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Exploring the Impact of Visual Complexity on Flow Experience in Online Visual Art Platforms: An Eye-Tracking Study

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Abstract. The flow experience of online platform users is an important factor affecting user stickiness and improving the quality of the platform. Analyzing the influencing factors of flow experience on online platform is a key step to improve the flow experience in the user's use process. From the perspective of visual perception, this study analyzes the impact of visual factors on the flow experience. Starting with the complexity of the online platform interface, the eye tracking experiment was used to explore the impact of complexity and visual search efficiency on the flow experience. The experimental results show that the quantity complexity and functional layout complexity have different effects on the flow experience, and the visual search efficiency is positively correlated with the flow experience. In addition, the relationship between flow experience and quantity complexity was inverted U-shaped; It is positively correlated with the complexity of functional layout, but the impact is not significant.

Keywords. Eye-tracking, flow experience, online visual platform, visual complexity, visual perception.

1. Introduction

As the proliferation of online art platforms unfolds, the reach of visual art transcends traditional boundaries, fostering a more inclusive, global platform for artistic expression. This evolution presents a manifold of opportunities and challenges to the operators of online visual art platforms. Characterized by their distinctive user engagement mechanics and potent visual allure, online visual art platforms fundamentally differentiate themselves from other digital platforms.

Online visual art platforms provide not only access to art information but also rich user experiences, which is increasingly recognized as valuable. According to some researchers, when a person is fully engaged in a task and reaches a state of optimal

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pleasure, they experience a flow state [1].

In this study, we used flow experience as a measure of user immersion, which represents an excellent user experience [2]. Trevino and Webster [3] explained that when in a flow state, "individuals become absorbed in the activity they are engaged in; gradually lose self-awareness and experience a sense of control over the environment in which they are situated". Flow also has a positive impact on user intention to continue use. Deng et al. [4] pointed out that cognitive absorption (similar to flow experience) affects user satisfaction, which further determines their intention to continue using mobile internet services. Hausman and Siekpe [5] have shown that flow can affect online consumers' purchase and return intentions. Shi et al. [6] examined the effect of flow experience on information sharing intention in short video platforms. This study explores the influence of flow experience on users' visual behavior from the perspective of visual complexity.

Online visual art platforms have unique characteristics that may result in distinct user visual behaviors and flow experiences compared to other platforms. Therefore, this study aims to investigate the relationship between visual complexity and flow experiences in user platform usage, specifically focusing on the impact of visual complexity on flow experiences.

2. Research methodology

The purpose of this study is to analyze the subjective and objective effects of visual complexity on user search behavior and flow experience on online visual art platforms. To achieve this goal, an eye-tracking experiment was designed, where participants were shown pre-designed interface samples and their visual exploration behavior was recorded using eye-tracking equipment during the experiment. This study proposes five hypotheses.

H1: The higher the quantity complexity, the lower the user's information acquisition efficiency.

H2: The higher the functional layout complexity, the lower the user's information acquisition efficiency.

H3: There is an inverted U-shaped relationship between the quantity complexity and user's flow experience. Compared with low and high complexity, moderate complexity is more likely to induce user's flow experience.

H4: There is an inverted U-shaped relationship between the functional layout complexity and user's flow experience. Compared with low and high complexity, moderate complexity is more likely to induce user's flow experience.

H5: The higher the user's information acquisition efficiency, the easier it is for the user to experience flow.

2.1. Participants

28 undergraduate and graduate students (3 undergraduates, 8 first-year master's students, and 17 second-year master's students) participated in the empirical study. The participant group mainly consisted of students majoring in design or art, as well as recent graduates. To minimize the influence of past experience, we recruited participants with one to three

years of experience using online visual art platforms, in order to maintain similar levels of experience. All participants were in good physical condition, with normal or corrected-to-normal vision and no astigmatism. After the experiment, the participants received a gift as a reward for their participation.

2.2. Apparatus

The eye-tracking device used in this study was the SMI ETG in Carrying Case eye-tracking system produced by SMI, a company based in Germany. The system consists of a recording computer, a subject computer with a screen resolution of 2560 × 1440 pixels and a refresh rate of 240 Hz, and an SMI eye-tracker. The eye movement data of the participants during the experiment were automatically recorded by BeGaze 3.7.

Before the formal experiment, the subjects were first adjusted to a comfortable sitting position, with about 90 cm between the monitor and the chair. At the beginning of the experiment, a calibration procedure was performed to control the error of the eye position within 0.5°. The experiment was conducted in a soundproof, well-lit, and temperature-appropriate laboratory.

2.3. Materials

In this experiment, features were extracted from current mainstream online visual art platforms and six sets of research samples were designed based on these prototypes (low-medium-high quantity complexity, low-medium-high functional layout complexity). In order to minimize the influence of unrelated design elements, such as search boxes and navigation bars, these were integrated from a range of popular online visual art platforms and held constant throughout the experiment. Additionally, to ensure that the experimental conditions resembled actual usage as much as possible, two page samples were created for each complexity level to provide a sufficient sample size. The prototypes employed in the experiment are displayed in Figure 1.

The following three methods were used for complexity verification of the prototype samples:

1. The average JPEG file size of the samples was calculated, which is a reliable, effective, and objective measure of visual complexity [7,8].

2. The research group manually coded the complexity of each image based on six design complexity principles (quantity, irregularity, similarity, detail, asymmetry of arrangement, irregularity of arrangement) in two groups of samples, and measured the design complexity by averaging the six principles [8]. The average complexity scores for the quantity complexity group were 0.21, 0.49, and 0.87 ($\alpha = 0.76$). The average complexity scores for the functional layout complexity group were 0.23, 0.50, and 0.94 ($\alpha = 0.82$).

3. EyeQuant was used to evaluate the visual complexity of the samples. EyeQuant is a computer vision-based tool that can rapidly and automatically assess the visual complexity and attention allocation of web pages. It generates a comprehensive visual complexity score by analyzing the elements such as color, contrast, layout, images, and text of the web page. The test results showed that the purity scores for the quantity complexity group were 69%, 59%, and 40%, while the purity scores for the functional

layout complexity group were 83%, 56%, and 42%.

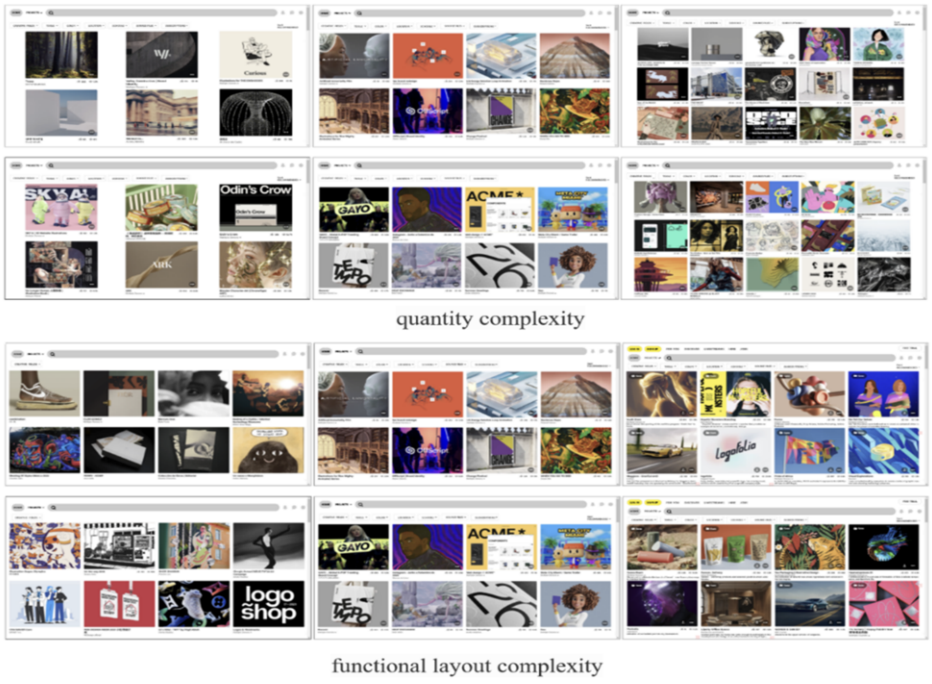

Figure 1. Prototypes of different levels

2.4. Experimental procedure

In this study, multiple sets of designs were selected to compare prototype pages with varying levels of complexity. This design approach enables the observation of the impact of different complexities on flow experience and visual behavior, facilitating a comprehensive analysis of their relationships. Prior to conducting the formal experiment, a pre-experiment was conducted to gain initial insights into the relationship between flow experience and visual behavior, as well as to familiarize participants with the experimental procedures. The pre-experiment involved a smaller sample size (n=8) and followed the same experimental process as the main experiment.

The main experimental procedure is as follows, encompassing a detailed explanation of the experiment to the participants, including its purpose, task requirements, and data collection procedures. The experimental process was recorded as shown in Figure 2.

1. Prior to the formal operation, a blank page lasting for 5000 milliseconds is presented to establish the baseline level of participants' state.

2. Keywords are displayed on the screen, and after a delay of 2000 milliseconds, the page switches to the first sample.

3. Participants are required to record their selected images and keywords after browsing the page and click to proceed to the next page.

4. Participants complete a comprehensive evaluation scale to assess the quality of page design and their flow experience after browsing the page.

5. The experiment continues, and following the completion of the first three tasks,

participants are provided with a rest period to restore their state to the baseline level.

6. After the experiment concludes, participants are given a predetermined period of rest to mitigate potential fatigue.

7. All participants are requested to fill out an online survey regarding their demographic information upon completing the final step.

The experimental procedure involves the utilization of prototype pages of varying complexity levels to conduct visual search tasks, wherein each task corresponds to a specific topic keyword. The complexity levels encompass both quantity and functional layout aspects. All participants engage in identical visual search tasks across six prototypes characterized by different complexities, with each task featuring a unique topic keyword. All sample pages are presented within a 1920 × 1080 pixel rectangle, centrally displayed on the participants' computer monitors. There is no imposed time limit for completing the experiment.

Figure 2. Experimental scene.

2.5. Subjective evaluation scale

This paper constructed a scale consisting of 14 question items based on previous studies of flow experience and combined with the characteristics of an online art platform, mainly using the Likert scale with 7 points. The study confirmed the dimensions of flow experience as perceived control, immersion, timely feedback, and enjoyment. The measurement items are shown in the Table 1.

We conducted a preliminary distribution of the scale and recruited a total of 86 participants to complete the questionnaire. The questionnaire data were subjected to exploratory factor analysis. Table 1 displays the Cronbach's alpha coefficient and factor loadings for each question item, demonstrating the favorable reliability of the evaluation scale.

Table 1. Subjective measurement items.

Measurement items		Loading
Sense of control (α=0.954)	I will have a clear goal in the perception task.	0.922
	During the process of browsing website pages, I knew the task objectives of each perception.	0.913
	In the experiment, my task matches my ability.	0.906
	I can master the skills required to meet the challenges.	0.821
	Every step of my search task is consistent and smooth.	0.798
	I am free to control my behavior.	0.784
Immersion (α=0.938)	During the process, I was absorbed and ignored the surrounding things.	0.909
	The process of the experiment will make me forget the time goes by.	0.868
	I concentrate on the experiment and ignore the time.	0.864
	During the experiment, I felt that I was in the world of visual art works.	0.817
Pleasure (α=0.898)	I feel excited while browsing website pages.	0.835
	In general, I felt great happiness during the browsing.	0.811
Feedback (α=0.859)	During the process, I can receive the feedback at any time.	0.842
	Appropriate information feedback (such as stage completion prompt) was provided to help me complete the experiment.	0.783

3. Results

3.1. Subjective results

The data was initially organized and subjected to a reliability test using the statistical software SPSS 26.0. Repeated measures ANOVA and post hoc analysis were then performed on the data. If the assumption of sphericity was not met (sig>0.05), the results were adjusted using Greenhouse-Geisser correction [9].

The results of the repeated measures ANOVA shown in Table 2. The post-hoc analysis of quantity complexity revealed that the score for the low level was higher than the high level ($P<0.001$). This suggests that as the quantity complexity increases, the flow experience first increases and then decreases, forming an inverted U-shape. However, as the functional layout complexity increases, the flow experience shows an upward trend, and there was no significant difference between the low and medium levels of functional layout complexity ($P>0.05$). These results support hypothesis H2 and reject H4. The estimated marginal means of the flow experience also showed this trend, as shown in Figure 3.

Table 2. Subjective evaluation results.

Flow experience	Low M (SD)	Medium M (SD)	High M (SD)	F	P
Q	4.250 (0.353)	4.997 (0.311)	4.642 (0.279)	36.44	<0.001
F	4.448 (0.240)	4.582 (0.279)	4.871 (0.329)	15.01	<0.001

"Q" = quantity complexity, "F" = functional layout complexity

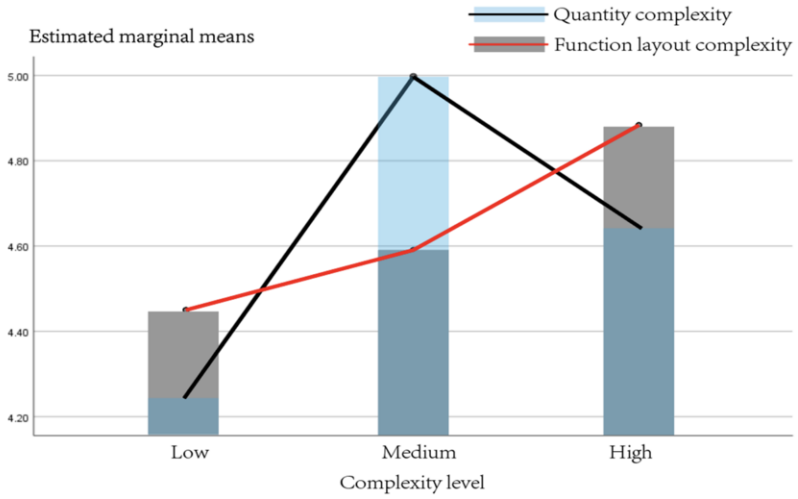

Figure 3. Estimated marginal means of flow experience.

3.2. Eye-tracking experiment results

We conducted a repeated-measures analysis of variance (ANOVA) to test the effect of visual complexity on eye-tracking metrics. All results were tested against the sphericity assumption. Based on previous research, this study selected time to first fixation (I_{TFF}), first fixation duration (I_{FFD}), fixation count (I_{FC}), and revisits count (I_{RC}) as eye-tracking metrics [10-12]. The experimental results are shown in Table 3.

Regarding the eye-tracking metrics for quantity complexity, the results of the repeated-measures ANOVA showed a significant effect of time to first fixation (I_{TFF}), first fixation duration (I_{FFD}), fixation count (I_{FC}), and revisits count (I_{RC}) on quantity complexity levels ($P < 0.005$). All eye-tracking metrics were positively correlated with quantity complexity levels. The specific trends were indicated by the post-hoc multiple comparisons of eye-tracking metrics.

Regarding eye-tracking metrics for functional layout complexity, the results of the repeated-measures ANOVA showed significant effects ($P<0.05$) for initial time to first fixation (I_{TFF}), first fixation duration (I_{FFD}), fixation count (I_{FC}), and revisits count (I_{RC}). Time to first fixation (I_{TFF}) and revisits count (I_{RC}) were positively correlated with functional layout complexity level. First fixation duration (I_{FFD}) and fixation count (I_{FC}) showed a U-shaped trend, with a decrease and then increase. These results indicated that only some metrics were positively correlated with complexity level, and hypothesis H3

was not supported.

Table 3. Repeated measurement ANOVA

Eye-tracking metrics		Low M (SD)	Medium M (SD)	High M (SD)	F	P
I_{TFF}	Q	1.204 (2.616)	1.806 (3.121)	3.725 (6.171)	23.065	<0.001
	F	1.378 (2.811)	1.760 (2.750)	2.786 (3.856)	13.756	<0.001
I_{FFD}	Q	0.216 (0.095)	0.248 (0.163)	0.429 (0.182)	9.403	0.001
	F	0.388 (0.195)	0.336 (0.155)	0.465 (0.357)	6.386	0.003
I_{FC}	Q	13.549 (8.173)	21.173 (13.567)	28.283 (18.071)	17.436	<0.001
	F	8.650 (11.236)	6.224 (7.311)	11.016 (8.048)	9.302	0.001
I_{RC}	Q	2.312 (3.101)	2.836 (3.287)	4.127 (5.168)	6.757	0.002
	F	3.046 (3.741)	3.876 (5.644)	5.140 (8.325)	8.013	0.001

"Q" = quantity complexity, "F" = functional layout complexity

Eye-tracking scanning paths provide a valuable tool for assessing participants' eye movement patterns during visual search tasks. By recording fixation counts, these paths can offer insights into the visual search behavior and the degree of visual attention that participants exhibit.

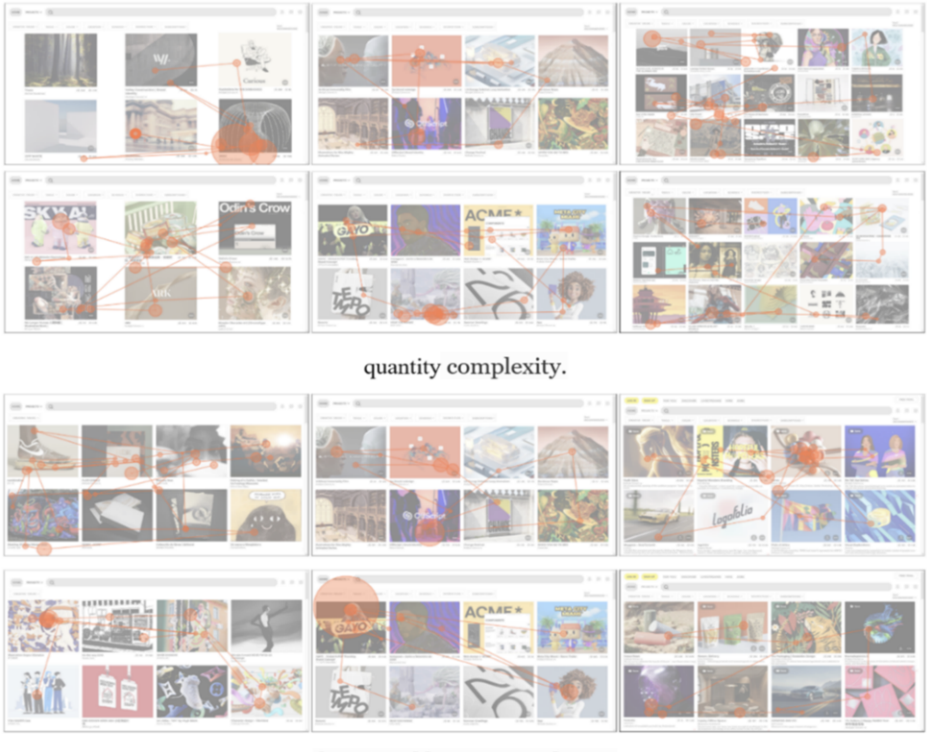

Figure 4. Scan path for different levels

Studies have shown that in visual search tasks of varying levels of complexity, participants tend to exhibit scanning paths that move from left to right. However, the specific characteristics of these scanning paths can vary depending on the layout complexity of the task. In tasks with simpler layouts, the scanning path tends to move downward and features more frequent saccades. In contrast, more complex layouts tend to elicit scanning paths with a more uniform distribution of fixations, fewer regular horizontal movements, and still with frequent saccades. Part of the obtained scan paths are shown in Figure 4.

3.3. Correlation analysis between visual search behavior and flow experience

In this study, the visual search behavior was analyzed through the subjects' measures of time to first fixation (I_{TFF}), first fixation duration (I_{FFD}), fixation count (I_{FC}), regression count (I_{RC}), and subjective evaluation of flow experience. To investigate the relationship between search behavior and flow experience, correlation analysis was conducted under two levels of visual complexity, as shown in Table 4.

The results showed that under quantity complexity, all eye-tracking metrics were significantly related to flow experience ($P < 0.05$). In addition, the Pearson coefficient indicated that the correlation between flow experience and time to first fixation (I_{TFF}) was weak. However, under functional layout complexity, only first fixation duration (I_{FFD}) and fixation count (I_{FC}) had a significant effect on flow experience ($P < 0.05$). The absolute values of the Pearson coefficients of these two eye-tracking metrics were small and less than 0.5. The results of the correlation analysis showed that under both complexities, eye-tracking metrics were negatively correlated with flow experience. There is a negative correlation between eye tracking indicators and visual search efficiency. When the four eye tracking indicators (I_{TFF}, I_{FFD}, I_{FC}, I_{RC}) increase, it indicates a decrease in visual search efficiency and flow experience, while visual search efficiency was positively correlated with flow experience. These results confirm the hypothesis H5.

Table 4. Correlation analysis between eye-tracking metrics and flow experience.

Eye-tracking metrics		Flow experience under quantity complexity	Flow experience under functional layout complexity
I_{TFF}	*r (p)*	-0.256 (0.041)	-0.172 (0.213)
I_{FFD}	*r (p)*	-0.343 (0.010)	-0.302 (0.019)
I_{FC}	*r (p)*	-0.378 (0.005)	-0.289 (0.027)
I_{RC}	*r (p)*	-0.278 (0.033)	-0.223 (0.117)

4. Discussion

In this study, eye-tracking technology was combined with questionnaire surveys to investigate the effects of visual complexity on users' visual search behavior and flow experience in two online visual art platforms using a combination of subjective and objective measures. The results showed that higher quantity complexity led to decreased

search efficiency and a U-shaped trend in users' flow experience. On the other hand, as functional layout complexity increased, the first fixation duration and revisits count increased, while the first fixation duration and fixation count showed a U-shaped trend. Flow experience also increased positively but not significantly. This indicates that an appropriate level of complexity helps users generate a better flow experience, while a low or high level of complexity can lower the level of flow experience. The visual search efficiency is positively correlated with the level of flow experience. When users can easily obtain useful information, they are more likely to experience immersive flow.

This study has several limitations: Firstly, the participants in this experiment were limited to college students aged 18-26, and thus the generalizability of the findings to other age groups is uncertain. Future studies should aim to include a broader age range to obtain more comprehensive data. Secondly, the eye-tracking experiment had limitations in terms of sample size and experimental time, which may have led to incomplete flow experiences. Moreover, the non-significant effect of functional layout complexity on flow experience may be related to the limitations of the experiment. Therefore, future research should aim to improve the details and scale of the experiment to better simulate real-world usage environments.

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