Breaking Focus: The impact of disruptive distractions on academic task performance

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Abstract

Over time, there has been a change in how students acquire and exchange information, with laptops and smartphones becoming increasingly important. The use of technology has evolved from being restrained du to the classroom to being crucial due to the COVID-19 pandemic. As education shifts towards hybrid models, students are now expected to learn at home, which can be challenging as excessive technology usage and a lack of self–discipline can lead to more distractions. This paper examines the effects of the influence of these distractions with the help of two concepts similar to assignments in students' lives: text comprehension & memorization, as well as example-based learning, in which the function of an apparatus was to be tested and described. The results show that distraction does not affect text comprehension but decreases information retention. Additionally, participants required more trials and repetitions to understand schemes in example-based learning when distracted.

Keywords: Education; Psychology; Instruction and teaching; Learning; Deductive & Inductive Reasoning; Logic

Introduction

In contemporary times, individuals often find themselves immersed in mobile technology–driven environment during their personal and professional interactions. Smartphones and laptops offer unprecedented flexibility, enabling constant communication and instant access to information from any location (Dennis, Fuller, & Valacich, 2008). It is common to see young people engaging in activities such as texting, using social media platforms, creating TikTok videos, or online gaming (Kwon et al., 2013). Jones (2008) has shown that the internet and smartphones hold equal significance for students' academic and social activities. Therefore, it is not surprising that it caused changes in classrooms, teaching methods, and student–teacher interactions (Baker, Lusk, & Neuhauser, 2012; Berry & Westfall, 2015; Tindell & Bohlander, 2012). Moreover, it has changed how students access and exchange information. Using the Internet for academic purposes, such as online searching and accessing resources, communicating, and researching various academic topics, has significantly improved educational results (Jones, 2008). Studies on the use of laptops in academic settings have revealed encouraging possibilities to enrich student learning experiences (Anshari, Shahrill, Wicaksono, & Huda, 2017; Cheng, Kuo, Lou, & Shih, 2016; Efaw, Hampton, Martinez, & Smith, 2004).

However, it is also the main cause of interruptions, and educators are increasingly concerned about academic disruptions. According to Rosen, Carrier, and Cheever (2013), students tend to interrupt their work about every six minutes, and refocusing and returning to work after being interrupted could take between 20 to 30 minutes (Aaron & Lipton, 2018; Gazzaley & Larry, 2016). In addition, Tindell and Bohlander (2012) found that as many as 92 students have texting using their smartphones or laptops during class sessions. Furthermore, Ragan, Jennings, Massey, and Doolittle (2014) and Ravizza, Uitvlugt, and Fenn (2017) found that in large university classes, students using laptops were focused on academic tasks, like note–taking or coursework for only 37% of the time. The remaining 63% were spent on off–task activities such as visiting social websites, web browsing, and playing games. Also, numerous research papers have reported a negative influence of using laptops on attention, academic achievement, comprehension, and overall course performance (Murphy & Manzanares, 2008; Sana, Weston, & Cepeda, 2013; Wood et al., 2012). While the classroom environment can provide a degree of control over student device use, the shift to online learning during the pandemic has introduced a new dynamic. As a result, students have to watch lecture recordings independently at the right time and work independently on exercises. The requirement for students to have increasing metacognitive skills, such as resisting distraction from technology, is a concern in education.

While much of the existing research has investigated the effects of interruptions lasting several minutes (Addas & Pinsonneault, 2015; DeMarco & Lister, 1999; Ellis, Daniels, & Jauregui, 2010; Storch, 1992), being self–reported (Jamet, Gonthier, Cojean, Colliot, & Erhel, 2020; Wammes et al., 2019) or examining engaging completely in off–lecture–task activities (Gaudreau, Miranda, & Gareau, 2014; Ragan et al., 2014; Tindell & Bohlander, 2012), this paper investigates the effects of short interruptions, similar to daily–life interruptions. Furthermore, we aim to introduce a distraction paradigm where they are linked to each other to better adapt the context to a real situation. In particular, we want to study the influence of pop–up interruptions on different academic tasks that vary in nature and complexity. Each task encapsulates different information processing operations and reflects a different level of comprehension. There is evidence that multitasking impairs performance, but to our knowledge, no studies have directly measured the influence of different kinds of short–linked distractions on academic tasks.

In L. K. Samuelson, S. L. Frank, M. Toneva, A. Mackey, & E. Hazeltine (Eds.), *Proceedings of the 46th Annual Conference of the Cognitive Science Society.*

Related Work

Academic Tasks

As mentioned above, there are several academic tasks a student is confronted with and represent different levels of comprehension of the concepts. That includes recognizing or reproducing previously encountered information, applying algorithms to solve problems, identifying transformed versions of information from texts or lectures, or selecting appropriate procedures for specific problem types(Doyle & Carter, 1984). These tasks can be divided into two types: inductive and deductive reasoning. The primary difference lies in their procedural sequences: Inductive reasoning, also known as "bottom-up" thinking, involves drawing general conclusions from specific instances by observing patterns and trends to form hypotheses or theories based on these observations. Conversely, deductive reasoning, referred to as "top-down" thinking, starts with a general statement or theory and then validates it using specific instances or empirical evidence (Ragni, 2020).

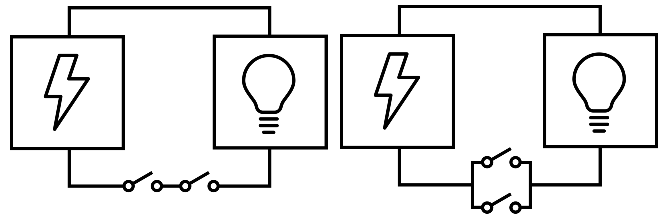
Syllogistic Reasoning We used the concept of syllogistic reasoning to identify transformed versions of textual information (e.g., deductive reasoning). Syllogistic reasoning, an enduring field of study with a rich history spanning more than a century (Störring, 1908), is a fundamental domain for studying human cognitive abilities. Let us examine a syllogism for illustrative purposes:

(1) All fish are excellent swimmers.

(2) Some fish are colorful.

Given these premises, what are the logical implications? In general, syllogisms have two premises that make quantified statements about the relationship between two concepts (e.g., colorful creatures and excellent flyers). These terms are linked by a middle term (e.g., birds) in both statements. In this case, the aim is to infer the connection between the concepts by considering how each relates to the middle term. Consequently, it can be inferred that at least some colorful creatures are excellent flyers, which implies that some excellent flyers are also colorful. As we see in this example, the premises of a syllogism consist of a quantifier (*all*), a subject (*birds*), and a predicate (*excellent flyers & colorful creatures*). In this paper, we used not only the quantifiers from first–order logic (such as *all, some, no, and some...not*, collectively called classical quantifiers) but also generalized quantifiers (e.g., Geurts, 2010) such as most and few. Furthermore, we have not restricted ourselves to two premises but have used syllogisms with three or four premises to be closer to reality (*e.g., All B are A, Some B are C, No D is C*).

Boolean Concepts The two remaining tasks were summarized under the concept of inductive reasoning. For that, we use "Boolean concepts" and a reverse–engineering task, which was successfully used by Goodwin and Johnson-Laird (2011) to investigate the human capability to acquire a comprehension of an unknown mechanism. Imagine an unknown apparatus with a light bulb and different switches for this task. The light bulb lights up for some combinations of the switches, while it remains turned off for others. If you were asked to identify valid switch combinations to turn on the light bulb, you would experiment and formulate an answer such as "switch one must be on and switch two must be off to turn on the light." The task has several advantages for the use in our study: First, it requires a systematic interaction with the apparatus, simulating systematic work tasks. Second, it requires participants to gain a comprehension of a concept, which is transferable to the task of comprehending abstract concepts while studying. Finally, "Boolean concepts" are common in everyday situations (e.g., weather conditions, traffic signals, or food preferences).



(a) Conjunction (AND;$\wedge$) (b) Disjunction (OR;$\vee$)

Figure 1: Representation of circuits of a conjunction (a) and a disjunction (b).

Boolean concepts rely on "Boolean operators", which include AND, OR, and NOT, logically combine variables. Figure 1 shows two possible circuit configurations with two switches, introducing us to the elementary Boolean operations: conjunction (using the AND operator) and disjunction (using the OR operator). The symbols $\wedge$, $\vee$, and $\neg$ replace AND, OR, and NOT in Boolean algebra. Conjunctions require all individual statements to be true for their validity, while disjunctions require at least one statement to be true. Referring to Figure 1a, the circuit demonstrates the conjunction concept, requiring both switches ($a \wedge b$) for the light to turn on. Figure 1b illustrates the disjunction concept, where the light illuminates with either switch activated. Notably, having both switches on also results in a shining light bulb. The third cardinal operation, negation, is denoted by the NOT operator ($\neg$), and performs the crucial function of reversing the state of a variable or statement. Despite the simplicity of the essential Boolean elements, combining multiple variables can lead to complex expressions that are difficult for humans to understand (Goodwin & Johnson-Laird, 2011). For this experiment, we will use the nine tasks defined by Goodwin and Johnson-Laird (2011).

Interruptions

Clapp, Rubens, and Gazzaley (2010) define interruptions as disruptive stimuli that demand attention, such as a secondary task like phone calls, while distractions refer to irrelevant stimuli that attract attention but need to be disregarded, for example, background noise. Efficiently managing these external interferences relies on attentional and working memory processes. Working memory involves executive control functions, including the capacity to inhibit irrelevant information and effectively practice and retain relevant information for a task(Baddeley, 2007). It plays a crucial role in juggling multiple tasks, that demand substantial attention, a finite resource (Pashler, 1994), where inadequate attention leads to performance deficits (Broadbent, 1958; Tulving & Thomson, 1973). Insights into multitasking are particularly relevant in the context of student learning. In general, multitasking is a frequently observed behavior that can potentially enable individuals to handle larger amounts of information without incurring negative consequences (Kirschner & Karpinski, 2010). Multitasking poses notable difficulties because of the need to divide attention and swiftly transition between different activities (Junco & Cotten, 2012). Such rapid shifts in attention can lead to decreased academic performance and less efficient results compared to consistent task completion (Frein, Jones, & Gerow, 2013; Paul, Komlodi, & Lutters, 2015; Sana et al., 2013). In academic settings, students typically engage in a dynamic interplay between academic (e.g., primary task) and non–academic (e.g., secondary task) activities (Fried, 2008). This results in a constant shift of focus between the primary and secondary tasks, putting pressure on limited attentional capacity and raising concerns about the learning process's effectiveness. It is worth mentioning that a secondary task can take the form of a quick interruption from a smart device. But what makes an interruption disruptive?

Disruptive interruptions There is considerable evidence that interruptions are disruptive in most cases. Specifically, several interruption–related characteristics have been identified as contributing to this disruptive nature. These include the complexity of the interruption (Cades, Davis, Trafton, & Monk, 2007; Hodgetts & Jones, 2006), the similarity of the interrupting task to the primary task (Oulasvirta & Saariluoma, 2004), and the close relationship between the interrupting task and the primary task (Cutrell, Czerwinski, & Horvitz, 2001). The impact of these disruptions is far–reaching. According to a study Iqbal and Horvitz (2007), individuals tend to become involved in unrelated activities for 10–15 minutes after responding to interruptions. Additionally, interruptions have been found to slow down the primary tasks (Gillie & Broadbent, 1989; Kreifeldt & McCarthy, 1981; Monk, Trafton, & Boehm-Davis, 2008; Trafton, Altmann, Brock, & Mintz, 2003). In addition, interruptions also lead to a higher frequency of errors in the primary task (Brumby, Cox, Back, & Gould, 2013; West, 1999) and has a detrimental impact on performance and learning success (Farlane, 2001; Zureick, Burk-Rafel, Purkiss, & Hortsch, 2018). In experiments conducted by Cutrell et al. (2001), it was observed that notifications disrupted performance in search tasks and led users to seek additional reminders regarding the search goal. Several theories attempt to explain their disruptive nature. One perspective, rooted in executive control and task switching, explores various theories, such as "loading" a task set after each switch (Monsell, 2003). Another approach from the field of prospective memory suggests that each interruption creates a prospective memory task and is treated similarly to other forms of memory and, therefore, overloads working memory (Einstein, McDaniel, & Brandimonte, 1996).

Method

This study was designed to explore the impact of distraction on the three identified constructs – recognizing or reproducing previously encountered information, applying algorithms to solve problems, and identifying transformed versions of information from texts – in the context of a daily study routine. In addition, varying the task–irrelevant disruptive interruption design will investigate whether successive interruptions have different effects than independent ones. Overall, processing time for both tasks is expected to increase with the appearance of interruption due to the need for repetition. Furthermore, memory performance on the text reading task and accuracy on the light bulb task are expected to decrease.

Participants

Through the platform Prolific[1], 103 people (43 female, 60 male) participated in the whole study. The average age was 37 years (*SD* = 12 years). Participation was remunerated at 9 euros per hour and took approximately 50 minutes to complete. A pilot investigation involving 21 of the 103 participants was conducted to assess the design without disruptions. The results indicated significant high interindividual differences in task performance and processing time, so that the no–pop–up condition in the main study would be matched to the no–pop–up tasks within each participant. The data set from the piloting is not analyzed further in this paper. The main study was based on a 2 x 2 mixed–factorial design with Task (text comprehension vs. light bulb) as within–design and Distraction (party pop–up vs. search pop–up) as between–design. The studies were activated one after the other on Prolific. Multiple participation was impossible. Data from 41 participants was collected for each of the two distraction conditions.

Materials and Procedure

Task design In this study, we used two different types of tasks to reflect the three concepts of everyday student life. We applied syllogistic reasoning to design the first main task for working with texts. This primary task included two different tasks: text comprehension, which involves interacting with texts (such as text comprehension or recalling previously encountered information), and a memorization task to assess participants' retention of information from the text.

Task 1: Text comprehension Five texts of about 160 words were presented in English. Each of these texts contained syllogisms with a different number of premises – two texts with three premises, two with four premises, and one text with five premises. Participants were asked to read the

[1] https://www.prolific.com/

text (without time limit) and then to judge the correctness of four conclusions. While answering the conclusions, the text was always visible, but the conclusions appeared one after the other. Figure 2 shows an example of a text with three premises and the first conclusion. After completing the final question, the participant was automatically presented with the next text. At the end of the second main task (e.g., the light bulb task), the remaining sub–task on memorizing was presented. Here, participants were asked ten additional yes or no questions (2 per text) about the content information of these texts without them being shown.

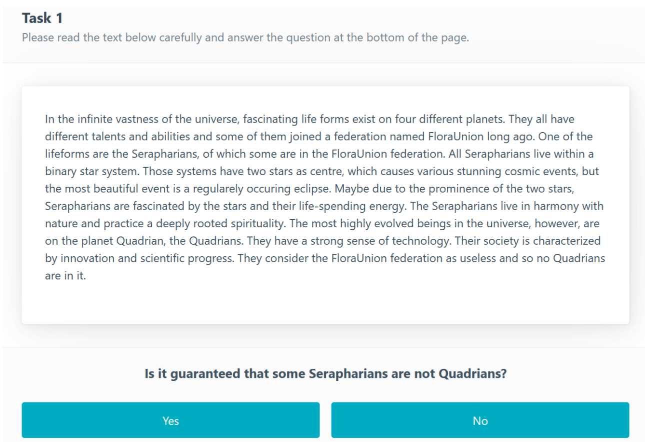
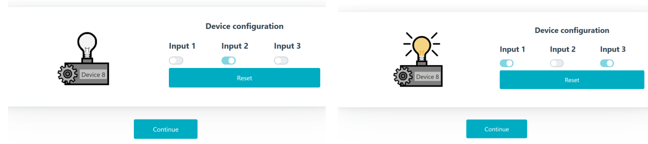


Figure 2: Example of a text task with three premises (quantifiers: some, all, no) and the first conclusion. The next conclusion will be displayed with a click on "Yes" or "No".

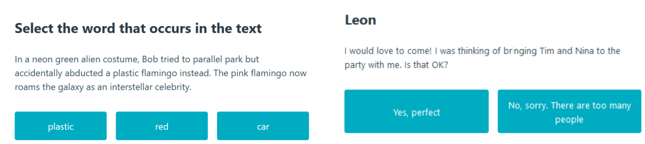
Task 2: Light Bulb The second task was selected to represent a systematic work approach. As described above, the participants were presented with nine devices representing boolean conceptual assignments of increasing difficulty. Participants had the option of turning three switches on and off and testing the effect on the bulb's illumination. Participants then had to reset the position of the switches before a new combination could be tested. When they felt they had tried enough combinations to understand how the device worked, they pressed a "Continue" button. Figure 3 shows two examples of the above–mentioned process. After clicking on "Continue", they were taken to an input box, where they were asked to briefly describe the light bulb's exact function in their own words. After pressing the "Continue" button, they proceeded to the next task. Participants had no time limit.

Distraction design During the distraction condition, all participants were exposed to 12 interruptions (6 interruptions per task) in the form of pop–ups while performing the two tasks. The first trial of each task always contained no interruption. Two of the reading texts and four of the light bulb tasks contained two interruptions each. The interruptions appeared in the reading texts while the participants answered the premises and in the light bulb task while trying the possible combinations. The type of interruption was the same among



(a) Light bulb off (b) Light bulb on

Figure 3: Example of a light bulb task. (a) shows a switch position where the bulb is not lit. (b) shows a switch position where the bulb is lit. Reset can be used to test a new combination. "Continue" takes the participant to the input box.



(a) Search pop–up (b) Party pop–up

Figure 4: Examples of pop–ups used. (a) shows the search pop–up (correct response "plastic"). (b) shows the party pop–up with the task of tracking the people joining the party.

participants but varied across them. There was no time constraint, the pop–up vanished upon clicking a button, and there were no consequences for providing an incorrect answer. In Task 1, the pop–ups appeared randomly after selecting either the "yes" or "no" options. In Task 2, the pop–ups also appeared randomly after clicking the "test" or "reset" buttons. The interruptions were either integrated as search pop–ups or had a sequential structure, which we call party pop–ups. The task in the search pop–ups was to read a short text of about 20 words and click one of the three buttons, depending on which word was contained in the text (see Figure 4a). The tasks of the party–pop–ups involved organizing a party during the experiment. In the first six pop–ups, participants had to keep track of the number of people; the pop–ups contained messages from friends about whether or not they were coming to the party and whether they could bring friends (see Figure 4b). The total number of people could not exceed seven. The participants had two buttons ("Yes, Perfect" or "No, sorry, there are too many people") and had to press the appropriate button depending on the number of people already present. In addition, people could not only confirm coming to the party, but also cancel, which the participant had to confirm. The following six pop–ups were about meal planning. Again, they received messages from friends who wanted to bring food to the party. The task was to avoid duplicate meals, i.e., to accept or reject a brought–in meal by pressing the appropriate button ("Yes, Perfect" or "No, sorry. Someone else will bring that food").

After completing each task, the participant was asked seven questions on a 7–point Likert–scale. Three of these questions related to the participant's subjective assessment of the level of distraction caused by the pop–up (e.g., "The pop–ups made the tasks more difficult for me."). The remaining four questions were taken and translated from the German Questionnaire on Current Motivation (QCM; Rheinberg, Vollmeyer, & Burns, 2001) to assess current motivation (e.g.,"After reading the instructions, I found the task very interesting."). At the end of the whole experiment, there was again a questionnaire with seven questions, 3 of which were taken from the Big Five Inventory (BFI–10; Rammstedt, Kemper, Klein, Beierlein, & Kovaleva, 2014) on Conscientiousness and the remaining questions were from the Need for Cognition questionnaire (NFC; Beißert, Köhler, Rempel, & Beierlein, 2015).

Results

In this section, we present the results for Task 1 and Task 2 separately, as they involve slightly different variables that require discussion. First, we will summarize the general outcomes and then delve into the results of task one followed by the results of task two. Most of the analysis involved conducting Mann–Whitney U tests to ascertain potential disparities between the groups. The Bonferroni correction method was used to reduce the risk of type 1 errors, so $\alpha = .007$.

Overall

The experiment showed no significant difference in the overall correctness (Task 1 and Task 2 together) between the presence of a distraction and its absence (U = 3816.5, Z = -1.12, p = .26, r = -.08.). Furthermore, no significant effect was found between the search and party pop–ups in any of the variables tested. However, there is some evidence within the means of a slight effect on the memorising subtask of text comprehension. It indicates that the number of correct responses in the memory task is slightly lower for the party pop–ups (M = 0.54, SD = 0.32) than for the search pop–ups (M = 0.62, SD = 0.35). This is supported by the self–disclosures of the study participants, who found that the party pop–ups were much more irritating (M = 3.4, SD = 1.1) than the search pop–ups (M = 4.5, SD = 1.2) in their feedback (U = 32980, Z = 6.83, $p < .001$, r = .16.) However, since the the pop–up categories show no other significant differences, they are merged for the analyses. In addition, the NFC, BIG–Five, and QCM questionnaires did not show a significant effect and are not discussed further.

Task 1: Text comprehension

The following section analyzes the correctness of the questions in the task comprehension (Task 1), the memory task correctness (Task 2), and the overall duration for sub–task 1. The respective values are shown in Table 1. For task correctness, there was no significant effect between the presence or absence of an interruption (U = 405061.0, Z = 0.499, p = .55, r = .01), which is not surprising as they were able to re–read the text at any time and then answer the questions without the interruption having any influence. In relation to the sub–task2 (memorization), a significant effect was found (U = 432743, Z = 2.81, p = .002, r = .06). Therefore, the uninterrupted trials tended to have higher memory scores, confirmed by the average scores in Table 1. This suggests that while text comprehension performance remains consistent, learning and memorizing in the distraction condition is notably inferior compared to learning without distraction. To better compare the processing time between conditions, the processing time of the distraction was subtracted from the total processing time of the trials. Surprisingly, there was no significant effect here (U = 409989, Z = 0.91, p = .36, r = 0.01), which may be due to large standard deviation.

Table 1: Means and standard deviation (in Brackets) of the task correctness and memory task (in percent) and the overall completion time in seconds for tasks with and without pop–ups for the text comprehension tasks.

	No Pop–Up	Pop–Up
Task Correctness	0.57 (0.27)	0.58 (0.31)
Memory Correctness	0.76 (0.42)	0.66 (0.38)
Time	17821 (15739)	30915 (27831)

Task 2: Light Bulb

The following section analyzes the correctness of the light bulb task, the number of tests and repetitions (i.e., the number of tests with an already tested configuration), and the processing time, as mentioned above. The respective values are shown in Table 2. For correctness, there was no significant effect between the distraction and no distraction (U = 96241, Z = .71, p = .48, r = .02). This is also not surprising because the light bulb task was not constrained by a specific time limit, allowing participants to explore various combinations for as long as they desired without being hindered by any distractions through pop–ups. When considering the number of combinations examined, the average (see Table 2) already displays a noticeable impact of distraction, which is also proven to be statistically significant (U = 89753, Z = 2.18, p = .003, r = .09). This indicates that the presence of the distracting pop–ups requires participants to conduct more attempts to comprehend how the light bulb operates. The repeated tests also demonstrate a significant impact (U = 65581 and Z = 143380, p $<$ .001, r = .33). This suggests that a significantly higher number of tests are conducted and that previously performed tests are carried out again, likely due to forgetting induced by the appearance of distractions. Unsurprisingly, the time taken to complete the task was also significantly impacted (U = 113380, Z = 3.89, $p < .001$, r = .15). Of course, the more tests performed to understand the concept, the longer the processing time.

Discussion

This study investigated the impact of brief interruptions on different aspects of routine academic tasks. Unlike previous research that focused on prolonged distractions or non–academic tasks (Storch, 1992; West, 1999), this study specif-

Table 2: Means and standard deviation (in Brackets) of the variable's correctness (in percent), the number of tests and repetitions, as well as the overall completion time in seconds for tasks with and without pop–ups for the light bulb tasks.

	No Pop–Up	Pop–Up
Correctness	0.78 (0.32)	0.77 (0.42)
Number of tests	5.18 (3.26)	8.43 (4.54)
Number of reps	1.60 (0.4)	3.4 (2.38)
Time	26428 (16739)	33052 (27996)

ically analyzed the impact of two types of disruptions on a normal academic workload. The main focus was on the comprehension of written material and the ability to establish a structured approach to work. As a result, participants were given two main tasks (one involving text comprehension and memorizing and another involving Boolean concepts), with subsequent questionnaires to collect their feedback. First of all, the results showed no significant difference in the type of distraction, either during the main tasks or in the overall results. An explanation may be provided through the memory–for–problem state theory, which suggests that the difficulty of the secondary task is inconsequential as long as it has a well–defined problem state (Borst, Taatgen, & van Rijn, 2015). Both pop–ups had a specified problem, possibly with differing levels of complexity (as evidenced by the greater irritation experienced by test participants with the party pop–up), but produced similar outcomes. Furthermore, unlike previous studies (Broadbent, 1958; Farlane, 2001; Tulving & Thomson, 1973) on multitasking and working memory, we did not observe any impact of interruptions on accuracy, whether in the reading task, light bulb task, or overall. This could be attributed to the nature of the task. As demonstrated by Farlane (2001), primary tasks are significantly affected when they demand sustained attention. The persistent presence of the task may mitigate the influence of temporary lapses in attention and allow for the retrieval of forgotten information without detrimentally affecting performance later on.

However, when the memory task is considered separately from the reading task, there is a noticeable effect on memory performance. This means that the participants did not experience declines in text comprehension but did experience significant declines in later memory–related tasks. This finding is highly relevant in the context of daily academic life. While disruptive interruptions do not affect comprehension of the task at hand, they significantly decrease information retention. This could have implications for future learning success. The light bulb experiments show that, when pop–ups appeared, participants needed significantly more trials to understand how the light bulb worked. This is consistent with Cutrell et al. (2001), which showed that the presence of pop–ups required more reminders to achieve search goals.

All of these findings could be explained with the help of research of West (1999). He shows that encountering a distractor during a memory task has a greater impact on executive efficiency and retention. This results in more intrusion errors compared to its interference with the encoding of relevant information in working memory. Despite the interruption, the important information for reading comprehension from task 1 can be encoded, and the direct questions can be answered without rereading the text, which could explain the insignificant processing time there. This is supported by the participants' self–report of not having to reread the text after the appearance of a pop–up. In contrast, for the memorization in task 1 or comprehending the light bulb of task 2, participants had to remember, e.g., use executive processes to manipulate information and compare different states of the inputs. As West (1999) postulates, distraction enhances this and leads to more errors, e.g., an increased number of tests. Unsurprisingly, processing time was significantly increased in the pop–up condition, also supported by findings of previous researchers (Gillie & Broadbent, 1989; Zureick et al., 2018)

In addition, the distraction condition of the light bulb task led to a significant increase in processing time, as shown by previous research (Gillie & Broadbent, 1989; Zureick et al., 2018). This is unsurprising, given that more trials were completed in this condition. Supplementary, participants had a significantly higher repetition rate of 40 % when distraction occurred and only 20 % without any distraction. But surprisingly, only 14 % of the repetitions were around the appearance of the distraction. So they mostly remembered what they tested before the pop–up but could not remember the tested combinations a longer time ago. This contrasts the theory of Einstein et al. (1996), which proposes an overload of the working memory through distraction. This would indicate that rather recently tested combinations should have been forgotten. Further research is required to address this different.

Conclusion

In summary, our study revealed a notable impact of distractions on performance in tasks involving memorization of read information. It also showed an increase in the number of tests and repetitions and the prolonged processing time for the tasks involving a systematic work approach. However, further investigation is needed to understand how pop–up interruptions affect new information or information stored in working memory over extended periods. This study's findings suggest that even brief and seemingly unobtrusive pop–up notifications, similar to those commonly encountered in academic settings, can substantially influence learning and working memory. Given their frequent presence on smartphones and laptops during daily activities, it is evident that even minor interruptions can impede learning performance. A practical recommendation would be to minimize these digital disruptions by disabling instant messaging systems during tasks requiring significant concentration or planning; likewise, turning off email alerts or using app–blocking systems could help create an uninterrupted learning environment.

Acknowledgements

This project has received partial funding from a grant to MR within the DFG projects 427257555 and 318378366. Furthermore, the "Freiraum 2022–Stiftung Innovationen in der Hochschullehre", FRFMM-526/2022, has provided additional funding.

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