates of mood among information workers. In*Proceedings of the 6th International Conference on Digital Health* (pp. 29–36). doi:10.1145/2896338.2896360

Mark, G., Iqbal, S., Czerwinski, M., Johns, P., & Sano, A. (2016, May). E-mail duration, batching and self-interruption: Patterns of e-mail use on productivity and stress. In *CHI‘16: Proceedings of the CHI Conference on Human factors in Computing Systems* (pp. 1717–1728). doi:10.1145/2858036.2858262

Mark, G., Voida, S., & Cardello, A. (2012, May). A pace not dictated by electrons: An empirical study of work without e-mail. In *CHI‘12: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 555–564). doi:10.1145/2207676.2207754

Mintzberg, H. (2007). Structured observation as a method to study managerial work. *Journal of Management Studies*, *71*, 87–104. doi:10.1111/j.1467-6486. 1970.tb00484.x

Monk, C. A., Trafton, J. G., & Boehm-Davis, D. A. (2008). The effect of interruption duration and demand on resuming suspended goals. *Journal of Experimental Psychology: Applied*, *144*, 299–313. doi:10.1037/a0014402.

Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences*, *10637*, 15583–15587. doi:10.1073/pnas.0903620106

Payne, S. J., Duggan, G. B., & Neth, H. (2007). Discretionary task interleaving: Heuristics for time allocation in cognitive foraging. *Journal of Experimental Psychology: General*, *1363*, 370–388. doi:10.1037/0096-3445.136.3.370

Robert, L. P., & Dennis, A. R. (2005). Paradox of richness: A cognitive model of media choice. *IEEE Transactions of Professional Communication*, *481*, 10–21. doi:10.1109/TPC.2004.843292

Salvucci, D. D., & Taatgen, N. A. (2011). *The Multitasking Mind*. Oxford University Press.

Vissers, G., Heijne, G., Peters, V., & Geurts, J. (2001). The validity of laboratory research in social and behavioral science. *Quality and Quantity*, *352*, 129–145. doi:10.1023/A:1010319117701