The relationships of viewing time for the cluster of circular objects image with aesthetic evaluation and the sensitivity of trypophobia

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https://hdl.handle.net/2324/7375860

Please use the following citation information when referencing this paper.

Kuroki, D., Sasaki, K., Yamada, Y., & Miura, K. (2025). The relationships of viewing time for the cluster of circular objects image with aesthetic evaluation and the sensitivity of trypophobia. *VISION*, *37*(3), 121–136. https://doi.org/10.24636/vision.37.3_121

The relationships of viewing time for the cluster of circular objects image with aesthetic evaluation and the sensitivity of trypophobia[i, ii].

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[i] This manuscript is an English translation of content published in *VISION Vol. 37, No. 3, 121–136, 2025* (Secondary publication). The translation was produced using ChatGPT, Copilot, and DeepL.

[ii] This research was supported by the 2022 Kyushu University Educational and Research Center for Mathematical and Data Science Support Program. We would like to express our sincere gratitude to Professor Hiroyuki Mitsudo and the members of their seminar for their insightful feedback and valuable suggestions throughout this study.

The relationships of viewing time for circular clusters with aesthetic evaluation.

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Abstract

A cluster of circular objects can evoke discomfort in observers. On the other hand, as represented by Yayoi Kusama's works, the cluster of circular objects seems to attract people. In this study, 270 participants were presented with images containing the cluster and were asked to adjust the duration of their observation. After the adjustment task, the participants aesthetically evaluated the images that were observed the longest and the shortest. For the longest observed cluster of circular objects image, we found the following correlation between the viewing time and *Interest* (r = .35), *Intellectual challenge* (r = .23), *Energy* (r = .20), *Enchantment* (r = .19), *Fascination* (r = .19), and *Joy* (r = .19), but the sensitivity of trypophobia (r = −.09). These results suggest that there could be clusters of circular objects which attract interest and make active in observers without triggering trypophobia.

Keywords: Trypophobia, aesthetic evaluation, viewing time

1． Introduction

A cluster of circular objects refers to a dense aggregation of circular objects, such as lotus seed pods or honeycombs, which can evoke feelings of discomfort in some observers. This discomfort, often referred to as trypophobia, has been suggested to stem from specific spatial frequencies of the image. Images of circular clusters exhibit higher contrast components in the mid-range spatial frequency domain (approximately[iii] 1.5 to 18 cycles per degree; cpd) compared to images without such clusters[1)]. This finding aligns with results from studies investigating the relationship between discomfort and spatial frequency in general images, including artworks[2)]. Furthermore, when measuring discomfort using circular-cluster images filtered to retain only specific spatial frequency ranges, it has been reported that discomfort decreases only when the retained frequencies are higher than 9.05 cpd[3)]. Although not directly focused on circular clusters, a study by Zhang et al. (2021) found that higher geometric regularity and more rounded components in shapes led to higher aesthetic

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[iii] Given that Experiment 1 in Cole & Wilkins (2013) analyzed multiple images of different sizes and that the conversion from cpi to cpd was based on the distance from the camera to the object, rather than on direct image presentation to observers, the term "approximately" was deemed appropriate in this context.

evaluations[4]. The effect of density was found to depend on the shape of the components; in the case of hexagons which is closer in shape to circles, higher density led to lower aesthetic evaluations. Zhang et al. speculated that this may be because high-density stimuli elicited trypophobia. Miura et al. (2016) also reported that higher density in circular clusters leads to increased discomfort[5].

The underlying mechanisms of trypophobia have been examined from an evolutionary perspective, with hypotheses suggesting that the aversion may serve as an adaptive response to avoid poisonous animals[1,6] or infectious diseases[7,8]. These theoretical frameworks have been comprehensively reviewed by Thiebaut et al. (2024). [9] There remains ongoing debate regarding whether the discomfort elicited by circular clusters is more closely associated with fear or disgust. Ayzenberg et al. (2018) investigated this issue by measuring pupillary responses while participants viewed images of circular clusters[10]. They observed a greater degree of pupil constriction in response to these images in comparison with threatening stimuli such as snakes or spiders. Based on this physiological evidence, the authors concluded that trypophobic responses are more consistent with disgust than with fear. Furthermore, a study conducted in China explored the relationship between trypophobia and demographic factors such as region and age. The findings indicated that older adults residing in non-urbanized areas exhibited a lower incidence of trypophobic reactions[11].

As the term "phobia" suggests, previous research has predominantly focused on the discomfort elicited by circular clusters[1,3,5–17]. However, it is also conceivable that such visual patterns possess an attractive quality for some observers. For instance, the renowned artist Yayoi Kusama frequently incorporates circular clusters into her artworks, and the French fashion brand Louis Vuitton has collaborated with her to produce products featuring these motifs. The glitter effects that are popular on the photo-sharing social media platform Instagram may also be interpreted as circular clusters. Furthermore, in Ethiopia's Omo Valley, certain ethnic groups are known to paint circular clusters onto their bodies[18]. On the other hand, previous studies have reported that overlaying circular clusters on images of animals, including humans, increases feelings of discomfort[19, 20]. Additionally, images depicting skin rashes are found to be aversive by individuals with both high and low sensitivity to trypophobia[7]. These findings suggest that the underlying factors contributing to individual differences in preference or aversion toward circular clusters remain unclear.

As mentioned above, although circular clusters may have the potential to attract viewers, this aspect has not been directly examined in previous research. Therefore, in the present study, we asked participants to evaluate images containing circular clusters using the AESTHEMOS scale developed by Schindler et al. (2017)[21]. The AESTHEMOS scale enables multidimensional evaluation, including not only prototypical aesthetic emotions such as feeling of beauty, but also epistemic emotions, amusement, animation and relaxation. Furthermore, the AESTHEMOS scale includes several negative emotions, allowing for a more detailed assessment of affective responses to circular clusters compared to the unidimensional pleasant–unpleasant evaluations employed in prior studies. According to Marković, the aesthetic experience—where one becomes deeply absorbed in an object to the point of losing awareness of oneself and the surroundings—shows only a weak correlation ($r = .11$) with pleasant–unpleasant evaluations (they referred to this as “affective tone”)[22]. Their findings support the relevance of employing the AESTHEMOS scale to assess not only unpleasant/discomfort but also a wide range of aesthetic responses to circular clusters.

In the present study, we further focused on a limitation of previous research, namely, that affective evaluations (e.g., pleasantness or unpleasantness) were averaged within stimulus categories, such as circular-cluster images or control images. As noted by Zhang et al. (2021) and Miura et al. (2016), the density and shape of the constituent elements within circular clusters may influence the degree of discomfort[4,5]. This suggests that some images previously categorized as circular clusters might not necessarily elicit trypophobic responses, and instead may receive higher aesthetic evaluations depending on the density and shape of their constituent elements. Accordingly, rather than conducting aesthetic evaluations across multiple images within the same category, the present study selected specific images that had been classified as circular clusters in prior research and evaluated them multidimensionally using the AESTHEMOS scale.

In selecting specific images from a set of circular-cluster images, the present study focused on viewing time. Viewing time has been widely employed as a behavioral measure of the motivation to observe visual stimuli. For instance, in studies measuring viewing time of infant faces, both male and female participants tended to look longer at images of cuter infants[23)], and female participants, compared to males, were more likely to avoid viewing images of infants with visible abnormalities[24)]. These studies typically employed tasks in which participants could regulate viewing time by pressing a designated key, thereby allowing the assessment of the strength of their desire to view. Using similar procedures, a study involving sexual stimuli found that male participants pressed keys more frequently to extend viewing time for images depicting the opposite sex, whereas female participants tended to extend viewing time for images of romantic couples with lower levels of sexual content[25)]. Another study showed that while male participants rated male and female targets equally high in terms of attractiveness, they exhibited longer viewing times only for attractive female targets[26)]. Furthermore, a link between viewing time and aesthetic emotion[iv] has been reported: positive aesthetic emotions are generally associated with longer viewing durations and an increased likelihood of returning to the image after a temporal delay[27)]. In a study comparing museum and laboratory settings, the relationship between viewing time and aesthetic evaluation of contemporary art photographs was examined using a free-viewing paradigm rather than a key-press-based regulation task. Longer viewing times were linked to greater liking and interest regardless of setting, although setting effects were also observed[28)]. In the present study, we prepared two image categories—those containing circular clusters and control images without such features—and administered a task in which participants adjusted viewing times across many images prior to aesthetic evaluation. Specifically, participants were asked to rate the images they had viewed for the longest and shortest durations in each category. While a free-viewing method was also considered, it was deemed unsuitable for the present online experiment, as

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[iv] The relationship between aesthetic emotion and aesthetic evaluation has been discussed in prior research as follows. "Aesthetic emotions are full-blown discrete emotions that, for all their differences in multiple emotion components, always include an aesthetic evaluation/appreciation of the objects or events under consideration" (Menninghaus et al., 2019, P185). In the present study, "aesthetic evaluation" is employed to denote the responses or behaviors of observers as measured using a Likert scale.

participants tend to minimize effort[29)] and prioritize task completion speed in such contexts. Therefore, following prior studies[24, 26)], we adopted a method in which viewing time was adjusted via key presses, and further implemented procedures to ensure that task duration remained as uniform as possible across participants (see Section 2.3.1 for details).

Furthermore, the present study measured individual sensitivity to trypophobia and examined its correlation with viewing time. If all the circular-cluster images used in this study were to elicit trypophobic responses, a negative correlation would be expected between viewing time and trypophobia sensitivity. However, if some circular-cluster images did not evoke trypophobic reactions, the viewing time for those images should be extended relative to images that do elicit trypophobia, and no substantial evidence for a correlation with trypophobia sensitivity would be obtained. This study had two primary objectives: (1) to explore the emotional responses elicited during the viewing of circular-cluster images by examining the relationship between viewing time and aesthetic evaluation, and (2) to determine whether images previously categorized as circular clusters include some that do not elicit trypophobic responses, by examining the relationship between viewing time and trypophobia sensitivity.

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2． Methods

2.1 Participants

Participants were recruited via Prolific, an international crowdsourcing platform. The only inclusion criterion was English fluency; no restrictions were imposed regarding participants' country of residence, age, or gender. However, in practice, Prolific users are primarily limited to OECD member countries, excluding Turkey, Lithuania, Colombia, and Costa Rica. Moreover, participation was restricted to individuals aged 18 or older, as per the platform's policy. An initial set of 25 participants was recruited on September 16, 2022, for the purpose of verifying the functionality of the experimental program. Subsequently, data were collected from 116 participants on October 14 and 140 participants on December 23 as part of the main experiment[v]. The experiment took approximately 20 minutes to complete, and each participant received £3.15 as compensation. The total number of participants was determined based on the available budget for participant compensation. In this article,

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[v] We also conducted Bayesian statistical modeling based on the results of this study. To improve the precision of the parameter estimates, we increased the number of data points. Detailed information is available at the following URL: https://psycho.hes.kyushu-u.ac.jp/~kurokid/trypo/Summary2.html

we report the results based on the pooled data from all three sessions, yielding a total sample size of 281 participants.

This study was approved by the Research Ethics Committee of the Department of Psychology, Faculty of Human-Environment Studies, Kyushu University (Approval No. 2022-016). Prior to beginning the experiment, participants were informed that (1) they would be asked to view a series of images and report their impressions, (2) some of the images might elicit unpleasant feelings, and (3) they could withdraw from the experiment at any time. Participants were considered to have consented when they clicked the start button to begin the experiment.

2.2 Apparatus and Stimuli

The experimental program was hosted online, and participants accessed it via a designated URL using their own personal computers. Participation via smartphones or tablets was not allowed. Although device restrictions could be specified on Prolific, they functioned only as on-screen warnings during recruitment and were not programmatically enforced. However, because the experimental procedure required the use of a keyboard, participants using devices without a keyboard were effectively unable to complete the study.

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The stimuli consisted of 20 images containing circular clusters (hereafter referred to as "circular-cluster images") and 20 control images containing non-clustered circles, as used in Experiment 2 of Le et al. (2015)[30]. These images also matched those used by Sasaki et al. (2017)[3]. All images were color images with a resolution of 512 × 512 pixels.

2.3 Procedure

The experiment consisted of three tasks: a viewing time adjustment task, an aesthetic evaluation of images, and a measurement of trypophobia sensitivity. The aesthetic evaluation was conducted on the images that were observed for the longest and shortest durations in each of the two categories (i.e., circular-cluster images and control images) during the observation-time adjustment task. Accordingly, the order of tasks was fixed such that the aesthetic evaluation always followed the observation-time adjustment task. Trypophobia sensitivity was measured at the end of the experiment. The experimental program was developed using jsPsych[31] and is available at https://osf.io/dbexc/

2.3.1 Viewing Time Adjustment Task

A stimulus image was presented at the center of the screen, accompanied by a green indicator (500 pixels wide and 20 pixels high) displaying the remaining time available for viewing the image. The indicator was updated every 100 ms. Pressing the right arrow key prolonged the viewing time, while pressing the left arrow key shortened it. The amount of change in viewing time per key press was determined based on the following formula, in accordance with previous studies[24, 26].

NewTotalTime = OldTotalTime + (ExtremeTime – OldTotalTime) / K

In this formula, NewTotalTime represents the updated viewing time, and OldTotalTime represents the viewing time prior to the update. ExtremeTime was set to 8 seconds when the right arrow key (hereafter referred to as the “prolong key”) was pressed to extend the viewing time, and 0 seconds when the left arrow key (the “shorten key”) was pressed to shorten it. The constant K, which determines the magnitude of change, was set to 10. This formula implies that the amount of change in viewing time diminishes with each consecutive key press. The rationale for using this formula was not explicitly stated by Aharon et al. (2001)[26], and while Yamamoto et al. (2009)[24] described its connection to operant procedures, their explanation remained brief and lacked detail. Based on our use of the formula in this experiment, we observed that it effectively imposed an upper limit on the total viewable time that could be accumulated, requiring participants who wished to continue observing the image to repeatedly press the key. For instance, regardless of how frequently the prolong key was pressed, participants could not accumulate more than 8 seconds of viewing time. They had to monitor the decreasing viewing time via the visual indicator and decide whether to press the key again. If participants did not press any key, the image automatically switched to the next stimulus after 4 seconds. No blank interval was inserted between trials.

A practice session was conducted using five images of stationery items that were not used in the main task. Following the practice, participants completed the viewing-time adjustment task using a total of 40 images: 20 images of circular clusters and 20 control images. These images were presented one at a time in a randomized order. The experimental program tracked the elapsed time from the beginning of the task and terminated the task if the total viewing time exceeded three minutes. The decision to continue or terminate the task was made each time the image changed. If participants completed the task (i.e., viewed all 40 images) within the three-minute window, the program was designed to implement a waiting period before transitioning to the subsequent aesthetic evaluation task. However, due to a programming error, the waiting period did not occur in practice. To discourage participants from shortening their viewing time by repeatedly pressing the shorten key or from hesitating to press the prolong key, they were informed in advance that the viewing-time adjustment task would be fixed to a total duration of three minutes. In both the practice and main trials, the order of image presentation was randomized for each participant to ensure counterbalancing.

2.3.2 Aesthetic Evaluation

The four images that were viewed for the longest and shortest durations within each image category (circular clusters and control images) during the viewing-time adjustment task were used as stimuli. However, in cases where participants did not press either the prolong or shorten key within a given image category, one image from that category was randomly selected. The four selected images were presented one at a time in a randomized order on the left side of the screen. On the right side, a set of questions related to aesthetic evaluation was displayed.

Aesthetic evaluations were conducted using the AESTHEMOS scale (Schindler et al., 2017)[21)vi]. This scale consists of 42 items and allows for scoring based on either a 7-factor or 21-factor structure (see Table 1). Responses were made on a 5-point Likert scale: "Not at all", "Slightly", "Moderately", "Considerably", and "Extremely." After data collection, numerical values from 1 to 5 were assigned to each response option from left to right. For each factor, the average rating across its constituent items was calculated (in the 21-factor structure, each factor comprises two items). In addition to the 42 main items, an attention check item was included that required participants to select the second option from the left ("Slightly"). This item was based on the Directed Questions Scale (DQS), which has been shown in prior research to correlate with indices of inattention such as Infrequency and Inconsistency scales, and to enhance statistical power when used for data screening[32)]. In the present study, one DQS item was embedded within the TQ (see Section 2.3.3), and four were included in the aesthetic evaluation. Only data from participants who answered all DQS items correctly

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[vi] The relationship between underlying factors and aesthetic emotions has been described in previous research as follows. “The factors can be interpreted in the following way: negative emotions (F7_1), prototypical aesthetic emotions (F7_2), epistemic emotions (F7_3), animation (F7_4), nostalgia/relaxation (F7_5), sadness (F7_6), and amusement (F7_7)”. (Schindler et al., 2017, Results, para. 5) In contrast, the 21 factors represent a more detailed subdivision of the original 7 factors and are described as subscales.

were included in the analysis. The order of item presentation was randomized for each participant.

Table 1

Correspondence between the 7 and 21 factors of the AESTHEMOS scale. This table was created based on S5 Table from Schindler et al (2017)[21)].

7 factors	21 factors
Amusement	Humor
	Joy
Animation	Enchantment
	Energy
	Vitality
Epistemic emotions	Insight
	Intellectual challenge
	Interest
Negative emotions	Anger

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	Boredom
	Confusion
	Feeling of ugliness
	Uneasiness
Nostalgia/relaxation	Nostalgia
	Relaxation
Prototypical aesthetic emotions	Awe
	Being moved
	Fascination
	Feeling of beauty/liking
	Surprise
Sadness	Sadness

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2.3.3 Measurement of Trypophobia Sensitivity

Trypophobia sensitivity was measured using the Trypophobia Questionnaire (TQ) developed by Le et al. (2015)[30)]. This questionnaire consists of 17 items rated on a five-point Likert scale. During the task, an image of a lotus seed pod and a honeycomb was presented on the left side of the screen, while the questionnaire items were displayed on the right. After completion of the task, the five response options were assigned numerical values from 1 to 5, from left to right, and the total TQ score was calculated by summing the responses to all 17 items. A TQ score greater than 31 indicates a higher sensitivity to trypophobia. In this study, the same procedure as Le et al. was followed, with one modification: in addition to the 17 questionnaire items, we included an attention check item that required participants to select the fourth option from the left ("Considerably"). The order of item presentation was randomized for each participant.

2.4 Data Analysis

A confirmatory factor analysis (CFA) was conducted on the AESTHEMOS scale[21)], which was used to assess aesthetic evaluation. However, because the number of participants in the present study was smaller than that in the original study (which collected responses from approximately 500 individuals across multiple events), no model modification was performed, and the factor structure identified in the original study was adopted without change. Although the AESTHEMOS scale allows for both a 7-factor and a 21-factor structure, this study reports the results based on the 21-factor structure. This decision was made because the primary aim was to examine the relationship between more fine-grained aesthetic evaluations and viewing time, and also because Schindler et al. (2017) reported internal consistency only for the 21-factor structure. Results based on the 7-factor structure are available at https://osf.io/dbexc/. A CFA was also conducted for the TQ scale. While JASP (version 0.19.2)[33)] was primarily used for analysis, it was not able to provide detailed output when the covariance matrix of the latent variables was not positive definite. Therefore, we additionally used R (version 4.4.2)[34)], RStudio (version 2024.12.0.467)[35)], the lavaan package (version 0.6-19)[36)], and the semTools package (version 0.5-6)[37)].

In the viewing-time adjustment task, we identified four images for each participant: (1) the circular-cluster image with the longest viewing time, (2) the control image with the longest viewing time, (3) the circular-cluster image with the shortest viewing time, and (4) the control image with the shortest viewing time. For each of these images, we calculated Pearson's correlation coefficients between viewing time and two psychological indices: aesthetic evaluation (i.e., the mean response across items comprising each AESTHEMOS factor) and the TQ score. All correlation analyses were conducted using JASP, with Bayes factors (BF_{10}) calculated to compare the alternative hypothesis (H_1: there is a correlation) against the null hypothesis (H_0: there is no correlation). The default prior settings in JASP were used, with the width of the stretched beta prior set to 1.0, corresponding to a uniform distribution over population correlation values ranging from −1.0 to 1.0. A Bayes factor between 3 and 10 was interpreted as moderate evidence for the alternative hypothesis, and a Bayes factor greater than 10 was interpreted as strong evidence[38)]. In addition, 95% Bayesian credible intervals were computed for each correlation coefficient. To examine gender and viewing motivation differences, Bayesian *t*-tests were also performed. For these analyses, we used the default Cauchy prior distribution in JASP (scale = 0.707) and computed Bayes factors (BF_{10}) comparing the alternative hypothesis (H_1: a difference exists between groups/conditions) with the null hypothesis (H_0: no difference exists).

3. Results

Of the 281 participants, data from two individuals were not properly recorded, and eight participants failed to respond correctly to the attention check task. In addition, one participant was excluded from analysis due to abnormal behavior in the viewing-time adjustment task, in which they deliberately avoided viewing the circular-cluster images by continuously viewing one of the control images for an extended period (approximately 4 minutes)[vii]. Thus, data from 270 participants were included in the final analysis. The distributions of participants' age (Figure 1), country of residence (Figure 2), and TQ scores (Figure 3) are presented. A TQ score greater than 31 is considered indicative of high sensitivity to trypophobia, and in this experiment, 77 out of 270 participants (approximately 28.5%) scored above this threshold. In addition, a CFA of the TQ was conducted, along with an analysis of the correlation between TQ and age, and an examination of gender differences in TQ scores. The CFA model fit indices were $CFI = 0.83$, $TLI = 0.80$, $RMSEA = 0.14$, and $SRMR = 0.07$, with high internal consistency ($\alpha = .95$). The correlation between TQ and age was $r = -.29$, 95% CI [−.39, −.17], $BF_{10} = 6524.45$（for women: n = 96, $r = -.38$, 95% CI [−.54, −.20], $BF_{10} = 196.45$; for men: n = 173, $r = -.23$, 95% CI [−.36, −.08], $BF_{10} = 9.04$; one participant did not report gender). The proportion of participants scoring above 31 on the TQ was 33.3% among women (32 of 96) and 26.0% among men

[vii] The experimental program recorded the duration of each trial at the moment participants finished viewing the image. Participants could continue viewing the stimulus as long as the prolong key was pressed. In a post-experiment introspective report, the excluded participant reported that they had deliberately kept viewing the control image to avoid looking at the circular-cluster image.

(45 of 173). To examine gender differences in TQ scores, a Bayesian independent samples *t*-test was conducted. The Bayes factor (BF_{10} = 1.63) indicated only anecdotal evidence for a difference between genders. However, the mean TQ score was higher for women than for men, with an estimated effect size (median) of .28, 95% CI [.03, .52].

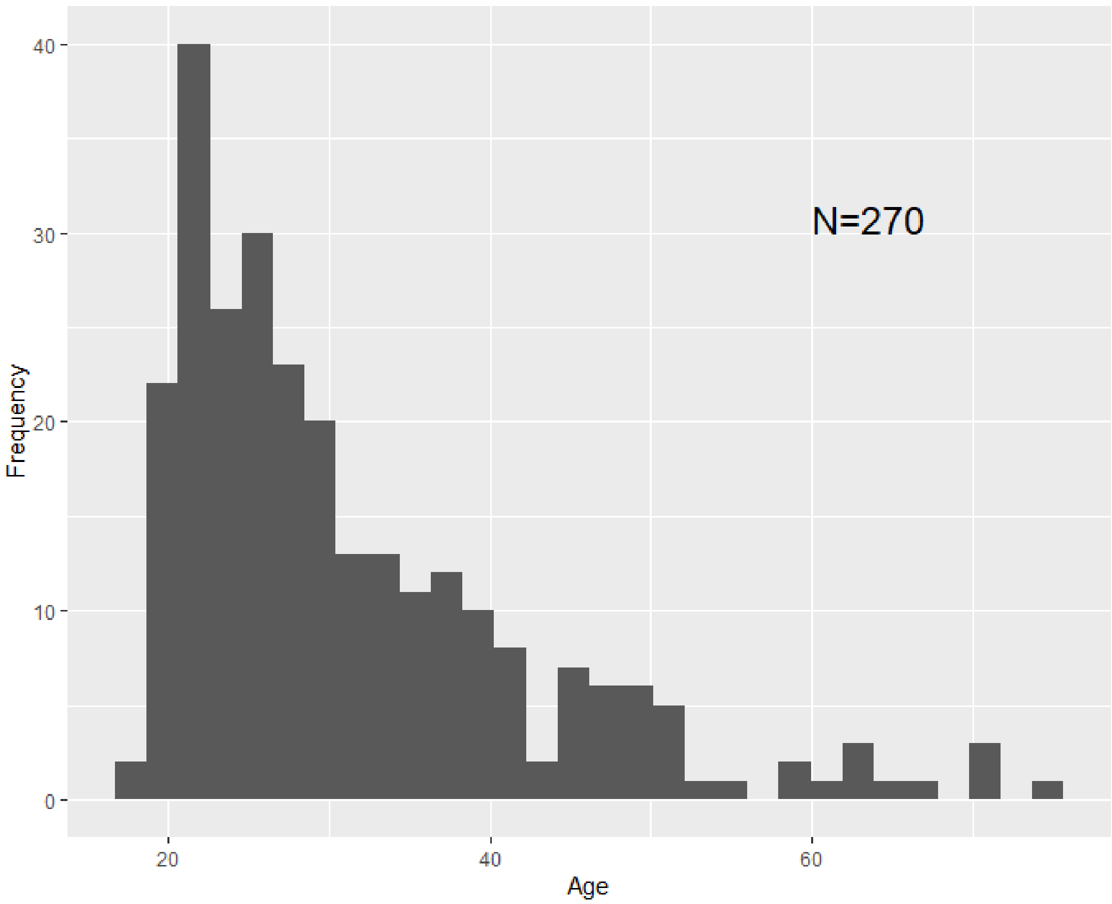

Figure 1. Histogram of Age

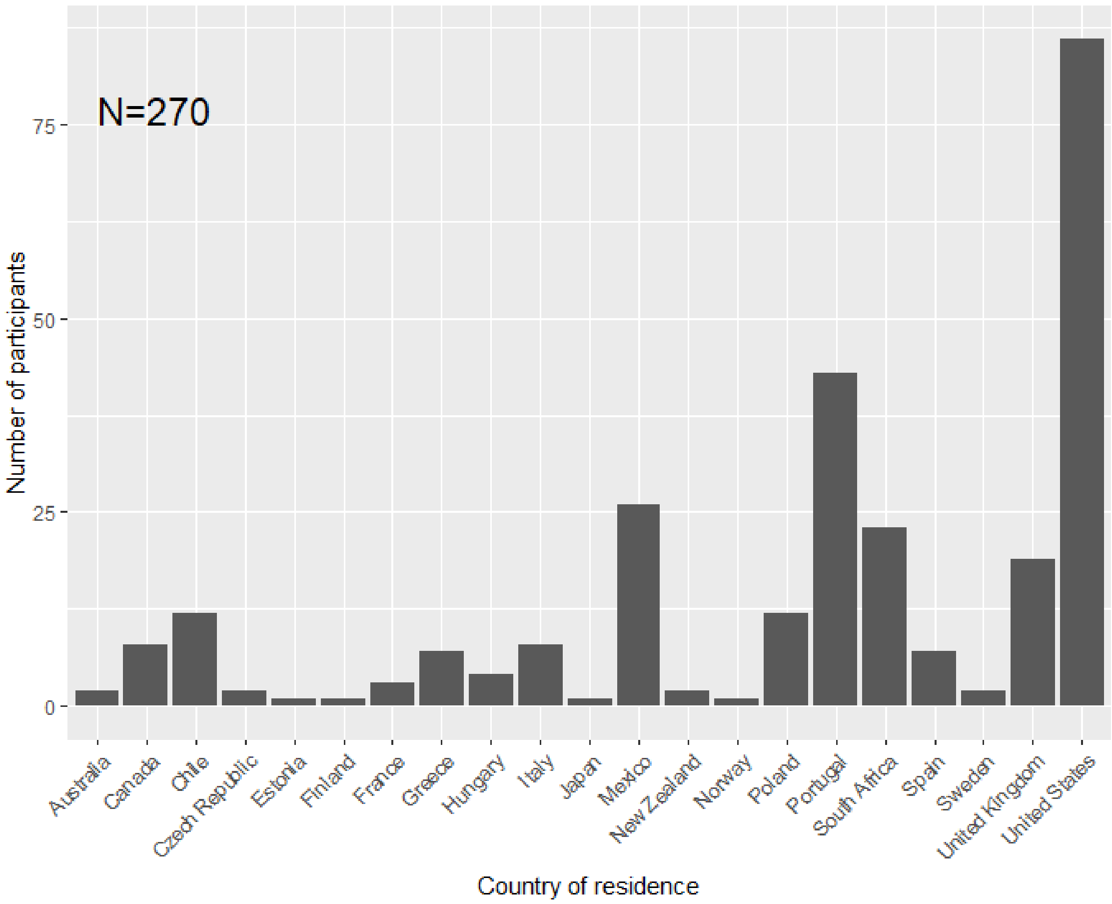

Figure 2. Number of participants by country of residence

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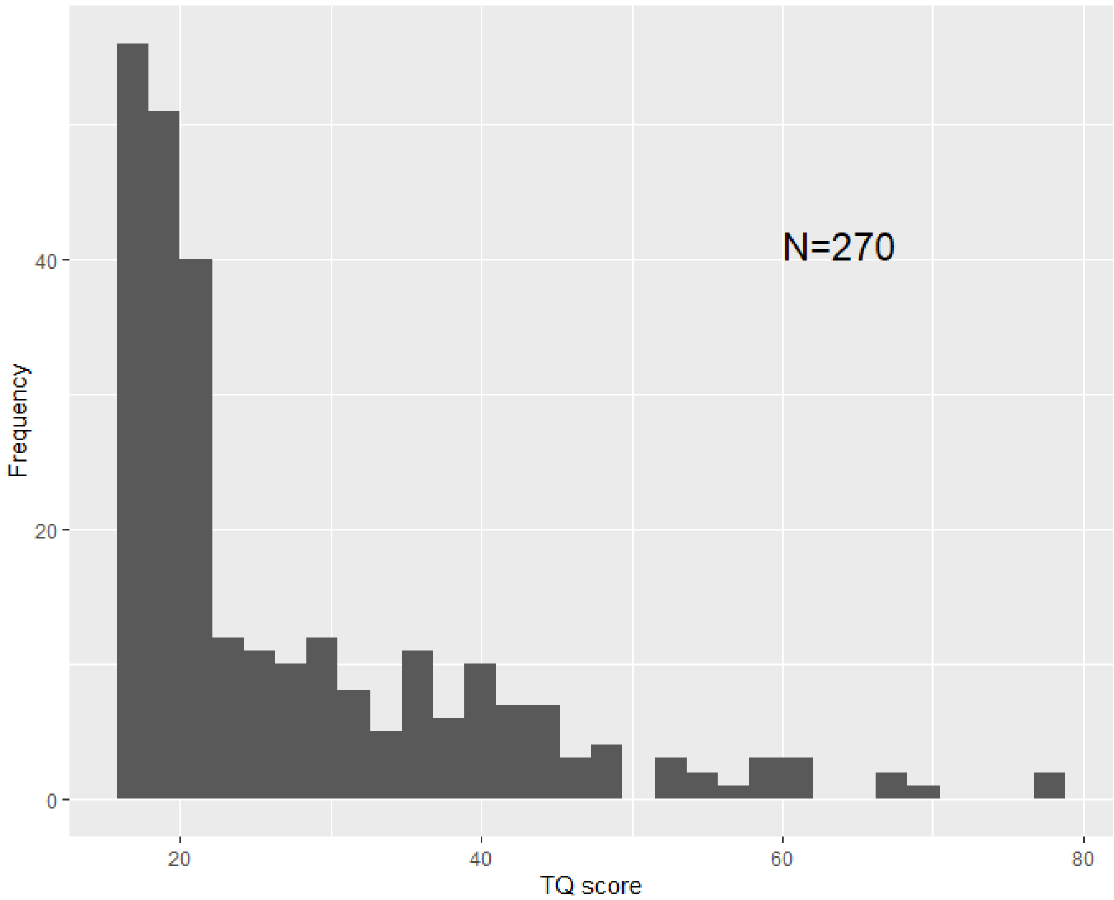

Figure 3. Histogram of TQ score

The maximum duration for the viewing-time adjustment task was 3 minutes (180 seconds). Among the participants, 182 individuals (67.4%) viewed all 40 images within this time limit. For these participants, the mean total viewing time was 157.98 seconds (*sd* = 17.48). In contrast, among those who did not manage to view all images, the mean number of images actually viewed was

29.78 (*sd* = 8.53). Additionally, during the viewing-time adjustment task, some participants did not press either the prolong key or the shorten key for any images in a given image category: this was the case for 22 participants (8.2%) for the circular-cluster images and 21 participants (7.8%) for the control images.

Aesthetic evaluations were conducted for the circular-cluster image and the control image that had been viewed for the longest and shortest durations, respectively. Figure 4 presents histograms of the viewing times for these images. Regardless of image category, the histograms exhibit a pronounced rightward skew relative to the default viewing time of 4 seconds (indicated by the black dotted line in Figure 4), suggesting that there were images for which participants chose to prolong their viewing time.

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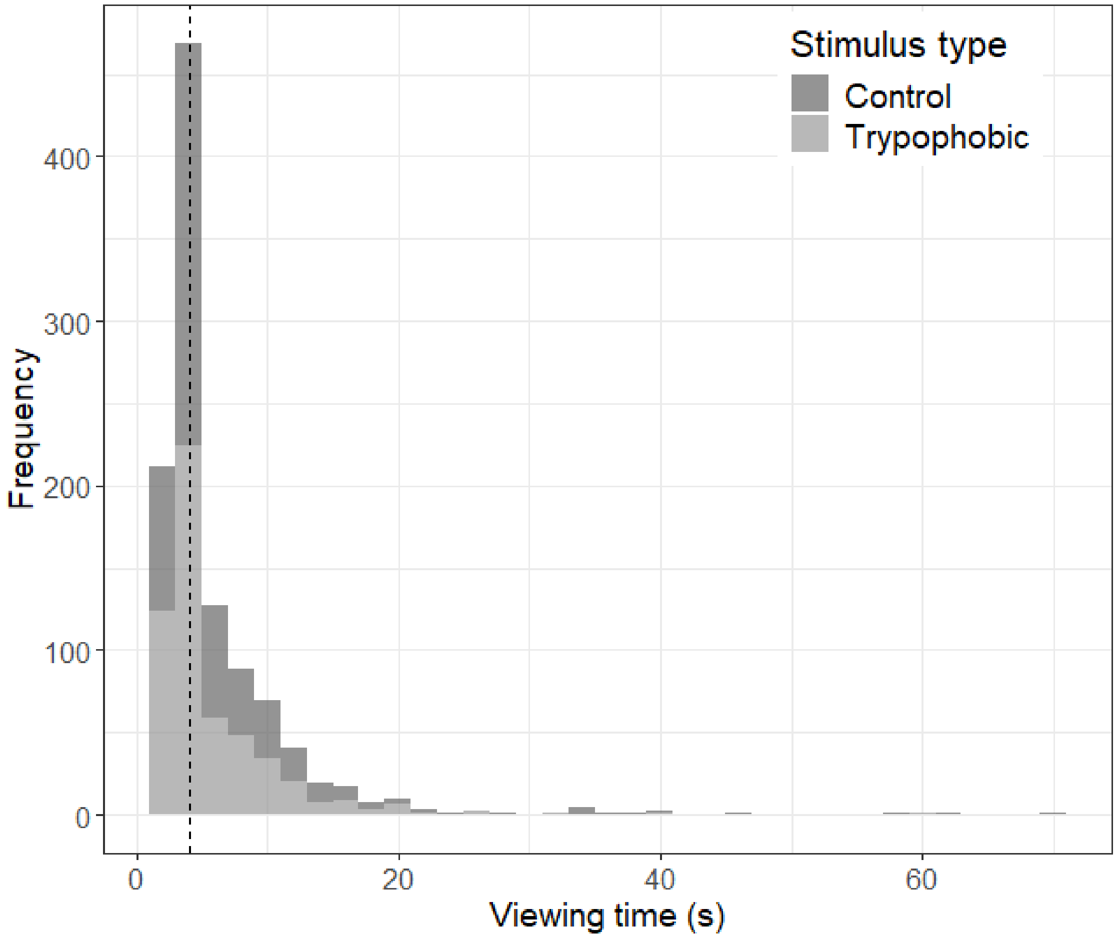

Figure 4. Histogram of viewing time for the control and trypophobic (cluster of circular objects) image. The bin size is 2 s, and the black dotted line shows the viewing time when none of the keys were pressed (4 s).

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3.1 The circular-cluster image with the longest viewing time

CFA based on 21 factors of aesthetic evaluations yielded the following fit indices: *CFI* = 0.92, *TLI* = 0.89, *RMSEA* = 0.06, and *SRMR* = 0.06. However, the covariance matrix of the latent variables was not positive definite. The correlation coefficients between each factor and the viewing time, as well as the internal consistency of each factor, are presented in Table 2 in descending order of Bayes factors.

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Table 2

For the longest observed cluster of circular objects image, correlation coefficients between aesthetic evaluation/TQ and viewing time with reliability coefficients

Factor	Correlation Coefficient	Lower 95% CI	Upper 95% CI	BF_{10}	Coefficient α (Present)	Coefficient α (Previous)
Interest	.35	.23	.44	1.55×10^6	.85	.69
Intellectual challenge	.23	.11	.34	105.90	.76	.78
Energy	.20	.09	.31	19.91	.74	.66
Enchantment	.19	.08	.31	12.66	.87	.79
Fascination	.19	.07	.30	11.02	.71	.77
Joy	.19	.07	.30	10.25	.90	.84
Insight	.19	.07	.30	8.66	.66	.64
Feeling of	.18	.06	.29	6.02	.91	.73

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beauty						
Vitality	.17	.05	.29	4.29	.78	.80
Boredom	−.16	−.27	−.04	2.14	.56	.75
Awe	.15	.04	.27	1.88	.73	.55
Surprise	.14	.02	.26	1.12	.60	.75
Humor	.14	.02	.25	1.06	.65	.85
Being moved	.12	.00	.23	0.47	.85	.77
Relaxation	.10	−.02	.22	0.28	.89	.60
Nostalgia	.10	−.02	.21	0.27	.71	.73
TQ	−.09	−.20	.03	0.22	.95	.96
Feeling of ugliness	−.08	−.20	.04	0.18	.85	.71
Confusion	.07	−.05	.18	0.14	.68	.75

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Anger	−.05	−.17	.07	0.11	.83	.75
Sadness	−.02	−.13	.10	0.08	.35	.73
Uneasiness	−.01	−.13	.11	0.08	.68	.75

Note. Sorted in descending order by Bayesian factor. Coefficient α (Previous) refers to the data reported in Schindler et al. (2017).

For each participant, the image with the longest viewing time was identified, and the top three images were examined in terms of how many participants selected each one. The stimulus images were the same as those used in previous studies[3, 30)], but detailed information about the content of each image was not available. In the present study, when the content of an image was unclear, we used Google image search to identify it. The longest observed circular-cluster image was a photo of white strawberries, selected by 24 participants (8.9%). This was followed by an image of a teapot decorated with clustered elements (20 participants, 7.4%), and an image showing a plant surface entirely covered with circular clusters (19 participants, 7.0%).[viii]

3.2 The control image with the longest viewing time

CFA based on 21 factors of aesthetic evaluations yielded the following fit indices: *CFI* = 0.90, *TLI* = 0.86, *RMSEA* = 0.07, and *SRMR* = 0.06. However, the covariance matrix of the latent variables was not positive definite. The correlation coefficients between each factor and the viewing time, as well as the internal consistency of each factor, are presented in Table 3.

[viii] Since obtaining permission to publish each image proved difficult, we chose not to include them in the manuscript.

The relationships of viewing time for circular clusters with aesthetic evaluation.

Table 3

For the longest observed control image, correlation coefficients between aesthetic evaluation/TQ and viewing time with reliability coefficients

Factor	Correlation Coefficient	Lower 95% CI	Upper 95% CI	BF_{10}	Coefficient α (Present)	Coefficient α (Previous)
Feeling of beauty	.27	.15	.37	1337.61	.89	.73
Relaxation	.24	.12	.34	156.55	.92	.60
Joy	.22	.10	.33	44.60	.87	.84
Intellectual challenge	.20	.08	.31	13.07	.67	.78
Awe	.15	.03	.26	1.56	.66	.55
Boredom	−.15	−.26	−.03	1.32	.57	.75

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Humor	.13	.01	.24	0.72	.54	.85
Interest	.12	.00	.23	0.50	.79	.69
Fascination	.12	.00	.23	0.47	.80	.77
Energy	.12	−.01	.23	0.44	.79	.66
Insight	.10	−.02	.22	0.29	.73	.64
Nostalgia	.09	−.03	.20	0.20	.79	.73
Enchantment	.07	−.05	.18	0.14	.81	.79
Uneasiness	−.06	−.18	.06	0.12	.45	.75
Being moved	.06	−.06	.17	0.12	.81	.77
Surprise	.06	−.06	.17	0.11	.46	.75
Sadness	−.04	−.16	.08	0.10	.42	.73
Feeling of ugliness	−.04	−.15	.08	0.09	.53	.71

The relationships of viewing time for circular clusters with aesthetic evaluation.

Anger	−.03	−.15	.09	0.09	.71	.75
TQ	.03	−.09	.14	0.08	.94	.96
Confusion	−.02	−.14	.10	0.08	.30	.75
Vitality	.01	−.11	.13	0.08	.69	.80

Note. Sorted in descending order by Bayesian factor. Coefficient α (Previous) refers to the data reported in Schindler et al. (2017).

We identified the image that was viewed for the longest durations by each participant and examined how many participants selected each image. In descending order of the number of selections, the most commonly viewed images were: a circular tool used for bird feeding (33 participants, 12.2%), an interior scene featuring a large circular window (32 participants, 11.9%), and a donut-shaped accessory case (30 participants, 11.1%).

3.3 The circular-cluster image with the shortest viewing time

CFA based on 21 factors of aesthetic evaluations yielded the following fit indices: *CFI* =

0.87, *TLI* = 0.82, *RMSEA* = 0.07, and *SRMR* = 0.08. However, the covariance matrix of the latent variables was not positive definite. The correlation coefficients between each factor and the viewing time, as well as the internal consistency of each factor, are presented in Table 4.

The relationships of viewing time for circular clusters with aesthetic evaluation.

Table 4

For the shortest observed cluster of circular objects image, correlation coefficients between aesthetic evaluation/TQ and viewing time with reliability coefficients

Factor	Correlation Coefficient	Lower 95% CI	Upper 95% CI	BF_{10}	Coefficient α (Present)	Coefficient α (Previous)
Interest	.26	.15	.37	1169.16	.78	.69
Feeling of ugliness	−.26	−.36	−.14	645.74	.82	.71
Intellectual challenge	.23	.11	.34	88.97	.60	.78
Fascination	.21	.09	.32	23.25	.67	.77
TQ	−.20	−.31	−.09	21.07	.95	.96
Anger	−.20	−.31	−.08	14.22	.85	.75

The relationships of viewing time for circular clusters with aesthetic evaluation.

Uneasiness	−.17	−.28	−.05	4.18	.80	.75
Feeling of beauty	.16	.04	.27	2.36	.86	.73
Relaxation	.16	.04	.27	2.13	.83	.60
Joy	.15	.04	.27	1.86	.78	.84
Confusion	−.15	−.26	−.03	1.43	.57	.75
Enchantment	.13	.01	.24	0.65	.77	.79
Sadness	−.09	−.20	.03	0.22	.54	.73
Boredom	−.09	−.20	.04	0.20	.58	.75
Energy	.08	−.04	.20	0.19	.73	.66
Awe	.08	−.04	.20	0.18	.64	.55
Humor	.08	−.04	.19	0.17	.65	.85
Being moved	.06	−.06	.18	0.12	.80	.77

The relationships of viewing time for circular clusters with aesthetic evaluation.

Insight	.06	−.06	.17	0.12	.65	.64
Nostalgia	.05	−.07	.17	0.11	.80	.73
Surprise	−.05	−.17	.07	0.11	.55	.75
Vitality	.03	−.09	.15	0.09	.59	.80

Note. Sorted in descending order by Bayesian factor. Coefficient α (Previous) refers to the data reported in Schindler et al. (2017).

We identified the image with the shortest viewing time for each participant and examined how many participants selected each image. In descending order of the number of selections, the most briefly viewed images were: a banksia seed pod (26 participants, 9.6%), a part of a plant with black spots on a white background (21 participants, 7.8%), and barnacles (20 participants, 7.4%).

The relationships of viewing time for circular clusters with aesthetic evaluation.

3.4 The control image with the shortest viewing time

CFA based on 21 factors of aesthetic evaluations yielded the following fit indices: *CFI* = 0.87, *TLI* = 0.81, *RMSEA* = 0.08, and *SRMR* = 0.07. However, the covariance matrix of the latent variables was not positive definite. The correlation coefficients between each factor and the viewing time, as well as the internal consistency of each factor, are presented in Table 5.

The relationships of viewing time for circular clusters with aesthetic evaluation.

Table 5

For the shortest observed control image, correlation coefficients between aesthetic evaluation/TQ and viewing time with reliability coefficients

Factor	Correlation Coefficient	Lower 95% CI	Upper 95% CI	BF_{10}	Coefficient α (Present)	Coefficient α (Previous)
Insight	.23	.11	.33	74.79	.75	.64
Vitality	.19	.08	.30	12.29	.66	.80
Intellectual challenge	.17	.05	.28	3.42	.60	.78
Confusion	.14	.02	.26	1.20	.60	.75
Interest	.14	.02	.25	0.91	.73	.69
Awe	.13	.01	.25	0.83	.74	.55
Enchantment	.13	.01	.24	0.64	.76	.79

The relationships of viewing time for circular clusters with aesthetic evaluation.

Surprise	.12	.00	.23	0.47	.55	.75
Joy	.11	−.01	.23	0.42	.84	.84
Sadness	.09	−.03	.21	0.24	.46	.73
Feeling of beauty	.09	−.03	.21	0.23	.86	.73
Uneasiness	.08	−.04	.19	0.16	.71	.75
Fascination	.07	−.05	.19	0.16	.86	.77
Energy	.07	−.05	.19	0.16	.75	.66
TQ	.07	−.05	.19	0.15	.95	.96
Being moved	.04	−.08	.16	0.10	.82	.77
Relaxation	.04	−.08	.16	0.09	.88	.60
Humor	.04	−.08	.16	0.09	.66	.85
Boredom	−.03	−.15	.09	0.09	.67	.75

The relationships of viewing time for circular clusters with aesthetic evaluation.

Nostalgia	−.02	−.14	.10	0.08	.72	.73
Anger	−.01	−.13	.11	0.08	.61	.75
Feeling of ugliness	.01	−.11	.13	0.08	.66	.71

Note. Sorted in descending order by Bayesian factor. Coefficient α (Previous) refers to the data reported in Schindler et al. (2017).

We identified the image with the shortest viewing time for each participant and examined how many participants selected each image. In descending order of the number of selections, the most briefly viewed images were: a roll of toilet paper (24 participants, 8.9%), a hole in the ceiling (23 participants, 8.5%), a large roll of tape (20 participants, 7.4%), and a hole in a wall (20 participants, 7.4%).

The relationships of viewing time for circular clusters with aesthetic evaluation.

3.5 Comparison between the circular-cluster images with the longest and shortest viewing times[ix]

We conducted Bayesian paired samples *t*-tests to compare aesthetic evaluations of the longest- and shortest-viewed circular-cluster images. The analysis targeted the factors that showed strong evidence for a positive correlation with viewing time (Bayes factor > 10), namely *Interest*, *Intellectual Challenge*, *Energy*, *Enchantment*, *Fascination*, and *Joy*. The estimated effect sizes and Bayes factors for each factor are presented in Table 6. For all factors, the mean aesthetic ratings were higher for the longest-viewed images. However, only for *Energy* did the Bayes factor fall below 1.

[ix] This exploratory analysis was carried out following a recommendation made by one of the reviewers.

The relationships of viewing time for circular clusters with aesthetic evaluation.

Table 6

Results of the Bayesian paired samples *t*-test between the longest and shortest observed clusters of circular objects image

Factor	Effect size δ(Median)	Lower 95% CI	Upper 95% CI	BF_{10}
Interest	.46	.33	.58	9.52×10^{9}
Intellectual challenge	.28	.16	.40	2383
Energy	.13	.01	.25	0.72
Enchantment	.34	.22	.46	244422
Fascination	.34	.22	.46	207361
Joy	.23	.11	.35	61.15

The relationships of viewing time for circular clusters with aesthetic evaluation.

4. Discussion

Using the TQ[30], we measured participants' sensitivity to trypophobia in this study. Approximately 28.5% of participants scored above 31 points, classifying them as high-sensitivity individuals. In previous studies, the proportion of participants classified as high sensitivity was reported as 7.4%[12] and 23.6%[39]. A negative correlation was observed between TQ scores and age, which is consistent with prior findings[11,40]. Although the reason for this negative correlation remains unclear, it supports a previous claim that older individuals living in non-urbanized regions of China are less likely to experience trypophobia[11]. In addition, there was no substantial evidence for gender differences in TQ scores.

For the longest-viewed circular-cluster images, the following factors exhibited strong evidence of positive correlations with viewing time, as indicated by Bayes factors exceeding 10: *Interest*, *Intellectual challenge*, *Energy*, *Enchantment*, *Fascination*, and *Joy*. No negative correlations were observed. A comparison of the internal consistency (Coefficient α) of these positively correlated factors with those reported in previous studies revealed slightly lower values for *Intellectual challenge* and *Fascination*, but comparable or higher values for the other factors. According to the AESTHEMOS scale (Table 1)[21], both *Interest* and *Intellectual challenge* are classified as epistemic emotions, although the latter includes a sense of overcoming difficulty. In prior research, *Interest* and *Challenged* were both categorized under the broader class of *Active* emotions, but *Challenged* was treated as a subordinate category along with emotions such as determination and confidence[41]. Regarding *Interest*, studies using artworks have shown that this emotion tends to arise in response to novel and complex stimuli, but it increases when the stimuli are also comprehensible; otherwise, it leads to confusion[42]. Moreover, *Interest* has been reported to promote absorption and exploration[43]. Taken together, these findings suggest that although circular-cluster images are not easily interpretable, they do not entirely inhibit interpretation either. Rather, they possess visual features that make participants feel as though the images could be understood with sufficient time. In contrast, for control images, a positive correlation between viewing time and *Intellectual challenge* was observed, whereas no such correlation was found for *Interest*. One possible explanation is that the control images included objects with low novelty, such as musical instruments and household items. The absence of a correlation with *Interest* further suggests that longer viewing times do not necessarily correspond to higher *Interest* ratings.

According to the AESTHEMOS scale[21], both *Energy* and *Enchantment* are categorized as animated emotions; however, they differ in the source of energy. *Energy* refers to a state of being invigorated by the drive to pursue and achieve a specific goal. While the specific goal-oriented motivation that may have emerged during the observation of circular-cluster images remains unclear, the fact that the longest viewing time was recorded for an image of white strawberries—a highly unusual item—suggests that participants may have experienced a desire to touch or taste it. However, as indicated by the findings in Section 3.5, the emotional response associated with the *Energy* factor appears to be limited. In contrast, *Enchantment* is characterized by a sense of fascination as if under a spell. Such an emotional evaluation may have been elicited by extraordinary stimuli like the white strawberries.

Regarding *Fascination*, previous research has defined it as an intense and prolonged state of concentration that spans a broad range and serves as a driving force for cognitive functioning[44]. Based on this, it is plausible that participants were in a sustained state of concentration while observing the circular-cluster images. In contrast, no positive correlation was observed between *Fascination* and viewing time for the control images. This result, similar to that of *Interest*, suggests that higher ratings of *Fascination* are not necessarily associated with images that were viewed for a longer duration.

Joy is an emotion characterized by high arousal and the receipt of some form of reward[45], and a positive correlation with viewing time was observed for both circular-cluster and control images.

The relationships of viewing time for circular clusters with aesthetic evaluation.

A potential link between circular clusters and reward can be seen in the body paintings of the Surma and Mursi peoples of the Omo Valley in Africa. These groups apply colorful circular-cluster patterns to their bodies using a wide range of natural pigments, not necessarily as part of a ritual, but purely for enjoyment[18)]. Since mirrors are not available in the region, the painting is done not by the individuals themselves but by others, suggesting that they may come to know their own appearance through the reactions of others[18)]. The case of the Omo Valley may serve as a counterexample to findings that overlaying circular clusters on faces enhances discomfort[19, 20)]. The difference in responses might be attributed to the relatively larger size of the circular elements in the former, or to the fact that they are clearly recognized as decorative body paint.

For the longest-viewed circular-cluster images, none of the factors that correlated with viewing time were associated with discomfort. This result aligns with previous findings suggesting that immersive aesthetic experiences are largely independent of pleasantness or unpleasantness ratings[22)]. Furthermore, no correlation was observed between viewing time and TQ scores, with a Bayes factor (BF_{10}) of 0.22 (more precisely, 0.215). The inverse of this value (BF_{01} = 4.65) represents the Bayes factor in support of the null hypothesis—i.e., no correlation between viewing time and TQ score—and indicates moderate evidence in favor of the absence of a relationship. These findings suggest that being attracted to circular-cluster images is not necessarily limited to observers with low trypophobia sensitivity. In other words, some images that had been classified as circular-cluster images in previous studies[3, 30] and in the current study elicited a strong desire to observe even among participants with high trypophobia sensitivity. While it remains unclear what differentiates images that promote observation from those that suppress it, prior studies by Zhang et al. (2021) and Miura et al. (2016) have suggested that factors such as the shape, density, and regularity of the elements comprising the clusters may play a role[4, 5].

For the most briefly viewed circular-cluster images, the factors that showed strong evidence of a positive correlation with viewing time, indicated by Bayes factors exceeding 10, were *Interest*, *Intellectual challenge*, and *Fascination*—consistent with the results observed for the longest-viewed circular-cluster images. However, the internal consistency (Coefficient α) of *Intellectual challenge* and *Fascination* was lower compared to previous studies. One possible reason for this may be the relatively short duration (4 seconds) during which the image remained on screen when neither the prolong key nor the shorten key was pressed. Setting a longer default viewing time and enhancing participants' motivation to avoid observation could lead to more accurate identification of images that are avoided, which in turn may improve the consistency of aesthetic evaluations. Factors that showed strong evidence of a negative correlation with viewing time were *Feeling of ugliness*, *TQ*, and *Anger*. Because the TQ score reflects sensitivity to trypophobia, participants with higher TQ scores were expected to avoid observing circular-cluster images. This idea was supported by the negative correlation between TQ scores and viewing time. While previous studies have validated the TQ by examining its correlation with subjective ratings of discomfort using Likert scales for circular-cluster images[30], the present study provides behavioral validation of the TQ through the reduction of viewing time. *Feeling of ugliness* and *Anger*, were both classified as negative emotions in the AESTHEMOS scale[21]. Whereas prior studies measured the discomfort elicited by circular-cluster images using ratings such as *Unpleasant*[30], *Discomfort/Uncomfort*[1,39], *Fear*, and *Disgust*[7], the present findings further specify that the discomfort may be particularly associated with *Feeling of ugliness* and *Anger*. Notably, for the control images, none of the three factors—*Feeling of ugliness*, TQ, or *Anger*—showed substantial Bayes factors in either the prolong or shorten conditions, indicating no substantial evidence for a correlation with viewing time.

Only in the longest viewing condition of the control images, a positive correlation was observed between viewing time and the two factors, *Feeling of beauty* and *Relaxation*. This result highlights a clear difference between control and circular-cluster images. For circular-cluster images, longer viewing times were not associated with increased perceptions of beauty or relaxation. Instead, they elicited more active emotional responses, such as *Energy* and *Enchantment*.

In this study, we employed a multidimensional aesthetic evaluation scale to explore emotional factors that correlate with viewing time for circular-cluster images. Under the longest viewing condition of the circular-cluster images, viewing time was positively correlated with the factors *Interest*, *Intellectual Challenge*, *Energy*, *Enchantment*, *Fascination*, and *Joy*. Furthermore, the data supported higher aesthetic ratings for the circular-cluster images with the longest viewing times compared to those with the shortest, except for *Energy*. In contrast, no correlation was found between viewing time and TQ scores. This result suggests that there could be circular-cluster images which attract interest and make active in observers without triggering trypophobia. Additionally, the present study demonstrated that, among the images previously categorized as circular-cluster images in prior research[3, 30], some facilitated prolonged observation, whereas others suppressed it. Viewing time for images that suppressed observation showed a negative correlation with TQ scores, consistent with earlier findings. While prior research has predominantly focused on the discomfort evoked by circular clusters, the current study offers a broader perspective on the emotional responses elicited during the observation of such images. It should be noted, however, that the current study used colored images as stimuli, and it is possible that color information influenced the viewing time of circular-cluster images. Novelty of the images may also have contributed to differences in viewing duration. Furthermore, the failure of the latent variable covariance matrix to achieve positive definite in the confirmatory factor analysis suggests the presence of multicollinearity within the assumed factor structure[46)]. By controlling for color information and the visual salience of circular clusters, assessing participants' prior exposure to the images, and refining the factor structure, future studies are expected to yield new insights into the aesthetic evaluation of circular-cluster images.

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