ЭКСПЕРИМЕНТАЛЬНЫЕ И ЭМПИРИЧЕСКИЕ ИССЛЕДОВАНИЯ

Do notifications cause errors? The impact of hover effect and notifications on attention

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Abstract

Introduction / Problem. Despite the widespread use of websites and notifications, few studies have examined whether distraction caused by notifications can lead to attentional errors. To the best of our knowledge, no previous study has investigated this issue while taking other website characteristics into account. **Objective**. The present study aimed to clarify whether attentional errors may arise from distraction by notifications while varying website hover effects, that is, perceptual feedback from interactive elements, and notification characteristics, including animation and content, in tasks assessing sustained attention and attentional shifting. **Methods**. Five experiments were conducted: Experiments 1–3 focused on sustained attention, whereas Experiments 4–5 examined attentional shifting. A modified Bourdon test was used as the primary task. **Results**. Accuracy in the sustained attention task was higher when hover effects were present, even when notifications appeared. However, this effect disappeared when notifications included content. Moreover, in the hover-effect condition, performance on the sustained attention task was associated with an increased number of errors after notifications were closed. For attentional shifting, no performance advantage was found in the hover-effect condition, nor was there an increase in errors after notifications appeared. In both tasks, notifications were detected more quickly when hover effects were present, suggesting a facilitative effect on selective attention. **Conclusions**. The findings indicate that notifications do not inevitably lead to errors. Such errors appear to arise only under a combination of conditions: high cognitive load and the presence of hover effects on a website.

Keywords: sustained attention, attention shifting, notifications, hover effect, attentional errors, overload, guidance, cognitive-digital interaction

Acknowledgements

The author expresses gratitude to Platon Tikhonenko, Eleonora Pikalo, and Sergej Polin for their assistance with coding the experiment, and to Elina Shaipova for her help with data collection.

Funding

This work is an output of a research project (HSE-BR-2025-046) implemented as part of the Basic Research Program at HSE University.

For citation:

Anufrieva A.A. Do notifications cause errors? The impact of hover effect and notifications on attention. Psikhologicheskie Issledovaniya, 2026, Vol. 19, No. 108, p. 8. https://psystudy.ru

Article address: https://doi.org/10.54359/ps.v19i108.2216

Received 03.04.2026
Revised 02.06.2026
Accepted 03.07.2026
Published 31.08.2026

Вызывают ли уведомления ошибки? Влияние эффекта наведения и уведомлений на внимание

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Аннотация

Введение/Проблема: несмотря на повсеместность использования веб-сайтов и уведомлений, редкие работы изучают, может ли отвлечение на уведомления вызывать ошибки. И ни одно из предыдущих исследований не изучало этот вопрос с учетом других характеристик веб-сайта. **Цель**: настоящее исследование было направлено на прояснение возможности возникновения ошибок внимания вследствие отвлечения на уведомления при варьировании эффекта наведения на веб-сайте (перцептивная обратной связи от интерактивных элементов) и характеристик уведомлений (анимации и содержания) в контексте задач на устойчивость и переключаемость внимания. **Методы**: было проведено пять экспериментов: Эксперименты 1–3 были посвящены изучению устойчивости внимания, а Эксперименты 4–5 были направлены на исследование переключаемости. В качестве методики использовался модифицированный тест Бурдона. **Результаты**: точность выполнения задачи на устойчивость внимания была выше в условиях наличия эффекта наведения, даже когда возникали уведомления. Однако данный эффект исчезал при добавлении содержания в уведомления. Кроме того, в условиях наличия эффекта наведения при выполнении задачи на устойчивость внимания увеличивалось количество ошибок после закрытия уведомлений. Для переключаемости внимания не было обнаружено преимуществ в выполнении задачи в условии с эффектом наведения, как и увеличения количества ошибок после появления уведомлений. В обеих задачах уведомления обнаруживались быстрее при наличии эффекта наведения, что свидетельствует о его облегчающем влиянии на избирательное внимание. **Выводы**: полученные результаты указывают на то, что уведомления не всегда приводят к возникновению ошибок. По-видимому, для их возникновения требуется сочетание условий высокой когнитивной нагрузки и наличия эффекта наведения на веб-сайте.

Ключевые слова: устойчивость внимания, переключаемость внимания, уведомления, эффект наведения, ошибки внимания, перегрузка, направление, когнитивно-цифровое взаимодействие

Благодарности

Автор выражает благодарность Платону Тихоненко, Элеоноре Пикало и Сергею Полину за помощь в программировании эксперимента, а также Элине Шаиповой за помощь в сборе данных.

Финансирование

Исследование осуществлено в рамках Программы фундаментальных исследований НИУ ВШЭ (HSE-BR-2025-046).

Ссылка для цитирования

Ануфриева А.А. Вызывают ли уведомления ошибки? Влияние эффекта наведения и уведомлений на внимание. Психологические исследования. 2026. Т. 19, № 108. С. 8.
URL: https://psystudy.ru

Адрес статьи: https://doi.org/10.54359/ps.v19i108.2216

Поступила в редакцию 03.04.2026
Поступила после рецензирования 02.06.2026
Принята к публикации 03.07.2026
Опубликована 31.08.2026

Introduction

When interacting with gadgets (smartphones, tablets, and computers), we are forced to absorb a large amount of information. We use our attention system to filter this information, but we can also cope with the flow of information using built-in digital functions, namely notification systems. Notifications are a transient element of the interface designed to convey additional, new, and important information to the user. Although notifications help us focus our attention on something new and important, they often act as distractions, interrupting our current activity [Paul, 2013]. Numerous studies demonstrate the negative impact of notifications on human activity [Okoshi et al., 2016; Wilmer et al., 2017; Firth et al., 2019; Kozyreva et al., 2020]. However, people still prefer to keep notifications enabled [Okoshi et al., 2016]. This study aims to clarify the impact of notifications as an interruption factor on attention, as well as the interaction of notifications with other interface elements. The latter seems to be a pivotal topic, since in everyday life we constantly interact with interfaces consisting of different elements, but few studies investigate their complex impact on attention [Anufrieva, 2025].

The impact of interruption

Since notifications are most often considered as an interruption, it is necessary to briefly review the relevant theories. Miyata and Norman's [Miyata, Norman, 1986] Theory of Interruption Cost (TIC) asserts that different stages of any activity involve different levels of workload and, therefore, different sensitivity (cost) to interruption [Miyata, Norman, 1986; Paul, 2013]. The worst moment for interruption is during the execution of the task, compared to the planning and evaluation phases. Another example is the DETOUR model, which explains the effects of interruption through the activation of task schemas and the cognitive resources required for this [Couffe, Michael, 2017]. The main task has a mental schema that is held in working memory (WM) during execution and requires active attention. At the moment of interruption, it becomes necessary to a) suppress the main task schema, b) activate the schema of the additional task, and c) inhibit the additional task schema to return to the main task. All these actions require resources, the allocation of which will depend on the duration and complexity of the interruption.

One well-studied phenomenon is the resumption error effect: after distraction, the probability of making a mistake increases [McCrickard et al., 2003a, 2003b; Trafton et al., 2003; Altmann, Trafton, 2002, 2004; Brumby et al., 2019]. A study by Altmann and colleagues [Altmann et al., 2017] showed that the longer the interruption lasted, the more errors there were, which was explained by the fading of the trace in WM of the next step in the main task. Two types of tasks can be distinguished: procedural and continuous [Altmann et al., 2017; Hirsch et al., 2023]. Procedural tasks have clear subtasks with start and end points. Moreover, there are two types of errors associated with procedural tasks: nonsequence errors (the step is correctly «chosen» but incorrectly performed) and sequence errors (the step is incorrectly chosen but correctly performed). Research by Altmann and colleagues [Altmann et al., 2017] demonstrates that sequence errors are sensitive to the duration of the interruption, while nonsequence errors are not. Sequence errors are believed to be related to working or prospective memory, while nonsequence errors are related to attention mechanisms [Hirsch et al., 2023]. Thus, only procedural tasks and sequence errors in them can be considered as the effect of resumption errors and are associated with memory mechanisms rather than attention mechanisms. Nevertheless, Brazzolotto et al. [Brazzolotto et al., 2021] suggest that it is not only memory that is sensitive to interruption. Their results showed that the time to resume the primary task was longer after a complex additional task; however, the later the interruption occurred relative to the start of the primary task, the faster the return after the distraction. Principal Component Analysis showed that the effects of interruption complexity were related to attention, and the effects of the interruption stage were related to WM. This supports the DETOUR model's view of the impact of interruption on both memory and attention. Thus, the question arises whether attention is sensitive to interruption in sense of errors occurrence, especially after notifications as an interrupter.

The impact of notifications on attention

Although notifications can be considered the main exogenous factor of interruption in the digital environment, there are relatively few experimental studies on the impact of notifications, and they differ in their methodologies. In general, studies in this area demonstrate the sensitivity of attention to the content and animation of notifications. For example, attention sustainability, or sustained attention increases if the notification contains a call for attention (vs. control group) [Chen, Huang, 2013]. Also, there is a correlation between the duration of returning to the main task and the resources spent on processing the notification content [Levy et al., 2016]. Another important component of a notification is animation:

fading, flickering, smooth movement, popping up, etc. [Matthews, 2004]. According to Wilson [Wilson, 2006], the more noticeable the notification (e.g., pop-up), the faster the RT, but the longer the period of resuming the task after distraction. Differences were also found in the stage of the main task (transcribing the text) at which subjects reported detecting the notification. If the notification appeared gradually, it was reported at the end of typing a word, and if it was a pop-up, it was reported in the middle. Taken together, this is consistent with TIC's views on the relationship between the stage of interruption and its consequences. Also, some studies show that the animation of notifications affects not only their noticeability but also their distractibility, measured by a survey [Klauck et al., 2017]. Thus, the more noticeable a notification is, the more distracting it is perceived. It is also interesting to note that scanning tasks (e.g., searching by name in a list) are more sensitive to notification interruptions, prolonging the time of primary task execution, than semantic tasks (e.g., searching by meaning) [Czerwinski et al., 2000]. They explain these results by the higher cost of returning after an interruption, since the task of scanning and detecting notifications involves similar mechanisms of attention. Although some studies report a decline in sustained attention following notification sounds (e.g. [Stothart et al., 2015]), very few works have examined task accuracy before and after the interruption in the visual modality, where notifications appear on the screen, and the task instructions require their dismissal. For example, it has been found that the appearance of smartphone notifications during the performance of a Stroop task on the same device does not lead to changes in error rates [Fournier et al., 2026]. Most studies discussed in this and preceding sections primarily focus on RT and resumption latency, and frequently employ secondary tasks (e.g., arithmetic operations) rather than notifications as the interrupter. Consequently, there is currently limited understanding of how notifications affect visual attention, particularly in terms of error rates in the primary task.

Notifications as a part of the interface

Another factor that must be considered when studying notifications is their potential interaction with other elements of the website interface design. For example, Anufrieva and Gorbunova [Anufrieva, Gorbunova, 2025] showed that the presence of a hover effect influences attention sustainability. The hover effect is a feature of an interactive interface that manifests itself in a change in the colour or state of an element when interacting with it. According to the research of Anufrieva & Gorbunova [Anufrieva, Gorbunova, 2025], when performing a task on attention sustainability (the Bourdon test) on a website with the hover effect, the indicators were higher than on a website without it. These results support the idea of the guiding influence of interface organisation – the interface is designed to help the user achieve their goal [Norman, 1992, 2008]. However, there is an idea that the number and variety of interface elements leads to attention overload [Huang, 2003]. According to the theoretical ideas of Anufrieva [Anufrieva, 2025], the hover effect and notifications are examples or aspects of the saturation of the digital environment, i.e., its ability to interact. These aspects are exogenous and affect attention specifically: selection, retention, and reallocation. The author suggests that aspects of saturation should not be viewed as exclusively overloading or guiding factors. Their effect on attention may depend on a combination of the characteristics of these aspects and their interaction effects. It is known from the study by Anufrieva and Gorbunova [Anufrieva, Gorbunova, 2025) that the hover effect exerts a guiding influence on measures of sustained attention. However, the nature of the interaction between notifications and the hover effect has not yet been investigated. This raises the question of whether adding notifications to a website with the hover effect will lead to overload, or the guiding influence of the hover effect will remain.

Problem of current research

In summary, according to some models and studies (e.g., [Altmann et al., 2017]), attention is not sensitive to interruption characteristics, while others emphasise its leading role (e.g., [Brazzolotto et al., 2021]). Also, although notifications are considered as an interrupting factor, few empirical studies have examined the impact of notification's occurrence on errors probability after it. Moreover, no study has included other interface elements as factors. The study poses two research questions:

Question 1: Can task interruption by a notification cause error?

Question 2: What is the nature of the interaction between notifications and the hover effect in terms of their impact on attention: is it guiding or overloading?

To answer these questions, five experiments were conducted: three of them were aimed at studying attention sustainability (Experiments 1–3), while the others were devoted to attention shifting (Experiments 4–5). The Bourdon test, which was used in the study by Anufrieva & Gorbunova [Anufrieva, Gorbunova, 2025], was chosen as the main task, as this task can be classified as a scanning task that is sensitive to interruption. Not only the mere presence of notifications in the trial was varied, but also their animation and content, as attention is sensitive to these factors, and it also allows a comprehensive assessment of the contribution of notification components [Paul, 2013]. Notifications always appeared in the middle of the trial, since according to TIC, the cost of interruption is highest at the execution stage. Considering the results of the study by Anufrieva & Gorbunova [Anufrieva, Gorbunova, 2025], the presence of the hover effect on the website was varied to test for the character of their interaction.

Attentional errors in this paper refer to clicking on a non-target word, i.e., false alarms. Therefore, it resembles nonsequence errors, in Altmann et. al terminology, when the participant does a correct action (click on slots) but incorrectly perform it (choose a wrong slot). Thus, if the fact of distraction by a notification disrupts attention, we should see an increase in false alarms after notifications. Also, an increase in attentional errors would indicate overload — a deterioration in task performance. If the combination of interface elements, such as the hover effect and notifications, leads to attention overload, then attention tests scores should be higher in the condition without the hover effect and in trials without notifications.

Current study

Transparency and Openness

This study was approved by the HSE Committee on Interuniversity Surveys and Ethical Assessment of Empirical Research. The study design was not preregistered. All data and code are available on the Open Science Framework (https://osf.io/qusy4/overview?view_only=9bb0e537ce01432ea5f7949974912517). Analyses were conducted in RStudio 2024.12.1. Sample size calculation, all measures, and data exclusions principles have been reported further.

Experiment 1. Attention sustainability: hover effect and notification

Experiment 1 aimed to clarify the possibility of attentional errors in the presence of notifications with different animations (without content) in conditions with and without the hover effect. Also, the aim was to replicate the influence of the hover effect on attention sustainability from the study by Anufrieva & Gorbunova [Anufrieva, Gorbunova, 2025]. Here and hereafter, with the hover effect condition was a website with all interactive elements. Without the hover effect condition was a screenshot of the same website implemented in the Psychopy programme (Pavlovia). Both conditions had the same appearance (Figure 1).

In the condition with the hover effect, all elements (the website itself, the browser panel, the operating system panel) were interactive, i.e. they had the hover effect - when the mouse was hovered or clicked, the colour and state of the element changed. In the condition without the hover effect, only when the slot area (blue rectangles; Figure 1) was clicked, a strikethrough

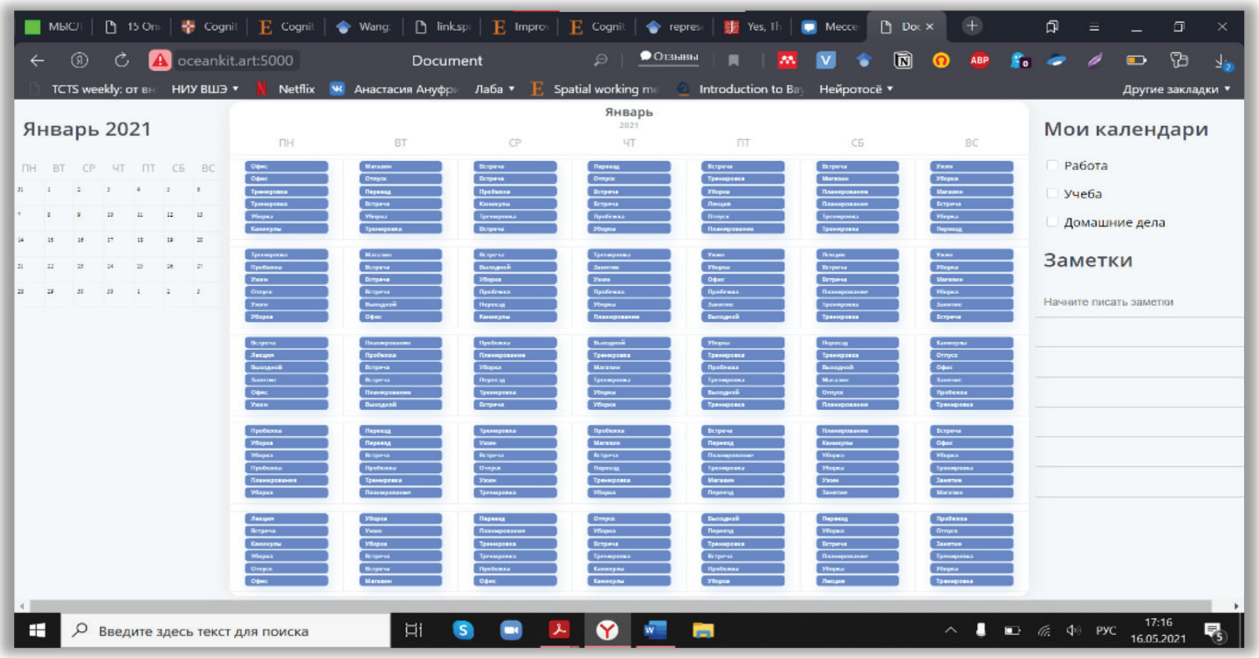

Fig. 1*. The task space for both groups.* / ***Рис. 1****. Пространство задачи для обеих групп.*

***Fig. 2**. The exterior view of notification. / **Рис. 2**. Внешний вид уведомления.*

word line appeared. The rest of the screenshot area had no interactivity. Five types of notification animation were selected: 1. gradually appearing; 2. pop-up; 3. flickering; 4. appearing through transparency reduction; 5. appearing at the bottom of the screen in the center with movement to the right corner. The exterior appearance of notifications was the same for all types of animation (see Figure 2), and notifications were empty.

Participants

A sample size analysis, using the G*Power 3.1.9.7 programme, based on study by Anufrieva & Gorbunova [Anufrieva, Gorbunova, 2025] was conducted. The effect size f was 0.27 with 0.05 or less alpha, and the achieved power was 62% for accuracy in the Bourdon test, and f = 0.36 with alpha 0.05 or less and 85% for execution rate. According to the results, the total sample size should have been 60 participants. This indicator served as a benchmark for all subsequent experiments. Hereinafter, all participants were provided with a written informed consent form. All data were anonymised. Students of the school of psychology were recruited and rewarded with points into university course. In addition, people were recruited using the Yandex.Toloka, where participation was rewarded with a fee (about 1.5 dollars). Participants were randomly divided into two groups with and without the hover effect. 30 people per group. The data was not accepted if the subject did not close more than 30% of notifications or made only three clicks in each trial. The final data analysis included 60 participants (age: M = 24.5, SD = 2.1, sex: 45 female): 30 people from Yandex.Toloka, and 30 people from the university (students).

Design

It was a mixed experimental design where two groups were distinguished from one another by the presence of the hover effect (yes or no), but all participants were presented with all the notification's type. All five types of notifications or their absence occurred in both groups, one notification per trial. Accuracy was measured as the number of correctly detected slots (CD) and the number of errors (false alarms, FA), which was measured by clicking on distractors. The RT (RT) on the notification was measured — the time since the notification appeared and was closed. The execution rate was calculated as the number of slots crossed out by the time of the trial (30 seconds). Also, the comparison of CD, FA, and execution rate before and after the notification was made using the fact of closing notification as a criterion for classifying trials as "before" and "after".

The overall number of stimuli in each probe was the same: 210 (the grid had 30 rows and 7 columns). The number of targets was 90, with 30 slots for each of the three words. Each column had 12–13 words in it, and within the columns was full random density. The trial's duration was 30 seconds. Thus, there were 5 types of notifications: 15 trials for each condition (75 trials), plus 22 trials without notifications (total of 97 trials). The duration of the experiment was 55 minutes. Notification randomly occurred between 13 and 17 seconds.

Procedure

A modified Bourdon test was used. The modified things was a format of task space — an organizer appearance, where participants search words in slots related to ordinary deals like a meeting, journey, etc. Participants had to memorize three words demonstrated for 5 seconds. Then they had to find all slots which contain the target words for 30 seconds (Figure 3). Crossing out was done by clicking on slots using the mouse. The notification occurred in the bottom right corner of the screen. After that, the participant had to click on the notification to close it and then return to the execution of the main task.

Results

Hereinafter, all results are presented with sphericity correction; pairwise comparisons are made with the Holm method. Trials with and without notifications were analysed separately.

A one-way ANOVA was conducted for trials without notification, where the factor was group (presence of the hover effect). According to the analysis, the group has a significant impact on the CD, $F(1.58) = 8.91$, $p < .01$, $\eta p2 = .13$, and the rate of execution, $F(1.58) = 8.51$, $p < .01$, $\eta p2 = .13$, but not on the FA, $F(1.58) = 1.27$, $p > .26$, $\eta p2 = .02$ (see Figures 4 and 5).

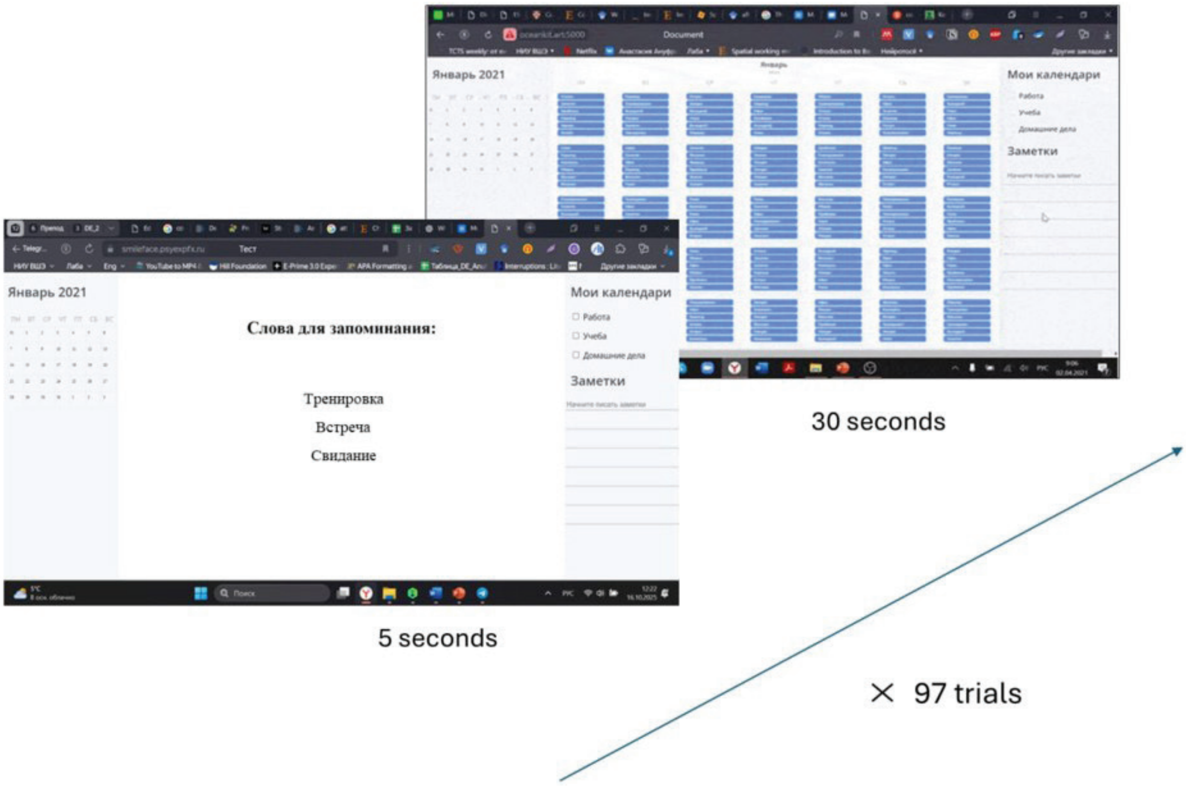

Fig. ***3***. *Experiment procedure. /* ***Рис. 3***. *Процедура эксперимента.*

Additionally, CD and FA were compared between trials without and with notifications (by animation type) within each group. For the group with the hover effect, Wilcoxon signed-rank tests with Holm correction for FA revealed a significant differences only between trials without notifications (WN) and the second type ($p < .001$). All other comparisons were not significant. For CD, significant differences were found between the second type and WN ($p < .003$), the fourth and WN ($p < .003$), and the fifth and WN ($p < .002$). All other comparisons were non-significant. For the group without the hover effect, both for FA and CD were non-significant.

A two-way mixed ANOVA was then conducted for trials with notifications, where the between-group factor was group (presence of the hover effect) and the within-group — type of notification. Ten participants from the group without the hover effect were excluded from the analysis because they never closed notifications. For the same reason, two participants from the group with the hover effect were also excluded. Consequently, the final analysis included 48 participants. No violations of homogeneity of variances were detected ($p > .05$). The analysis revealed a significant effect of group factors on CD, $F(1.46) = 6.83$, $p < .01$, $\eta p2 = .11$, rate of execution, $F(1.46) = 6.48$, $p < .02$, $\eta p2 = .11$ (without the hover effect: $M = 0.57$; with the hover effect: $M = 0.67$), and RT, $F(1.46) = 45.67$, $p < .01$, $\eta p2 = .33$, but not FA, $F(1.46) = 4.31$, $p = .05$, $\eta p2 = .02$. Notifications' type has an effect on RT, $F(4.184) = 50.25$, $p < .01$, $\eta p2 = .35$, but not on CD, $F(4.184) = 1.42$, $p = .23$, $\eta p2 = .01$, FA, $F(4.184) = 2.53$, $p > .06$, $\eta p2 = .04$, and execution rate, $F(4.184) = 1.73$, $p = .15$, $\eta p2 = .01$. Significant interactions were found only for FA, $F(4.184) = 3.91$, $p < .01$, $\eta p2 = .06$, and RT, $F(4.184) = 31.15$, $p < .01$, $\eta p2 = .34$ (see Figures 4–6).

A separate one-way RM ANOVA analysis showed the following. For the group without the hover effect, no significant impact of the notification type factor was found on any parameters (all $p > .49$) other than RT, $F(4.72) = 38.03$, $p < .00$, $\eta p2 = .52$. The pairwise comparisons showed a significant difference between the fourth type of notification and the others (all $p < .001$).

For the group with the hover effect, an effect of notification type on FA, $F(4.112) = 40.57$, $p < .00$, $\eta p2 = .43$, and RT, $F(4.112) = 4.94$, $p < .00$, $\eta p2 = .17$, was. Pairwise comparisons showed a significant difference between the second type of notification and the others in terms of FA (all $p < .001$), and a significant difference was found between the fourth

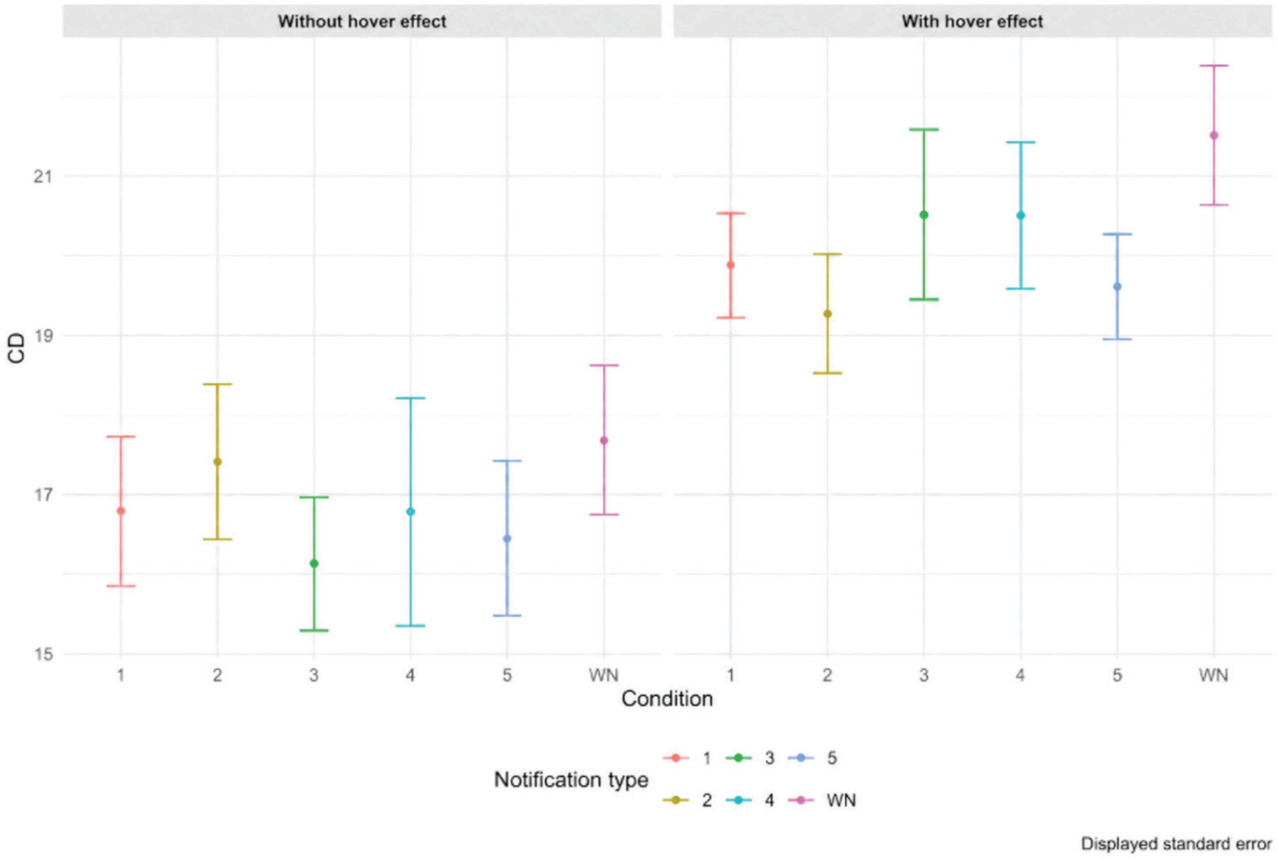

***Fig. 4**. Results of Experiment 1 for correctly detected slots (CD) in groups without and with the hover effect. / **Рис. 4**. Результаты эксперимента 1 по количеству верно найденных слотов (CD) в группах без эффекта наведения и с эффектом наведения.*

Notes. Notification types: 1 — An appearance of slow upper-movement, 2 — An appearance of a pop-up manner, 3 — An appearance of the window followed by flickering, 4 — An appearance of the window through a reduction in transparency, 5 — An appearance at the bottom of the screen center, then moves to the right corner, WN — trials without notifications. / Примечания. Типы анимации уведомлений: 1 — постепенно появляющееся (медленное возникновение с движением вверх); 2 — pop-up (внезапное возникновение без каких-либо дополнительных движений); 3 — мерцающее (после появления совершает нерегулярную серию быстрых движений, многократно появляясь и исчезая); 4 — появляющееся через снижение прозрачности (постепенно становится видимым и отчетливым); 5 — появляющееся в нижней части экрана в центре с перемещением в правый угол (внезапное возникновение, как в условии pop-up, но в нижней и центральной части экрана, затем перемещается к правому углу); WN — пробы без уведомлений.

and third ($p < .001$), fourth and fifth ($p < .001$) types of notification in terms of RT.

The paired samples Wilcoxon test (Wilcoxon signed-rank test) was used to compare indicators before and after notification. For the group without the hover effect, there were no differences for CD, $V = 4602$, $p > 0.26$, $r = .09$. However, it was for FA, $V = 1380.5$, $p < 0.04$, $r = .21$, and execution rate, $V = 715$, $p < .01$, $r = .73$ (before: $M = 0.49$; after: $M = 1.83$). Significant differences were found for the group with the hover effect: CD, $V = 1470.5$, $p < .01$, $r = .63$, FA, $V = 1116.5$, $p < .01$, $r = .45$, execution rate, $V = 387$, $p < .00$, $r = .81$ (before: $M = 0.55$; after: $M = 1.34$).

Discussion of Experiment 1

Even under conditions with notifications, the group with the hover effect was more accurate and faster, both in terms of execution rate and closing notifications. This is consistent with the results of Anufrieva and Gorbunova [Anufrieva, Gorbunova, 2025] and supports the idea that the hover effect serves as a cue for attention. Differences in the number of errors (FA) between

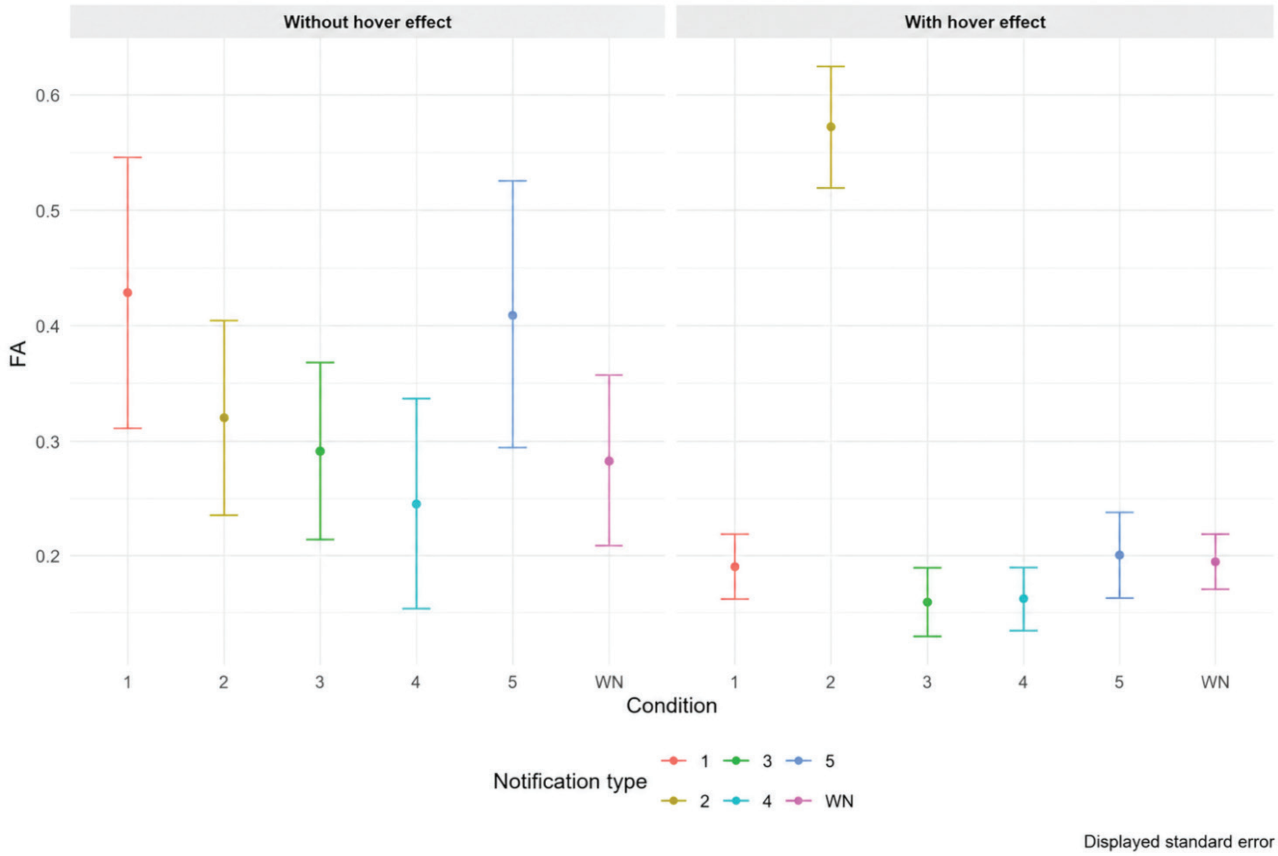

Fig. 5. *Results of Experiment 1 for false alarms (FA) in groups without and with the hover effect. /* ***Рис. 5***. *Результаты эксперимента 1 по количеству ложных тревог (FA) в группах без эффекта наведения и с эффектом наведения.*

Notes. Notification types: 1 — An appearance of slow upper-movement, 2 — An appearance of a pop-up manner, 3 — An appearance of the window followed by flickering, 4 — An appearance of the window through a reduction in transparency, 5 — An appearance at the bottom of the screen center, then moves to the right corner, WN — trials without notification. / Примечания. Типы анимации уведомлений: 1 — постепенно появляющееся (медленное возникновение с движением вверх); 2 — pop-up (внезапное возникновение без каких-либо дополнительных движений); 3 — мерцающее (после появления совершает нерегулярную серию быстрых движений, многократно появляясь и исчезая); 4 — появляющееся через снижение прозрачности (постепенно становится видимым и отчетливым); 5 — появляющееся в нижней части экрана в центре с перемещением в правый угол (внезапное возникновение, как в условии pop-up, но в нижней и центральной части экрана, затем перемещается к правому углу); WN — пробы без уведомлений.

trials with and without notifications were found only in the group with the hover effect and with the second type of notifications (pop-up). That is, the presence of notifications in general did not affect the accuracy of task performance. Regarding the notification type, the RT to the fourth type (reduction of transparency) was the slowest on average for both groups, which is consistent with the results of Wilson's [Wilson, 2006] study. However, the second type (pop-up) did not get any advantage. The results demonstrate the interaction between hover effect and notification type: under the condition without the hover effect, participants closed the fourth type of notification the most slowly, while under the condition with the hover effect and the second type of notification, the number of FAs was the highest on average. Regarding the occurrence of attentional errors, after distraction by notifications, there was an increase in FAs, but only in the condition with the hover effect. Moreover, as the number of FAs increased, so did the number of CDs, and the execution rate was getting faster. In contrast, in the condition without the hover effect, although the execution rate

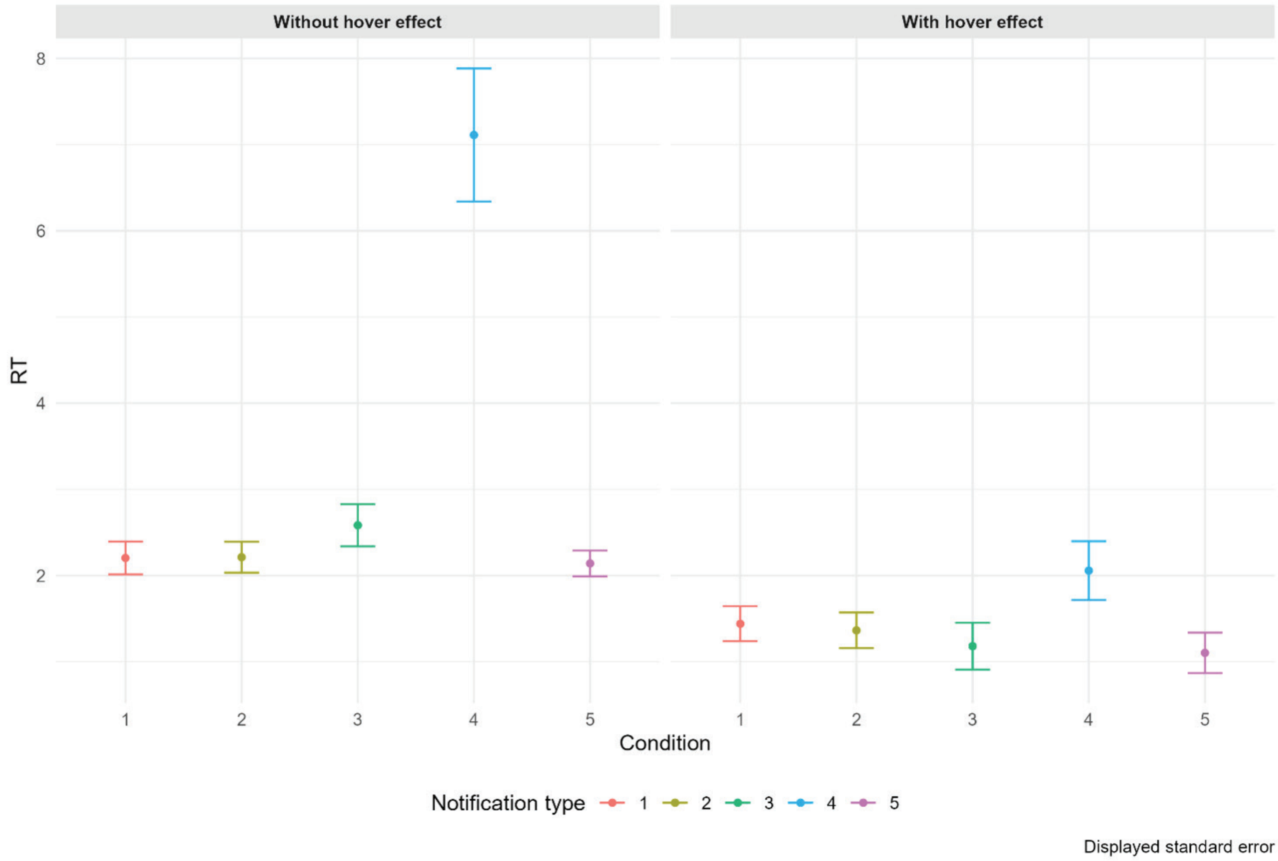

Fig. 6. *Results of Experiment 1 for reaction time (RT) in groups without and with the hover effect. /* ***Рис. 6***. *Результаты эксперимента 1 по времени реакции (RT) в группах без эффекта наведения и с эффектом наведения.*

Notes. Notification types: 1 — An appearance of slow upper-movement, 2 — An appearance of a pop-up manner, 3 — An appearance of the window followed by flickering, 4 — An appearance of the window through a reduction in transparency, 5 — An appearance at the bottom of the screen center, then moves to the right corner. / Примечания. Типы анимации уведомлений: 1 — постепенно появляющееся (медленное возникновение с движением вверх); 2 — pop-up (внезапное возникновение без каких-либо дополнительных движений); 3 — мерцающее (после появления совершает нерегулярную серию быстрых движений, многократно появляясь и исчезая); 4 — появляющееся через снижение прозрачности (постепенно становится видимым и отчетливым); 5 — появляющееся в нижней части экрана в центре с перемещением в правый угол (внезапное возникновение, как в условии pop-up, но в нижней и центральной части экрана, затем перемещается к правому углу).

was getting faster, the number of FAs decreased. This contradicts the idea of the auxiliary function of the hover effect for attention. Thus, according to the results of Experiment 1, an increase in attentional errors after notifications was found, but only in the condition with the hover effect. However, there was no overloading effect from the combination of notification and hover effect on performance in general.

Experiment 2. Attention sustainability: hover effect, notification and its content (with call to attention)

Experiment 2 aimed to investigate the possibility of attentional errors following distraction by notifications, given the presence of content in them. As some studies (e.g., [Chen & Huang, 2013]) have shown, attention is sensitive to the content of notifications. Moreover, the presence of content in notifications can be said to be a more familiar condition for interacting with them — rarely do we interact with empty notifications.

Participants

The principle of subject recruitment and data exclusion is the same as in Experiment 1. The final

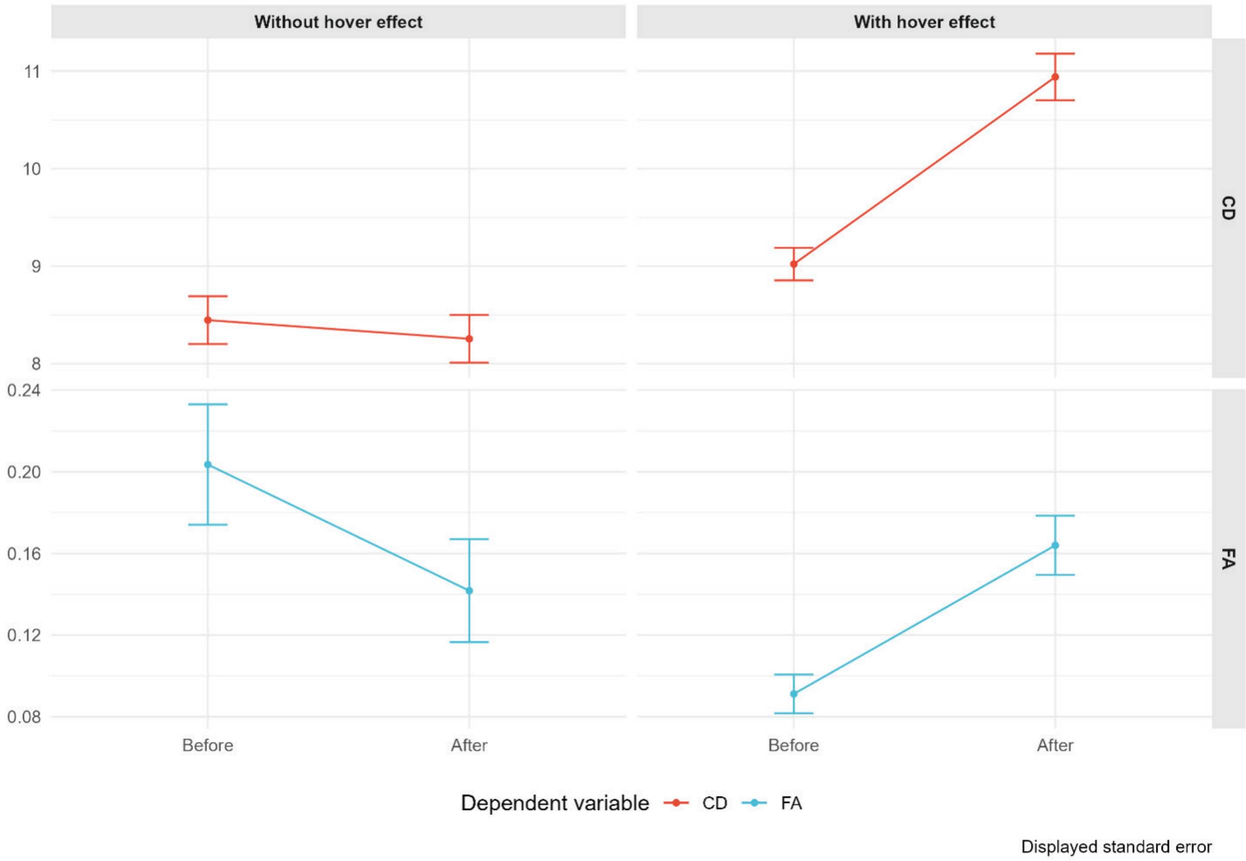

Fig. 7. Results of Experiment 1 for correctly detected slots (CD) and false alarms (FA) before and after notifications. / Рис. 7. Результаты эксперимента 1 по количеству верно найденных слотов (CD) и ложных тревог (FA) до и после уведомлений.

data analysis included 60 participants (age: M = 23.2, SD = 2.3, sex: 47 female), 30 per group.

Design

The design was the same as in Experiment 1. The only difference is that one independent variable has been added — content in notifications. The following types of content were used: absence of content, distractor words (words related to ordinary deals like shopping, calling, etc.), call to attention ("Be careful!"). Thus, there were 5 types of notifications, 15 trials for each type, and among these 15 trials, 5 were notifications with a call to action, 5 were distracting words as content, and 5 were empty notifications.

Procedure

The procedure was the same as in Experiment 1.

Results

A one-way ANOVA was used for trials without notification, where the factor was group (presence of the hover effect). According to the analysis, the group factor had no effect on any of the measures: CD, $F(1.58) = 3.08$, $p > .09$, $\eta p2 = .05$, FA, $F(1.58) = 1.48$, $p > .24$, $\eta p2 = .02$, rate of execution, $F(1.58) = 2.93$, $p > .09$, $\eta p2 = .05$ (see Figures 8 and 9).

Comparison of trials with and without notifications in the group with the hover effect demonstrated a significant difference in CD rate between WN and the third type ($p < .004$). Other comparisons for FA and CD were not significant. For the group without the hover effect, no significant differences were observed for FA and CD.

A three-way mixed ANOVA, where the between-group factor was group and the within-group factors were notification type and content were used. Data from eight participants in the group without the hover effect and one participant in the group with the hover effect who did not close notifications were preliminarily excluded from the analysis. Consequently, data from 51 participants were included in the final analysis. No violations of homogeneity were detected ($p > .05$). It was found no effect of the group factor: CD, $F(1.49) = 1.64$, $p > .21$, $\eta p2 = .04$, FA, $F(1.49) = 0.16$, $p > .78$, $\eta p2 = .01$, rate of execution, $F(1.49) = 1.70$, $p > .29$, $\eta p2 = .03$. The exception was the RT, $F(1.49) = 27.28$, $p < .00$, $\eta p2 = .29$. For the notification type as a factor,

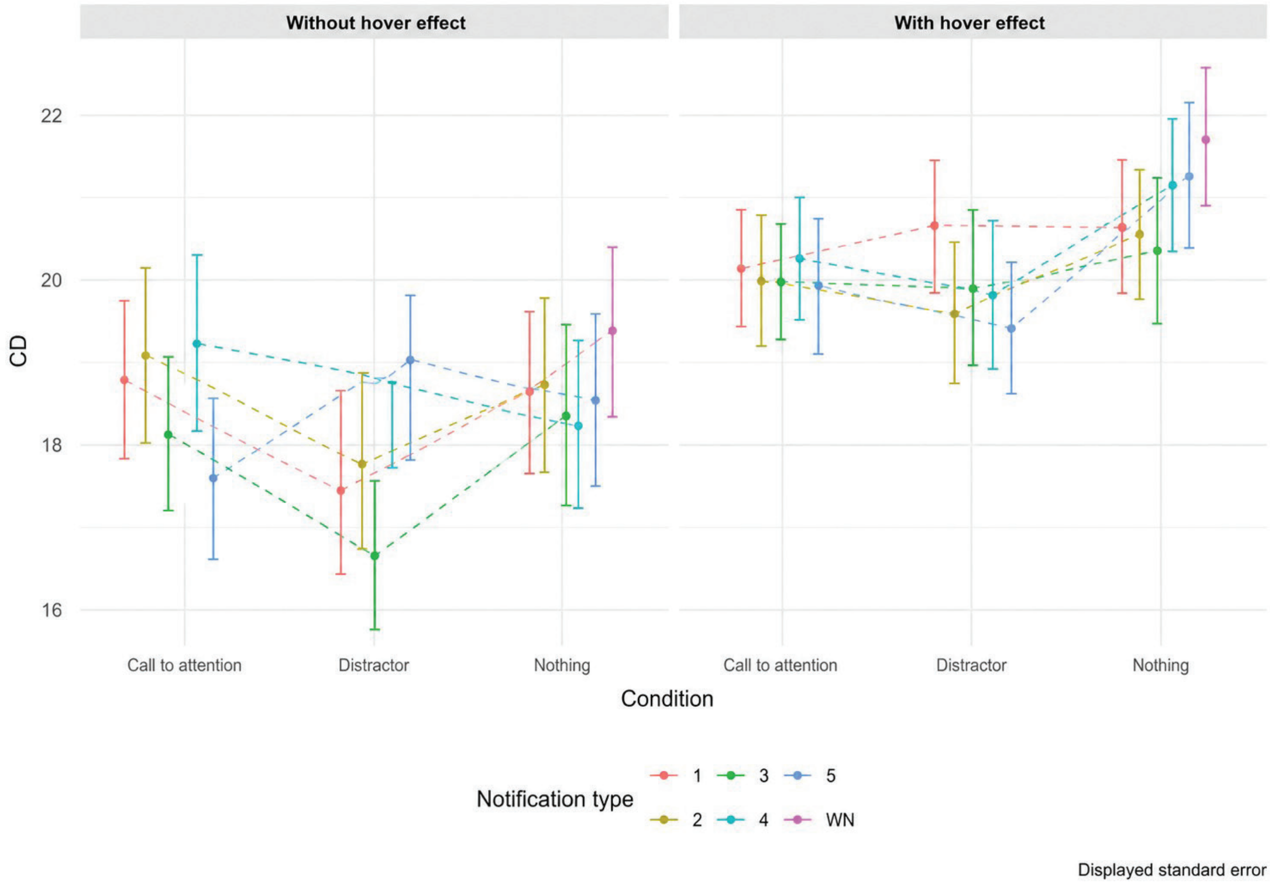

***Fig. 8**. Results of Experiment 2 for correctly detected slots (CD) in groups without and with the hover effect and three types of content (call to attention, distractor, or nothing). / **Рис. 8**. Результаты эксперимента 2 по количеству верно найденных слотов (CD) в группах без эффекта наведения и с эффектом наведения, а также при трех типах содержания уведомлений (привлечение внимания, дистрактор или отсутствие содержания).*

Notes. Notification types: 1 — An appearance of slow upper-movement, 2 — An appearance of a pop-up manner, 3 — An appearance of the window followed by flickering, 4 — An appearance of the window through a reduction in transparency, 5 — An appearance at the bottom of the screen center, then moves to the right corner, WN — trials without notification. / Примечания. Типы анимации уведомлений: 1 — постепенно появляющееся (медленное возникновение с движением вверх); 2 — pop-up (внезапное возникновение без каких-либо дополнительных движений); 3 — мерцающее (после появления совершает нерегулярную серию быстрых движений, многократно появляясь и исчезая); 4 — появляющееся через снижение прозрачности (постепенно становится видимым и отчетливым); 5 — появляющееся в нижней части экрана в центре с перемещением в правый угол (внезапное возникновение, как в условии pop-up, но в нижней и центральной части экрана, затем перемещается к правому углу); WN — пробы без уведомлений.

it was found that there was no effect on CD, $F(4.196) = 1.46$, $p > .35$, $\eta p2 = .00$ and execution rate, $F(4.196) = 2.27$, $p > .07$, $\eta p2 = .01$. However, type influenced FA, $F(4.196) = 9.93$, $p < .01$, $\eta p2 = .14$, RT, $F(4.196) = 55.75$, $p < .01$, $\eta p2 = .13$. The content factor had a significant effect on measures: CD, $F(2.98) = 7.63$, $p < .01$, $\eta p2 = .01$, FA, $F(2.98) = 22.12$, $p < .01$, $\eta p2 = .15$, rate of execution, $F(2.98) = 3.73$, $p < .03$, $\eta p2 = .01$. The exception here was the RT, $F(2.98) = 0.86$, $p > .39$, $\eta p2 = .01$. Significant interactions of all three factors were found for all indicators (all $p < .03$). See Figures 8–10.

A two-way RM ANOVA for the group without the hover effect showed that the notification type factor only had an impact on the RT, $F(4.84) = 46.42$, $p < .001$, $\eta p2 = .25$. The pairwise comparisons revealed

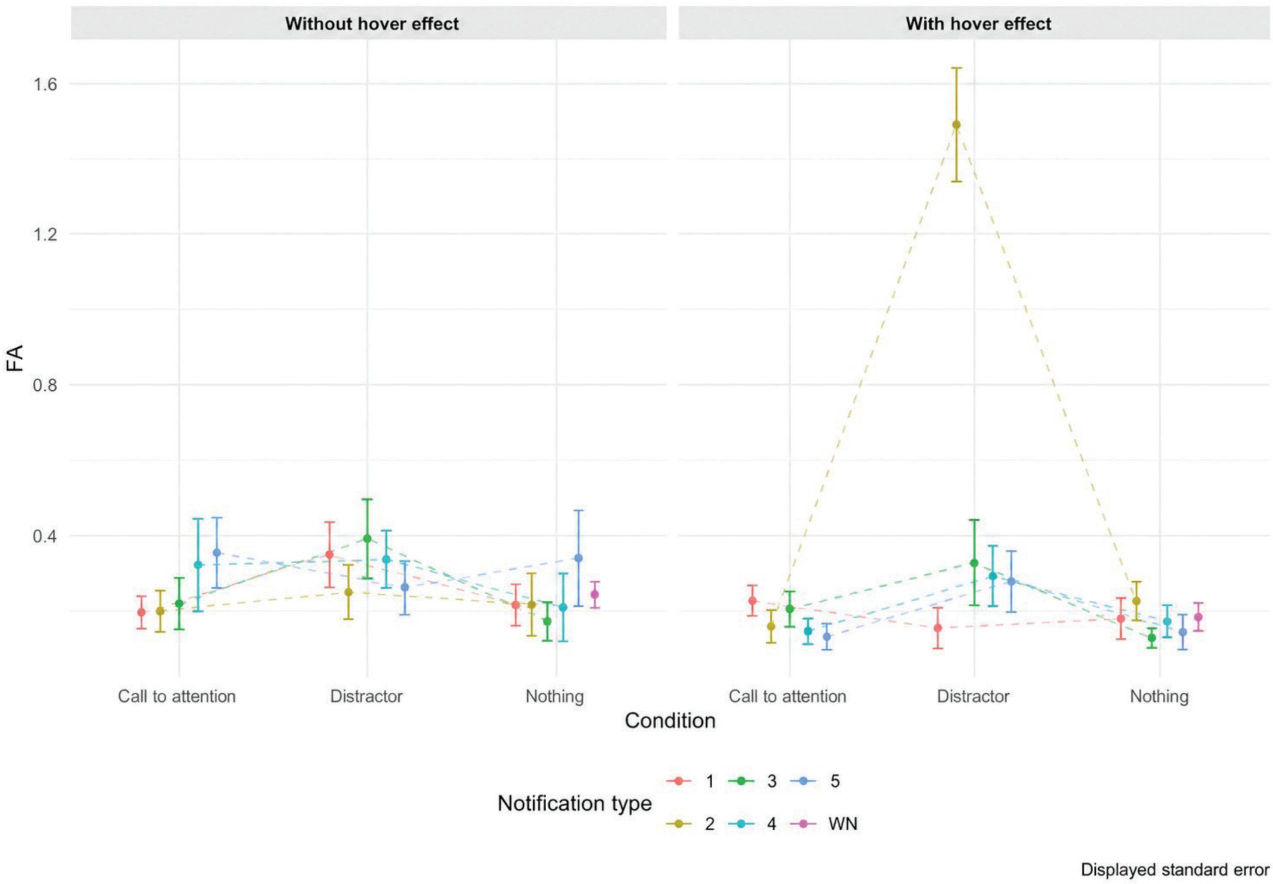

Fig. 9. *Results of Experiment 2 for false alarms (FA) in groups without and with the hover effect and three types of content (call to attention, distractor, or nothing). /* ***Рис. 9***. *Результаты эксперимента 2 по количеству ложных тревог (FA) в группах без эффекта наведения и с эффектом наведения, а также при трех типах содержания уведомлений (привлечение внимания, дистрактор или отсутствие содержания).*

Notes. Notification types: 1 — An appearance of slow upper-movement, 2 — An appearance of a pop-up manner, 3 — An appearance of the window followed by flickering, 4 — An appearance of the window through a reduction in transparency, 5 — An appearance at the bottom of the screen center, then moves to the right corner, WN — trials without notification. / Примечания. Типы анимации уведомлений: 1 — постепенно появляющееся (медленное возникновение с движением вверх); 2 — pop-up (внезапное возникновение без каких-либо дополнительных движений); 3 — мерцающее (после появления совершает нерегулярную серию быстрых движений, многократно появляясь и исчезая); 4 — появляющееся через снижение прозрачности (постепенно становится видимым и отчетливым); 5 — появляющееся в нижней части экрана в центре с перемещением в правый угол (внезапное возникновение, как в условии pop-up, но в нижней и центральной части экрана, затем перемещается к правому углу); WN — пробы без уведомлений.

significant differences between the fourth notification type and the others (all $p < .001$). The content type factor had no effect on any of the dependent variables (all $p > .15$).

A two-way RM ANOVA for the group with the hover effect demonstrated that the notification type factor influenced FA, $F(4.112) = 37.82$, $p < .001$, $\eta p2 = .28$, and RT, $F(4.112) = 7.32$, $p < .001$, $\eta p2 = .03$. The pairwise comparison analysis showed that FA was significantly different under the second type of notification condition from the others (all $p < .001$). For the RT, pairwise comparisons showed that first type significantly differed from second, third and fourth ($ps < .001$), but not from fifth ($p = .71$). Second type differed from fourth and fifth ($ps < .001$), but not from third ($p = .89$). The third significantly

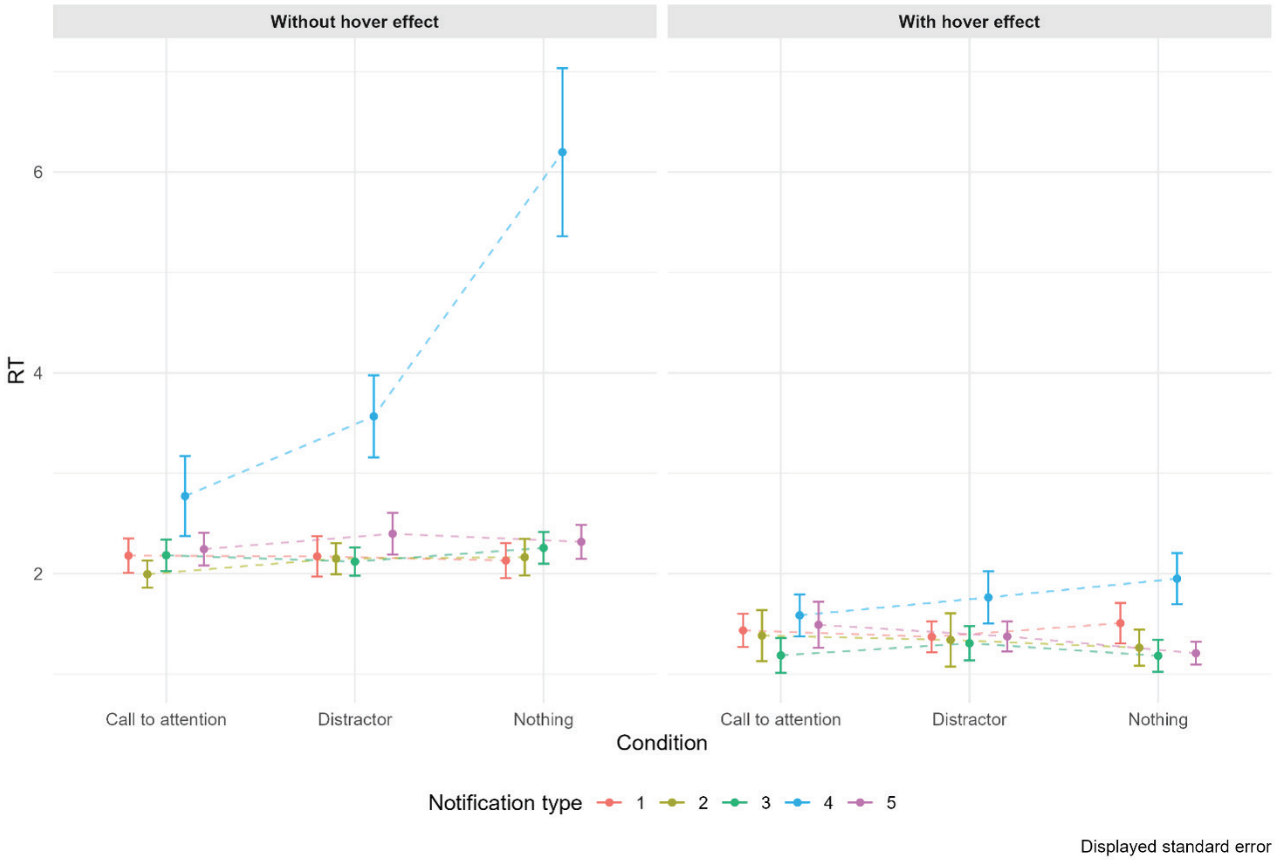

***Fig. 10**. Results of Experiment 2 for reaction time (RT) in groups without and with the hover effect and three types of content (call to attention, distractor, or nothing). / **Рис. 10**. Результаты эксперимента 2 по времени реакции (RT) в группах без эффекта наведения и с эффектом наведения, а также при трех типах содержания уведомлений (привлечение внимания, дистрактор или отсутствие содержания).*

Notes. Notification types: 1 — An appearance of slow upper-movement, 2 — An appearance of a pop-up manner, 3 — An appearance of the window followed by flickering, 4 — An appearance of the window through a reduction in transparency, 5 — An appearance at the bottom of the screen center, then moves to the right corner. / Примечания. Типы анимации уведомлений: 1 — постепенно появляющееся (медленное возникновение с движением вверх); 2 — pop-up (внезапное возникновение без каких-либо дополнительных движений); 3 — мерцающее (после появления совершает нерегулярную серию быстрых движений, многократно появляясь и исчезая); 4 — появляющееся через снижение прозрачности (постепенно становится видимым и отчетливым); 5 — появляющееся в нижней части экрана в центре с перемещением в правый угол (внезапное возникновение, как в условии pop-up, но в нижней и центральной части экрана, затем перемещается к правому углу).

differed from fourth and fifth ($ps < .001$), while fourth significantly differed from all other notification types ($ps < .001$).

Type of content influenced CD, $F(2.56) = 7.44$, $p < .001$, $\eta p2 = .01$, FA, $F(2.56) = 36.78$, $p < .001$, $\eta p2 = .26$, and execution rate, $F(2.56) = 6.77$, $p < .001$, $\eta p2 = .01$. The analysis of the pairwise comparisons showed that the CD, FA, and execution rate for different types of content within notifications differed. For the CD, the condition without the content significantly differed both from call to attention ($p < .001$) and distractor ($p < .001$), whereas the difference between call to attention and distractor was not significant ($p = .35$). For the FA, the condition without the content significantly differed from distractor ($p < .001$), but not from call to attention ($p > .58$). The difference between call to attention and distractor was also significant ($p < .001$). For the execution rate, the condition without

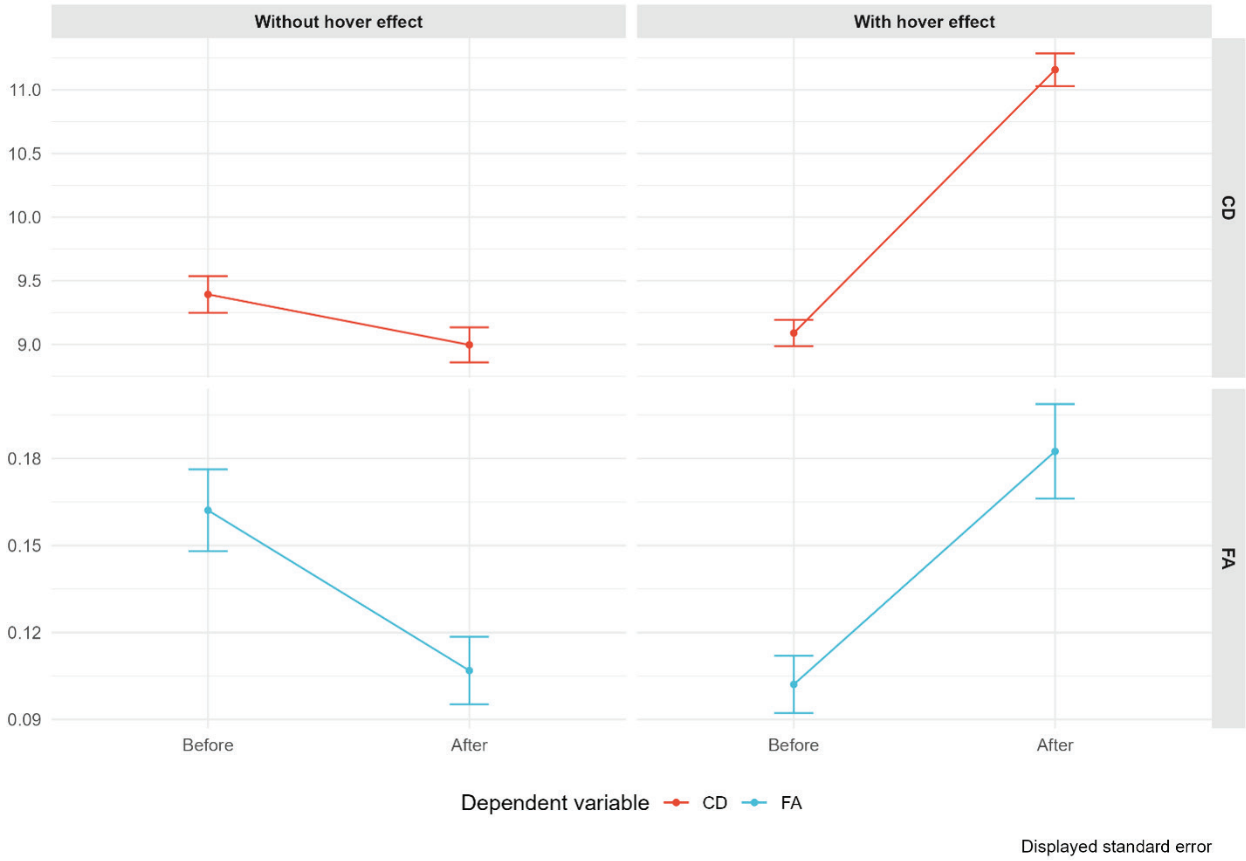

***Fig. 11**. Results of Experiment 2 for correctly detected slots (CD) and false alarms (FA) before and after notifications. / **Рис. 11**. Результаты эксперимента 2 по количеству верно найденных слотов (CD) и ложных тревог (FA) до и после уведомлений.*

the content significantly differed from call to attention ($p < .001$), but not from distractor ($p = .06$). The difference between call to attention and distractor was also nonsignificant ($p = .43$).

The paired samples the Wilcoxon test (Wilcoxon signed-rank test) was used to compare parameters before and after notification (Figure 11). Analysis of CD, $V = 51028$, $p < .01$, $r = .13$, and FA, $V = 12760$, $p < .001$, $r = .20$, as well as execution rate, $V = 567642$, $p < .01$, $r = .23$ (before: $M = 0.56$; after: $M = 0.79$), for the group without the hover effect showed significant differences before and after notification. For the group with the hover effect, significant differences were also found in all parameters before and after notification: CD, $V = 9578.5$, $p < .01$, $r = .69$; FA, $V = 5225$, $p < .01$, $r = .26$; execution rate, $V = 11282$, $p < .01$, $r = .85$ (before: $M = 0.56$; after: $M = 0.87$).

Discussion of Experiment 2

The results of Experiment 2 differ from the previous findings in one key respect: no differences were observed between the conditions with and without the hover effect in terms of average accuracy. Otherwise, the data were replicated. It can be assumed that such type of content as a call to attention influenced endogenous mechanisms of attention, increasing vigilance, independently of exogenous factors (the hover effect). Nevertheless, the highest number of FA occurred in the condition with the hover effect, the second notification type, and the distractor content. This may indicate that attention is sensitive to the content of notifications: participants attended to the information in notifications, and in the presence of distractors, it was more difficult for them to avoid interference. However, the call to attention increased the level of effort exerted to maintain focus. The effect of such content might be generalised and resembled the effect obtained in the study by Chen and Huang [Chen, Huang, 2013]. To test this assumption, Experiment 3 was conducted.

Experiment 3. Attention sustainability: hover effect, notification and content (without call to attention)

According to the results obtained in Experiment 2, the content inside notifications has affected attention sustainability. It is suggested that the call for attention influenced endogenous mechanisms of attention — subjects made more effort to complete the task, which offset the influence of exogenous factors. Based on this assumption, it was decided to conduct an additional experiment where only distractors (words related to ordinary deals like shopping, calling, etc.) were in the notifications' content or nothing. It was expected that without calling attention, the influence of the hover effect would occur again. Thus, the concepts, experimental design, and procedure were the same as in Experiment 2. The only difference was that the content as an independent variable contains two levels: the distractor word or nothing.

Participants

The principle of subject recruitment and data exclusion is the same as in Experiment 2. The final data analysis included 60 participants (age: $M = 24.4$, $SD = 2.1$, sex: 38 female) per 30 in the group.

Design

The experimental design was the same as in Experiment 2. The only change was the number of trials on each level of the content variable. There were 5 types of notifications, 15 trials for each type, and among these 15 trials, 8 were for distracting words as content and 7 were for empty notifications.

Results

Analysis with a one-way ANOVA for trials without notification showed that the group factor had no effect on any of the dependent variables: CD, $F(1.58) = 0.01$, $p > .93$, $\eta p2 = .01$, FA, $F(1.58) = 0.51$, $p > .48$, $\eta p2 = .01$, rate of execution, $F(1.58) = 0.01$, $p > .93$, $\eta p2 = .01$ (see Figures 12 and 13).

Here, only in the group with the hover effect in the context of CD significant differences were found between the first type and WN ($p < .012$), the third and WN ($p < .012$), and the fourth and WN ($p < .033$). The remaining comparisons were not significant for this group as well, as for the group without the hover effect.

For the analysis of trials with notifications, eight participants from the group without the hover effect who never closed notifications were excluded. Consequently, the final analysis included data from 52 participants: 22 from the group without the hover effect and 30 from the group with the hover effect. No violations of homogeneity of variances were detected ($p > .05$). A three-way mixed ANOVA for trials with notification demonstrated that the factor group had an effect only on RT, $F(1.50) = 9.04$, $p < .00$, $\eta p2 = .17$. The notification type factor had a significant impact on all measures: CD, $F(4.200) = 3.15$, $p < .03$, $\eta p2 = .01$, FA, $F(4.200) = 5.55$, $p < .01$, $\eta p2 = .02$, RT, $F(4.200) = 4.10$, $p < .02$, $\eta p2 = 03$. Exception was an execution rate, $F(4.200) = 2.15$, $p > .91$, $\eta p2 = .01$. The content type factor had an effect only on FA, $F(1.50) = 4.79$, $p < .03$, $\eta p2 = .03$. Significant interactions were found for FA, $F(4.200) = 4.44$, $p < .01$, $\eta p2 = .01$, and RT, $F(4.200) = 3.47$, $p < .02$, $\eta p2 = .01$.

A two-way RM ANOVA for the group without the hover effect showed that the notification type factor impacted execution rate, $F(4.84) = 3.53$, $p < .02$, $\eta p2 = 0.01$, the other factors were not significant (all $p > .05$). The content type factor had no impact on parameters (all $p > .14$). And significant interaction was only for RT, $F(4.84) = 5.68$, $p < .001$, $\eta p2 = .05$.

For the group with the hover effect, notification type had an impact on FA, $F(4.116) = 25.484$, $p < .01$, $\eta p2 = .05$, and RT, $F(4.116) = 5.611$, $p < .01$, $\eta p2 = .04$. The pairwise comparison analysis showed that FA was significantly different for the second type of notification than the other types (all $p < .001$). Pairwise comparisons for the RT indicator in the group showed significant differences between notification types: third type vs. first ($p < .001$); third vs. fourth ($p < .001$); fourth vs. fifth ($p < .001$). No other pairwise comparisons reached statistical significance ($ps > .05$). The content type affected CD, $F(1.29) = 5.60$, $p < .03$, $\eta p2 = .01$, FA, $F(1.29) = 5.358$, $p < .02$, $\eta p2 = .07$, and execution rate, $F(1.29) = 4.619$, $p < .04$, $\eta p2 = .01$. The pairwise comparisons for CD and FA under different content type conditions showed significant differences (all $p < .001$).

The paired samples the Wilcoxon test (Wilcoxon signed-rank test) was used to compare parameters before and after notification. For the group without the hover effect, differences in FA, $V = 9708$, $p < .01$, $r = .22$, and execution rate, $V = 305172$, $p < .02$, $r = .16$ (before: $M = 0.58$; after: $M = 0.84$), before and after notification were found, but not for CD, $V = 19332$, $p > .88$, $r = .01$. Analysis of CD, $V = 2535.5$, $p < .01$, $r = .77$, and FA, $V = 3933.5$, $p < .01$, $r = .31$, as well as execution rate, $V = 3394$, $p < .00$, $r = .86$ (before: $M = 0.53$; after: $M = 0.83$), for the group with the hover effect showed significant differences before and after notification.

Discussion of Experiment 3

The results of Experiment 3 replicated Experiment 2. In particular, the presence of the hover effect had no effect on accuracy in either trials without or with notifications, but the advantage in RT per notification for the condition with the hover effect persisted. The hypothesis that call to attention content is responsible for the disappearance of the impact of the hover effect has not been supported.

Summary of Experiments 1–3

Before proceeding to the generalisation of the findings obtained across the three experiments on sustained attention, it is necessary to report the results of the post hoc power analysis and sensitivity analysis conducted using G*Power 3.1.9.7 to estimate the achieved statistical power for the effects observed across experiments. In Experiment 1, for trials without notifications, a one-way ANOVA revealed significant effects of group on CD and execution rate ($\eta p^2 = .13$), with achieved power of approximately 83%. For trials with notifications, a two-way mixed ANOVA demonstrated that significant effects with large effect sizes—particularly for reaction time (RT), including the main effects of group ($\eta p^2 = .33$), notification type ($\eta p^2 = .35$), and their interaction ($\eta p^2 = .34$) — were associated with high statistical power (approximately 97–99%). In contrast, significant effects of group on CD and execution rate ($\eta p^2 \approx .11$) demonstrated moderate power (≈66%). In Experiment 2, a three-way mixed ANOVA revealed a significant main effect of group on RT ($\eta p^2 = .29$), with achieved power of approximately 87%. In addition, statistically significant effects of notification type and content, characterised by small effect sizes ($\eta p^2 \approx .01–.03$), were associated with low achieved power (approximately 6–39%), indicating limited sensitivity despite statistical significance. In Experiment 3, a three-way mixed ANOVA demonstrated a significant main effect of group on RT ($\eta p^2 = .17$), with achieved power of approximately 70%, indicating moderate sensitivity. Significant effects of notification type and content ($\eta p^2 \approx .01–.03$), although statistically reliable, were associated with low achieved power (typically below 10–15%), reflecting small effect sizes and limited sensitivity of the design to detect such effects. Across all experiments, statistically significant Wilcoxon signed-rank test results showed large effects, particularly for execution rate ($r \approx .70–.86$) and for CD in the hover condition ($r \approx .63–.77$), which were associated with high statistical power, typically exceeding 90–99%. Medium-sized effects, such as those observed for FA ($r \approx .20–.45$), demonstrated moderate power (approximately 40–70%). A sensitivity analysis indicated that the minimum detectable effect sizes were in the medium-to-large range across all experiments. Specifically, in Experiment 1 the design was sensitive to effects of approximately $f = 0.39$ for the one-way ANOVA and $f = 0.56$ for the mixed ANOVA. In Experiment 2, the three-way mixed ANOVA was sensitive to effects of approximately $f = 0.62$, and in Experiment 3 to effects of approximately $f = 0.53$. These results suggest that the experimental designs were adequately powered to detect moderate-to-large effects but underpowered for detecting small effects, particularly in more complex designs involving multiple factors and interactions.

An important observation, which on the one hand reduced the achieved statistical power but on the other hand reflected a robust empirical pattern, was that notifications appearing through transparency reduction (the fourth notification type) were most frequently left unclosed, specifically on the website without the hover effect. In this group, approximately 35–58% of notifications of this type were not closed by participants. This finding suggests substantial difficulty in detecting this notification type under conditions without the hover effect. Consistently, analyses of the available data demonstrated that the longest reaction times were also observed in this group and differed significantly from all other conditions. In contrast, this pattern was not observed in the group exposed to the hover effect condition. These results were consistently replicated across all three experiments and therefore represent an important finding of the present study. A similarly consistent pattern across all three experiments was observed for the interaction between the presence of the hover effect and pop-up notifications (the second notification type), particularly in relation to the increase in false alarms, the increase in correctly detected slots and false alarms following notification closure in the group with the hover effect, and the shorter reaction times to notifications in the same group. However, no stable increase in errors or reduction in the number of detected slots was observed when comparing trials with and without notifications.

The primary inconsistency across experiments — namely between Experiment 1 and Experiments 2–3 — concerned the effect of the hover effect on mean accuracy (across trials with and without notifications), which was not replicated in the latter two experiments. Considering the achieved statistical power (66–83%) and sensitivity estimates, this effect may be regarded as context-dependent despite its moderate effect size ($\eta p^2 \approx .11–.13$): the introduction of the content factor appeared to alter the mechanisms underlying the previously observed effect. Because content was manipulated within subjects, there is a high probability that exposure to content-bearing notifications generalised across all trial types. In other words, participants may have inferred that the presence of content was intended to distract them and interfere with performance on the primary task. Therefore, they may have exerted greater effort to maintain focus on the task, thereby attenuating the exogenous influence of the hover effect. A detailed discussion and interpretation of all findings is provided in the General Discussion section. Additionally, participant exclusion and the overall complexity of the design limited the ability to detect small-to-medium effects of the exogenous factor (i.e., the hover effect) under conditions involving content manipulation. The present findings suggest that future studies may benefit from larger sample sizes to increase statistical power and improve sensitivity for detecting small and less stable effects. Furthermore, the experimental design requires refinement, particularly through manipulating notification type and notification content using a between-subjects design. This approach would facilitate the analysis of their interaction with the hover effect while minimising the potential generalisation of exposure to a particular animation type or content across all trial types.

Overall, within the context of sustained attention, the study demonstrated that the appearance of notifications increased errors only when the task was performed on a website featuring the hover effect. At the same time, mean accuracy did not systematically differ between trials with and without notifications under any condition. Replicable interactions between the hover effect and notifications were also identified for both reaction time and accuracy measures, including faster reactions to notifications on websites with the hover effect, an increase in false alarms in response to pop-up animations, and the longest reaction times to notifications appearing through transparency reduction in the absence of the hover effect.

Experiment 4. Attention shifting: hover effect and notification

This experiment aimed to examine the effects of the presence and animation of notifications on attention shifting. Additionally, the aim was to test the reproducibility of Anufrieva and Gorbunova's [Anufrieva, Gorbunova, 2025] results in the context of the absence of an influence of the hover effect on attention shifting.

Participants

The principle of subject recruitment is the same as in Experiment 1. The final data analysis included 60 participants (age: M = 25.3, SD = 2.6, sex: 35 female) per 30 in the group. In addition to the exclusion criteria described in Experiment 1, a criterion was used here to check which target words were clicked by the subject. Thus, it was not allowed to have fewer than 5 presses for one of the three target words. This would indicate that the subject did not follow the instruction and did not change the target at the sound.

Design

The experimental design was the same as in Experiment 1.

Procedure

The procedure was equal to Experiment 1. One difference was that while searching, participants had to change the target by sound, which occurred every 10 seconds for 30 seconds. The sound was like a phone ringing. Therefore, it was two times when subjects needed to change the target. For example, if the subject was presented with 3 target words «training, meeting, shopping», for the first 10 seconds he had to search for the word training, then after a sound the word meeting, and finally after another signal the word shopping. Notifications as in Experiment 1 appeared between 13th and 17th seconds.

Results

A one-way ANOVA was performed to compare trials without notification between groups. According to the results, the group had no effect on any of the measures: CD, $F(1.58) = 2.03$, $p > .16$, $\eta p2 = .03$, FA, $F(1.58) = 2.136$, $p > .15$, $\eta p2 = .04$, execution rate $F(1.58) = 1.75$, $p > .28$, $\eta p2 = .03$ (see Figures 12).

Comparison of trials with and without notifications in the group with the hover effect revealed the significant difference between the second type and WN ($p < .001$) regarding FA, and the second and WN ($p < .001$), the third and WN ($p < .001$), the fourth and WN ($p < .001$), and the fifth and WN ($p < .001$) in the context of the CD. All other comparison were not significant.

A two-way mixed ANOVA was conducted for trials with notification. Here, the factors were group (presence of the hover effect) and type of notification. Eleven participants were excluded from the analysis: seven from the group without the hover effect and four from the group with the hover effect. Consequently, the final analysis included 49 participants. No violations of homogeneity were detected ($p > .05$). The result of the analysis showed that the factor group had an effect only on RT, $F(1.47) = 9.27$, $p < .001$, $\eta p2 = .09$. The notification type factor had an effect only on FA, $F(4.188) = 3.12$, $p < .03$, $\eta p2 = .04$, and RT, $F(4.188) = 14.61$, $p < .001$, $\eta p2 = .13$. However, significant interactions were found between group and notification type for CD, $F(4.188) = 3.12$, $p < .03$, $\eta p2 = .001$, FA, $F(4.188) = 7.02$, $p < .001$, $\eta p2 = .09$, and RT, $F(4.188) = 6.54$, $p < .001$, $\eta p2 = .06$. See Figures 12–14.

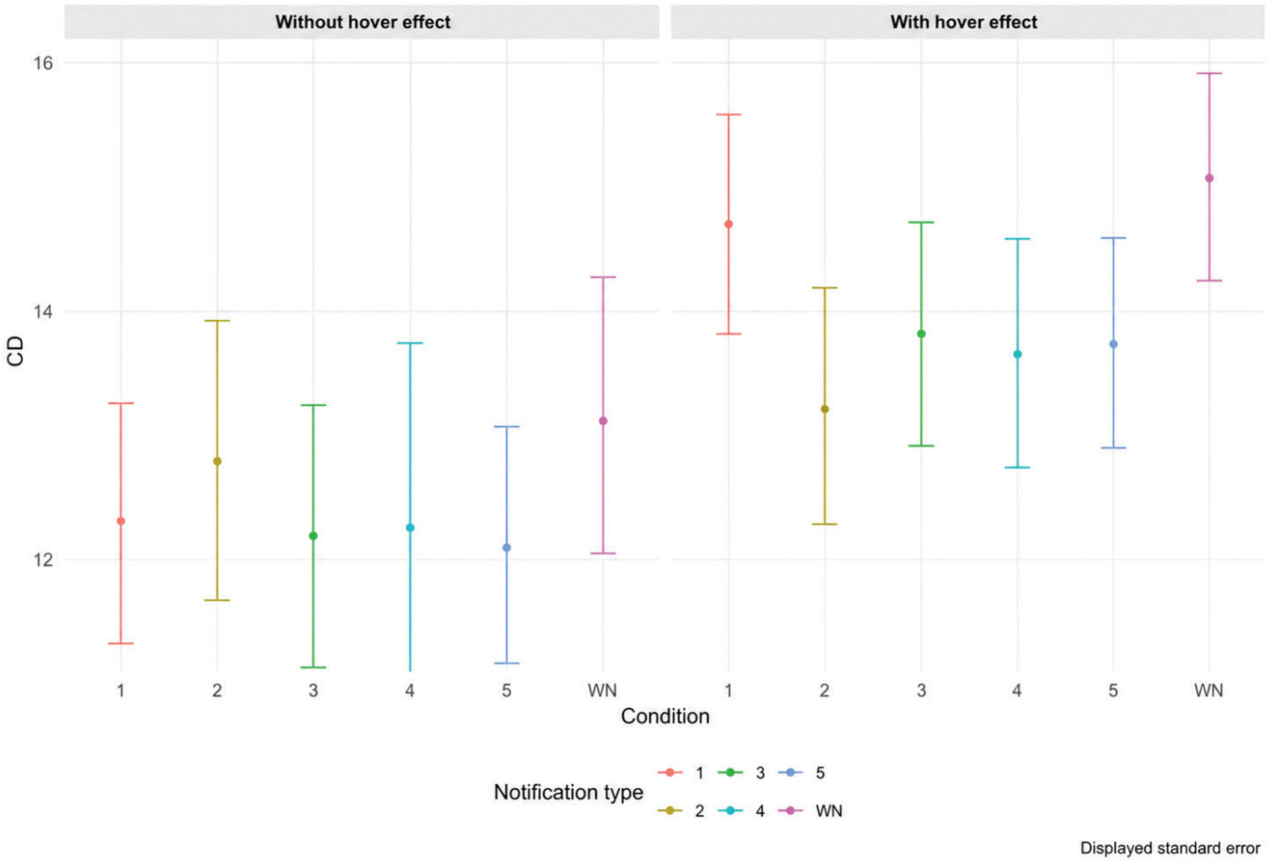

Fig. 12*. Results of Experiment 4 for correctly detected slots (CD) in groups without and with the hover effect. /* ***Рис. 12****. Результаты эксперимента 4 по количеству верно найденных слотов (CD) в группах без эффекта наведения и с эффектом наведения.*

Notes. Notification types: 1 — An appearance of slow upper-movement, 2 — An appearance of a pop-up manner, 3 — An appearance of the window followed by flickering, 4 — An appearance of the window through a reduction in transparency, 5 — An appearance at the bottom of the screen center, then moves to the right corner, WN — trials without notification. / Примечания. Типы анимации уведомлений: 1 — постепенно появляющееся (медленное возникновение с движением вверх); 2 — pop-up (внезапное возникновение без каких-либо дополнительных движений); 3 — мерцающее (после появления совершает нерегулярную серию быстрых движений, многократно появляясь и исчезая); 4 — появляющееся через снижение прозрачности (постепенно становится видимым и отчетливым); 5 — появляющееся в нижней части экрана в центре с перемещением в правый угол (внезапное возникновение, как в условии pop-up, но в нижней и центральной части экрана, затем перемещается к правому углу); WN — пробы без уведомлений.

A one-way RM ANOVA for group without the hover effect showed that notification type had an effect only on RT, $F(4.84) = 13.30$, $p < .001$, $\eta p2 = .31$. The pairwise comparisons demonstrated that RT were significantly different for the fourth type of notification from others (all $p < .001$).

A one-way RM ANOVA for the group with the hover effect showed a significant effect of notification type on CD, $F(4.104) = 7.28$, $p < .001$, $\eta p2 = .01$, and FA, $F(4.104) = 14.45$, $p < .001$, $\eta p2 = .25$. According to the pairwise comparisons, FA was significantly different under the second type of notification condition from others (all $p < .001$).

The paired samples the Wilcoxon test (Wilcoxon signed-rank test) was used to compare parameters before and after notification (see Figure 15). For the group without the hover effect there were no significant differences in FA, $V = 338.5$, $p > .30$, $r = .08$. However, CD, $V = 5209$, $p < .01$, $r = .24$, and the execution rate, $V = 1209$, $p < .001$, $r = .64$ (before: $M = 0.37$; after: $M = 0.58$), was different before and after notification. For group with the hover effect analyses

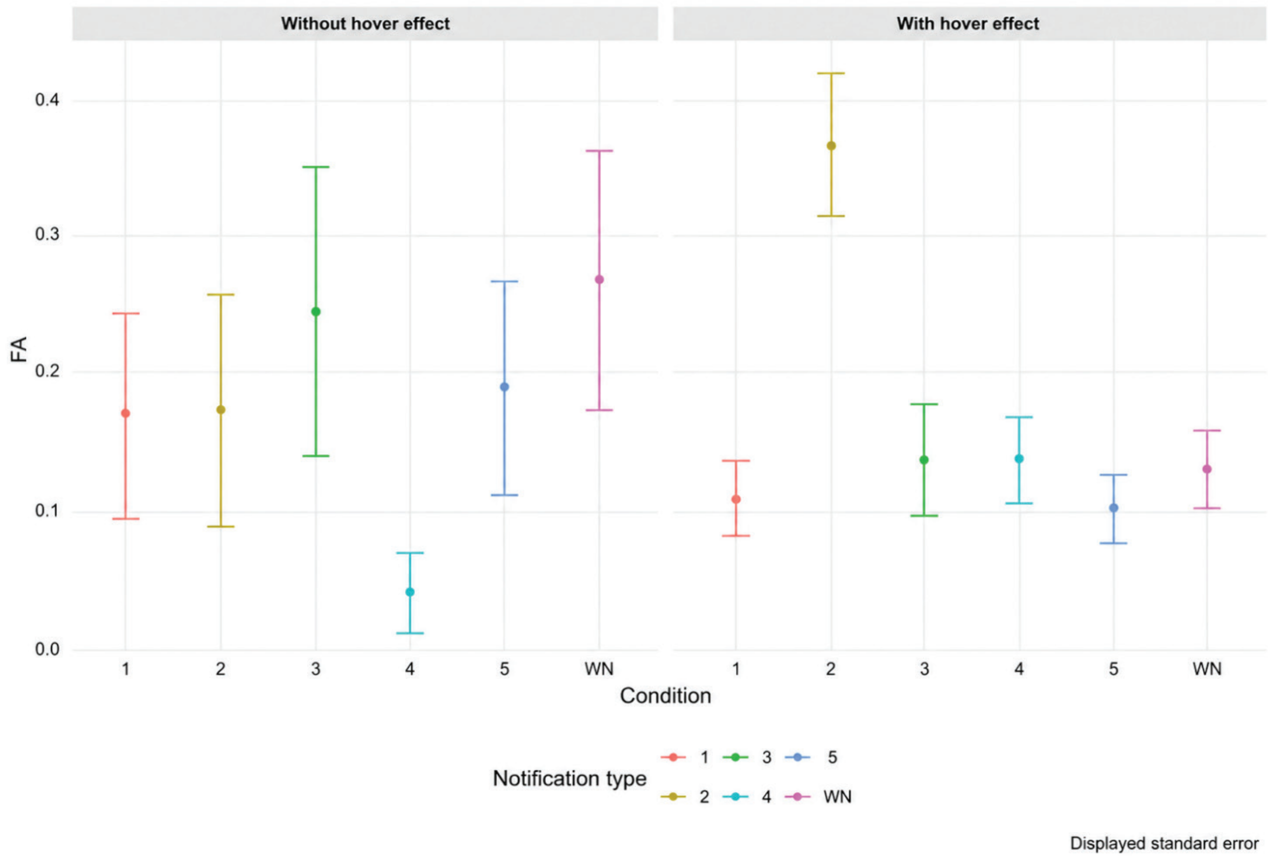

Fig. 13. *Results of Experiment 4 for false alarms (FA) in groups without and with the hover effect. /* ***Рис. 13***. *Результаты эксперимента 4 по количеству ложных тревог (FA) в группах без эффекта наведения и с эффектом наведения.*

Notes. Notification types: 1 — An appearance of slow upper-movement, 2 — An appearance of a pop-up manner, 3 — An appearance of the window followed by flickering, 4 — An appearance of the window through a reduction in transparency, 5 — An appearance at the bottom of the screen center, then moves to the right corner, WN — trials without notification. / Примечания. Типы анимации уведомлений: 1 — постепенно появляющееся (медленное возникновение с движением вверх); 2 — pop-up (внезапное возникновение без каких-либо дополнительных движений); 3 — мерцающее (после появления совершает нерегулярную серию быстрых движений, многократно появляясь и исчезая); 4 — появляющееся через снижение прозрачности (постепенно становится видимым и отчетливым); 5 — появляющееся в нижней части экрана в центре с перемещением в правый угол (внезапное возникновение, как в условии pop-up, но в нижней и центральной части экрана, затем перемещается к правому углу); WN — пробы без уведомлений.

showed significant differences in CD, $V = 572.5$, $p < .001$, $r = .77$, and rate of execution, $V = 733$, $p < .001$, $r = .74$ (before: $M = 0.39$; after: $M = 0.49$), but not FA, $V = 2007.5$, $p > .87$, $r = .03$.

Discussion of Experiment 4

Experiment 4 replicated the results of Anufrieva and Gorbunova [Anufrieva, Gorbunova, 2025]: the hover effect had no effect on attention shifting. Only RT was sensitive to the presence of the hover effect, similar to the results for sustained attention — notifications closed faster in its presence. Also, differences between trials with and without notifications were found only for the second type (pop-up) in the group with the hover effect in the FA context. Thus, the mere presence of notifications did not generally affect the accuracy of the task. Additionally, the same interactions between animation type and the presence of the hover effect were observed as in the attention sustainability task (Experiment 1). Finally, measures of the number of CDs before and after changed — it increased in the group with the hover effect and decreased in the group without it. This may suggest that after distraction, the hover effect facilitates retrieval. However,

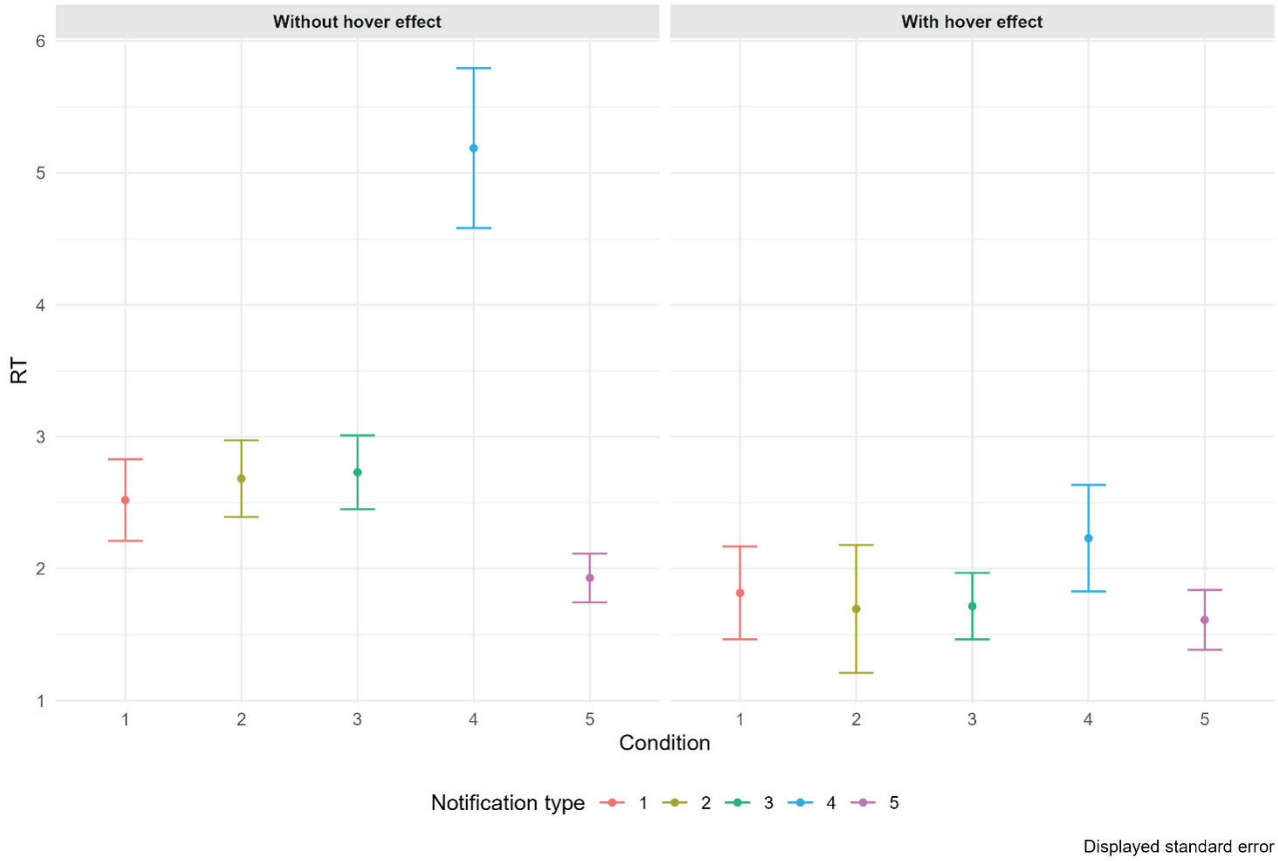

Fig. 14. *Results of Experiment 4 for reaction time (RT) in groups without and with the hover effect. /* ***Рис. 14***. *Результаты эксперимента 4 по времени реакции (RT) в группах без эффекта наведения и с эффектом наведения.*

Notes. Notification types: 1 — An appearance of slow upper-movement, 2 — An appearance of a pop-up manner, 3 — An appearance of the window followed by flickering, 4 — An appearance of the window through a reduction in transparency, 5 — An appearance at the bottom of the screen center, then moves to the right corner. / Примечания. Типы анимации уведомлений: 1 — постепенно появляющееся (медленное возникновение с движением вверх); 2 — pop-up (внезапное возникновение без каких-либо дополнительных движений); 3 — мерцающее (после появления совершает нерегулярную серию быстрых движений, многократно появляясь и исчезая); 4 — появляющееся через снижение прозрачности (постепенно становится видимым и отчетливым); 5 — появляющееся в нижней части экрана в центре с перемещением в правый угол (внезапное возникновение, как в условии pop-up, но в нижней и центральной части экрана, затем перемещается к правому углу).

this contradicts the results and interpretation in Experiment 1. An analysis of the comparison between the results of the two experiments is presented in the General Discussion.

Experiment 5. Attention shifting: hover effect, notification and content (with call to attention)

The purpose of Experiment 5 was to explore the influence of content in notifications on attention shifting. The concepts, experimental design, and procedure are equal to Experiment 4. The difference is only in adding the content to notifications by analogy with Experiment 2.

Participants

The principle of subject recruitment and data exclusion is the same as in Experiment 4. The final data analysis included 60 participants (age: M = 22.5, SD = 2.1, sex: 43 female) per 30 in the group.

Design

The experimental design was the same as in

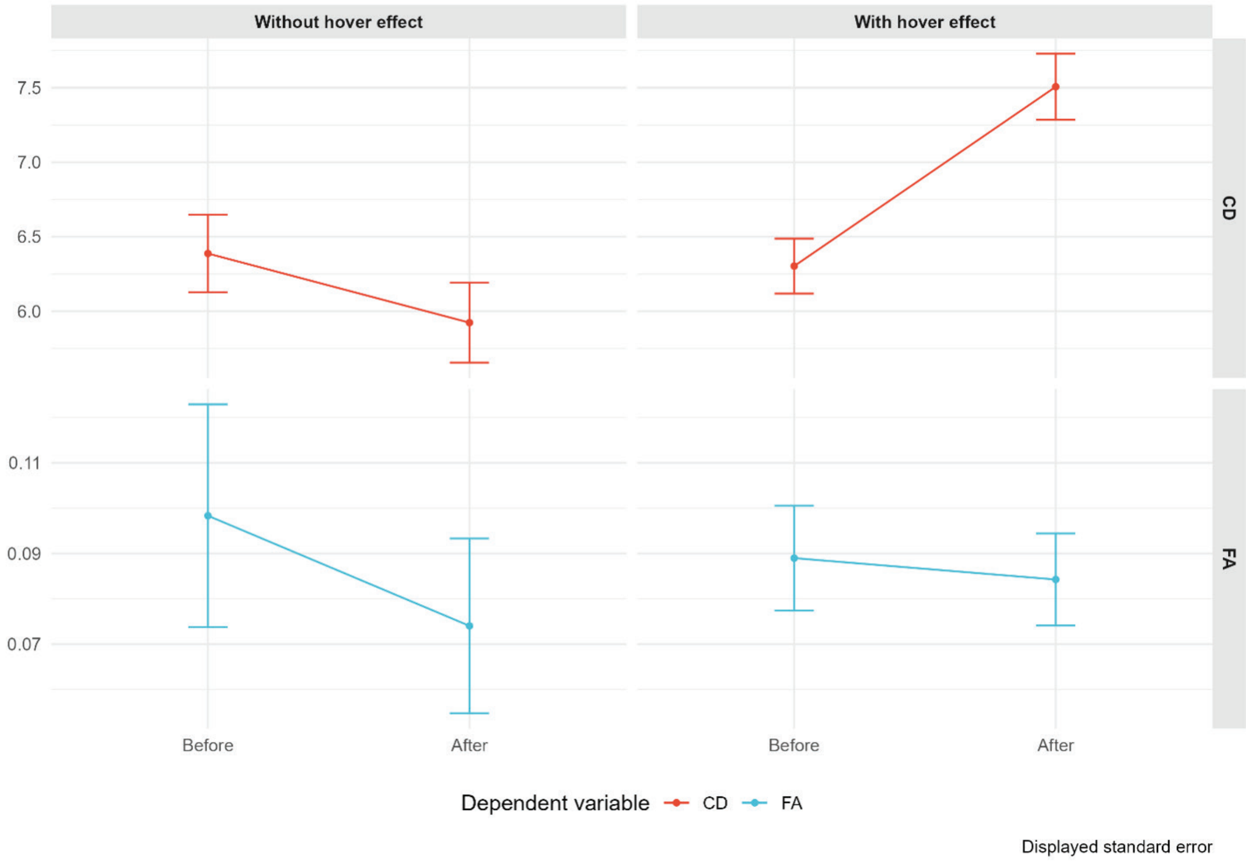

***Fig. 15**. Results of Experiment 4 for correctly detected slots (CD) and false alarms (FA) before and after notifications. / **Рис. 15**. Результаты эксперимента 4 по количеству верно найденных слотов (CD) и ложных тревог (FA) до и после уведомлений.*

Experiment 4. There were 5 types of notifications, 15 trials for each type, and among these 15 trials, 5 were notifications with a call to attention, 5 were with the distractor, and 5 were empty.

Results

A one-way ANOVA was used for trials without notification. The analysis showed that the group factor had no significant effect on any of the measures: CD, $F(1.58) = 0.76$, $p > .48$, $\eta p2 = .01$, FA, $F(1.58) = 3.21$, $p > .17$, $\eta p2 = .05$, rate of execution, $F(1.58) = 0.68$, $p > .41$, $\eta p2 = .01$.

For the group with the hover effect, a significant difference between trials with and without notifications was found only between the third and WN ($p < .014$) in the context of CD. For the group without the hover effect, a significant differences emerged between conditions the first and WN ($p < .002$), the third and WN ($p < .001$), and the fifth and WN ($p < .002$), also in the CD rate. All pairwise comparisons were non-significant.

In the analysis of trials with notifications, nine participants were excluded because they systematically failed to close notifications of the fourth type: eight from the group without the hover effect and one from the group with the hover effect. Consequently, the final analysis included 51 participants. No violations of homogeneity were detected ($p > .05$). According to the results of a three-way mixed ANOVA, where group was the between-group factor and notification type and content were within-group factors, it was found that the group factor only influenced RT, $F(1.49) = 12.3$, $p < .00$, $\eta p2 = .18$. Notification type influenced FA, $F(4.196) = 3.21$, $p < .03$, $\eta p2 = .01$, and RT, $F(4.196) = 39.02$, $p < .00$, $\eta p2 = .15$. The content had an impact on CD, $F(2.98) = 4.29$, $p < .02$, $\eta p2 = 001$, execution rate, $F(2.98) = 5.23$, $p < .01$, $\eta p2 = .\ 001$, and RT, $F(2.98) = 3.34$, $p < .04$, $\eta p2 = .01$. Interactions between notification type and content were found for CD, FA, and RT (all $p < .01$).

A two-way ANOVA for the group without the hover effect showed a significant impact of notification type on RT, $F(4.84)= 36.42$, $p < .001$, $\eta p2 = .304$. The content also had an effect only on RT, $F(2.42) = 5.02$, $p < .001$, $\eta p2 = .01$. In addition, there was a significant interaction between notification type and content for

RT, $F(8.168) = 2.18$, $p < .04$, $\eta p2 = .03$. The pairwise comparisons showed that the RT was significantly different for the fourth type of notification (all $p < .001$). But no differences were found between content levels (all $p > .11$).

A two-way ANOVA for the group with the hover effect showed a significant impact of notification type on FA, $F(4.112) = 6.02$, $p < .001$, $\eta p2 = .03$, and RT, $F(4.112) = 6.43$, $p < .01$, $\eta p2 = .05$. But there was no significant impact of the content (all $p > .13$). Significant interactions between content and notification type were found for CD, $F(8.224) = 3.18$, $p < .01$, $\eta p2 = .01$, and FA, $F(8.224) = 5.38$, $p < .01$, $\eta p2 = .18$. The analysis of the pairwise comparisons for the showed that FA differed significantly for the second type of notification as well as for the presence of a distractor in the content (all $p < .001$). Also, RT differed for the fourth type (all $p < .001$).

The paired samples the Wilcoxon test (Wilcoxon signed-rank test) was used to compare parameters before and after notification. For the group without the hover effect, it showed that CD, $V = 53623$, $p < .001$, $r = .24$, and execution rate, $V = 9697$, $p < .001$, $r = .69$, were significantly different but not FA, $V = 3450.5$, $p = 0.49$, $r = .05$. For the group with the hover effect, significant differences in CD, $V = 11346$, $p < .001$, $r = .65$, and execution rate, $V = 32030$, $p < .001$, $r = .83$, were found, but no in FA, $V = 4856$, $p > 0.76$, $r = .07$.

Discussion of Experiment 5

The iteration replicated the pattern of Experiment 4. These findings emphasise the stability of the impact of interface elements (the hover effect and notifications) on attention shifting. Regarding the effect of content, only the interaction between the second type (pop-up), content (distractor), and the group factor (the hover effect) was found. This interaction replicates the results of Experiment 2 and 3. Regarding the occurrence of attentional errors (FA), there was no increase for both groups.

Summary of Experiments 4–5

By analogy with the discussion of the sustained attention experiments, the analysis of achieved statistical power for Experiments 4–5 on attentional shifting is presented first. A mixed ANOVA revealed a significant main effect of group on RT ($\eta p^2 = .09$), with relatively low achieved power (≈34%), indicating limited sensitivity for detecting small-to-medium effects. The main effect of notification type was significant for FA ($\eta p^2 = .04$) and RT ($\eta p^2 = .13$). The corresponding achieved power was low for FA (≈16%), reflecting a small effect size, and moderate for RT (≈51%), indicating improved sensitivity for larger effects. Regarding the Wilcoxon signed-rank tests assessing performance before and after notification presentation, significant differences in the group without the hover effect were observed for CD ($r = .24$), with moderate power (≈61%), and for execution rate ($r = .64$), with high power (≈99%). In the group with the hover effect, large effects were observed for both CD ($r = .77$) and execution rate ($r = .74$), with correspondingly high achieved power (≈99%). In Experiment 5, a mixed ANOVA revealed a significant main effect of group on RT ($\eta p^2 = .18$), with moderate achieved power (≈56%). The main effect of notification type was significant for FA ($\eta p^2 = .01$) and RT ($\eta p^2 = .15$), with low power for FA (≈6%) and moderate power for RT (≈46%), again reflecting differences in effect size. Significant effects of content were observed for CD, execution rate, and RT ($\eta p^2 \approx .01$), all of which were associated with very low achieved power (below 6%), indicating that these statistically significant effects were small and detected with limited sensitivity. In the group without the hover effect, significant effects were found for CD ($r = .24$), with moderate power (≈58%), and for execution rate ($r = .69$), with high power (≈99%). Regarding the Wilcoxon signed-rank tests assessing performance before and after notification presentation, large effects were observed in the group with the hover effect for both CD ($r = .65$) and execution rate ($r = .83$), each associated with high achieved power (≈99%). Thus, similarly to the power analysis for Experiments 1–3, the experimental design and sample size employed in Experiments 4–5 were sufficient primarily for detecting large effects. This once again highlights the necessity of replication with larger samples and modifications to the experimental design to increase sensitivity to small effects.

The experimental data presented in this section demonstrated a high degree of consistency. No effect of the hover effect on task accuracy or execution rate was observed either in trials without notifications or in trials with notifications. However, reaction times to notifications were consistently shorter in the presence of the hover effect. Stable interaction effects were also observed: in the condition without the hover effect, the notification appearing through transparency reduction (the fourth notification type) was associated with the longest reaction times, whereas in the condition with the hover effect, the pop-up notifications (the second notification type) produced the greatest number of false alarms. Furthermore, across both experiments, the presence of notifications did not lead to a significant increase in errors or a decrease in accuracy compared with trials without notifications. The number of correctly detected targets consistently increased following distraction by notifications. At the same time, comparisons between trials with and without notifications did not reveal a stable decline in performance under notification-present conditions. The consistency of the findings across Experiments 4–5 indicates the stability of the observed effects for attentional shifting. Overall, within the attentional shifting task, no evidence was found that notifications induced errors, whereas the interaction between the hover effect and notifications demonstrated a pattern of influence similar to that observed in the sustained attention task.

General Discussion

First and foremost, the answer should address the research question regarding the possibility of attentional errors after notifications. This study showed that the presence of notifications during tasks does not lead to an increase in the average error rate compared to performing these tasks without notifications. However, attentional errors occur immediately after being distracted by notifications, but only on a website with the hover effect and in an attention sustainability task (Experiments 1–3). Nevertheless, along with the increase in errors, there is also a rise in correctly found items, which limits the possibility of concluding that distraction by notifications has an exclusively detrimental effect. A possible explanation can be found within Anufrieva's [Anufrieva, 2025] model. The hover effect serves as an exogenous perceptual cue that aids in the selection and maintenance of attention during task execution. However, this leads to a strategy of relying on this external cue instead of investing one's own endogenous efforts of attention in retaining information in WM and monitoring the search space. Being distracted by the notification, attentional resources are spent on inhibiting and reactivating the main task schema through endogenous attention mechanisms [Nguyen et al., 2020]. It is likely that at this moment, the information in the WM, which is already weakly retained, fades away or interferes (in the case of distractors in notifications), leading to a situation where the subject continues to search for some targets correctly, while «confusing» the rest. The results for attention shifting task may support this explanation (Experiments 4–5). When comparing the sustainability and shifting tasks, we can note differences in their complexity. The sustainability task requires holding three activated targets simultaneously and matching each slot with each of them for verification, both before and after notification. In the shifting task, only one target is activated at a time, and then it is replaced by another when an audible signal occurs, without requiring further searching. In other words, during the tasks, the subject holds one fewer target with each signal. Thus, the shifting task can be considered easier in terms of cognitive load. It may not require an external cue, which could explain why the presence of the hover effect has no effect on performance, as shown in Experiments 4 and 5 that replicated the results of Anufrieva and Gorbunova [Anufrieva, Gorbunova, 2025]. Thus, the hover effect serves as an attentional cue in complex tasks. However, this reliance on the cue reduces the effort devoted to retaining and monitoring information. When a task becomes more difficult due to distraction, attentional resources are first depleted, and information in WM may then fade or interfere, resulting in reduced accuracy. In relatively simple tasks, the hover effect has no significant impact because cognitive resources are optimally distributed. Yet, as task difficulty increases under distraction, attentional resources become exhausted, and the hover effect begins to function as a cue that facilitates further searching. Therefore, there is a variation in the impact of interface elements on performance under different combinations of cognitive load (as an intrinsic cognitive load; [Sweller, 2024]) and demands for attentional resources. This reasoning highlights the intricate relationship between attention and WM [Unsworth et al., 2021] and supports the DETOUR model's view of the key role of attention in distraction [Couffe, Michael, 2017]. Alternative explanations also emphasise the connection between attention and WM. According to the theory of perceptual load [Lavie, Tsal, 1994], the condition with the hover effect can be considered more perceptually rich. Consequently, earlier perceptual filtering occurs, which reduces cognitive load but consumes executive attentional resources. When distraction by a notification further consumes these resources, attentional capacity becomes depleted. This depletion can increase cognitive load, which in turn leads to poorer task performance [Lavie, Dalton, 2014]. Finally, the findings can be interpreted within the framework of the two-stage model of visual search [Maxfield, Zelinsky, 2012]. Visual search consists of a guidance stage and a verification stage. In the presence of the hover effect, perceptual cues may enhance target guidance. However, when a distractor appears during the verification stage, a criterion shift may occur — a decision to click is made even when the stimulus bears only a slight resemblance to the target retained in WM (or activated long-term memory) [Wolfe, 2021]. Such a shift in filtering criteria may result from the depletion of attentional resources caused by distraction. Overall, in response to the research question placed within this work, attentional errors due to distraction by notifications appear to arise only when a high cognitive-load task coincides with the presence of the hover effect on the website where the notification occurs.

In addressing the second research question of the present study, several interactions between the hover effect and notifications were found. First, across all iterations (Experiments 1–5), an advantage was found in the time it took to close notifications on a website with the hover effect. This indicates the influence of the hover effect on selective attention mechanisms. The hover effect is designed to indicate the interactivity of an interface element — to signal the potential for interaction to perform a function, acting as a signifier [Norman, 2008]. Perceptually, this is accompanied by a change in the state or colour of the element when interacting with it or moving the mouse over its active area, which can cause a sensation of movement. It can therefore be assumed that the acceleration of the RT to notifications is due to their appearance, which is accompanied by movement (animation). This acts as relevant information in a situation where movement is already present due to the hover effect. This is consistent with studies that show that it is easier to detect the movement of an object in a moving environment (e.g., [Takemura, 2010]). It also corresponds to studies of the banner blindness effect, where it was reduced in cases where the information on the website and banner was relevant [Sapronov, Gorbunova, 2022]. An alternative explanation for the advantage in detecting notifications on a website with the hover effect may involve the auxiliary function of the hover effect: in its presence, sustained attention is facilitated, which can conserve resources for responding to emerging stimuli. This explanation is supported by execution rate results — the rate is higher on the website with the hover effect than without it. It can be assumed that under the condition without the hover effect, participants found the task more difficult, so they were more focused and spent more resources on performance. Consequently, the notification was harder to notice due to the focus on the task itself (narrowing of focus) or due to a lack of resources for detection (depletion of attentional resources). Further research using an eye-tracker, as well as measurements of cognitive load or fatigue, is needed to clarify this issue.

Another result in favour of the idea of facilitating notification detection through the hover effect is that, in the absence of the hover effect and with the notification appearing through reduced transparency, the longest RT was obtained in most of the experiments (Experiments 1–5). These results are consistent with Wilson's study [Wilson, 2006], where the slow-growth notifications were noticed later. Thus, the slower a notification appears, the more difficult it is to detect. In the absence of movement on the website, this becomes even more difficult, as evidenced by the fact that the results of the 8–12 subjects were excluded because they missed this notification in most trials on the website without the hover effect. Another example of the interaction between the hover effect and notification animation is that the greatest number of errors occurred when pop-up notifications appeared on websites with the hover effect (Experiments 1–5). This can be explained by the capture of attention due to a suddenly occurring object, which requires substantial resources for immediate attention reallocation [Anderson, 2021]. Nevertheless, this type of notification did not benefit RT — it was not closed faster. It might be assumed that there was a chunking behaviour [Cutrell et al., 2000] when participants noticed the notification but postponed closing it. This assumption can be tested by adding an eye-tracker for further analysis of gaze behaviour in future studies. The fact that such interaction occurred only in the case of a website with the hover effect supports the idea of facilitating detection through the relevance of movement information — pop-up notifications are comparatively easier to notice [Wilson, 2006], and their visibility may increase in the presence of the hover effect. At the same time, such attention capture not only causes a waste of resources for reallocation but also requires more resources to inhibit an immediate reaction to complete the current subtask within the main task.

Finally, results showed that adding content neutralises the exogenous influence of the hover effect on attention sustainability (Experiments 2–3). It is noteworthy that the advantage in RT remains. Based on the results of Experiment 2, it was assumed that content such as a call for attention is the reason for the disappearance of differences due to the activation of endogenous mechanisms, which, when activated, are generalised across all trials. It seemed that this type of content led to an increase in concentration, similar to the study by Chen and Huang [Chen, Huang, 2013]. However, testing this assumption in Experiment 3, where this type of content was absent, did not lead to the hover effect influence. It can be assumed that the mere presence of content in notifications within the experimental procedure leads to increased alertness and concentration. Since the content in this study varied according to a within-subject design, unlike in Chen and Huang [Chen, Huang, 2013], the activation of endogenous attention was not limited to a single trial. It is also noteworthy that the average number of errors was highest and significantly different only in the case of content with a distractor in pop-up notifications on a website with the hover effect, both in the sustainability task (Experiments 2–3) and in the shifting task (Experiment 5). As discussed above, this type of notification presumably captures attention, but there is a «braking of the closing reaction» to complete the ongoing activity (chunking behaviour). When distractor content is added to such notifications, the text is automatically read, leading to interference between the target stimuli and the distractor word. As a result, a significant increase in errors occurs. Thus, the presence of the hover effect facilitates the detection of notifications, while pop-up notifications, which are the most attention-grabbing on their own, induce additional distraction when they contain distractor. At the same time, probably due to the within-group design, in trials without such content but with the same type of animation, it was relatively easier, and the appearance of such an empty notification did not lead to an increase in errors, as was observed earlier (Experiments 1 and 4).

In response to the question about the nature of the influence of the combination of hover effects and notifications, the following can be noted. The hover effect facilitates the detection of notifications; however, the appearance of notifications themselves leads to an increase in errors. This, however, is true only in the case of a relatively complex task: in a simple task, the hover effect facilitates target detection after distraction by notifications. Moreover, interactions are observed between the type of animation and the presence of the hover effect, as well as a reduction in the influence of the hover effect when the notifications contain content. Consequently, it is not possible to describe the combination of the hover effect and notifications as having a purely overloading or guiding effect on attention. This highlights the need for further research to reveal the mechanisms underlying the interaction and influence of all these factors (task complexity, notification animation and content).

Limitations

The main limitation of this study is the relatively low achieved statistical power of the analyses, resulting from the exclusion of participants who did not close notifications of certain types, as well as the overall complexity of the design, which was not sufficiently sensitive to detect small-to-medium effect sizes. Therefore, direct replications with a larger sample size are required to increase both statistical power and sensitivity. In addition, conceptual replications are needed in which the design is modified by manipulating the presence of notifications and their content in a between-subjects manner. This would help to avoid potential generalisation effects of exposure to notifications, their animations and content across all trials. The conclusions are also limited by the fact that the observed patterns were obtained using the example of a scanning task. As Czerwinski [Czerwinski et al., 2000] points out, other types of tasks may not be as sensitive. First, this highlights the need for further research using other types of tasks. Second, the significance of the task itself once again emphasises that its structure and complexity are factors that must be explicitly considered when planning, conducting, and interpreting data on the impact of interruption. Another limitation related to the generalisability of the conclusions is that this study did not use interactive notifications. In everyday life, notifications usually contain a piece of information, the full version of which can be found by clicking on the notification. Also, notifications often contain a call to action, enticing the user to visit a website or service. This study did not consider such notifications and mechanics. This could be a logical continuation of this study with the aim of assessing the separate influence of the notification itself and the fact of switching to another website and returning to the task.

Conclusion

According to the findings, an overloading effect by notifications appears to depend on a combination of factors, including task complexity and the presence of the hover effect on the website. The probability of attentional errors also increases when a notification appears abruptly (i.e., as a pop-up) and contains distracting content on a website with the hover effect. These results highlight the complex interplay between the hover effect, the characteristics of notifications, and the complexity of the task. Specifically, the presence of the hover effect was found to facilitate the detection of notifications, enhance attention sustainability when notifications did not contain content. However, the presence of content may activate endogenous attention mechanisms, increase concentration and thereby neutralise the exogenous influence of the hover effect. Future research should aim to clarify the mechanisms underlying these effects, considering not only exogenous factors (interface elements), but also task-related variables such as type and complexity, as well as the potential increase in attentional focus due to prior exposure.

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Conflict of Interest

The authors declare no conflict of interest.

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Конфликт интересов

Автор заявляет об отсутствии конфликта интересов.