Task-Relevance predicts Visual Short-term Memory on Hotel-Websites

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Abstract

The experience of websites is linked to the constraints of visual selective attention. Task-relevant information is preferentially selected by visual attention for Visual Short-term Memory. This thesis explored the influence of task-relevance on the recall of information on hotel booking websites using a one-shot change blindness paradigm. Moreover, the role of pseudo-neglect for change detection in task-relevant and task-irrelevant information was investigated. Participants (N=19) completed a hotel-search task for a matching hotel offer based on provided search criteria, alongside a change detection task. Font changes in the price, destination, number of guests or date information were either task-relevant or task-irrelevant depending on the search criteria. The hypothesis that changes are better detected when they occur in task-relevant information was confirmed. Further analysis revealed that this effect occurred when information was displayed in the right visual field. This finding might be attributed to the search strategies that participants employed. While participants showed an improvement in general change detection over time, changes in task-relevant information were persistently detected more accurately.

Keywords: Attention, Change Blindness, Ecological Validity, Pseudo-neglect, UX, Visual Short-Term Memory.

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Our cognition affects our experience and responses to the external visual world. User experience (UX) design aims to acknowledge this influence of mental processes and utilizes insights form cognitive science to define guidelines for user-friendly websites (Blanco et al., 2010; Ma et al., 2022; Ware, 2021). A central consideration for web design are the biases of our visual attention and memory, as we focus preferentially on information that is currently relevant to attain our goals (Johnson, 2021; Roda, 2011). With the hospitality sector transferring toward online distribution channels, it is urgent to investigate whether this influences the way we interact with hotel-booking websites (Chan et al., 2021; Shanhong, 2023). Thus, the present study employs mock-hotel websites to provide a realistic example of a visual environment in which attention is guided toward information by means of a hotel-search task. To make informed design decisions in response to user needs, one must gain a clear understanding of pertinent cognitive mechanisms and their characteristics.

Visual selective attention and visual short-term memory are central to processing visual information. Visual selective attention (VSA) comprises external selective attention, governing the influx of perceptual information, and internal selective attention, the selection and retrieval mechanism of information from memory (Chun et al., 2011; Van der Lubbe et al., 2023). Importantly, VSA serves the attainment of our goals by selecting information based on its relevance to enable us to reach our aims (Awh et al., 2012).

The content chosen by selective attention is held in Visual short-term memory (VSTM) (Kuo et al., 2012; Van der Lubbe et al., 2023). VSTM is the repository for storage and recall of visual information for a short duration (Martin & Becker, 2021). A notable feature of VSTM is its limited capacity. Research aimed at defining this capacity approximated that 4 items are memorized, while disagreeing on whether objects or features are stored (Cowan, 2001; Luck & Vogel, 2013; Oberauer, 2019). Chiefly, recent studies on VSTM suggest that capacity limits may be overcome in more realistic settings, including websites (Asp et al., 2021; Brady & Störmer, 2022; Ngiam et al., 2019; Suhani, 2023; Thibeault et al., 2024).

VSA and VSTM are affected by our goals, since they serve to enable behaviour (Buzsáki, 2019). The Affordance Competition Hypothesis (ACH) by Cisek (2007) provides an ethological perspective on the selection of task-relevant information by visual cognitive processes. It posits that the visual environment provides us with affordances, or opportunities for humans to act

(Gibson, 1979). On this basis, humans are engaged in a continuous analysis of their surroundings, specifying what actions are viable and subsequently selecting the most appropriate manner to act. Importantly, action selection is conceptualized as biased by attention and higher cognitive goals. Therefore, higher-order goals that motivate behavior modulate selective attention toward information most relevant for goal attainment. This selection may also lead us to overlook information that is not relevant to our goals.

Such allocation of attention makes us fail to notice obvious changes in visual scenes or objects, also referred to as change blindness (CB) (Rensink, 2002, 2009; Simons & Rensink, 2005). Subsequently, CB has implications for many aspects of our daily life and has therefore been investigated in many contexts, ranging from work environments, driving scenes, to Human-computer interfaces (Bittner, 2024; Galpin et al., 2009; Solomon et al., 2021; Suhani, 2023). Research on CB frequently involves the exploration of VSA and VSTM. A common way to utilise CB in research is via the 'one-shot' gap-contingent methodology where participants see two images for a short time separated by a mask (Luck & Vogel, 2013; Phillips, 1974; Rensink, 2009). The mask overwrites iconic memory and hinders the transient of change to attract attention which would facilitate change detection. Thereafter, participants are asked to indicate whether they detected the change that occurred in the second image.

Besides the impact of our goals, change detection might be affected by pseudo-neglect, defined as the attentional bias toward the left visual hemifield in visual attention (Bowers & Heilman, 1980; Brooks et al., 2014; Iyilikci et al., 2010). More specifically, eye movements appear to focus first on the left visual field and only after shift right-ward (Foulsham et al., 2013). This even occurs when it is known that search targets are to be found in the right visual field (Nuthman & Clark, 2023). Pseudo-neglect has been shown to occur in a variety of visual presentations (Ossandón et al., 2014). Thus, it likely occurs when using websites. However, while Iylikci et al. (2010) found that change detection was improved for the left visual field, it has not been shown to affect behavioural responses in a significant way (Nuthman & Clark, 2023). Moreover, Nuthman & Clark (2023) note that the absence of such effects might be due to the tasks used in pseudo-neglect research. Surprisingly, a study by Steffner & Schenkman (2012), investigating change detection on websites with images, found that changes on the right were better perceived. Given that hotel websites usually present images with their offers, the inconclusive findings pose the question whether CB in mock-hotel websites is affected by pseudo-neglect or whether the findings of Steffner & Schenkman would be replicated. Such biases would have implications for the detection of changes on goal-irrelevant information and websites.

Research Aim

This paper investigated the effect of task-relevance on VSTM on hotel websites when visual selective attention is directed by search goals. By employing mock-hotel websites with two layouts, this paper provided an ecologically valid approach to studying the influence of task goals on CB while exploring the effect of pseudo-neglect. In using websites, the study set out to provide a realistic setting to advance research on goal-directed selective attention in a digital world. Its findings may provide insight into what VSTM contains when users search for information on a hotel website. This might result in suggestions for UX design. The effect of our task-goals and pseudo-neglect on VSTM might necessitate adjustments in presenting information that is important, but rarely task-relevant to users. The study anticipates (1) better performance of change detection for task-relevant changes than task-irrelevant changes. In addition, it is suggested that (2) pseudo-neglect may impact change detection in task-relevant or irrelevant information if participants are engaged in goal-directed visual search.

Methods

Participants

A convenience sample (N = 21) was recruited either through the SONA system of the University of Twente or directly by the researcher. Participants recruited through SONA received course credit in exchange for their participation. The sample was predominantly male (14 males, 65%). Ages ranged from 18 to 55 (M_{age} = 28.2, SD=11.17). Twelve participants were German with the remaining sample having other nationalities. All participants had normal or corrected-to-normal vision acuity as tested at a measured distance of 80 cm using the Landolt C Acuity test from the FrACT10 Freiburg Vision Test (Bach, 2006). Participants had normal colour vision according to the Ishihara color blindness test accessible via color-blind-test.com. A preliminary survey recorded the participants' familiarity with hotel websites, with 74% of participants stating they were visiting hotel websites or comparable applications 1-5 times monthly. Four other participants claimed using such services less frequent, while another reported visiting hospitality websites more than 6 times in a month. The experiment was approved by the ethics committee of the Faculty of Behavioural, Management, and Social Sciences at the University of Twente (request number 240145). All participants provided informed consent to participate in the study.

Apparatus and Software

The entire experiment was conducted using a computer running MacOS Sonoma 14.4.1. featuring a 13.3-inch screen at a pixel resolution of 2560 x 1600. The participants' distance to the screen would range based on their preferences from 50 to 80 cm during the main experiment. The experiment was coded and operated in Visual Studio Code 1.86.1 using Python 3.12. The web application Figma was used in the creation of the website mocks and their different variants. The survey tool Qualtrics survey was used to present information about the study and collect informed consent, demographic information, and inquired about the frequency of visiting hotel websites. It was also used to collect feedback after the experiment.

Stimuli and Task

Websites

A total of six hotel booking websites were created, inspired by examples on *booking.com* and following recommendations of Johnson (2021) to ensure display diversity. Of these websites, three featured a left-aligned layout while another three featured a right-aligned layout to explore the effect of pseudo-neglect. For each website, two distinct offers were created. Each offer was displayed with two different pictures depicting a hotel bed. Pictures were acquired through *pixabay.com*. In total, this yielded 24 displays. Next, five variants of each display were produced. One contained no change for the control condition, while the other four variants featured changes in font (See Figure 1 & 2).

Changes occurred in the font of text items conveying the price, destination, number of guests, or the travel dates. Pilot testing revealed that the change font should be clearly discernable. Thus, the fonts in the no-change condition, Inter and Kadwa for each layout respectively, were changed to informal script serif font Telma Bold. In the change condition, only one type of information would be changed. Therefore, every offer was presented as a control variant and in all four change variants. For an exemplary change variant, please regard

Figure 2. A variety of aspects across websites were held constant to reduce potential bias. The pictures on the websites were chosen to be as neutral as possible in color and contrast. In addition, the size of the images was also held constant for all websites and offers. In addition, the amount of textual content was identical across all websites and offers to keep a consistent visual complexity. Varying amount of text could affect the effort that participants would need to find the cued information and impede information processing.

Figure 1

Offer 1 in Control Condition

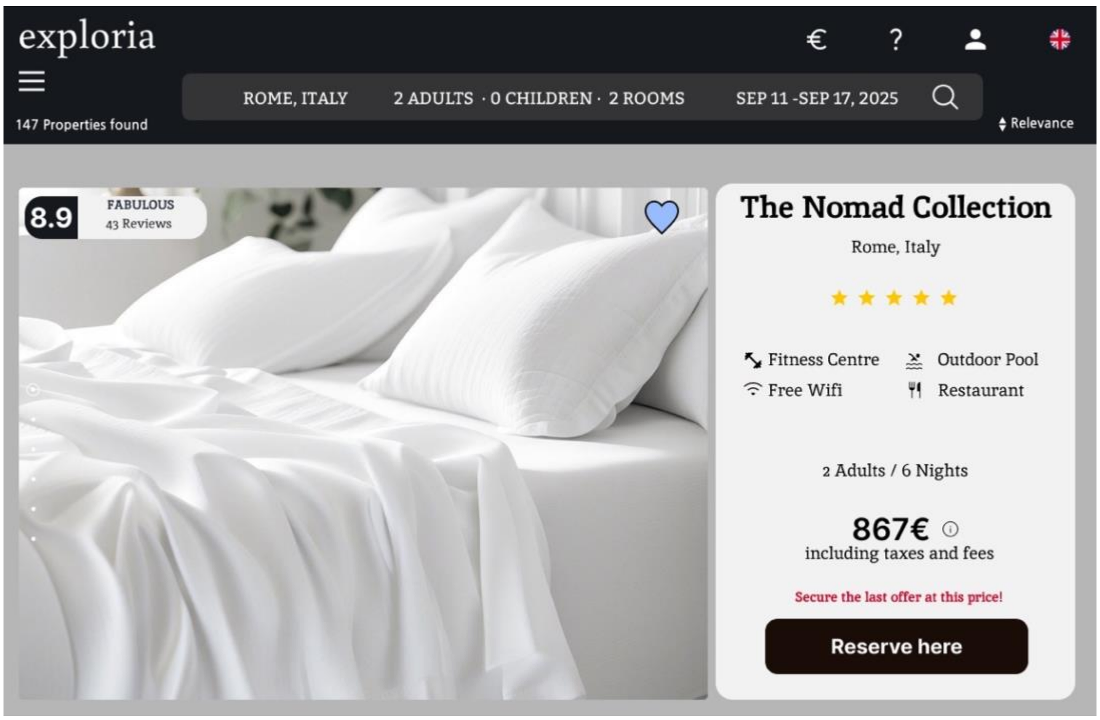
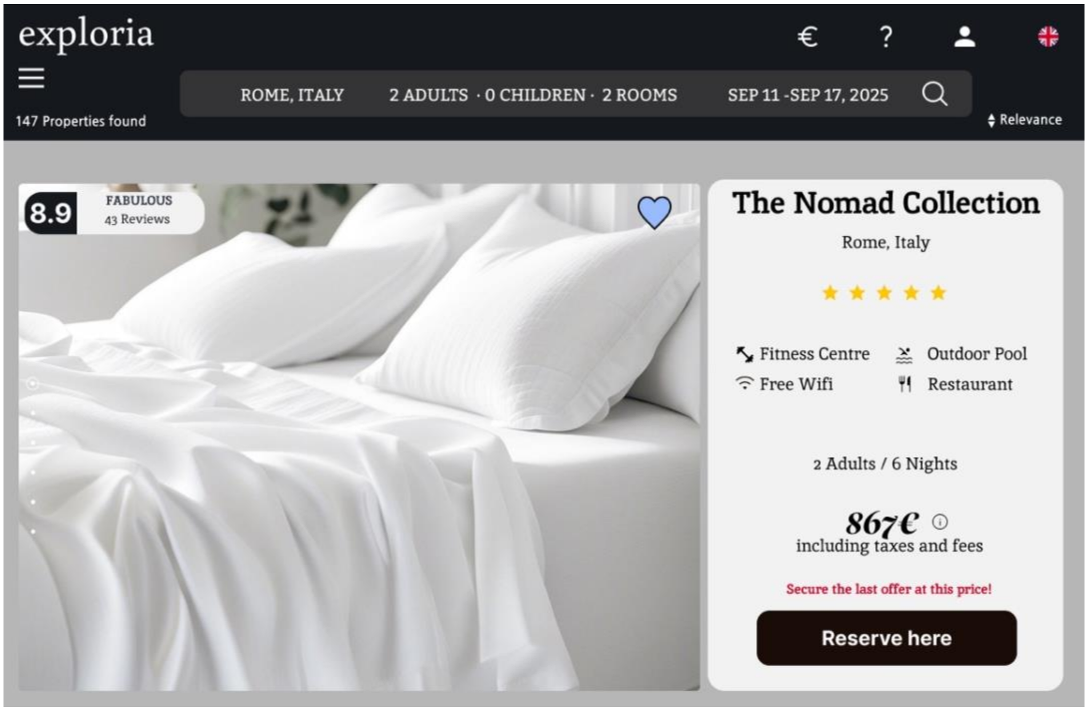


Figure 2

Offer 1 in Change Condition with a Font Change in the Price



Task-Relevance & Hotel-search Task

The task-relevance of changes was contingent upon the instructional task as it directed attention towards specific information. These tasks were formulated to simulate real-life search goals ("You search a hotel in Rome, Italy for 2 Guests"). As each task contained two items of information at a time, two items were simultaneously raised into a 'relevant' state, of which one was possibly changed. As a result, changes were task-irrelevant if they were not defined as search criteria in the Hotel-search task of a given trial. Search tasks contained two search criteria, making six possible unique pairings, i.e. price and destination or price and guest. Two Hotel-search tasks were formulated for each criteria pairing, yielding 12 instructional tasks in total. An overview over how offers relate to hotel-search tasks can be found in Appendix A.

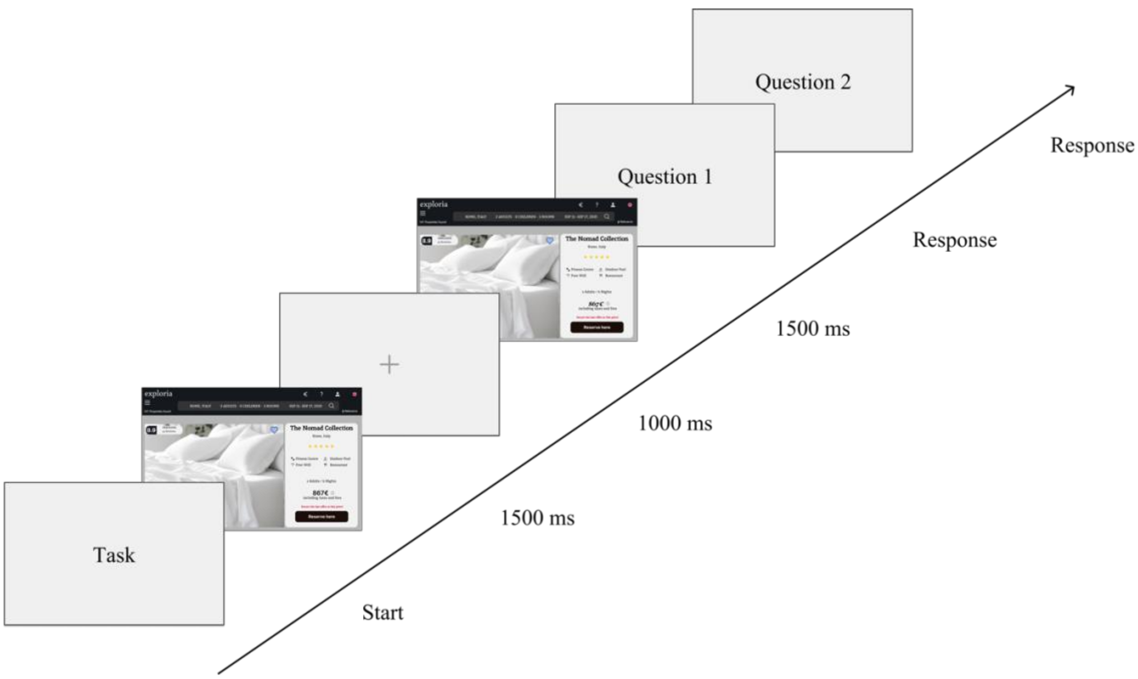
Procedure

The researcher was present in the room for the entire duration of the experiment. Participants were seated at a table in a quiet room. After giving informed consent, completing the preliminary survey and pre-tests, the participant was introduced to the main experiment. This involved informing the participant about the sequence of events per trial and tasks they had to perform. For further information of the sequence of a trial, please Figure 3.

Participants could ask questions and received answers until they indicated that had understood the instructions thoroughly and could start the main experiment. A total of 192 randomised trials were completed per participant, with intermissions of 1-minute breaks every 48 trials. Following the main experiment, a second Qualtrics survey presented the debriefing information and allowed participants to provide feedback, which included the opportunity to explain any search strategies they might have used.

Figure 3

Sequence of Events on one Trial



Note. A trial starts with the presentation of a hotel-search task (i.e., “You search for a hotel in Rome, Italy for two guests”). After reading the task, participants used the cursor to press the “Begin” button presented on-screen. A hotel offer was displayed twice for 1500ms, separated by a mask with a fixation cross. The second display either showed the offer without changes (control) or containing a changed item. The changed item was either relevant to the search task (task-relevant) or not (task-irrelevant). Ensuing, participants answer Question 1 ("Did the Hotel offer fit the requirements for the hotel?") and Question 2 (Did you notice a change?"). Both questions could be answered with yes or no by clicking buttons shown on-screen. After, participants progress automatically to the next trial.

Data Analysis

Data preparation and analysis were done in RStudio Version 2024.04.1+748 and Excel 16.85. Demographic information and survey responses were prepared and analysed using RStudio. Following the study of Bittner (2024), a learning effect was investigated to ascertain the impact of the experimental design on performance. To allow for further analysis pertaining to a learning effect, data preparation included the categorisation of trials as belonging to either the first or second half of the experiment. Thus, the variable Block was created with the levels “First” and “Last”. Based on the randomised order of trials for each participant, “First” contained the first 48 control trials, first 24 task-irrelevant change trials, and first 24 task-relevant change trials. Consequently, the remaining trials were assigned to Block “Last”. Secondly, data preparation for further analysis included the creation of the 2-level variable “Offer match”. This was done as participants reported starting the search for changes sooner when the Hotel offer did not match the search criteria. When the first piece of information (. i.e. the price) did not fit the search criteria, participants stopped searching for the second criteria and subsequently focused on detecting changes. This search strategy could have attenuated the difference between task-relevant and task-irrelevant changes. Therefore, performance was compared between trials were the offer matched the search criteria with performance on ‘no-Match’ trials.

Based on signal detection theory, d-prime (d') and the natural logarithm of beta (ln(ß)) were calculated for various conditions for each participant. First, d' and ln(ß) were calculated per participant per change condition for each layout. Thereafter, both measures were calculated per participant and per change condition and for the first and second half of the experiment. In addition, d' and ln(ß) were computed per participant per change condition for each level of the variable ‘Offer Match’.

To compute d' and ln(ß), the hit rate and false- alarm rate and their Z-Scores were calculated for each participant and each change condition. For d', the Z-score of the false alarm rate was subtracted from the Z-score of the hit rate. For ln(ß), the squared Z-score for the false alarm rate is subtracted by the squared Z-score of the hit rate. The difference was then divided by two. Due to the occurrence of hit and false alarm rates of 0, loglinear recommendation was applied by adding 0.5 to the hit and false alarm count as well as increasing the total number of noise (no change) and signal (relevant or irrelevant change) trials by 1 (Stanislaw & Todorov, 1999). As a performance index for each participant, d' was interpreted according to Macmillan &

Creelman (2005) and prior research (Bittner, 2024; Suhani, 2023). Hence, d' = 4.65 was received as the upper limit for effective values. Generally, values around d' = 2 are considered average and d'=1 as “69% correct”. Following prior research with a comparable study design by Bittner (2024), performance was classified as poor if $d' < 1$, while $1 \leq d' \leq 1.5$ was considered as average. Values of $d' > 1.5$ were considered as performing well above chance level or ‘good’. Values below zero indicate that performance was below chance level.

Secondly, ln(ß) was taken as a measure of response bias. Participants responded without bias if ln(ß) equalled 0. A liberal tendency to answer "yes" was indicated by $\ln(ß) < 0$, whereas a conservative tendency is reflected by $\ln(ß) > 0$ (Stanislaw & Todorov, 1999).

Homogeneity and normality were tested by using Shapiro and Wilk’s and Levene test prior to each analysis. Values of d' and ln(ß) were compared by multiple two-way 2 x 2 repeated measures ANOVA using the Rstatix package (Kassambara, 2023). The first ANOVA explored the potential effect of pseudo-neglect and task-relevance as well as their interaction by comparing d' and ln(ß) per layout and per change condition. Secondly, d' and ln(ß) per participant, change condition and Block were submitted to a second ANOVA, exploring performance over time. Potential interaction effects in d' were specified by Bonferroni-corrected pairwise t-tests.

Based on participant feedback, a post-hoc analysis was conducted via 2 x 2 repeated measures ANOVA to assess the effect that focusing on change detection in ‘no-Match’ trials might have on change detection accuracy. This might have affected the difference between detecting task-relevant and task-irrelevant changes.

Exclusion of Participants

The preliminary inspection of d', ln(ß) and hits and misses per participant showed that two participants obtained one hit or four hits for all 192 trials, resulting in hits rates of 0,02 and 0,04 respectively. Finally, data of these participants was excluded due to a performance below change level at $d' < 0$.

Results

Layout & Pseudo-neglect

Change detection was better for task-relevant changes compared to task-irrelevant changes in both layouts (See Figure 4). The repeated measures ANOVA revealed that the difference between change conditions was significant, (F (1,18) = 8.28, p =.01, ηp^2=.315). While layout had no significant effect on d' (F (1,18) = 0.21, p =.656, ηp^2 =.011), a significant interaction between layout and change condition was found (F (1,18) = 12.7, p =.002, ηp^2 =.414). Two Bonferroni-corrected pairwise t-tests unveiled that change detection performance was significantly higher for task-relevant change ($M_{d'}$ = 2.47, *SD* = 1.12) than task-irrelevant change ($M_{d'}$ = 1.99, *SD* = 1.18), on the right-aligned layout (t (19) = - 3.67, p =.002). In contrast, the test for the left-aligned layout did not present a statistically significant difference (p = .217) between change conditions (Task-Relevant: $M_{d'}$ = 2.35, *SD* = 1.13; Task-Irrelevant: $M_{d'}$ = 2.22, *SD* = 1.16). Thus, we conclude that change detection for task-relevant changes was only significantly better for the right-aligned layout. Pseudo-neglect did not affect change detectability overall.

The response bias of participants was conservative (See Figure 5). The ANOVA revealed no significant effect of Layout on log(ß) (F (1,18) = 1.13, p =.30, ηp^2 =.059), while the effect of Change Condition appeared to be significant, (F (1,18) = 5.33, p= .033, ηp^2 =.228). The interaction of change condition with Layout was also significant, (F (1,18) = 13.9, p=.002, ηp^2 =.435). Concerning this interaction, it appears that responses were significantly less conservative for the right-aligned layout in the task-relevant change condition (*M*= 0.34, SD=0.78) compared to the left-aligned Layout (*M*=0.65, SD=0.91). For task-irrelevant change, participants were equally conservative for both layouts with a mean log(ß) of approximately 0.73 (SD_{Left}=0.89; SD_{Right}=0.83). On this basis, we conclude that response bias was significantly less liberal only when in the task-irrelevant change condition on the right-aligned layout.

Figure 4

Bar Plot with Error Bars for d' per Layout and Change Condition

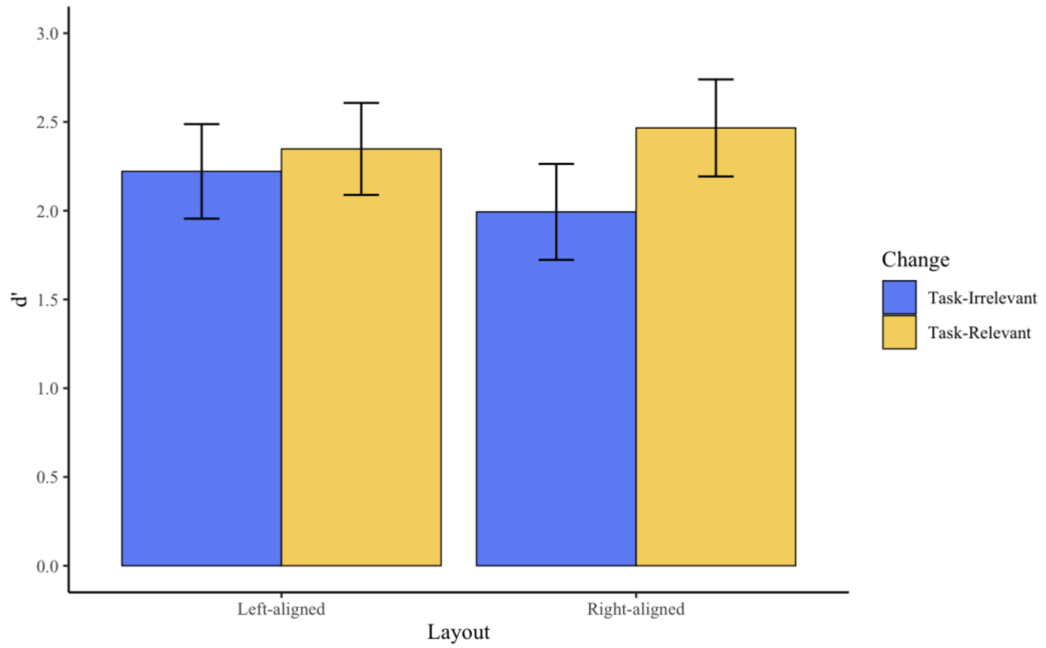
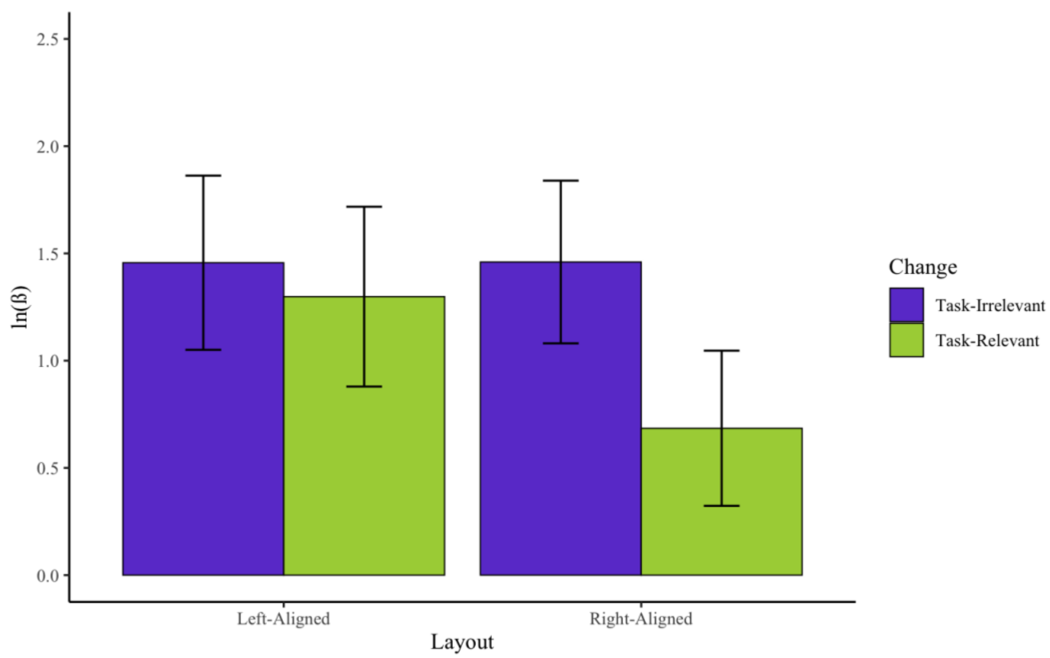


Figure 5

Box Plot for ln(ß) per Layout and Change Condition



Learning Effect

Performance improved in both change conditions from the first to second half of the experiment by approximately 1 (Figure 6). The repeated measures ANOVA was conducted to compare means for each change condition in each block. A significant difference between Change Conditions (F (1,18) = 7.95, p = .011, ηp^2 = .306) and Block (F (1,18) = 16.49, p < .001, ηp^2 = .478) was found. Moreover, there was a non-significant interaction effect between Block and Change Condition (F (1,18) = 0.26, p = .613, ηp^2 = .014). Therefore, it can be concluded that d' remained consistently and significantly higher for task-relevant change.

The response bias of participants appeared to be more liberal in the first half of the experiment for the task-relevant (*M* = 0.37, *SD* = 0.85) and task-irrelevant condition when compared to the second half of the experiment, where responses increased to be more conservative for task-relevant (*M*=0.54, *SD* =0.95) and task-irrelevant change (*M*=0.77, *SD* =0.99). The ANOVA showed no significant effects for Change Condition (F (1,18) = 4.41, p=.05, ηp^2 = .197), Block (F (1,18) = 0.9, p =.36, ηp^2 =.53) and the Change Condition-Block interaction (F (1,18) = 0.003, p = .958, ηp^2 <.001).

Figure 6

Barplot of d Prime with Error bars per Block and Change Condition

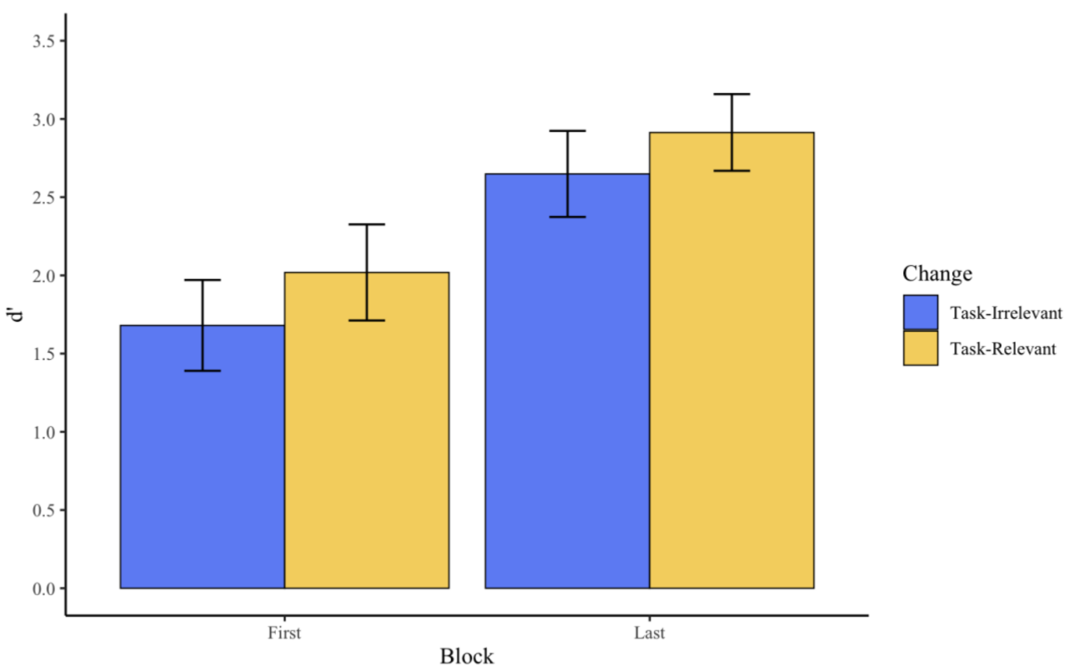
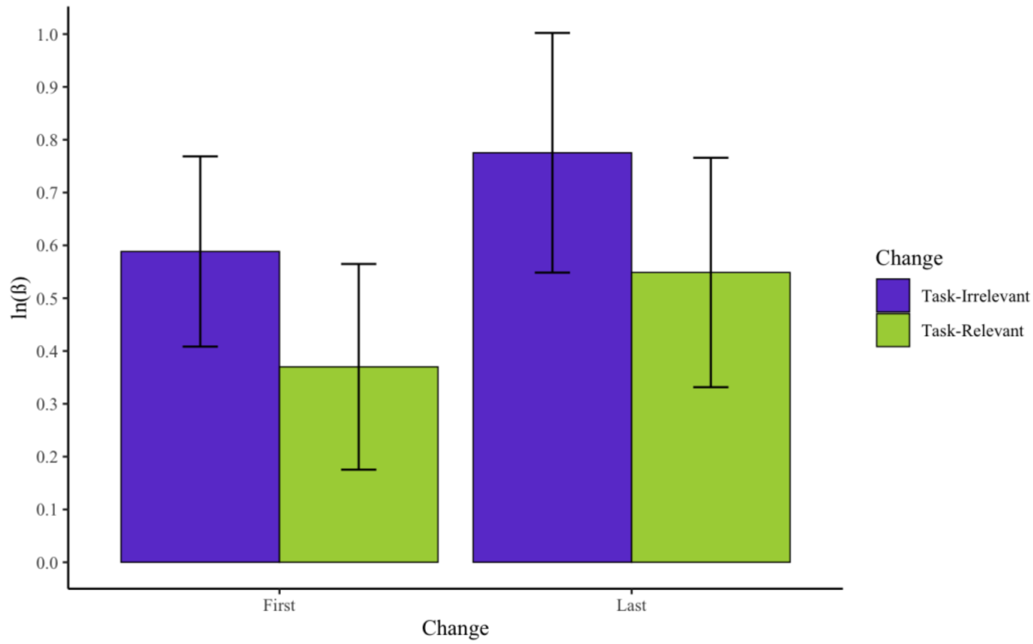


Figure 7

Barplot with of ln(ß) Error Bars per Block and Change Condition



Task-Offer Match

Figure 6 depicts the difference in performance when the offer matched the search criteria and when they did not. Post-hoc, a repeated measures ANOVA indicated no significant main effect of Offer Match (F (1,18) = 0.26, *p* = .61, ηp^2 = .014). Yet, it was confirmed that besides a significant effect of Change Condition on performance (F (1,18) = 7.99, *p* =.01, ηp^2 = .307), there was a significant interaction with Offer Match (F (1,18) = 7.85, *p*=.013, ηp^2 = .299). Two Bonferroni-corrected t-tests were performed to investigate this interaction effect. It was shown that d' was significantly higher for task-relevant changes (*M* = 2.53, *SD* = 1.12) compared to d' for task-irrelevant changes (*M* = 2.07, *SD* = 1.03) when the offer matched the search criteria, *t* (19) = -3.47, *p*=.003. However, when the offer did not match the search criteria, the difference between the higher performance for task-relevant change ($M_{d'}$ = 2.3, *SD* = 1.24), when contrasted to task-irrelevant change ($M_{d'}$ = 2.16, *SD* = 1.25), was not statistically different, *t* (19) = -1.24, *p*=.231. This shows that the benefit for change in task-relevant information was contingent upon whether the offer fit the search criteria.

Concerning response bias, there appeared to be a further significant interaction effect between Change condition and Offer Match (F (1,18) = 5.69, p= .028, η_p^2 = .240). explaining a moderate proportion of the variance found in ln(ß). Comparatively, the effect of Change condition was significant (F (1,18) = 5.2, p = .035, η_p^2 = .224), as opposed to the non-significant effect found for Offer fit (F (1,18) = 0.96, p = .34, η_p^2 = .051). As depicted in Figure 8, participants were more likely to indicate was present if a change was task-irrelevant and occurred when the offer matched the instructions (M = 0.89, SD = 0.9).

Figure 6

Bar Plot with Error Bars for d' per Offer Match and Change Condition

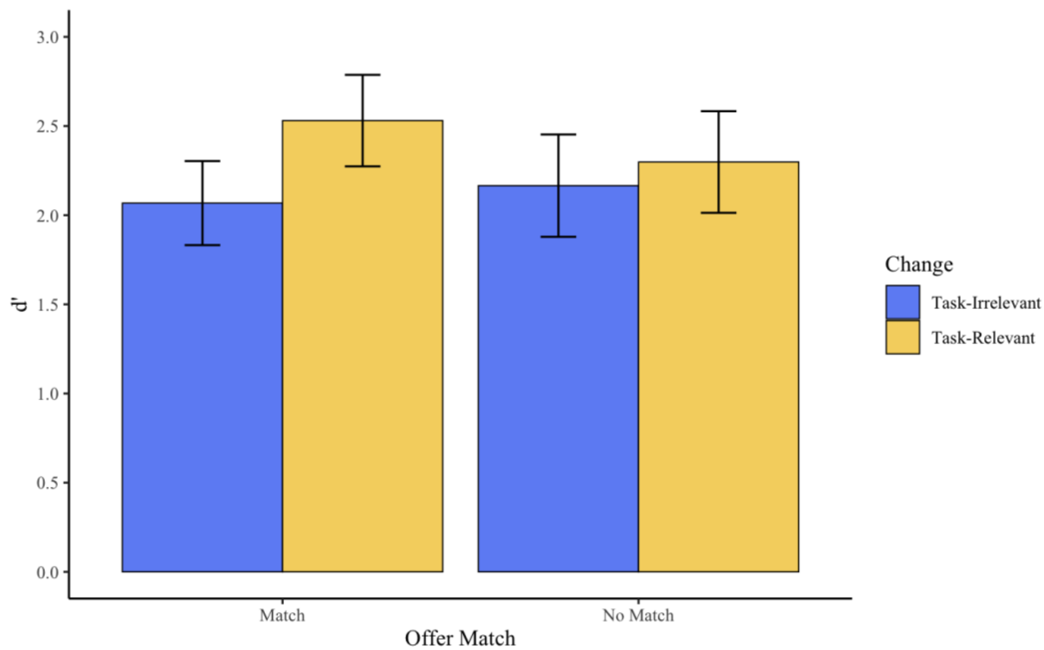
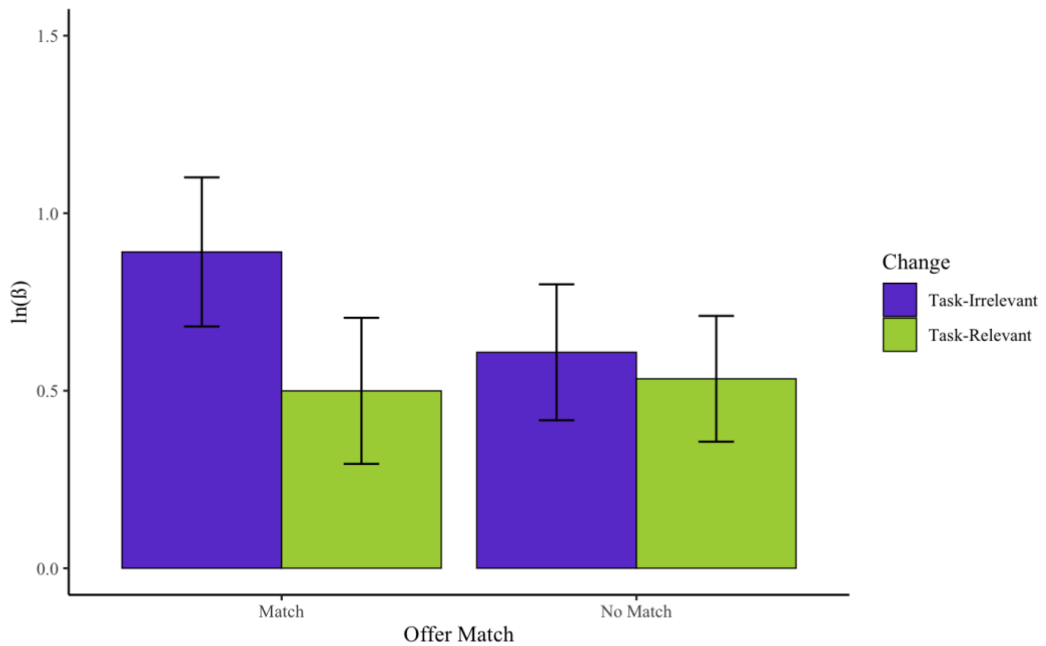


Figure 7

Bar Plot with Error Bars for ln(ß) per Offer Match and Change Condition



Discussion

The present study investigated the influence of task-relevance on VSTM in hotel-websites and explored the potential impact of pseudo-neglect. Information that is relevant to action goals seems to be selectively attended to and subsequently contained in VSTM (Heuer et al., 2017; Kuo et al., 2012; Maxcey-Richard & Hollingworth, 2013; Olivers & Roelfsema, 2020). Moreover, visual attention has been found to be biased toward the left visual field, assisting people in detecting changes earlier in the left visual field (Bowers & Heilman, 1980; Brooks et al., 2014; Iyilikci et al., 2010). However, studies employing behavioural measures do not suggest that the faster detection also improves target detection performance in the left visual field (Nuthmann & Clark, 2023). The present study investigated whether change detection is affected by pseudo-neglect on websites. In a new approach, this study utilised mock hotel-websites in combination with hotel-search tasks to engage participants in realistic goal-directed visual search, attempting to emulate visual selective attention and VSTM processes in a realistic setting. This study intended to showcase that VSTM, as a process in service of behaviour, selectively retains information that is relevant for a search task. In addition, the effect of pseudo-neglect was investigated as it might have impacted the detection of change on layouts.

Participants showed good change detection performance with d' >1.5 that were close to a value of 2 in almost all conditions. Performance was shown to be significantly higher for task-relevant changes which persisted over time. In all conditions, participants responded conservatively and did not become significantly more liberal over time (Macmillan & Creelman, 2005).

The present study presents evidence for a significant benefit in the detection of task-relevant change. This shows that our selective attention is also influenced by our goals, impacting what we retain in VSTM, when we search for hotel offers online. Therein, this study is part of a broader range of research supporting that visual selective attention is influenced in a top-down manner and that the selection into VSTM is linked to our goals (Awh et al., 2012; Olivers & Roelfsema, 2020).

Moreover, there appeared to be no significant influence on whether information was displayed on the left or right. However, the discrepancy in performance between task-relevant and irrelevant change was only significant when the layout was right-aligned, showing key information in the right visual field. This finding could be linked to pseudo-neglect, as participants mentioned that they had adopted search strategies to detect changes in the displays.

Secondly, this study found that the memory benefit of task-relevant information remained constant throughout the experiment, further supporting the notion that VSTM representations, suggesting that the learning of experimental stimuli and increasing efficiency in conducting the search task did not influence the effect that task-relevance exerts on attention. Similarly, Bittner (2024) equally found a learning effect due to repeated exposure to stimuli. This improvement reflects the inherent influence of asking participants to report changes in CB paradigms, which might constitute a secondary action goal and thus affects visual attention and the representations in VSTM. Cuing attention toward a location has been found to predict detection accuracy in research (Posner et al., 1980). In addition, selection history appears to play a role in what kind of information will be inhibited and not attended to (Gaspelin & Luck, 2018). Therefore, participants might have first attended to the information specified in the search-task. Thereafter, they might have directed attention toward the other two criteria that were referred to in previous search tasks. More specifically, since changes were only present in the four items that were criteria in the search task, participants may have checked these first due to prior success with detecting changes in these items.

In relation to this, a post-hoc investigation found that the strategic allocation of attention, which participants reported, had influenced change detection. When the hotel offer would not match, participants would allocate more attention toward finding the changed item in the picture. This might be due to the inability of participants to prematurely shift attention toward detecting changes, as task-irrelevant change was noticed the least when the hotel offer had to be confirmed as matching. This adoption of a scanning strategy to identify changes in the display could be linked to the non-significant difference for change conditions in the left-aligned layout since pseudo-neglect was shown to affect reaction times in exploratory target search. Given that the changes were only displayed for a brief time, search from the left to the right might have taken more time than required to find changes on the right of the displayed picture.

Limitations

A first limitation of the present study is the association of search-tasks with websites. Each search task was consistently presented with two offers, of which one suited the search criteria while the other did not. This required participants to check the information on the page during every trial. Importantly, these offers were presented on the same website. While this ensured that offers were shown in all five variants (control and change) with the same search-task, it could have enabled participants to anticipate the layout that would be presented. This, in turn, may have assisted in finding the necessary information on the page for the hotel search task and thus allowed participants to search for changes in the display for a longer time.

Secondly, some changes were displayed at different locations at the same time. Price and Date change, on the other hand, was shown only once. This might have affected the pseudo-neglect measure, as participants did not need to attend the entire display to determine whether a hotel offer matched the search criteria. Therefore, the absence of pseudo-neglect might be attributable to the distribution of relevant information across the site.

Thirdly, the present study focussed on calculating Signal detection theory measures with a sufficient number of trials per condition, which prohibited data analysis via a comprehensive model. The number of trials was kept at 192 to keep the cognitive demand on participants acceptable and consider time constraints. However, per participant d' and ln(ß) were calculated separately for each ANOVA. Therefore, the interaction of Block and Offer Match condition with Layout and Change condition could not clearly be elucidated, potentially omitting relevant interaction effects.

Future Directions

Firstly, the choice of font will impact change detectability overall and therefore might mitigate the effect of top-down goal-directed guidance of visual search due to its bottom-up salience. Despite generally conservative response behaviour, change detection accuracy was generally high, insinuating that the noticeability of the Telma Bold font may have assisted in the identification of change. In turn, this could have helped participants in detecting task-irrelevant changes due to the discrepancy of the change font in relation to the original fonts. Moreover, the differences in items to which changes were administered might have impacted whether change was detected. Information such as the price have, by design, are presented to attract consumer attention and thus are salient on purpose. Guided search, as Wolfe (2021) states, is critically affected by bottom-up salience. The salience of information on hotel websites is also impacted by general habits of users, as participants have specific criteria are important to booking decisions in real life (Eibl & Auinger, 2023). Therefore, some information might be preferentially attended to regardless of its importance to the hotel-search task. Future research could investigate the interplay of bottom-up salience, based on its appearance, and top-down salience, based on the meaning to the participants, of information on websites and ascertain whether this affects CB.

The effect of pseudo-neglect in the present study was investigated by regarding behavioural data. As Nuthman & Clark (2023) suggest, behavioural data may lack explanatory power on its own, and propose that other techniques like eye-tracking would provide more information about the actual gaze paths of participants. Future research might utilize eye-tracking to determine whether the left-ward bias of pseudo-neglect also affects the search visual search in studies using one-shot methodologies and two search targets. The data may provide insight into why the discrepancy between task-irrelevant and task-relevant changes found in the present paper pertained to the right-aligned layout.

Conclusion

To conclude, this study has shown that what we retain in VSTM is dependent on our action goals when searching for a hotel offer on a website. Moreover, this study suggests that change detection of information that is irrelevant to the users' action goals may be improved for websites that adopt a left-aligned layout. This effect appears to be present over time, suggesting that familiarity with the study design or website may attenuate CB overall, but still does not mitigate preferential attention to task-relevant information. The study has shown that CB paradigms have limitations when investigating the effect of action-relevance, due to inadvertently rendering change detection as a secondary action for which visual attention is employed. Future research should aim at exploring the effect of task-relevance in other natural contexts to further the understanding of the interaction of task-relevance, visual selective attention and VSTM.

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Appendix A

Matrix for Connection of Task, Layout, Offer and Match/No Match condition.

Layout	Picture	Task	Offer	Match
Layout I	Picture A	You search for a hotel in Tokyo, Japan with a budget of 1100€.	1	Yes
			2	No
		You search for a hotel, for two guests in Rome, Italy.	3	Yes
			4	No
		You search for a hotel for one guest for May 2025.	7	Yes
			8	No
	Picture B	You search a hotel for three guests for August 2025.	2	Yes
			1	No
		You search for a hotel with a budget of 800€ for June 2025.	4	Yes
			3	No
		Please complete the task: You search for a hotel in Sydney, Australia with a budget of 600€.	8	Yes
			7	No
Layout II	Picture A	You search a hotel in Madrid, Spain for July 2025.	5	Yes
			6	No
		You search for a hotel with a budget of 800€ for two guests.	9	Yes
			10	No
			11	Yes

		You search for a hotel October 2025 for a budget of 600€.	12	No
	Picture B	You search for a hotel for four guests with a budget of 800€.	6	Yes
			5	No
		You search for a hotel in Miskolc, Hungary for April, 2025.	10	Yes
			9	No
		You search for a hotel in Munich, Germany for three guests.	12	Yes
			11	No

Appendix B

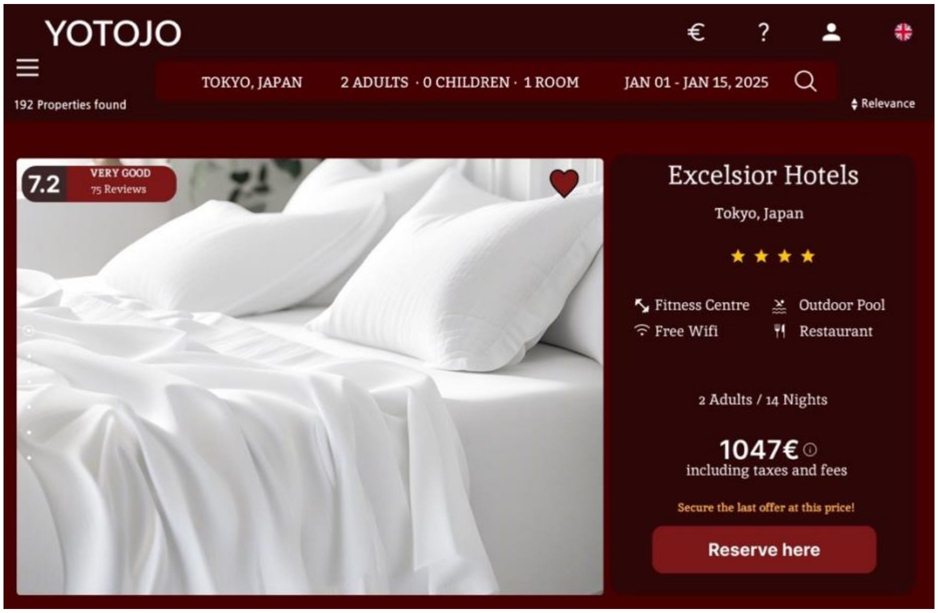
Stimuli

The stimuli of this study are presented below.

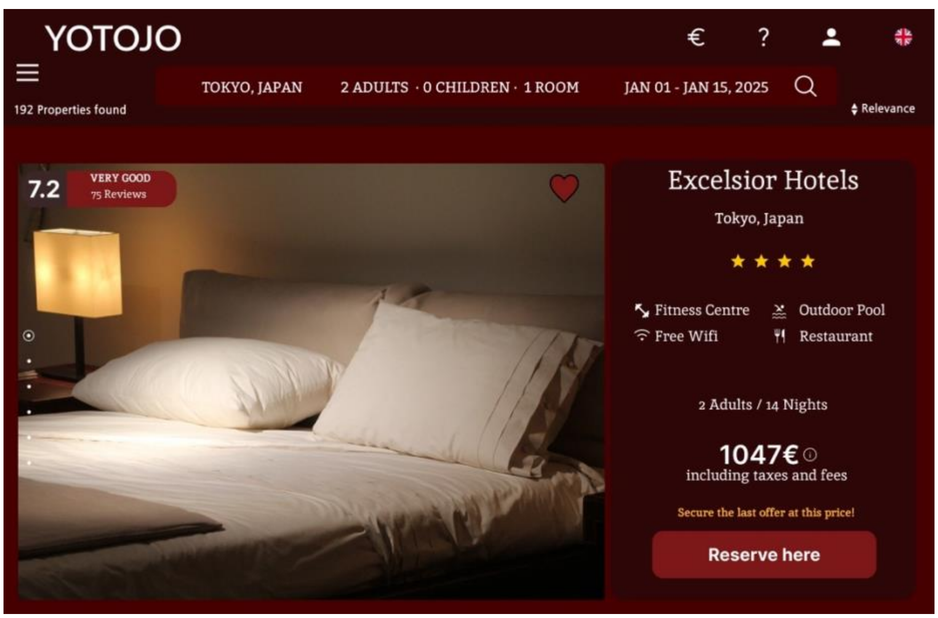
To gain access to the folders containing the hotel-search tasks and high-resolution images of the stimuli, please use the link below.

BA VSTM HF K.KUPSTOR STIMULI APPENDIX B

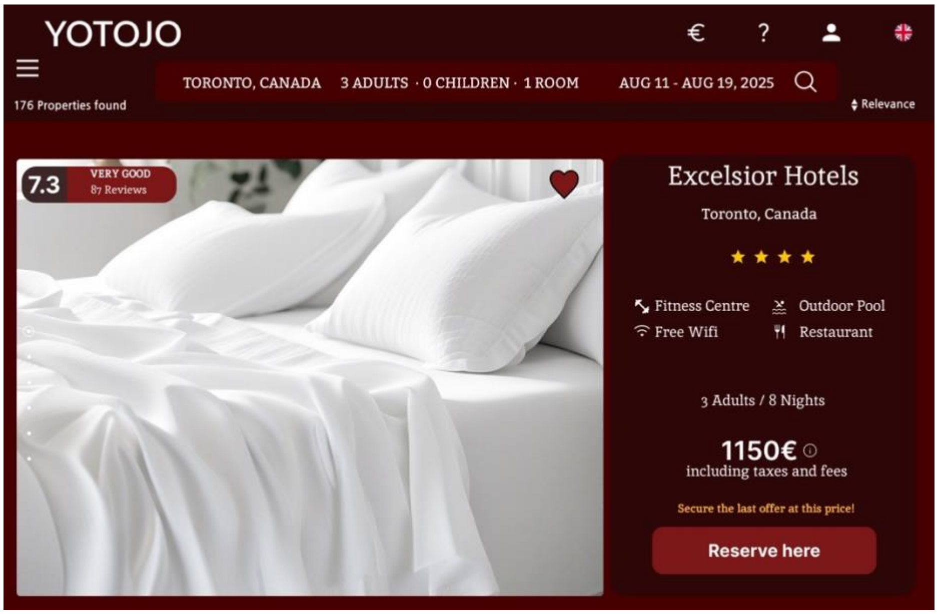
Offer 1 A



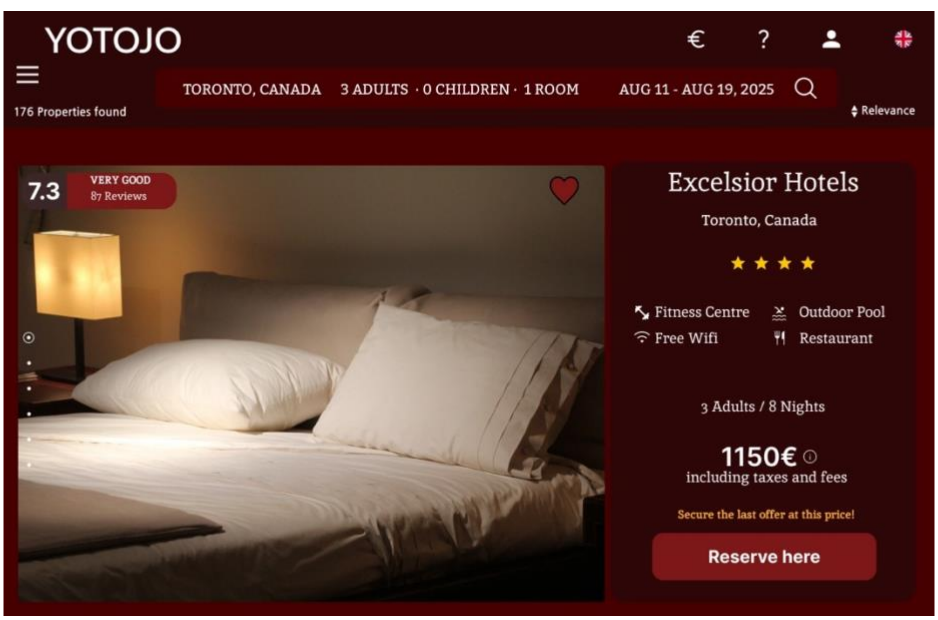
Offer 1 B



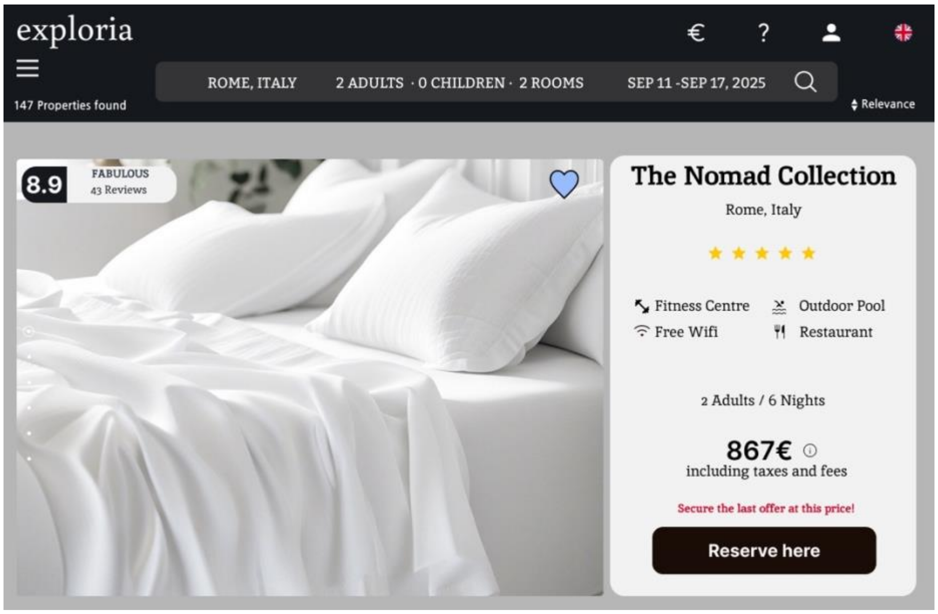
Offer 2 A



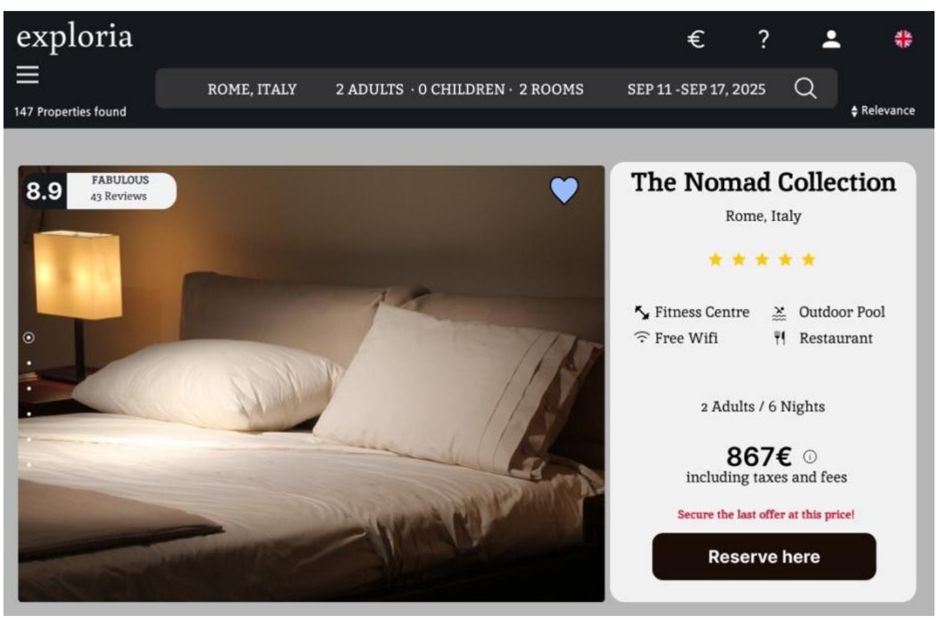
Offer 2 B



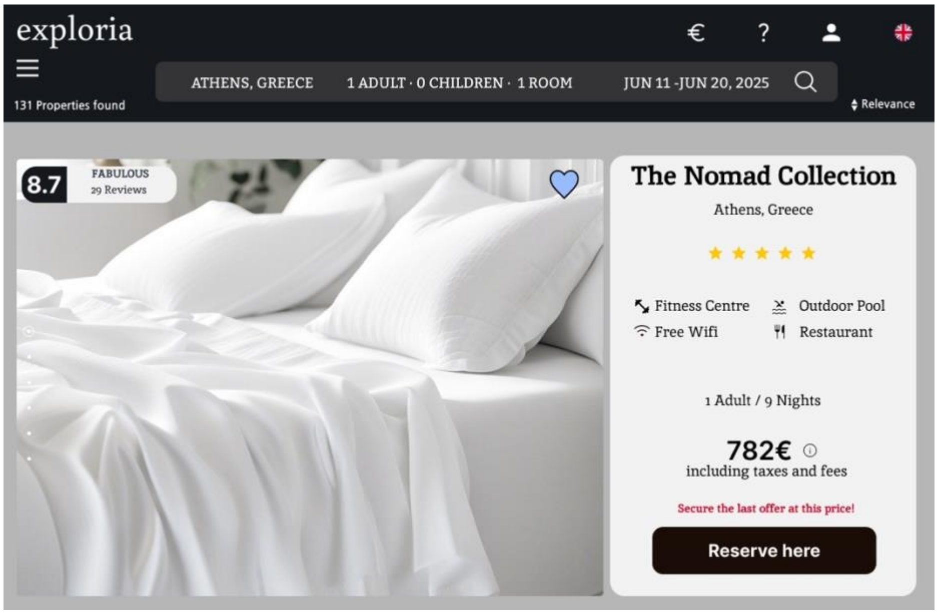
Offer 3 A



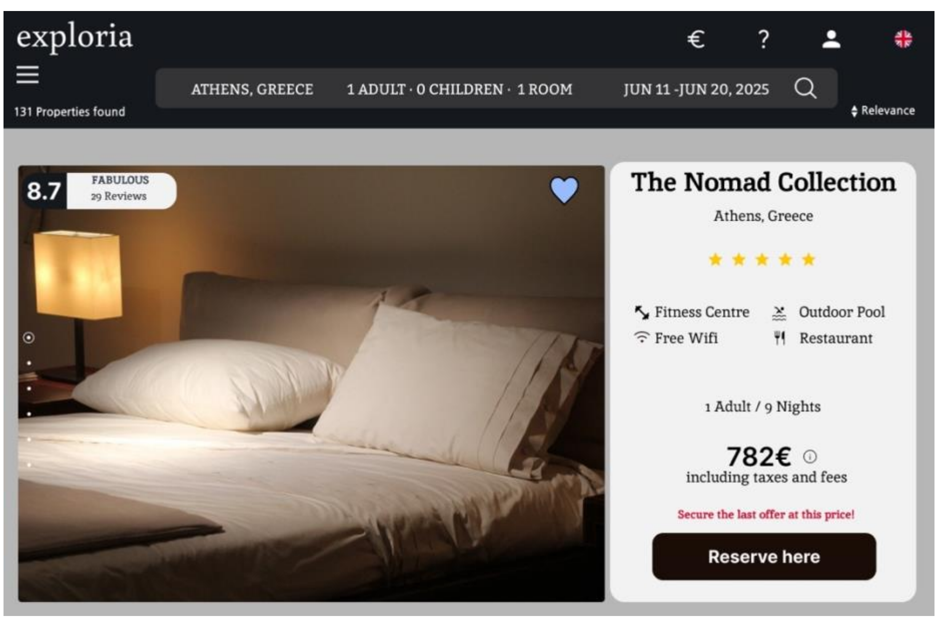
Offer 3 B



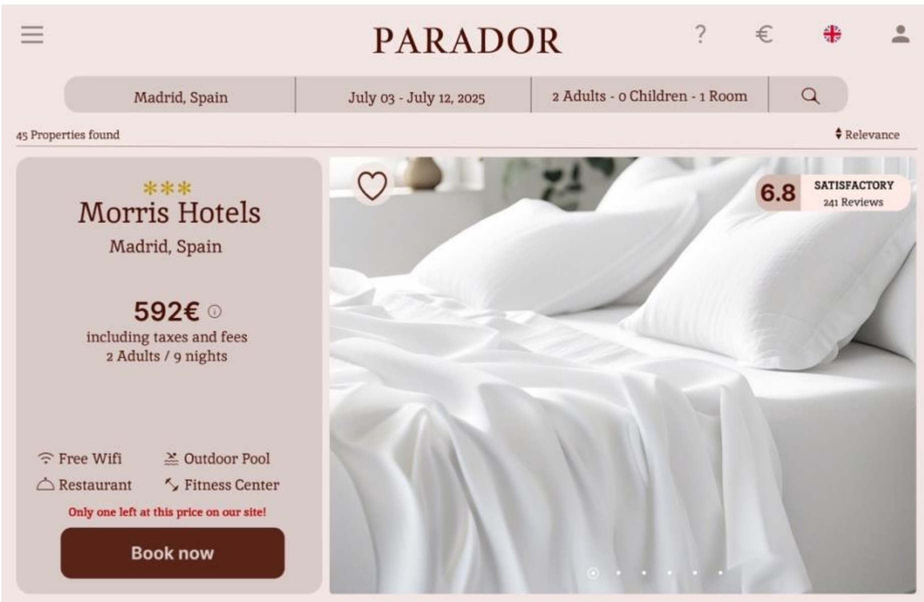
Offer 4 A



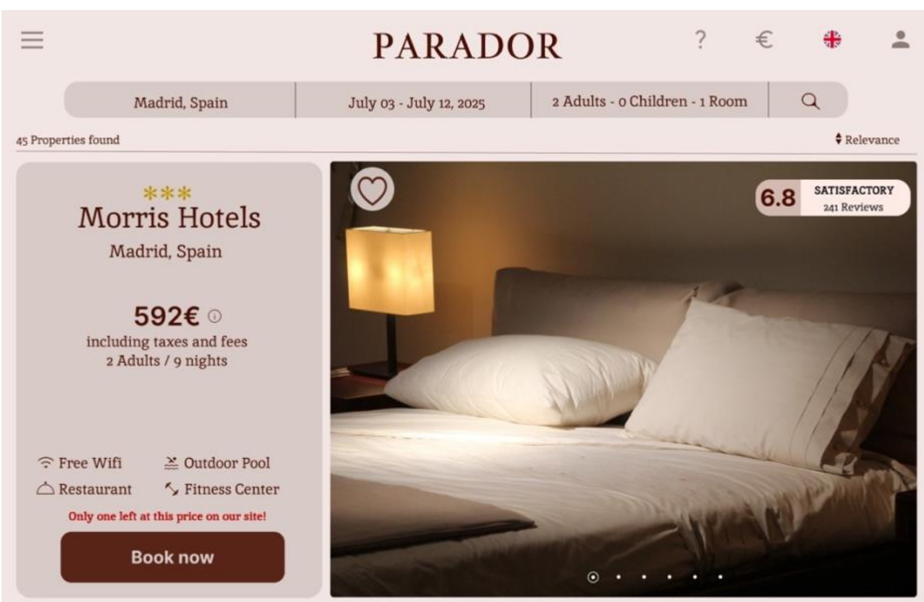
Offer 4 B



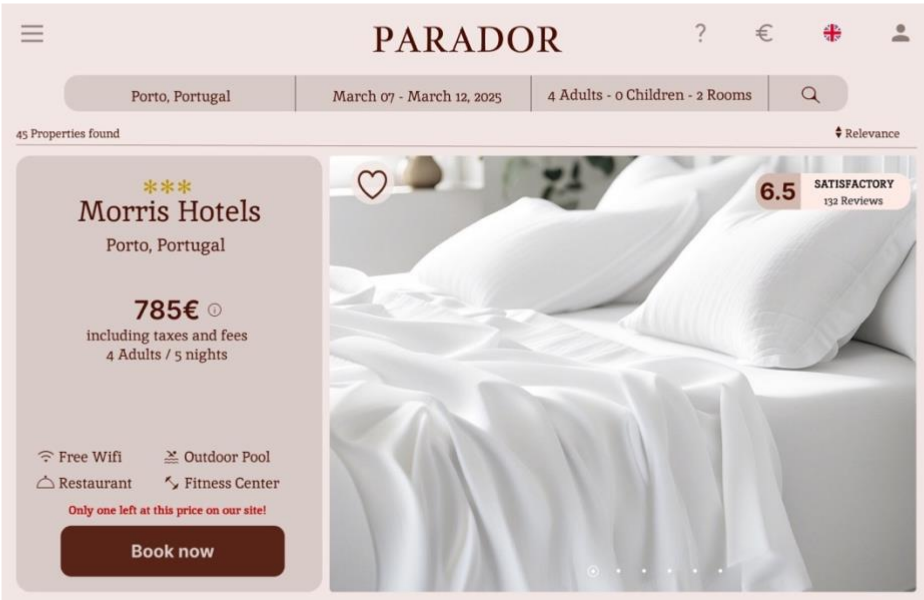
Offer 5 A



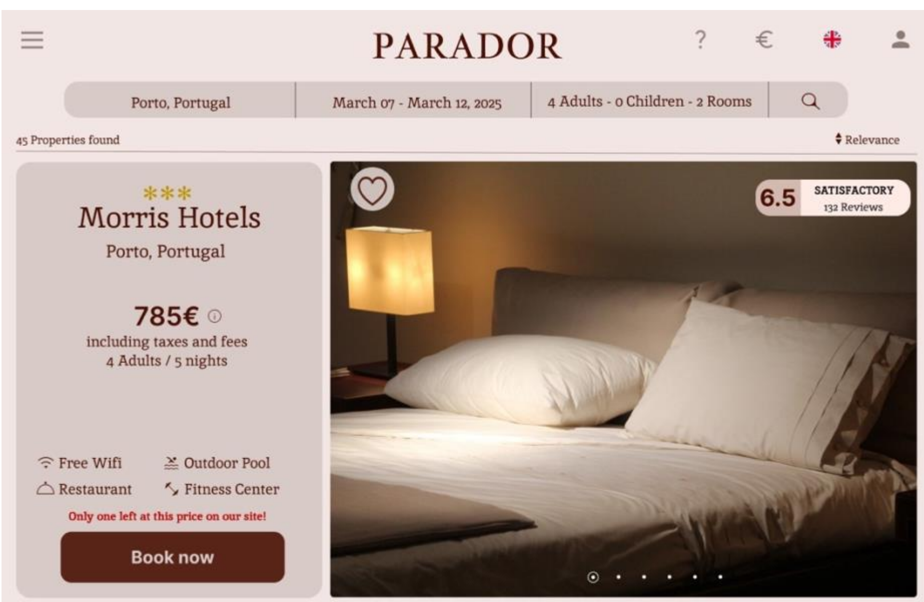
Offer 5 B



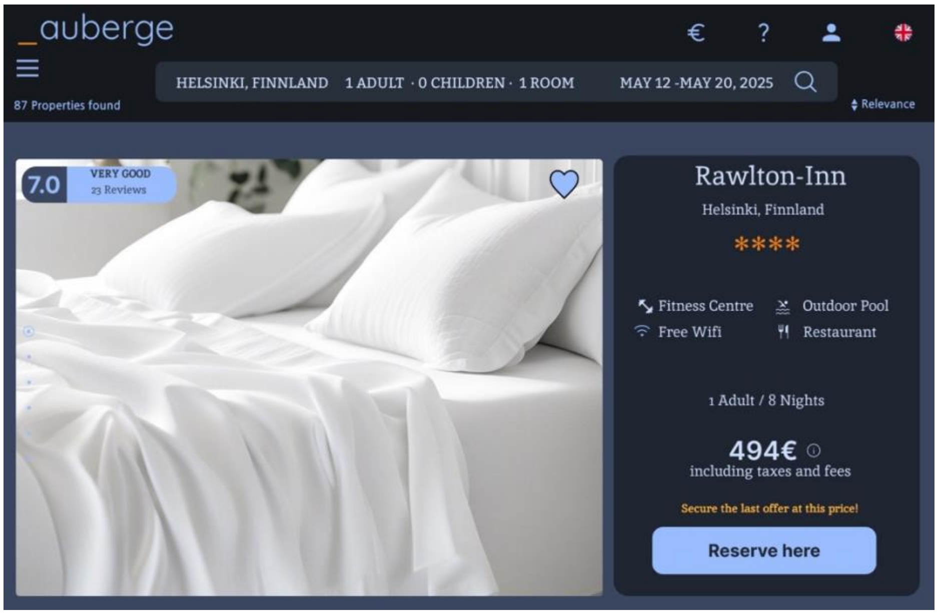
Offer 6 A



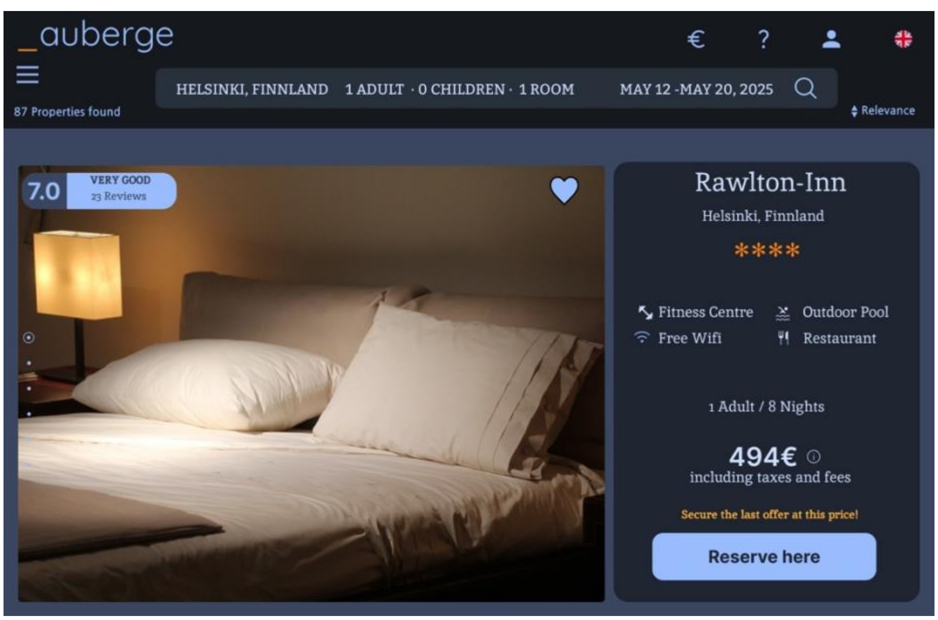
Offer 6 B



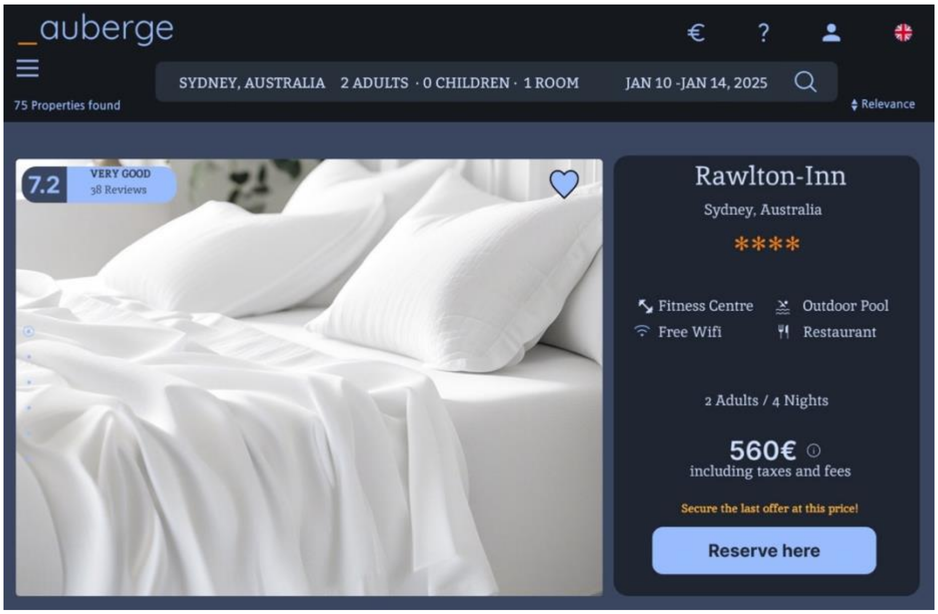
Offer 7 A



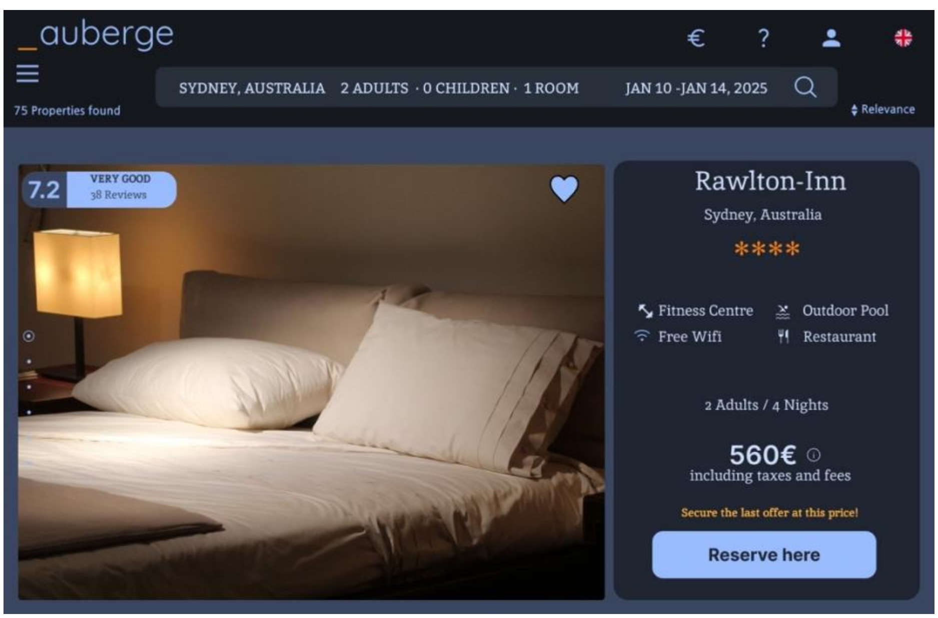
Offer 7 B



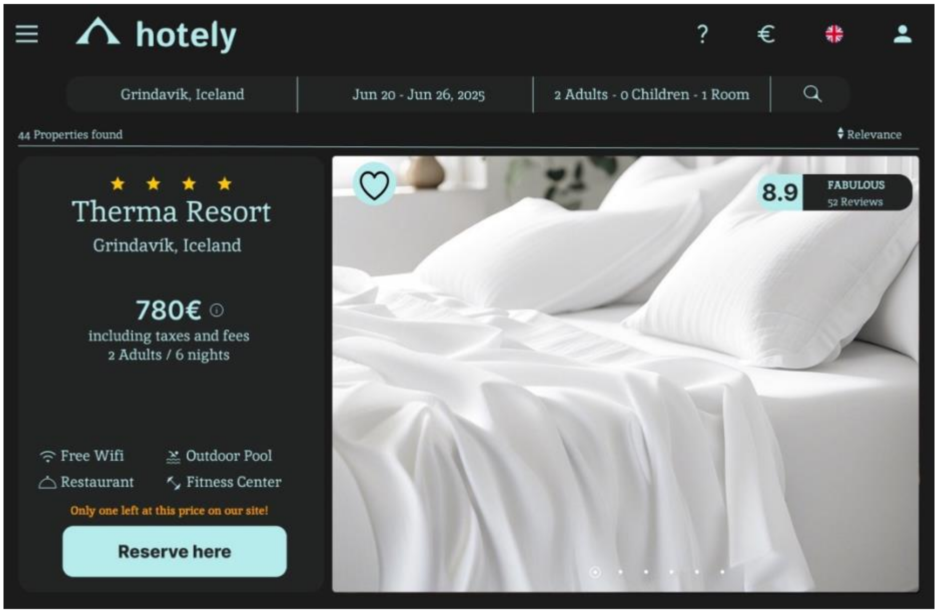
Offer 8 A



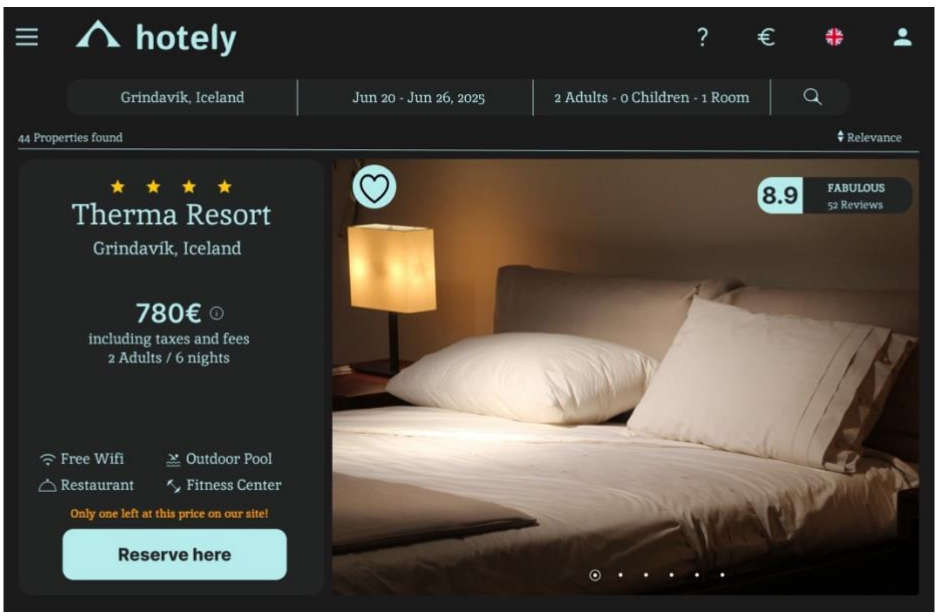
Offer 8 B



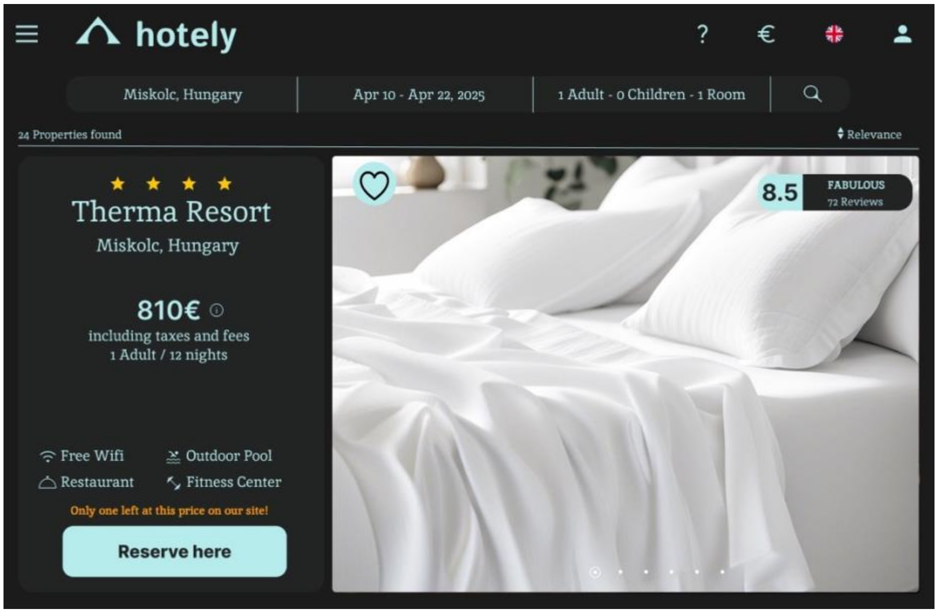
Offer 9 A



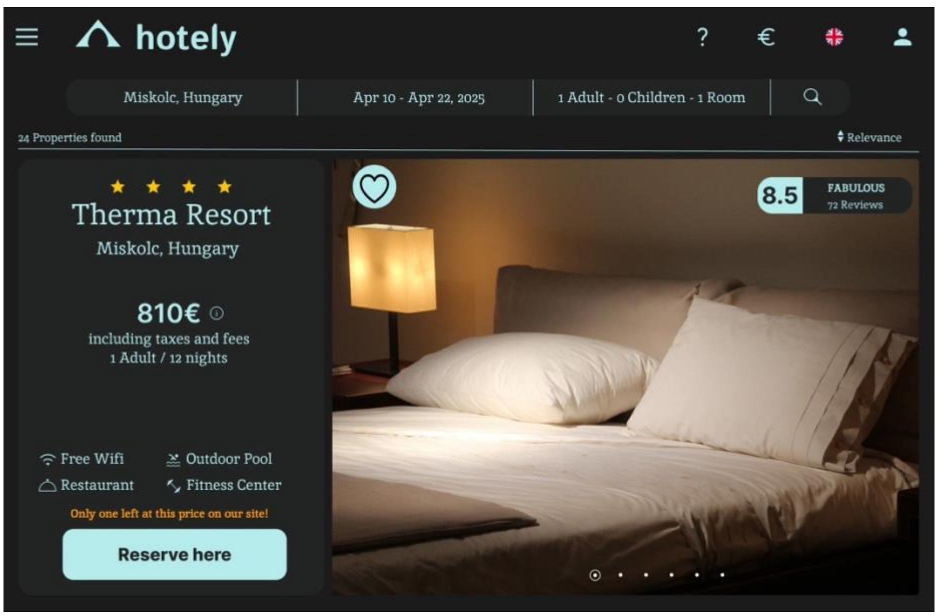
Offer 9 B



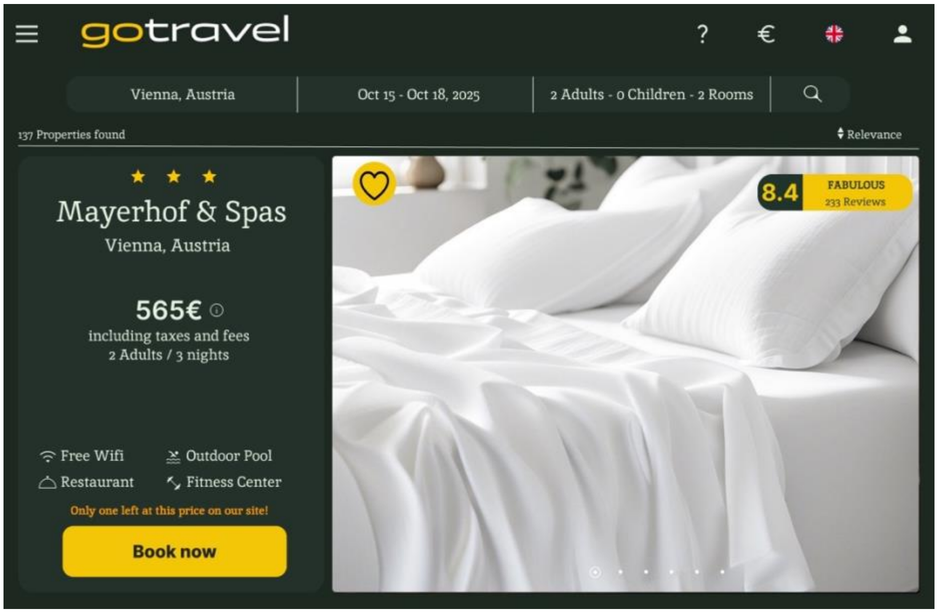
Offer 10 A



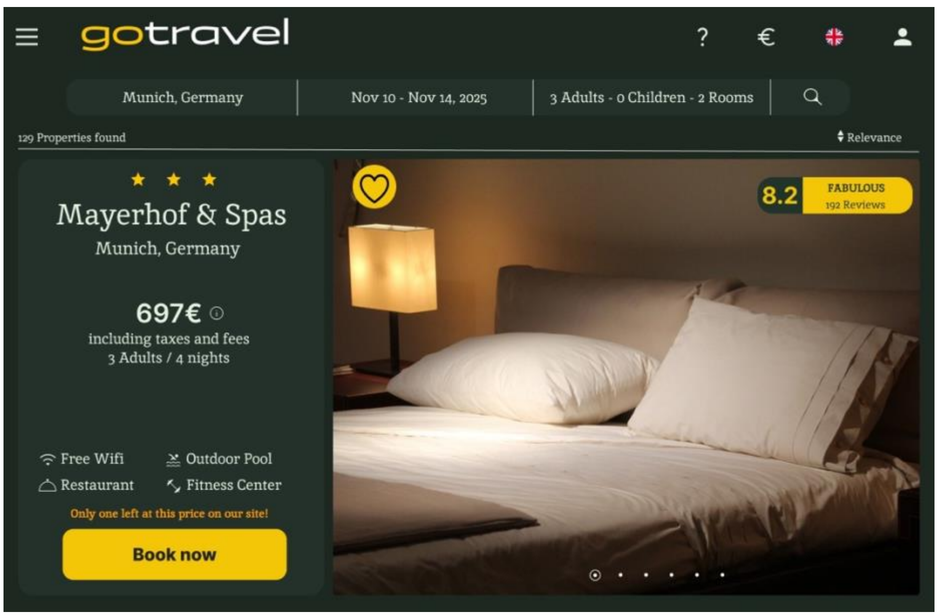
Offer 10 B



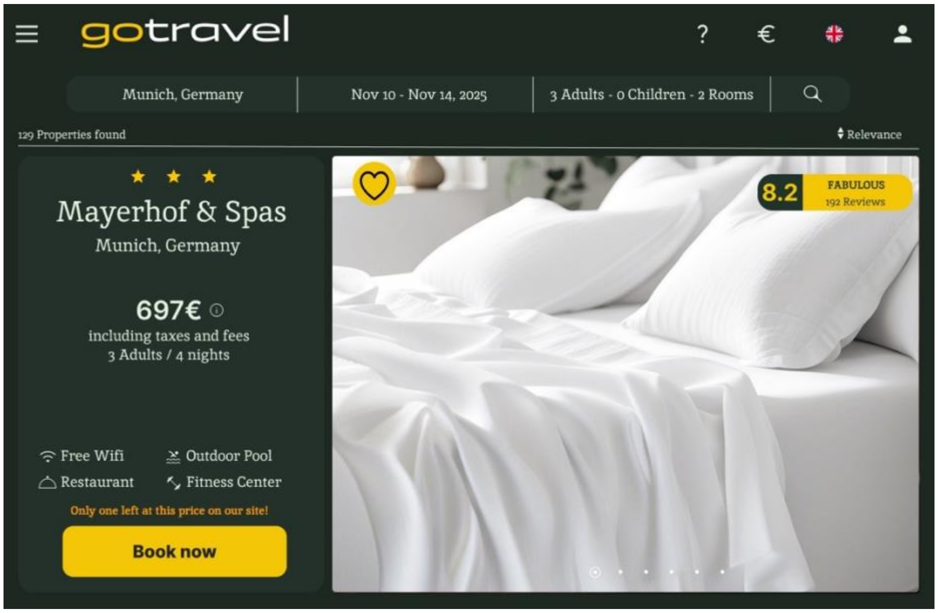
Offer 11 A



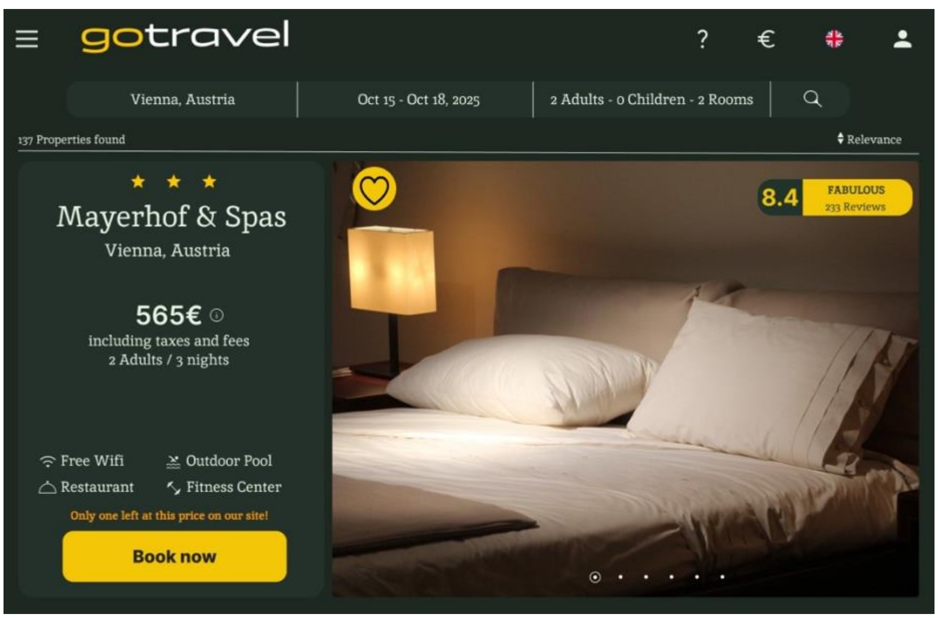
Offer 11 B



Offer 12 A



Offer 12 B



Appendix C

Informed Consent Form

Informed Consent Fom

Informed Consent Form

- Before proceeding, please read the following information carefully -

You are about to take part in the research study *" Working Memory and (Web)design: Task-Relevance & Memory of Hospitality Websites"*. This investigation is done by Konstantin Kupstor under the supervision of Dr. Rob van der Lubbe. It concludes the Bachelor's programme of Psychology at the faculty of Behavioural, Management, and Social Studies at the University of Twente.

Aim

The study aims to investigate the influence of task-relevance of a change on the detection of such change. The experiment uses a change blindness methodology, taking 45-90 minutes to complete. The study consists of 192 trails separated into four blocks of 48 trails. Between each block, a 1-minute pause is implemented.

Potential Risks

There is no physical, legal or financial risk associated with participation in this study. The study received approval from the Ethics Committee / domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences. Participation may include a compensation in SONA points, if the participant accesses the study through SONA. There is no alternative compensation.

Confidentiality

All data provided by the participant will be safeguarded with the aim of privacy protection. Therefore, no personal or confidential data will be disclosed if this would allow the participant to be identified. The collected data will be anonymised. Pseudonyms may be used in publication. Secure storage of all research data will be done using encrypted devices. The data will be stored for 3 years, following data deletion or anonymisation. Data of this research can be made available in anonymised form to external parties for control of scientific integrity.

Participation and Withdrawal

Participation is a voluntary choice.The participant has the right to withdraw from the study at any time or deny the use of their data, without requiring an explanation. There are no negative consequences following withdrawal or the refusal to provide data.

For any questions, uncertainties or to express the wish to withdraw from the study, please contact:
Konstantin Kupstor - k.kupstor@student.utwente.nl.

For further information on participants rights or other concerns regarding this study, please inquire with the Ethics Committee / domain Humanities & Social Sciences for the faculty of Behavioural, Management, Social Sciences at the University of Twente via ethicscommittee-hss@utwente.nl (Request 240145). In case of concerns regarding the confidentiality of your personal information, please consult the Data Protection Officer at the University of Twente via dpo@utwente.nl.

Informed Consent

I have read and understood the study information dated [28/04/2024], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.

- ○ Yes
- ○ No

I am more than 18 years old.

- ○ Yes
- ○ No

I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.

- Yes
- No

I have expressed my questions about the experiment, which have been answered to my satisfaction.

- Yes
- No

I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.

- Yes
- No

I agree that my information can be quoted in research outputs

- Yes
- No

I understand that all data I provide during participation in this study may be analyzed for research on visual working memory on hotel websites.

- Yes
- No

I comprehend that personal information potentially identifying me, such as age and nationality, will not be shared to parties outside the research team.

- ○ Yes
- ○ No

IF "NO"

Thank you for your interest in the study! Unfortunately, it not possible to continue without providing consent as outlined above. In case of an error, please contact the researcher under: k.kupstor@student.utwente.nl

- ○ I have read and understand this information.

Demographics

Participant number (as provided by the researcher)

[ ]

Age

[ ]

Nationality (Please indicate the country)

- ○ Netherlands
- ○ Germany
- ○ Other: [ ]

Gender

- Male
- Female
- Non-binary / third gender
- Prefer not to say

Hotel-site Visiting Frequency

On average how often do you search for hotel offers online a month?

- Never
- 1-5 times
- 6-10 times
- More than 11 times

Continue Participation

Thank you for participating! Please follow the instructions of the researcher.
If there are any issues please tell the researcher. In the following, you will conduct the preliminary tests for colour blindness and vision acuity.

Finally, please conduct the following pre-tests:

The researcher should assist you.

- ☐ https://www.color-blind-test.com/ishihara-color-blind-test-more
- ☐ LooC (Bach) application

Appendix E
R Studio Code

```
#Final R Script
library(tidyverse)
install.packages("dplyr")
library(dplyr)
conflicts()
library(tibble)
library(psycho)
library(rstatix)
library(plotrix)
library(Rmisc)
library(readr)
install.packages("Hmisc")
library
install.packages("lme4")
library(lme4)
install.packages("readxl")
library(readxl)
install.packages("ggplot2")
library(ggplot2)
install.packages("scales")
library(scales)


# All particpants with complete data

coall_participants = list()
for (i in 19:39) {
  file_name = paste0("Participant_", i, ".csv")
  coall_participants[[i]] = read.csv(file_name, header = TRUE)
}
# Bind list
allp_data = dplyr::bind_rows(coall_participants)


#Rename Answers for Q1 & Q2

allp_data <- allp_data %>%
  mutate(
    Answer_1 = ifelse(Answer_1 == "Yes", 1, 0),
    Answer_2 = ifelse(Answer_2 == "Yes", 1, 0))
```

```
# Create Column Change based on column Change type ()
allp_data$Change = ifelse(allp_data$Change_Type %in% c(1, 2), 1, 0)

# Create Column Change Condition
allp_data = allp_data %>%mutate(ChangeCondition = case_when(Change_Type == 2 ~ "Task-
Relevant", Change_Type == 1 ~ "Task-Irrelevant",Change_Type == 0 ~ NA))
str(allp_data)

allp_data$Sequence <- as.numeric(sub("Sequence ", "", allp_data$Sequence))


#Create Match varibale
allp_data$Offer.Match <- ifelse(allp_data$Offer %in% c(1, 3, 5, 7, 9, 11, 14, 16, 18, 20, 22, 24),
1, 0)

# Create Layout variable
allp_data$Layout_1 <- ifelse(allp_data$Offer %in% c(1, 2, 3, 4, 7, 8, 13, 14, 15, 16, 19,
20),"Right-Aligned", "Left-Aligned")




########## FUNCTION FOR LABELLING TRIALS BY OCCURENCE.
# If first half: "First" if second half: "Last"

# Create empty column to fill
allp_data$Block = NA

AddBlock <- function(allp_data) {
  TOTALIR <- 0
  TOTALRE <- 0
  TOTALcontrol <- 0

  for (i in 1:nrow(allp_data)) {
    if (allp_data$Change_Type[i] == 1) {
      if (TOTALIR < 24) { allp_data$Block[i] <- "First"
      TOTALIR <- TOTALIR + 1}
      else { allp_data$Block[i] <- "Last"}

    } else if (allp_data$Change_Type[i] == 2) {
      if (TOTALRE < 24) {
        allp_data$Block[i] <- "First"
        TOTALRE <- TOTALRE + 1
      } else {
        allp_data$Block[i] <- "Last"
      }
```

```
    } else {
      allp_data$Block[i] <- NA
    }
    if (allp_data$Change_Type[i] == 0) {
      if (TOTALcontrol < 48) {
        allp_data$Block[i] <- "First"
        TOTALcontrol <- TOTALcontrol + 1
      } else {
        allp_data$Block[i] <- "Last"
      }}
  }

  return(allp_data)
}

### OPERATE FUNCTION AND ADD LABEL IN DATAFRAME
allp_data <- allp_data %>%
  dplyr::group_by(Participant) %>%
  dplyr::group_modify(~ AddBlock(.x)) %>%
  ungroup()



#    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
*    *    *

#                                    P R E P A R E  D A T A
-----

#    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
*    *    *


########################################## Prepare datasets for calculating d' and ß
###
### For d' and ß overall per participant
###
# Calculating overall by pa hits, misses, false alarms and correct rejections per prticipant

Q2_data = allp_data  %>%
  dplyr::group_by(Participant) %>%
  dplyr::summarise(
    H = sum( Change == 1 & Answer_2 == 1),
    M = sum(Change == 1 & Answer_2 == 0),
    FA = sum(Change == 0 & Answer_2 == 1),
    CR =sum(Change == 0 & Answer_2 == 0))
```

```
write.csv(Q2_data, "Q2_data.csv", row.names = FALSE)


###
### For d' and ß per participant per change Condition
###



TR_TI_FA = allp_data %>%
  dplyr::group_by(Participant) %>%
  dplyr::summarise(
    FA = sum(Change == 0 & Answer_2 == 1))

## Correct rejection
TR_TI_CR = allp_data %>%
  dplyr::group_by(Participant) %>%
  dplyr::summarise(
    CR = sum(Change == 0 & Answer_2== 0))


TR_TI_data = allp_data %>% left_join( TR_TI_FA %>%
                                dplyr::select(Participant, FA), by = c("Participant"))

TR_TI_data = TR_TI_data %>% left_join(TR_TI_CR %>%
                                dplyr::select(Participant, CR), by = c("Participant"))


ex_TR_TI_data <- TR_TI_data %>%
  group_by(Participant, ChangeCondition) %>%
  reframe(
    hits = sum(Change == 1 & Answer_2 == 1),
    misses = sum(Change == 1 & Answer_2 == 0),
    FA = FA,
    CR = CR
  ) %>% distinct() %>% filter(!is.na(ChangeCondition))

write.csv(P_q2data, "TR_TI_data.csv", row.names = FALSE)



###
### For d' and ß per participant per change Condition per Layout
###
```

```
# False alarm
TR_L_FA = allp_data %>%
  dplyr::group_by(Participant, Layout_1) %>%
  dplyr::summarise(
    FA = sum(Change == 0 & Answer_2 == 1))

## Correct rejection
TR_L_CR = allp_data %>%
  dplyr::group_by(Participant, Layout_1) %>%
  dplyr::summarise(
    CR = sum(Change == 0 & Answer_2== 0))


TR_L_data = allp_data %>% left_join( TR_L_FA %>%
                                       dplyr::select(Participant,Layout_1, FA), by = c("Participant",
"Layout_1"))

TR_L_data = TR_L_data %>% left_join(TR_L_CR %>%
                                      dplyr::select(Participant,Layout_1, CR), by =
c("Participant","Layout_1"))


ex_TR_L_data <- TR_L_data %>%
  group_by(Participant,Layout_1, ChangeCondition) %>%
  reframe(
    hits = sum(Change == 1 & Answer_2 == 1),
    misses = sum(Change == 1 & Answer_2 == 0),
    FA = FA,
    CR = CR
  ) %>% distinct() %>% filter(!is.na(ChangeCondition))

write.csv( ex_TR_L_data , "TR_L_data.csv", row.names = FALSE)







###
###  For d' and ß per participant per change Condition per Block
###

TR_LE_FA = allp_data %>%
  dplyr::group_by(Participant, Block) %>%
  dplyr::summarise(
```

```
    FA = sum(Change == 0 & Answer_2 == 1))

## Correct rejection
TR_LE_CR = allp_data %>%
  dplyr::group_by(Participant, Block) %>%
  dplyr::summarise(
    CR = sum(Change == 0 & Answer_2== 0))


TR_LE_data = allp_data %>% left_join( TR_LE_FA %>%
                                        dplyr::select(Participant, Block, FA),
                                      by = c("Participant", "Block"))

TR_LE_data = TR_LE_data %>% left_join(TR_LE_CR %>%
                                        dplyr::select(Participant, Block, CR),
                                      by = c("Participant", "Block"))


ex_TR_LE_data <- TR_LE_data %>%
  group_by(Participant,Block, ChangeCondition) %>%
  reframe(
    hits = sum(Change == 1 & Answer_2 == 1),
    misses = sum(Change == 1 & Answer_2 == 0),
    FA = FA,
    CR = CR
  ) %>% distinct() %>% filter(!is.na(ChangeCondition))

write.csv( ex_TR_LE_data , "TR_B_data.csv", row.names = FALSE)






###
###  For d' and ß per participant per change Condition per Offer Match
###

# False alarm
TR_OM_FA = allp_data %>%
  dplyr::group_by(Participant, Offer.Match) %>%
  dplyr::summarise(
    FA = sum(Change == 0 & Answer_2 == 1))

## Correct rejection
```

```
TR_OM_CR = allp_data %>%
  dplyr::group_by(Participant, Offer.Match) %>%
  dplyr::summarise(
    CR = sum(Change == 0 & Answer_2== 0))


TR_OM_data = allp_data %>% left_join( TR_OM_FA %>%
                                  dplyr::select(Participant, Offer.Match,FA), by =
                                  c("Participant", "Offer.Match"))

TR_OM_data = TR_OM_data %>% left_join(TR_OM_CR %>%
                                  dplyr::select(Participant, Offer.Match, CR), by = c("Participant",
"Offer.Match"))



ex_TR_OM_data <- TR_OM_data %>%
  group_by(Participant, Offer.Match, ChangeCondition) %>%
  reframe(
    hits = sum(Change == 1 & Answer_2 == 1),
    misses = sum(Change == 1 & Answer_2 == 0),
    FA = FA,
    CR = CR
  ) %>% distinct() %>% filter(!is.na(ChangeCondition))

write.csv( ex_TR_OM_data, "TR_OM_data.csv", row.names = FALSE)



# * * * * * * * * * * * * * * * * * * * * * *
* * *

#                     D A T A   A N A L Y S I S
-----

# * * * * * * * * * * * * * * * * * * * * * *
* * *


Exp_xlsx_TR_L_data <- "/Users/k/Desktop/BHF9_PY/konstaProject/Participant
data/TR_L_data.xlsx"
Exp_xlsx_TR_OM_data <- "/Users/k/Desktop/BHF9_PY/konstaProject/Participant
data/TR_OM_data.xlsx"
Exp_xlsx_TR_B_data <- "/Users/k/Desktop/BHF9_PY/konstaProject/Participant
data/TR_B_data.xlsx"
```

```
DA_TR_L_data <- readxl::read_excel(Exp_xlsx_TR_L_data)
DA_TR_OM_data <- readxl::read_excel(Exp_xlsx_TR_OM_data)
DA_TR_B_data <- readxl::read_excel(Exp_xlsx_TR_B_data)


DA_TR_L_data = subset(DA_TR_L_data, !(Participant %in% c(27, 31)))
DA_TR_OM_data = subset(DA_TR_OM_data,!(Participant %in% c(27,31)))
DA_TR_B_data = subset(DA_TR_B_data,!(Participant %in% c(27 , 31)))



### Change and Layout


 psych::describe(DA_TR_L_data$d_prime)
 psych::describe(DA_TR_L_data$lnbeta)


 levene_test(DA_TR_L_data, d_prime ~ ChangeCondition)
 levene_test(DA_TR_L_dataa, d_prime ~ Layout_1)
 levene_test(DA_TR_L_data, lnbeta ~ ChangeCondition)
 levene_test(DA_TR_L_dataa, lnbeta ~ Layout_1)



DA_TR_L_data %>%
  dplyr::group_by(Layout_1, ChangeCondition,) %>%
  rstatix::shapiro_test(d_prime)

DA_TR_L_data %>%
  dplyr::group_by(Layout_1, ChangeCondition) %>%
  rstatix::shapiro_test(lnbeta)

## Perform ANOVA d'



aov_TRL_d <- DA_TR_L_data %>%
  rstatix::anova_test(
    dv = d_prime,
    wid = Participant,
    within = c(Layout_1, ChangeCondition),
    effect.size = "pes"
  )
```

```
rstatix::get_anova_table(aov_TRL_d)
Bonf_TRL_d <- DA_TR_L_data %>%
  group_by(Layout_1) %>%
  pairwise_t_test(
    d_prime ~ ChangeCondition, paired = TRUE,
    p.adjust.method = "bonferroni"
  )
Bonf_TRL_d



## Perform ANOVA ln(ß)


aov_TRL_ß <- DA_TR_L_data %>%
  rstatix::anova_test(
    dv = lnbeta,
    wid = Participant,
    within = c(Layout_1, ChangeCondition,),
    effect.size = "pes"
  )
rstatix::get_anova_table(aov_TRL_ß)




vis_TRL_d = summarySE(DA_TR_L_data, measurevar="d_prime",
                      groupvars=c("ChangeCondition","Layout_1"))



vis_TRL_ß = summarySE(DA_TR_L_data, measurevar="lnbeta",
                      groupvars=c("ChangeCondition","Layout_1"))


ggplot(vis_TRL_d, aes(x=Layout_1, y=d_prime, fill=ChangeCondition)) +
  geom_bar(position=position_dodge(), stat="identity", colour="black", linewidth=.3) +
  geom_errorbar(aes(ymin=d_prime-se, ymax=d_prime+se),width=.2,
position=position_dodge(.9)) +
  scale_y_continuous(limits = c(0, 3), breaks = seq(0, 3.5, by = 0.5)) +
scale_fill_manual(values=c("#6f90f5", "#f5d46f"), name="Change") +
  labs(y="d", x="Layout") + theme_classic() + theme(text = element_text(family = "Times New
Roman"))

ggplot(vis_TRL_d, aes(x=Layout_1, y=lnbeta, fill=ChangeCondition)) +
  geom_bar(position=position_dodge(), stat="identity", colour="black", linewidth=.3) +
```

```
  geom_errorbar(aes(ymin=d_prime-se, ymax=d_prime+se),width=.2,
position=position_dodge(.9)) +
  scale_y_continuous(limits = c(0, 3), breaks = seq(0, 3.5, by = 0.5)) +
scale_fill_manual(values=c(""#6c44d1","#A9D144"),name="Change") +
  labs(y="ln(ß)", x="Layout") + theme_classic() + theme(text = element_text(family = "Times
New Roman"))



### Change and Offer Match


psych::describe(DA_TR_OM_data$d_prime)
psych::describe(DA_TR_OM_data$lnbeta)


levene_test(DA_TR_OM_data, d_prime ~ ChangeCondition)
levene_test(DA_TR_OM_data, d_prime ~ Offer.Fit)
levene_test(DA_TR_OM_data, lnbeta ~ ChangeCondition)
levene_test(DA_TR_OM_data, lnbeta ~ Offer.Fit)



DA_TR_OM_data %>%
  dplyr::group_by(Offer.Fit, ChangeCondition) %>%
  rstatix::shapiro_test(d_prime)

DA_TR_OM_data %>%
  dplyr::group_by(Task_Relevance, ChangeCondition) %>%
  rstatix::shapiro_test(lnbeta)

levene_test(DA_TR_OM_data, d_prime ~ ChangeCondition)
levene_test(DA_TR_OM_data, d_prime ~ Offer.Fit)
levene_test(DA_TR_OM_data, lnbeta ~ ChangeCondition)
levene_test(DA_TR_OM_data, lnbeta ~ Offer.Fit)



## Perform ANOVA d'



aov_OM_d <- DA_TR_OM_data %>%
  rstatix::anova_test(
    dv = d_prime,
    wid = Participant,
```

```
    within = c(Offer.Fit, ChangeCondition),
    effect.size = "pes"
  )
rstatix::get_anova_table(aov_OM_d)



## Perform ANOVA ln(ß)


aov_OM_ß <- DA_TR_OM_data %>%
  rstatix::anova_test(
    dv = lnbeta,
    wid = Participant,
    within = c(Offer.Fit, ChangeCondition),
    effect.size = "pes"
  )
rstatix::get_anova_table(aov_OM_ß )



Bonf_TROM_d <- DA_TR_OM_data  %>%
  group_by(Offer.Fit) %>%
  pairwise_t_test(
    d_prime ~ ChangeCondition, paired = TRUE,
    p.adjust.method = "bonferroni"
  )
Bonf_TROM_d

Bonf_TROM_dII <- DA_TR_OM_data  %>%
  group_by(ChangeCondition) %>%
  pairwise_t_test(
    d_prime ~ Offer.Fit, paired = TRUE,
    p.adjust.method = "bonferroni"
  )
Bonf_TROM_dII


vis_TR_OM_d = summarySE(DA_TR_OM_data, measurevar="d_prime",
                      groupvars=c("ChangeCondition","Offer.Fit"))



ggplot(vis_TR_OM_d, aes(x=Offer.Fit, y=d_prime, fill=ChangeCondition)) +
  geom_bar(position=position_dodge(), stat="identity", colour="black", linewidth=.3) +
```

```
  geom_errorbar(aes(ymin=d_prime-se, ymax=d_prime+se),width=.2,
position=position_dodge(.9)) +
  scale_y_continuous(limits = c(0, 3), breaks = seq(0, 3.5, by = 0.5)) +
scale_fill_manual(values=c("#6f90f5", "#f5d46f"), name="Change") +
  labs(y="d'", x="Offer Match") + theme_classic() + theme(text = element_text(family = "Times
New Roman"))


ggplot(DA_TR_OM_data, aes(x=Offer.Fit, y=lnbeta, fill=ChangeCondition))  +
  geom_boxplot(outlier.size = 0) +scale_y_continuous(breaks = seq(-4, 6, by = 1.0))  +
scale_fill_manual(values=c( "#6c44d1", "#A9D144"), name="Change") +
  labs(y="ln(ß)", x="Offer Match") + theme_classic() + theme(text = element_text(family =
"Times New Roman")) + geom_hline(yintercept = 0, linetype ="dashed", colour = "black")



### Change and Block (Learn Effect)



psych::describe(DA_TR_B_data$d_prime)
psych::describe(DA_TR_B_data$lnbeta)


levene_test(DA_TR_B_data, d_prime ~ ChangeCondition)
levene_test(DA_TR_B_data, d_prime ~ Block)
levene_test(DA_TR_B_data, lnbeta ~ ChangeCondition)
levene_test(DA_TR_B_data, lnbeta ~ Block)



DA_TR_B_data %>%
  dplyr::group_by(Block, ChangeCondition) %>%
  rstatix::shapiro_test(d_prime)

DA_TR_B_data %>%
  dplyr::group_by(Block, ChangeCondition) %>%
  rstatix::shapiro_test(lnbeta)



## Perform ANOVA d'
```

```
aov_B_d <- DA_TR_B_data %>%
  rstatix::anova_test(
    dv = d_prime,
    wid = Participant,
    within = c(Block,ChangeCondition),
    effect.size = "pes"
  )
rstatix::get_anova_table(aov_B_d)



## Perform ANOVA ln(ß)


## Reassurance residual normality
aov_B_ß <- DA_TR_B_data %>% afex::aov_ez(
  id = "Participant",
  dv = "d_prime",
  within = c("Block", "ChangeCondition")
)

get_anova_table(aov_B_ß)

residuals <- residuals(aov_B_ß)
shapiro.test(residuals)



# vis_TR_B_d = summarySE(DA_TR_B_data, measurevar="d_prime",
#                      groupvars=c("ChangeCondition","Block"))

# vis_TR_B_ß = summarySE(DA_TR_B_data, measurevar="lnbeta",
#                      groupvars=c("ChangeCondition","Block"))


ggplot(vis_TR_B_d, aes(x=Block, y=d_prime, fill=ChangeCondition)) +
  geom_bar(position=position_dodge(), stat="identity", colour="black", linewidth=.3) +
  geom_errorbar(aes(ymin=d_prime-se, ymax=d_prime+se),width=.2,
position=position_dodge(.9)) +
  scale_y_continuous(limits = c(0, 3), breaks = seq(0, 3.5, by = 0.5)) +
scale_fill_manual(values=c("#6f90f5", "#f5d46f"), name="ChangeCondition") +
  labs(y="d'", x="Block") + theme_classic() + theme(text = element_text(family = "Times New
Roman"))

ggplot(vis_TR_B_ß, aes(x=Block, y=lnbeta, fill=ChangeCondition)) +
  geom_bar(position=position_dodge(), stat="identity", colour="black", linewidth=.3) +
```

```
  geom_errorbar(aes(ymin=d_prime-se, ymax=d_prime+se),width=.2,
position=position_dodge(.9)) +
  scale_y_continuous(limits = c(0, 3), breaks = seq(0, 3.5, by = 0.5)) +
scale_fill_manual(values=c("#6f90f5", "#f5d46f"), name="ChangeCondition") +
  labs(y="ln(ß)", x="Block") + theme_classic() + theme(text = element_text(family = "Times
New Roman"))
```