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Effect of Expectation on Visual Attention: An Eye Tracking Study

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Abstrak. Penelitian sebelumnya umumnya memanipulasi ekspektasi menggunakan petunjuk perifer ganda (double peripheral cues), yang mungkin tidak secara akurat merepresentasikan situasi di dunia nyata. Selain itu, pendekatan ini memungkinkan partisipan menggunakan strategi tertentu untuk mengantisipasi lokasi objek, sehingga berpotensi memengaruhi validitas hasil penelitian. Untuk mengatasi kesenjangan tersebut, penelitian ini menggunakan permainan hidden object sebagai bentuk manipulasi ekspektasi yang lebih naturalistik. Penelitian ini bertujuan untuk menginvestigasi pengaruh ekspektasi terhadap perhatian visual dengan menggunakan permainan hidden object sebagai stimulus dan eye tracking sebagai alat ukur. Dengan menggunakan desain eksperimen, partisipan dibagi ke dalam dua kelompok: kondisi objek kongruen dan inkongruen. Penelitian ini melibatkan 8 partisipan. Perhatian visual diamati menggunakan Tobii Eye Tracking, dengan fokus pada jumlah fiksasi (fixation counts) sebagai indikator usaha pemrosesan kognitif. Hasil penelitian menunjukkan adanya perbedaan signifikan dalam jumlah fiksasi antara kedua kelompok, di mana kondisi kongruen menunjukkan jumlah fiksasi yang lebih sedikit dibandingkan kondisi inkongruen. Hal ini mengindikasikan bahwa objek kongruen diproses lebih efisien karena sesuai dengan ekspektasi partisipan, sedangkan objek inkongruen memerlukan usaha kognitif yang lebih besar dalam proses pencarian visual. Temuan ini mendukung peran mekanisme top-down dalam mengarahkan perhatian visual serta menyoroti pengaruh ekspektasi terhadap pemrosesan perseptual.

Kata kunci: *Ekspektasi, Atensi Visual, Eye Tracking*

Abstract. *Previous studies have primarily manipulated expectations using double peripheral cues, which may not accurately represent real-world scenarios. Additionally, this approach allows participants to use specific strategies to anticipate object locations, potentially affecting the validity of the results. To address these gaps, the present study employs hidden object games as a more naturalistic manipulation of expectations. This study investigates the effect of expectation on visual attention using hidden object games as stimuli and eye tracking as a measurement tool. Using an experimental design, participants were divided into two groups: congruent and incongruent object conditions. The study involved 8 participants. Visual attention was observed using Tobii Eye Tracking, focusing on fixation counts as an indicator of cognitive processing effort. Results showed a significant difference in fixation counts between the two groups, with fewer fixations observed in the congruent condition compared to the incongruent condition. This suggests that congruent objects are processed more efficiently due to aligned expectations, whereas incongruent objects require more cognitive effort for visual search. These findings support the role of top-down mechanisms in guiding visual attention and highlight the influence of expectations on perceptual processing.*

Keywords: *Expectation, visual attention, eye tracking*

Human visual information processing is a highly dynamic process. According to the Bayesian Predictive Processing Theory, the human brain can automatically perform programmed actions (Bottemanne et al., 2021). For example, if an individual is presented with an image of a human face and asked to locate the mouth, the brain will automatically program the eye muscles to move to the mouth area within a fraction of a second. However, if the mouth’s position is intentionally altered, the brain will undergo a longer process to locate the mouth in the presented image.

Visual information processing is also closely related to visual attention. Visual attention can be categorized by its function into top-down attention and bottom-up attention (Katsuki & Constantinidis, 2013; Connor et al., 2004). Bottom-up attention is related to stimuli that are salient among many other stimuli; it occurs automatically, rapidly, and may happen without conscious awareness, as it is driven by external factors. Meanwhile, top-down attention involves consciously controlled focus based on goals or needs driven by internal factors (Connor et al., 2004). Although there is often debate about which of these two functions has a greater impact on attention, both play significant roles (Chen & Zelinsky, 2006).

Top-down attention is closely linked to prior knowledge. Research has shown that with prior knowledge, individuals can perceive objects more quickly (Kaiser, 2019). In a review of various studies, it was explained that people tend to perceive objects faster when the object's position is consistent with its usual location. For example, a lamp is typically found at the top of a room, and a carpet is on the floor. This is because humans are continuously exposed to objects and their typical locations, enhancing the neural representation of these objects in the visual cortex. Objects that are consistent with their usual locations are called congruent, while those that are inconsistent are termed incongruent. However, this finding contradicts the study by Spaak et al. (2022), which found no difference in object recognition speed between congruent and incongruent objects.

Prior knowledge also enables individuals to create expectations when perceiving objects (Gipson, Gorman, & Hessler, 2016). Expectations are defined as top-down mechanisms induced by spatial probabilities. Expectations influence visual perception by predicting the likelihood of a target or distractor appearing in a specific location. These expectations are determined by the probability of a stimulus occurring at a particular location and are regulated separately from attention using double peripheral cues, affecting the stimulus location while remaining independent of attention (Zhou, Chen, & Fu, 2022). In this study, expectations were manipulated using double peripheral cues that divided the visual space into left-right and top-bottom areas. Expectations were manipulated orthogonally from attention, meaning they were placed on different dimensions (e.g., expectations on the top-bottom area, while attention was on the left-right area). However, a limitation of this manipulation is that participants might still use specific strategies to anticipate the location of the target or distractor, potentially affecting the results. Additionally, this manipulation does not accurately represent real-world expectations.

To address this gap, the present study employs hidden object games as a manipulation tool. Hidden object games are puzzle games where players must find predefined items listed in a scene (Feng et al., 2012). These games are known to stimulate attention (Fasulo, Shukla, & Bennett, 2017) and have been widely used in research to enhance various cognitive functions (Triana, Ariyani, & La Sunra, 2023; Hong et al., 2022). Recent studies have also developed computerized visual search paradigms to investigate attentional mechanisms. For example, Ahmad et al. (2025) developed the "Find the Key" paradigm to examine how distractor object configurations influence visual search time and visual attention performance. Experimental studies involving visual-spatial processing have also shown that cognitive performance can be influenced through interactive visual tasks and object-based manipulations (Saputra et al., 2026). Using hidden object games, the present study aims to stimulate human expectations by combining congruent and incongruent objects. Hidden object games are considered more natural and closer to real-world contexts for manipulating expectations. The influence of these expectations can be measured using eye tracking, specifically by counting the number of eye fixations (Hollingworth & Bahle, 2019). Previous experimental studies have also utilized computerized visual stimuli and PsychoPy-based paradigms to investigate perceptual and affective processing in early adulthood populations (Ahmad et al., 2024).

This study aims to examine the effect of expectations on visual attention using hidden object games as stimuli and eye tracking as a measurement tool. Expectations are manipulated through a combination of congruent and incongruent objects to observe differences in the number of eye fixations on these objects. The hypothesis of this study is that there will be a significant difference in the number of fixations between congruent and incongruent object groups. The study's findings are expected to deepen the understanding of the role of expectations in visual attention and contribute to developing more natural and contextually relevant methods for manipulating expectations. Furthermore, the results are expected to serve as a foundation for developing educational or cognitive training applications that utilize hidden object games to enhance attention and visual information processing functions.

METHODS

Design

This study uses an experimental approach. Experimental research requires the presence of both an independent and a dependent variable, where the independent variable is the manipulation, and the dependent variable is the response to that manipulation (Kantowitz, Roediger, & Elmes, 2020). This study employs a quasi experimental posttest-only experimental group design with two groups.

Subject

The participants are young adults aged 18 to 25 years, consisting of both males and females, with no visual impairments. The sampling technique used is convenience sampling, which involves selecting participants who are easily accessible (Edgar & Manz, 2017). A total of 8 participants are involved in this study, with each group consisting of 4 individuals.

Procedure

The experiment lasted approximately 40 minutes, including room categorization and object categorization tasks. Before participating in the study, all participants were provided with an informed consent form explaining the purpose of the study, the experimental procedures, confidentiality of the data, voluntary participation, and their right to withdraw from the study at any time without consequences. Participants who agreed to participate then proceeded with the experiment. Participants were seated in front of a computer screen connected to a Tobii Eye Tracker. Two tasks were conducted: a preliminary task and the main task.

Preliminary Task

Before the main data collection, we commissioned an illustrator to draw the objects used as potential stimuli. Then, a preliminary study was conducted. In this preliminary stage, participants completed object recognition and object categorization tasks. The purpose of this stage was to select objects that could be used as the main stimuli, focusing on objects that are consistently recognizable and strongly associated with specific rooms to serve as stimuli for prior knowledge and expectations. In this stage, 92 objects were tested. Participants were asked to name each object and categorize which room they believed the object typically belongs to. This process was conducted using Google Forms, with 50 individuals participating in the preliminary study. From the 92 objects, 24 were consistently recognized by the same name and strongly associated with specific rooms. These 24 objects were grouped into four rooms: bedroom, kitchen, bathroom, and garage/storage. These rooms were designed to resemble culturally typical Indonesian homes.

Main Visual Search Task

In the main task, a hidden object game was created using the PsychoPy software to deliver the stimuli. The game was divided into two versions, one for each group. In the first game (congruent object group), target objects were placed in rooms that matched the objects' typical locations (e.g., a pillow in the bedroom). In the second game (incongruent object group), objects were placed randomly (e.g., pliers in the bathroom), preventing participants from predicting the objects' locations. The game featured four rooms of equal size: a bathroom, a bedroom, a kitchen, and a garage/storage room. These rooms were chosen to reflect common cultural settings in Indonesian homes, aligning with participants' expectations. During the first task, participants were asked to label each room using the provided answer choices. In the second task, participants searched for all listed objects in the four rooms. A total of 24 objects were presented in random order. No time limit was set for completing the game, but the session ended once all items were found. During the task, participants' eye movements were recorded using Tobii Eye Tracking.

Data Measurement and Data Analysis Method

To examine differences in visual attention between two groups, we analyzed the number of fixations or eye movements on each object. Fixation counts are suitable for measuring visual attention (Sharafi, Soh, & Gueheneuc, 2015). An independent sample t-test was used to compare fixation counts between the congruent object group and the incongruent object group. All statistical analyses were performed using the jamovi statistical software.

RESULTS

Assumption Tests

We conducted homogeneity and normality tests as prerequisite analyses before performing the hypothesis test. The results of the homogeneity test are as follows.

Table 1. Homogeneity test

	F	*df*	*df2*	*p*
Levene's	1.46	1	8	0.261
Variance ratio	1.77	4	4	0.594

The homogeneity of variance test using Levene's test showed that the assumption of homogeneity of variance was met, $F(1,8) = 1.46$, $p > 0.05$.

Table 2. Normality test

	Statistic	*p*
Shapiro-Wilk	0.921	0.366
Kolmogorov-Smirnov	0.171	0.886
Anderson-Darling	0.332	0.439

The normality test using the Shapiro-Wilk test showed that the data in both groups were normally distributed, $W = 0.921$, $p = 0.366$

Descriptive test

Table 3. Descriptive test

Group	*n*	Mean	Median	*SD*	*SE*
Congruent	5	251	230	78.9	39.4
Incongruent	5	409	408	33.8	16.9

Based on the descriptive results, the Congruent group (n=5) had an average response time of 251 ms (SD=78.9,SE=39.4) with a median of 230 ms. Meanwhile, the Incongruent group (n = 5) showed a higher average response time of 409 ms (SD = 33.8, SE = 16.9) with a median of 408 ms.

Hypothesis Testing

Table 4. Independent Samples T-Test

	Statistic	*df*	*p*	Mean Difference	Effect Size
Student's t	-3.69	6.00	0.005	-158	-2.61

The results of the independent samples t-test showed a significant difference between the congruent object group (M = 251, SD = 78.9) and the incongruent object group (M = 409, SD = 33.8), $t(8) = -3.69$, $p = 0.005$). Therefore, there is a statistically significant difference between the congruent object group and the incongruent object group, with the congruent object group having a much lower mean than the incongruent object group. Below is the sample of the results from the congruent group and the incongruent group.

Figure 1. Left: Congruent Objects, Right: Incongruent Objects

DISCUSSION

The results of this study are consistent with the proposed hypothesis, indicating a significant difference in the number of eye movement fixations between congruent and incongruent objects. These findings align with Kaiser's (2019) study, which showed that objects positioned in expected locations (congruent) are perceived more quickly due to stronger neural representations in the visual cortex. In this study, congruent objects tended to attract less attention because matching expectations helped individuals process information more efficiently, thus reducing the need for multiple fixations. Conversely, incongruent objects that did not match expectations required more fixations as the search and processing of visual information demanded greater cognitive effort.

Moreover, these findings support the role of expectation as a top-down mechanism that influences visual perception by predicting the likelihood of objects appearing in specific locations (Gipson, Gorman, & Hessler, 2016). By using a hidden object game, expectations were manipulated more naturally, contributing to the development of more realistic expectation manipulation methods relevant to real-world scenarios.

The study was divided into two experimental groups: congruent objects and incongruent objects. The fixation pattern was lower in the congruent object group compared to the incongruent object group. This pattern is influenced by the salience of stimuli within a scene, domain knowledge (including declarative, procedural, and conditional), interest, and task requirements (Polatsek, 2018). Congruent stimuli were processed more quickly than incongruent stimuli due to a balanced movement between psychological and spatial distances (Jang et al., 2010). As a result, congruent objects had faster reaction times because they were more relevant to existing schemas, facilitating easier identification (Nicholls et al., 2024).

The reaction speed and fixation patterns observed are likely related to the mechanism of prior knowledge. Prior knowledge contributes to bridging top-down processing. This top-down mechanism triggers attention shifts based on individual interests to focus on and search for specific features or locations (Gruner et al., 2023). Additionally, prior knowledge influences how individuals observe particular features, as features relevant to prior knowledge are more easily fixated upon compared to irrelevant features (Kim & Rehder, 2011).

However, this study has certain limitations. The use of a hidden object game was restricted to static visual contexts, which may not accurately represent the dynamics of object movement in real-world situations. This limitation could affect the generalizability of the findings to more complex and dynamic visual environments. Furthermore, this study did not consider individual variables such as gaming experience and visual-spatial abilities, which could influence fixation patterns and the speed of object perception. These limitations also serve as suggestions for future research.

CONCLUSION AND IMPLICATION

This study demonstrates that expectation significantly influences visual attention, as indicated by differences in the number of eye movement fixations on congruent and incongruent objects in a hidden object game. Congruent objects required fewer fixations compared to incongruent objects, suggesting that matching expectations can facilitate the processing of visual information. These findings support the Bayesian predictive processing theory and highlight the crucial role of expectation as a top-down mechanism that guides visual attention more efficiently.

The results of this study have important implications, such as paving the way for using hidden object games in cognitive training, particularly to enhance attention and visual perception functions in a natural and contextually relevant manner.

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