

# The Effect of Painting Beauty on Eye Movements

Tomasz Jankowski, Piotr Francuz, Piotr Oleś, Elżbieta Chmielnicka-Kuter, and Paweł Augustynowicz

Institute of Psychology, The John Paul II Catholic University of Lublin, Poland

## ABSTRACT

The current study aimed to determine relationships between oculomotor behavior and aesthetic evaluation of paintings. We hypothesized that paintings evaluated as beautiful compared to nonbeautiful would be associated with different oculomotor behavior in terms of fixation duration, viewing time, and temporal and spatial distribution of attention. To verify these hypotheses, we examined forty participants that looked at and evaluated 140 figurative paintings while their eye movements were recorded. To analyze data, we used divergence point analysis (DPA) and recurrence quantification analysis (RQA). The results of the DPA suggested that fixation durations longer than 229 ms are sensitive to the effect of aesthetic evaluation. We also found that the effect of aesthetic evaluation was significant in the time window between 2.3 s and 19.8 s of viewing a painting. The results of the RQA suggested that the participants viewed paintings evaluated as beautiful in a more structured manner compared to those evaluated as nonbeautiful, which suggests higher involvement of top-down processes while facing beautiful artwork. We discuss and refer these results to the literature on cognitive processes related to aesthetic evaluation of paintings.

## KEYWORDS

eye-tracking  
aesthetical evaluation  
survival analysis  
recurrence quantification  
analysis

## INTRODUCTION

Contemplating an artwork is a process that develops across time. This simple, one might say obvious, statement, is a fundamental assumption of most prominent models that describe and explain aesthetic experience (Brieber et al., 2018; Pelowski et al., 2016). Conceptualizing the act of looking at artwork as a process makes it possible to analyze it in different timescales. A lower level of analysis can refer to a simple fixation. During this small viewing unit, a person perceives and processes pieces of information, depending on the fixation duration, at a more or less deep level. Thus, the analysis of simple fixation duration allows for drawing conclusions about the most basic attentional and cognitive processes related to artwork contemplation. A higher level of analysis refers to the total time of looking at a painting, which consists of a sequence of fixations differentiated in terms of duration and location. The analysis of a sequence of fixations separated by saccades gives insight into the dynamics of attentional and cognitive processes when viewing an entire painting as well as into cognitive strategies that a person takes when looking at a painting (i.e., bottom-up vs. top-down strategies; Rosenberg & Klein, 2015).

The current study aimed to explore viewing artwork in two different timescales using eye-tracking data. We investigated whether an effect of aesthetic evaluation can be observed at the level of a simple fixation duration as well as at the level of an entire sequence of fixations. In this study, we define aesthetic evaluation of a painting as a subjective rating of its liking by the individual person. This understanding contrasts with other conceptualizations of aesthetic evaluation as a rating of more objective, artistic value of a painting (Hayn-Leichsenring et al., 2017). We take this approach after Sidhu et al. (2018) who, using a large sample of subjects ( $N = 598$ ) and paintings ( $N = 480$ ), found that liking (subjective) ratings were much more predictable than aesthetic value ratings.

Corresponding author: Tomasz Jankowski, Institute of Psychology, The John Paul II Catholic University of Lublin, Al. Raclawickie 14, 20-950 Lublin, Poland.  
E-mail: tojankowski@kul.lublin.pl

## Fixation Duration and Aesthetical Evaluation

Looking at a painting comprises a sequence of fixations during which information about the stimuli is perceived and saccades relocate attention to different places on the painting. An average fixation duration is about 250-400 ms, however a large variability is observed (Rosenberg & Klein, 2015). Different models, developed mostly in the context of lexical processing, try to explain this variability (e.g., Feng, 2006; Nuthmann et al., 2010). According to one of the most widely accepted models, that is, the mixture model, there are different fixation durations while viewing a scene or reading a text and the observed distribution of fixation durations can be decomposed into several overlapping distributions related to different types of fixation durations. Accordingly, Yang and McConkie (2001) distinguished three types of fixation durations while reading a text: short, medium, and long. Short fixation durations while reading are terminated 125-150 ms after the fixation onset. They are supposed to represent indirect control of eye movement, that is, control that is not related to the processing of stimulus patterns and content in the fixation area. Medium fixation durations are terminated 175-250 ms after the fixation onset. During these types of fixation durations, some information about the fixated-upon word can be processed, and if no difficulty with reading is detected, the next saccade is initiated. Although there is some controversy regarding the eye movement control related to medium fixation durations, there is empirical evidence showing that they are directly controlled. In other words, saccades are programmed during medium fixation durations based on the processed information. This is the main difference compared to early saccades that are thought to be programmed randomly or based on assumptions not related to the particular locations on which gaze becomes fixated. Long fixation durations, that is, exceeding 225-250 ms, are expected when some inappropriate aspects of a stimulus have been perceived. Normal saccades are then canceled or delayed, and the word can be additionally processed.

Although the existence of different fixation duration types is well confirmed in lexical studies (e.g., Feng et al., 2001), it is also reasonable to assume that similar types of fixation durations can be observed when viewing a scene. This assumption is based on a study by Luke and Henderson (2016) who argued that eye movement mechanisms during reading and viewing a scene are similar. Two types of fixation durations were also found during scene viewing in the study by Henderson and Pierce (2008); these authors observed relatively short fixation durations that were not influenced by stimulus perception and longer fixation durations, which were strictly dependent on stimulus delay (i.e., they were controlled by processing information related to a stimulus). Tatler and Vincent (2008) also suggested that the duration of fixation may depend on the position that a fixation has in the sequence of all fixations when viewing a natural scene and that at the end of a period characterized by local viewing, the duration of fixation is much shorter. On the other hand, the first fixation after the global "shift" of attention related to the long saccade is much longer than fixations during local scanning periods (Tatler & Vincent, 2008). Based on these findings, we assumed that looking at the image, at least two types of fixation durations with different functional meanings could be observed.

One of the problems that we addressed relates to the relationship between fixation duration and aesthetical evaluation. According to the model of aesthetic appraisal proposed by Silvia (2005), understanding of painting content and interest in it are essential factors influencing aesthetical evaluation. Therefore, in line with Silvia's model, the more informative and interesting the painting, the more aesthetically valuable it is perceived as. Because more information included in a painting requires longer processing, that is, longer fixation, the appraisal model predicts that aesthetical evaluation positively correlates with fixation duration. We expected that aesthetical evaluation would affect only particular types of fixation durations, that is, ones sufficiently long to process information related to aesthetical evaluation. Our hypothesis was partially supported by Molnar (1981), who found that viewing a painting under the aesthetical evaluation condition involves longer fixation durations compared to the semantic condition. Also, Glaholt et al. (2009) and Guo et al. (2019) found a significant positive association between aesthetical ratings of stimuli and fixation durations.

## Viewing Time

How much time people devote to looking at paintings? Research suggests that the answer to this question depends on the context. For example, Smith and Smith (2001) reported that in large museums, such as the Metropolitan Museum of Art in New York, the median viewing time was 17 s, while Brieber et al. (2014) observed a median viewing time of approximately 38 s during smaller art exhibitions. In the laboratory context, when paintings are presented on a monitor, the viewing time is significantly shorter (Brieber et al. 2014). The variance in viewing time also relates to factors not associated with the research context. The greater the size of the stimulus, the longer the viewing times due to stimulus complexity and novelty (Brieber et al., 2018). More ambiguous results refer to subjective factors that influence viewing time. Some studies suggest that stimuli evaluated as more attractive, emotionally arousing, and liked are perceived for a longer time than stimuli associated with negative experiences (Brieber et al. 2014). Other studies, however, showed no correlation between aesthetical evaluation and viewing time (Smith et al., 2006).

Another critical question refers to minimum time, after which aesthetical evaluation impacts the decision to stop or to continue viewing a painting. Neurophysiological correlations of aesthetical experience are observed at the very beginning of viewing a painting. Cela-Conde et al. (2013) proposed a two-stage processing of aesthetical information: the first is about 500-750 ms after the stimulus onset, while the second, involving the activation of the default mode network (DMN), begins about 1500 ms after the stimulus onset. The latter result is particularly interesting because the DMN is also observed during inner speech, and can be interpreted as a period when a person integrates and interprets information perceived at the earlier stage. In line with a study by Locher et al. (2007), people begin to verbally narrate their evaluation 3 s after the painting presentation on average. Therefore, we hypothesized that the minimum time required to report aesthetical evaluation involving the processes mentioned by Cela-Conde et al. (2013) is about 3 s.

## Spatial and Temporal Distribution of Attention While Viewing a Painting

When looking at an artwork, people direct their attention to its different parts, often referred to as areas of interest (AOIs). Sometimes people focus on one or a few AOIs on a painting. At other times, they distribute their attention across the entire painting, looking at many AOIs (e.g., [Locher et al., 2019](#)). Even if people look at many AOIs, some of them are looked at many times while other AOIs—only a few times (e.g., [Locher et al., 2007](#)). On the other hand, attention can also be equally distributed across a lot of AOIs, with no AOI drawing more attention than others (e.g., [Quiroga et al., 2011](#)). The distribution of attention when viewing a scene is known based on, for example, the study by [Francuz and Augustynowicz \(2016\)](#). We assumed that the complexity of a painting positively relates to its aesthetical evaluation ([Berlyne, 1971](#)). This suggests that viewing complexity, which may increase both when the number of AOIs attended to increases and when the distribution of attention between the AOIs is balanced (i.e., each AOI is looked at equally frequently), can also relate to aesthetical evaluation. However, we propose that both aspects of viewing complexity predict aesthetical evaluation in opposite directions. It means that the more AOIs and the less balanced the distribution of attention, the painting would receive a more positive evaluation. In other words, we expected that people would look at many AOIs on paintings they evaluate as beautiful, but their attention would not be equally distributed between these AOIs (some of them draw more attention).

As the spatial distribution of attention can reveal bottom-up processes related to the formal and content structure of a painting ([Findlay & Walker, 1999](#)), a temporal sequence of fixated-upon AOIs can reveal different strategies that people take while looking at a painting ([Wu et al., 2014](#)). For example, people can view a painting in a way resembling a “random walk,” that is, looking at each of the AOIs independently of the previous AOI. On the other hand, scan paths can be entirely predictable, for example when a fixation on a given AOI is always preceded by a fixation on another AOI, the same one every time. This kind of viewing is perfectly ordered and manifests intended information searching in the scene ([Krejtz et al., 2014](#)). Between these two extremes there are situations in which people can return to some AOIs more often than to others, can investigate some AOIs for a longer time than others, and can repeat the same sequences of fixated-upon AOIs several times ([Anderson et al., 2013](#)). We hypothesized that a positive evaluation of a painting relates to a successful integration or grouping of information from its different parts ([Chatterjee, 2011](#)), which results in an understanding of the artwork’s meaning. As the process of information integration and grouping requires some strategy in viewing the painting (e.g., refixating), we expected that a temporal sequence of fixated-upon AOIs in paintings evaluated as beautiful would be more ordered and structured than in paintings evaluated as non-beautiful. In other words, temporal sequences of fixations could reveal a top-down strategy of viewing a painting that facilitates its understanding. These strategies can manifest in a greater number of refixations and repeated sequences of fixations when viewing a painting.

In sum, the current study aimed to test several hypotheses regarding different time scales. At the level of simple fixation duration, we expected an effect of aesthetical evaluation only in populations of long fixation durations. At the higher level—the total viewing time, we hypothesized that the minimum viewing time affected by aesthetical evaluation is about 3 s after the presentation of a painting. Finally, we expected that, for paintings rated as beautiful as opposed to non-beautiful, attention would be distributed between a greater number of AOIs, with few AOIs capturing more attention than others and that the sequence of AOIs would be more structured.

To verify the hypotheses, we used data collected in our previous study ([Jankowski et al., 2018](#)). In that study, the participants viewed a series of 100 figurative paintings, and after looking at each painting, they reported how much they liked it. Eye-tracking data were recorded but not analyzed in [Jankowski et al. \(2018\)](#). We focused our previous study on the interaction between personality traits, expertise level, and formal characteristics of paintings as a predictor of its appreciation. Therefore, although the sample and the stimuli were the same, the results described below concern different problems and data.

## METHODS

### Participants

We recruited the participants through social media advertisements and information addressed to students and graduates of art studies. Forty people qualified for the survey: 19 experts (who met the criteria of higher education or currently study art history) and 21 laymen (people who did not attend an art course and did not show any interest in art in the initial interview). We informed each person of the general purpose of the study, its conditions, and remuneration (equivalent to 25 USD). Twenty-eight women and 12 men ( $M_{\text{age}} = 24.33$  years,  $SD = 4.07$ ) took part in the study.

### Stimuli

The starting point for selecting the final pool of images was a collection of 422 reproductions (dating from 16th to 19th century), selected from web resources by six competent judges (three experts in art and three nonexperts). At the next step, the selection criteria for the paintings included (a) moderate picture complexity (operationalized as the number of elements depicted), (b) a wide range of aesthetic ratings by the judges (unequivocally beautiful vs. non-beautiful paintings), and (c) a “narrative quality,” that is, the capacity to suggest to the viewer that the scene is a part of a developing story. The last criterion was important for analyses described in our previous study ([Jankowski et al., 2018](#)). Finally, based on the above criteria, 100 paintings depicting figurative art were selected to assess their aesthetic value.

### Apparatus

The paintings were displayed on a computer screen with a resolution of  $1680 \times 1050$  pixels ( $50.8 \times 33.1^\circ$  of visual angle). The SMI RED-500 (SensoMotoric Instruments GmbH, Germany) eye tracker

was used to record eye movements at a sampling rate of 250 Hz. Calibration accuracy was kept below 1° for each participant during all sessions. A dispersion-based fixation detection algorithm was used with the following parameters: minimum fixation duration = 80 ms, maximum dispersion = 100 px (SensoMotoric Instruments, 2011). The program for exposing paintings and registering the participants' reactions was written using E-Prime 2.0. The participants sat about 50 cm away from the screen and made their choices using a standard computer mouse.

## Procedure

We informed the participants about the study procedure and asked them to give their written consent to take part in the research. The participants looked at and assessed 100 figurative paintings presented in a random sequence. The time given to look at the paintings was not limited. Using the mouse, the participants evaluated the viewed painting on a scale from 0 to 5, which answered the question about how much they liked the painting.

## Data Analysis

Depending on the hypothesis and the timescale analyzed, we used different statistical techniques. To distinguish various populations of fixation durations when looking at a painting, we applied Gaussian mixture modelling (GMM; McLachlan, 1987). Divergence point analysis (DPA; Reingold et al., 2012) was used to determine the earliest effect of aesthetical evaluation on fixation duration and overall viewing time. Based on the entropy concept, we also computed two metrics described by Krejtz et al. (2014) to measure the complexity of the viewing process. Finally, recurrence quantification analysis (RQA; Anderson et al., 2013) was used to reveal strategies applied by the participants while viewing a painting. We will describe all these analyses in details in the relevant sections below.

## RESULTS

### Types of Fixation Durations While Viewing a Painting

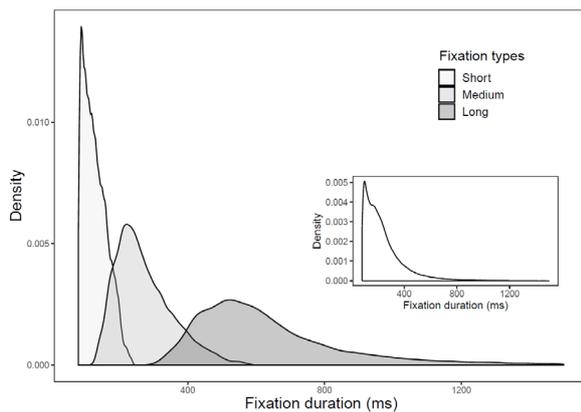
To determine whether different populations of fixation durations are mixed when looking at a painting, we used the GMM. This is a standard unsupervised clustering algorithm that makes it possible to uncover different groups of similar observations (in this case—durations of fixations). The GMM is a model-based technique that gives information about the uncertainty of classification results. It also enables a comparison between models with different assumptions (i.e., about the number of components, equality/difference in components variance, etc.). To determine the optimum number of fixation duration clusters, we used the Bayesian information criterion (BIC; Schwartz, 1978), the integrated complete-data likelihood criterion (ICL; Biernacki et al., 2000) and the bootstrap likelihood ratio test (LRTS; McLachlan, 1987). The analysis was

performed with the *mclust* package (Scrucca et al., 2016) in the *R* environment.

Before we analyzed the data, we removed the outliers, that is, fixation durations that exceeded 1500 ms, and log-transformed the raw data. Next, we group-centered the data (i.e., we subtracted single fixation durations from a participant's averaged fixation duration) to avoid finding fixation duration clusters that reveal differences between the participants instead of differences between processes manifested in fixation duration. To find the optimum number of clusters, we first compared the BIC values for models with different numbers of components. The BIC values indicated a five-cluster model as the most probable under the given data. The number of clusters in the model with the best BIC values exceeded theoretical assumptions (i.e., two or three clusters). Consequently, we suspected that models with more than three components may be over-fitted and might reveal spurious effects, that is, might identify clusters that overlap with each other, resulting in a high uncertainty of fixation duration classification. To verify this hypothesis, we computed an ICL index that includes information about uncertainty related to the clustering effects. The ICL suggested models with one to three clusters to be the best.

The last step included calculating the LRTS, which makes it possible to test formally whether a model with a higher number of components is significantly better fitted to data compared to a model assuming a smaller number of components. The LRTS showed that the model with two components explains the data structure significantly better than the model with only one component (LRTS = 2993.09,  $p < .001$ ). Moreover, the model with three components was significantly better fitted to data than the model with two components (LRTS = 1971.44,  $p < .001$ ). However, the model that included four clusters did not improve the fit compared to the model with three components (LRTS = -105.5,  $p < .99$ ). Finally, we chose a model suggesting three fixation duration clusters as the most probable considering the given data (logL = -104622,  $df = 6$ , BIC = -209313, ICL = -268392).

The model can be described by three kinds of parameters: (a) a mixing probability that defines the Gaussian function size for each fixation duration cluster, (b) a mean for each cluster that defines its center, and (c) a variance for each cluster that defines its width. Mixing probabilities for short, medium, and long fixation durations was .43 ( $N = 59124$ ), .47 ( $N = 67692$ ), and .09 ( $N = 10672$ ), respectively. Figure 1 presents density plots for three types of fixation durations observed in the study. The mean for short fixation durations was 129 ms ( $SD = 35$  ms, median = 126 ms, min = 80 ms, max = 236 ms). For medium fixation durations, the mean was 272 ms ( $SD = 83$  ms, median = 256 ms, min = 128 ms, max = 584 ms). Long fixation durations were distributed around the mean of 631 ms ( $SD = 207$  ms, median = 584 ms, min = 320 ms, max = 1500 ms). Durations of different types of fixations detected in the painting viewing task were longer than those observed by Yang and McConkie (2001) in the text reading task.



**FIGURE 1.**

Density plots for three populations of fixations observed in the present study. The density plot for unclassified fixations is also displayed as a small graph inside the main figure.

## Fixation Duration and Aesthetical Evaluation

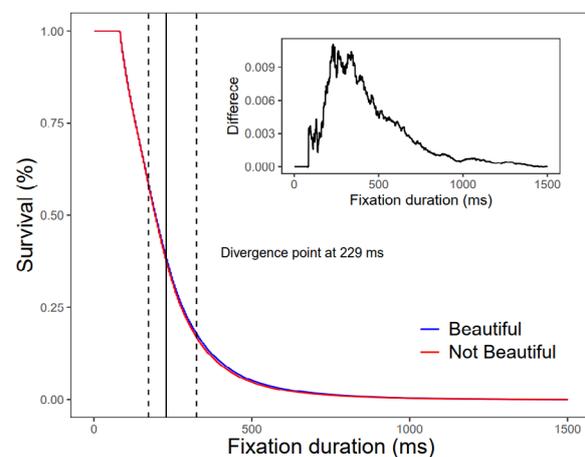
To test whether an aesthetical evaluation predicts fixation duration, we performed a multilevel regression with fixation duration averaged in a single painting viewing as a dependent variable and group mean-centered (within-subject) aesthetical evaluation as a predictor (see Table 2). The intercepts for the average fixation duration and the effect of aesthetical evaluation were nested in both painting and subject cross-levels (we treated them as random variables). We observed a large between-subjects ( $\sigma_{bs}^2 = 1091$ ) and within-subject variance ( $\sigma_{ws}^2 = 1324$ ) while the between-paintings variance was small ( $\sigma_{wp}^2 = 180$ ). The intercept (i.e., mean averaged fixation duration for neutrally evaluated paintings) was 233 ms. The fixed effect of aesthetical evaluation was significant but small ( $B = 1.42$ ,  $SE = 0.70$ ,  $\beta = .04$ ,  $p = .044$ ). This means that the higher the painting was evaluated in terms of aesthetical value, the longer average fixation duration was observed.

To test whether aesthetical evaluation affects fixation duration and—more precisely—what kind of fixation durations are affected by aesthetical evaluation, we performed a DPA. The DPA is a kind of distributional analysis method introduced by Reingold et al. (2012) to determine the earliest effect of an independent variable by contrasting survival curves across two levels of an independent variable. This technique uses a bootstrapping procedure to find the time point at which two survival curves diverge. Thus, in the case of the fixation durations distribution, the divergence point can be interpreted as the minimum detected time at which an independent variable (i.e., aesthetical evaluation) affects the saccade delay. The DPA procedure includes very conservative criteria aimed to avoid a Type I error (i.e., finding a divergence point too early). It also provides information on the interval at which an effect of an independent variable is significant. Therefore, this method seems to be very useful in determining which type of fixation duration is affected by aesthetical evaluation. We applied the RTsurvival package (Matsuki, 2019) in the R environment to compute an original version of the DPA.

As in the previous analysis (i.e., the GMM), we removed outlier fixation durations (i.e., ones exceeding 1500 ms) before performing the DPA. Because the DPA allows to compare only two conditions in one analysis,

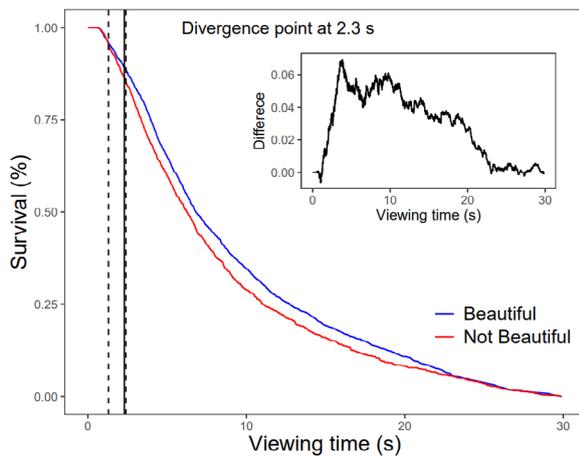
we additionally dichotomized aesthetical evaluation in two categories: non-beautiful (0, 1, and 2 points on the original scale) and beautiful (3, 4, and 5 points on the original scale). The data included 78458 fixations for the beautiful category and 37081 fixations for the nonbeautiful category. Next, we computed survival curves for fixation duration separately for beautiful and nonbeautiful categories. For each 1-ms time bin  $t$  (in a 0–1500 ms time window), the percentage of fixation durations that exceeded  $t$  constituted the percentage of survival at time  $t$ . The survival curves were computed separately for each participant and then averaged across the entire sample. Further, the value for each 1-ms bin in the nonbeautiful survival curve was subtracted from the corresponding point in the beautiful survival curve. This analysis was repeated with 10000 bootstrap samples. The bootstrap procedure allowed to compute 99% CI for the difference between beautiful and nonbeautiful survival curves at each of the 1-ms bins. The point that represented the earliest significant difference point (i.e., the 99% bootstrap CI did not include zero) and was part of a sequence of five consecutive difference points was identified as the divergence point (see Reingold et al., 2012).

The earliest significant divergence point between the survival curves for beautiful and nonbeautiful paintings was about 229 ms and the aesthetical evaluation effect was observed up to 1432 ms, with its maximum observed at 240 ms. Although the effect is subtle, it suggests that fixation durations of the first type (i.e., with a mean of about 129 ms) are too short to be used as a basis for distinguishing between beautiful and nonbeautiful paintings. The results suggest that to distinguish between beautiful and nonbeautiful images, certain micro-processes must be involved and these micro-processes require fixation durations longer than 229 ms.



**FIGURE 2.**

Survival curves contrasting fixation duration on paintings evaluated as beautiful (blue line) versus not beautiful (red line). The divergence point estimate is marked by vertical line (with two dashed lines indicating 95% CI), and it indicates the fixation duration from which survival percent was significantly greater for beautiful compared to not beautiful paintings. The difference between survival curves for paintings evaluated as beautiful vs not beautiful paintings (color lines) is shown in the top right section of the panel. The observed effect is subtle (the survival lines seem to overlap), but it is significant in the interval between 229 ms and 1432 ms, with a maximum at 240 ms.



**FIGURE 3.**

Survival curves contrasting total viewing time on paintings evaluated as beautiful (blue line) versus not beautiful (red line). The divergence point estimate is marked by vertical line (with two dashed lines indicating 95% CI), and it indicates the viewing time from which survival percent was significantly greater for beautiful compared to not beautiful paintings. The difference between survival curves for paintings evaluated as beautiful vs not beautiful paintings (color lines) is shown in the top right section of the panel. The effect was significant in the interval between 2.32 s and 19.58 s with its maximum at 3.82 s.

## Viewing Time

Before analyzing viewing times, we removed outliers, that is, durations exceeding 30 s. To test whether aesthetical evaluation predicts viewing time, we performed a multilevel regression with viewing time as a dependent variable and group mean-centered (within-subject) aesthetical evaluation as a predictor (see Table 2). The intercept for viewing time and an effect of aesthetical evaluation were nested in both painting and subject cross-levels (we treated them as random variables). A significant between-subjects variance and within-subject variance ( $\sigma_{bs}^2 = 30.2$  s and  $\sigma_{ws}^2 = 23.8$  s, respectively) was observed, while the between-paintings variance was smaller ( $\sigma_{wp}^2 = 1.3$  s). The intercept (i.e., mean viewing time for neutrally evaluated paintings) was 9.36 s. The fixed effect of aesthetical evaluation was significant but small ( $B = .49$ ,  $SE = .12$ ,  $\beta = .08$ ,  $p < .001$ ). This means that the higher the painting's aesthetic evaluation, the longer the viewing time (we also performed a parallel analysis using logarithmized values of viewing time and the results did not change).

To determine the minimum time required to notice an effect of aesthetical evaluation on the total viewing time, we performed a DPA using a distribution of 3467 viewing times and the procedure described above (Reingold et al., 2012). Two survival curves were compared: for paintings evaluated as beautiful and nonbeautiful. As in the previous case, to avoid making the type I error, we used conservative criteria: 10000 bootstrap samples, 99% CI, and a five-point sequence of significant divergence points required to detect the minimal divergence point.

Figure 3 presents survival curves for total viewing times in the beautiful and nonbeautiful evaluation categories. The DPA revealed that the minimal divergence point that detects the difference between survival curves for beautiful and nonbeautiful viewing time distributions was

about 2.32 s. The significant effect of the aesthetical evaluation was observed up to 19.58 s, and the maximal effect was detected by about 3.82 s. This means that the minimum time to make an aesthetical evaluation in the task was barely over 2 s and was optimal at about 4 s. However, the decision to evaluate a painting when it is being looked at could be prolonged up to about 20 s. On the other hand, viewing times longer than 20 s were not determined by aesthetical evaluation.

## Spatial and Temporal Distribution of Fixations

To describe the complexity of the sequence of AOIs, we computed two metrics described by Krejtz et al. (2014): the entropy of stationary distribution of AOIs and the entropy of AOI transition process. The stationary entropy reveals the extent to which the participants distribute their visual attention equally between the AOIs. Thus, it could indicate whether the participants' attention is focused on a few AOIs or whether the entire painting is viewed with equal visual attention. A value of zero means that the fixation involved only one AOI, while a higher value means a higher attentional balance between the AOIs. The dynamic entropy is computed based on a Markov chain describing probabilities of transition between the AOIs. It reveals whether the participants switch AOIs predictably or unpredictably. A value of zero means that each AOI is always preceded by the same AOI, while the maximum value means that the participants visually explore a painting in a very complex or even random way. Because the values of both stationary and dynamic entropy are sensitive to the number of viewed AOIs, we normalized both metrics by dividing them by maximum values possible to obtain in a given sequence of fixations. Controlling both the number of visited AOIs and two types of entropy allows to determine which aspect of complexity is related to aesthetical evaluation. Equations needed to compute both variables are included in the Supplementary Material.

To compute the stationary and dynamic entropy of a sequence of AOIs, we first divided each painting into a grid of 25 ( $5 \times 5$ ) rectangular AOIs ( $5.44 \times 3.40^\circ$  of visual angle for each grid element). Then, for each of the fixation sequences, we computed the number of fixated-upon AOIs, as well as values of the stationary and dynamical entropy. Descriptive statistics are shown in Table 1. As the data gathered in this study were hierarchical (observations cross-nested in the subjects and paintings), we estimated a multilevel model with an aesthetical evaluation factor (beautiful vs. nonbeautiful) as a predictor (see Silvia, 2005) for each of the three variables above. Multilevel models included random intercepts both for the subjects and paintings. Given that the distribution of stationary entropy was skewed, we transformed its values to achieve distribution normality (i.e., the scores were raised to a third power). All analyses were carried out in R using the lme4 package (Bates et al., 2015). Detailed results of multilevel analyses are presented in the Table 2.

Aesthetical evaluation positively predicted the number of fixated-upon AOIs ( $\beta = .06$ ,  $p < .001$ ) and negatively predicted stationary entropy ( $\beta = .06$ ,  $p = .002$ ), but did not predict dynamic entropy ( $\beta = .001$ ,  $p = .95$ ). This means that high aesthetical evaluation is related to at-

**TABLE 1.**  
Descriptive Statistics for Fixation Sequences

Variable	Beautiful paintings		Nonbeautiful paintings	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Fixation duration (ms)	234	55	231	51
Viewing time (ms)	9997	8282	8180	7154
Stationary Entropy	0.876	0.07	0.887	0.064
Dynamic Entropy	0.405	0.122	0.404	0.135
Number of AOIs	8.668	3.94	8.04	3.792
Recurrence rate	11.279	7.303	12.196	7.666
Determinism	33.206	19.36	31.8	19.185
Maximal determinism line	3.122	2.378	2.853	1.619
Laminarity	67.021	17.055	66.084	18.039
Clustering coefficient	1.57	4.49	1.29	4.09
Center of refixation mass	32.00	8.56	32.72	8.74

tention distributed in a relatively unbalanced way between many AOIs (i.e., some AOIs draw more attention than others). However, it seems to be unrelated to the predictability of AOIs switching.

## Fixation Sequence

We used the RQA (Anderson et al., 2013) to reveal strategies applied by the participants while viewing a painting. The RQA is a technique that enables describing the behavior of dynamic systems and has recently been used to analyze eye-tracking data (e.g., Wu et al., 2016). The RQA makes it possible to compute several measures that allow for examining temporal characteristics of fixation sequences. Based on the recurrence plot (Figures 4 and 5, Panel c), we computed six measures: recurrence rate (RR), determinism (DET), maximal determinism line ( $DET_{max}$ ), laminarity (LAM), clustering coefficient (CLUST), and the center of recurrence mass (CORM). The RR denotes the percent of recurrent fixations (i.e., the number of refixations). It can be interpreted as the tendency to draw attention back to the previously fixated-upon

AOIs. The DET represents the percentage of repeating gaze patterns in the recurrence diagram, with maximal repeated sequence indexed by the  $DET_{max}$  measure. Its interpretation refers to the tendency to look at a painting using repeating patterns of fixations and allows some relationships between the AOIs to be discovered. The LAM refers to the percentage of fixations that were rescanned in detail over consecutive fixations at a later time (e.g., several fixations later) or fixations that were first scanned in detail and then briefly refixated upon later. It can be interpreted as finding and focusing on particularly important AOIs. The CLUST indicates how many recurrences are the result of clusters of laminant points. Higher CLUST values indicate prolonged explorations of some group of AOIs in which both laminarity and determination occur at the same time. Lower CLUST values suggest that laminarity and determination are well-separated effects observed when viewing a painting. The CORM indicates whether most recurrent fixations are separated or close in time to the first fixation at a particular AOI. Thus, small CORM values mean that refixations occurred close in time, whereas large values indicate that refixations were separated by a relatively wide period. Equations used to compute the RQA measures can be found in the Supplementary Material.

Two fixations were considered recurrent if they were at a distance of 64 pixels from each other (see Wu et al., 2016). Based on this assumption, we computed the above RQA measures (see Figures 4 and 5). We applied multilevel models to predict each of these variables by aesthetic evaluation. As in the previous case, we allowed the intercepts in each model to vary across the subjects and paintings. Because of a non-normal distribution of RR, LAM, and CLUST, we transformed the former into squared values and we log-transformed the latter. In the case of the  $DET_{max}$  having a Poisson distribution, we used a generalized linear mixed model. As before, we performed all analyses in R using the lme4 package.

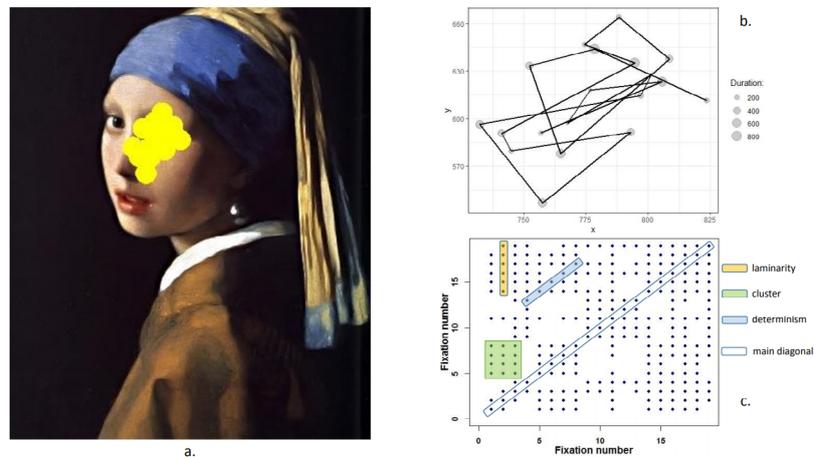
Aesthetical evaluation positively predicted DET ( $\beta = .05, p = .001$ ),  $DET_{max}$  ( $\beta = .03, p = .029$ ), LAM ( $\beta = .03, p = .067$ ), and CLUST ( $\beta =$

**TABLE 2.**

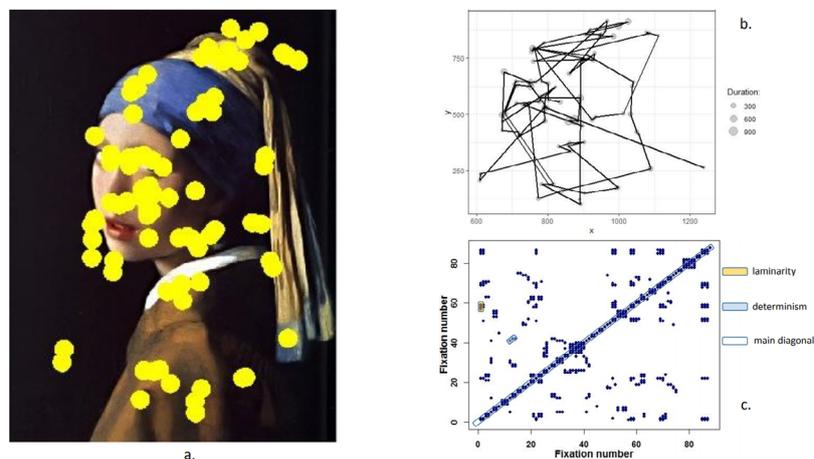
Results of Multilevel Models With Dichotomous Aesthetical Evaluation (0 = Beauty, 1 = Nonbeauty) as the Predictor of Several Stationary and Dynamical Parameters of Oculomotor Behavior During a Painting Viewing

Criterion variable	Fixed effects						Random effects				
	<i>B</i> (se)	$\beta$	<i>t</i>	<i>p</i>	<i>F</i> (1)	Marginal $R^2$	Conditional $R^2$	$\sigma^2$	$\tau_p$	$\tau_s$	
Fixation duration	1.42 (0.70)	0.04	2.02	.044	4.02	.001	.490	1324	180	1091	
Viewing time	0.49 (0.12)	0.08	3.94	< .001	15.48	.008	.572	23.8	1.3	30.2	
Number of AOIs	-0.45 (0.13)	-0.06	-3.51	< .001	12.33	.003	.610	5.95	2.26	7.15	
Stationary Entropy	-0.06 (0.02)	-0.04	-2.71	.007	9.6563	.002	.583	0.18	0.09	0.17	
Dynamic Entropy	< 0.01 (< 0.01)	< 0.01	-0.06	.952	0.0037	< .001	.160	0.01	< 0.01	< 0.01	
Recurrence rate	0.02 (0.03)	0.01	0.67	.505	0.445	< .001	.369	0.68	0.22	0.17	
Determinism	-2.16 (0.66)	-0.05	-3.28	.001	10.759	.003	.245	284.51	28.23	63.21	
Maximal determinism line	0.95 (0.03)*		-2.19	.029	5.222	.002	.283	0.32	0.02	0.12	
Laminarity	-117.59 (64.24)	-0.03	-1.83	.067	3.3508	.001	.254	2743888	278158	651876	
Clustering coefficient	-0.35 (0.09)	-0.06	-3.98	< .001	15.803	.004	.258	5.08	.43	1.31	
Center of recurrence mass	0.46 (0.30)	0.03	1.53	.127	2.332	.001	.174	61.65	3.45	9.53	

Note. \* = an estimate based on incidence rate ratios in general linear model;  $\sigma^2$  = residual variance;  $\tau_p$  = between-paintings variance;  $\tau_s$  = between-subject variance

**FIGURE 4.**

The figure presents Participant 32's fixations (a), the fixations map (b) and the recurrence plot for all fixations (c). Looking at this painting, the participant visited 3 AOIs (a). The analysis of the fixations map (b) indicates that the stationary entropy = .84 and dynamic entropy = .82. Points at the recurrence plot represents recurrent fixations (recurrence rate = 71.93); the long rectangle in the main diagonal represents self-recurrent fixations; small diagonals (an example of which is shown in the blue rectangle) represent the repeated sequences of (e.g. five) subsequent fixations (determinism = 89.43, maximal determinism line = 7); vertical lines (an example of which is shown in the yellow rectangle) represent fixations that was rescanned in detail at a later time (laminarity = 95.09); clustering coefficient indicating prolong periods of focusing on the same location = 67.25; the corm parameter indicating whether the particular AOIs were visited shortly vs. long after the first visit = 38.57.

**FIGURE 5.**

The figure presents Participant 29's fixations (a), the fixations map (b) and the recurrence plot for all fixations (c). Looking at this painting, the participant visited 14 AOIs (a). The analysis of the fixations map (b) indicates that the stationary entropy = .91 and dynamic entropy = .42. Points at the recurrence plot (c) represents recurrent fixations (recurrence rate = 5.46); the long rectangle in the main diagonal represents self-recurrent fixations; small diagonals (an example of which is shown in the blue rectangle) represent the repeated sequences of subsequent fixations (determinism = 45.45, maximal determinism line = 5); vertical lines (an example of which is shown in the yellow rectangle) represent fixations that was rescanned in detail at a later time (laminarity = 80.43); clustering coefficient indicating prolong periods of focusing on the same location = 1.28; the corm parameter indicating whether the particular AOIs were visited shortly vs. long after the first visit = 26.18.

-.06,  $p < .001$ ), but did not predict RR ( $\beta = .01, p = .51$ ) or CORM ( $\beta = .03, p = .127$ ). It means that the number of refixations are not related to aesthetical evaluation but that repeating the same sequences of fixated-upon AOIs significantly relates to higher aesthetical evaluation. Moreover, the longer the pattern of a repeated sequence of fixations, the higher the aesthetical evaluation of a given painting. As the LAM and CLUST coefficients indicate, detailed and prolonged observations of the chosen AOIs were also significantly related to the perception of painting beauty.

## DISCUSSION

The present study aimed to explore the relationship between the aesthetical evaluation of paintings and oculomotor behavior analyzed in two different timescales. We found several effects, most of them in line with our expectations. First, the distributional analysis of fixation durations suggests that there are three types of fixation durations when looking at a painting. They differ in terms of the mechanism delaying the triggering of a saccade. The shortest fixation durations last about 129 ms, the medium ones last about 272 ms, and the longest ones last about 631 ms. An effect of aesthetical evaluation can be detected at 229 ms after the fixation onset. This means that when viewing beautiful paintings, significantly fewer fixation durations of the first type were observed compared to those that were evaluated as nonbeautiful.

At the level of the total viewing time, a similar effect was observed as at the level of a simple fixation duration. The paintings evaluated as beautiful were contemplated for longer than paintings evaluated as nonbeautiful. However, as expected, the effect of aesthetical evaluation was observed not earlier than 2.3 s after the fixation onset, with its maximum at 3.82 s. It was observed further up to 19.58 s after the fixation onset. Thus, the results suggest that in the context of viewing a collection of 100 paintings in a laboratory, aesthetical evaluation is made in the time window of 2.3 s to 19.58 s after displaying a painting.

In addition, we explored the distribution of the participants' attention while looking at a painting. We expected a positive relationship between aesthetical evaluation and the type of viewing strategy that suggests grouping and integrating information in higher-order, meaningful chunks (Chatterjee, 2011). In line with this expectation, we found that in the case of paintings evaluated as beautiful, participants looked at more AOIs and their attention was distributed less equally across the AOIs compared to those not evaluated as beautiful. The analysis of scan paths indicated that the participants viewed paintings evaluated as beautiful in a more ordered way than paintings evaluated as nonbeautiful.

The results of this study can be discussed in the context of two main problems related to aesthetic experience and aesthetic appreciation. The first one considers aesthetical evaluation times, while the other is associated with cognitive activity during aesthetical evaluation.

## How Much Time is Needed to Make an Aesthetical Evaluation?

The present study aimed to explore the relationship between the aesthetical evaluation of paintings and oculomotor behavior analyzed in two different timescales. We found several effects, most of them in line with our expectations. First, the distributional analysis of fixation durations suggests that there are three types of fixation durations when looking at a painting. They differ in terms of the mechanism delaying the triggering of a saccade. The shortest fixation durations last about 129 ms, the medium ones last about 272 ms, and the longest ones last about 631 ms. An effect of aesthetical evaluation can be detected at 229 ms after the fixation onset. This means that when viewing beautiful paintings, significantly fewer fixation durations of the first type were observed compared to those that were evaluated as nonbeautiful.

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The answer to this question is not straightforward because of various findings from previous studies (e.g., Brieber et al., 2014; Cela-Conde et al., 2013; Locher et al., 2007). We believe that considering at least two timescales, that is, the perspective of simple fixation duration and the perspective of total viewing time can assist in finding a more comprehensive and concise answer, mainly because these two time perspectives make it possible to focus on different cognitive processes that contribute to aesthetical evaluation.

The results of our study suggest that only fixation durations longer than 229 ms are sensitive to the effect of aesthetical evaluation. If we assume that each fixation is analogical to looking at a new stimulus, this

result could mean that aesthetic evaluation is related to processes that begin about 230 ms after the stimulus onset, that is, after the fixations begin. This interpretation is congruent with the results of neurophysiological studies by Cela-Conde et al. (2013) that reveal a two-stage processing of information during aesthetic evaluation. Cela-Conde et al. (2013) proposed that fast aesthetic, appreciative perception, termed aesthetic appreciation sensu stricto, begins about 250 ms after the stimulus onset and is formed about 500 ms later. Further cognitive processes referred to as appreciation sensu lato occur in the 1000-1500 ms time window. Although the methodology used in our study does not allow for appreciation sensu stricto and sensu lato to be dissociated, the combined time window in which we observed the effect of aesthetic evaluation—229-1432 ms—precisely corresponds to the time window to be expected based on the neurophysiological findings. The results suggesting that only medium and long fixation durations are sensitive to the effect of aesthetic evaluation are further supported by Fudali-Czyż et al. (2018)'s study. Using the eye fixation-related potentials (EFRPs) methodology, they found differences in the amplitude of potentials (P2 and N2) between paintings evaluated as beautiful compared to those evaluated as nonbeautiful, but only in the focal mode, that is, in the case of long but not short fixation durations.

The effect of aesthetic evaluation was also observed at the level of total viewing time. It was detected 2.3 s after the beginning of painting presentation and was observed for about 18 s. This result is congruent with findings by Locher et al. (2007) who observed that participants asked to evaluate a painting verbally usually begin their narration about 3 s after the presentation of a painting. We propose that making an evaluative judgment—if not expedited by experimental instructions—involves self-talk that requires at least 2 s to be prepared. Moreover, the more beautiful a painting is perceived as, the more time is devoted to contemplating it. Analyses of the distribution of spatial and temporal fixations suggest some processes that discriminate between paintings evaluated as beautiful and as nonbeautiful.

## What Processes Contribute to Positive Aesthetic Evaluation?

The effects of aesthetic evaluation were observed both in the simple fixation duration timescale and in the total viewing timescale. As fixation durations are longer in the case of beautiful paintings, the total viewing time is also longer. We propose that while making aesthetic evaluations, people process information in parallel at several levels. At the level of a simple fixation duration, attentional processes play the central role—they make it possible to explore pieces of information located in a small part of a painting and information that captures attention more profoundly, and can be used as a base for aesthetic evaluation. The presence of a higher number of long fixation durations in the case of beautiful paintings suggests that the length of fixations while viewing a painting does not represent the fluency of processing, but probably indicates more comprehensive processing. This supports the appraisal model of aesthetic experience by Silvia (2005). Comparing these results to the findings from lexical studies, where long fixation durations are often interpreted as an index of processing

difficulty (Yang & McConkie, 2001), we emphasize that looking at a painting is a different mental activity than reading a text. Long fixation durations during the aesthetic evaluation of paintings can enable cognitive processes related to a default network system observed in the time window of 1000-1500 ms after the stimulus onset (Cela-Conde et al., 2013). These processes, identified as aesthetic appreciation sensu lato, are observed only in the case of paintings perceived as beautiful (Cela-Conde et al., 2013). Additionally, in the study by Francuz et al. (2019), average fixation duration in an aesthetic evaluation task was positively predicted by average fixation duration in a task involving a search for a mystery in a painting as well as a task of inventing a title for a painting. These results suggest that instead of indicating a struggle with processing, longer fixation durations observed for beautiful paintings can reveal attempts to give meaning to intriguing content.

Analyzing sequences of all eye fixations when looking at a painting, we found that the more elements on the painting that capture attention and the less balanced distribution of attention across these elements, the more beautiful a painting is perceived as. This effect is partly congruent with Berlyne's (1971) theory claiming that the complexity of a painting is a good predictor of aesthetic appreciation. In our case, we can refer to complexity of viewing (manifested in a number of visited AOIs) than complexity of a painting. Effects of DET, LAM and fixation clustering suggest that people find meaningful connections between salient elements of a beautiful painting (i.e., they repeat the same patterns of fixated locations, as revealed by the DET measure). Thus, particularly beautiful paintings capture most attention in a few AOIs. However, they also have complex backgrounds that are viewed less extensively. In other words, people focus on essential elements of a beautiful painting, though not neglecting its other elements. We suggest that these results indicate the top-down processes described in Chatterjee's (2011) model of aesthetic experience as grouping small pieces of information into sensible chunks. The higher RR, DET and LAM observed for paintings evaluated as beautiful could indicate that the more informative a painting is, the more positively it is evaluated. Thus, the main conclusion from our study is that perceiving a painting as beautiful is a process involving a combination of the complexity of information found in a painting and a successful integration of such information into a meaningful story.

Subsequent research should investigate several issues that were not possible to address in the present study. For example, it is not clear whether aesthetic evaluation drives oculomotor behavior or whether the manner people look at a painting leads to aesthetic evaluation. There is a third possibility—oculomotor behavior and aesthetic evaluation interact with each other. Further experimental research using both dynamic measurements of aesthetic evaluation and eye-tracking could resolve this problem. The present study was also limited to figurative paintings. Therefore, it should be replicated on other sets of artworks, for example, abstract paintings. In future research, familiarity of the paintings should be also taken into account, because it can moderate effects related to oculomotor behavior. However, we believe that the findings presented in this study refer to basic processes that can be generalized to aesthetic evaluation per se.

## ACKNOWLEDGEMENTS

We thank Agnieszka Fudali-Czyż, Małgorzata Łysiak, Natalia Kopiś, Anna Szymańska for their help with discussing and conducting this study. The study was funded by a National Science Centre (Poland) grant UMO-2013/11/B/HS6/01816, "Psychological and neurophysiological determinants of aesthetic judgments."

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RECEIVED 08.10.2019 | ACCEPTED 20.07.2020

## SUPPLEMENTARY MATERIAL

To compute stationary and dynamic parameters of a fixation sequence, we used following equations. Two of them – first and second – was based on the article by Krejtz et al. (2014), while the next were based on the article by Anderson et al. (2012).

1. Stationary entropy ( $H_s$ ) can be defined as:

$$H_s = - \sum_{i \in S} \pi_i \log_2 \pi_i$$

where  $\pi_i$  is the stationary probability of AOI  $i$  in the set of AOIs  $S = \{1, \dots, s\}$  (i.e. probability of fixation at AOI  $i$ ).

2. Dynamic entropy ( $H_t$ ) can be defined as:

$$H_t = - \sum_{i \in S} \pi_i \sum_{j \in S} p_{ij} \log_2 p_{ij}$$

where  $\pi_i$  is the stationary probability of AOI  $i$  and  $p_{ij}$  means probability of transition from the AOI  $i$  to the AOI  $j$  in the set of AOIs  $S = \{1, \dots, s\}$ .

3. Recurrence rate (REC) can be defined as:

$$REC = 100 \frac{2R}{N(N-1)}$$

where  $N$  is the number of fixation in the sequence and  $R$  is the sum of recurrences in the upper triangle of the recurrence plot.

4. Determinism (DET) can be defined as:

$$DET = 100 \frac{|D_L|}{R}$$

where  $D_L$  the number of diagonal lines of length at least  $L$  (in our case  $L = 2$ ), and the  $R$  is the sum of recurrences in the upper triangle of the recurrence plot.

5. Laminarity (LAM) can be defined as:

$$LAM = 100 \frac{|H_L| + |V_L|}{2R}$$

where  $H_L$  and  $V_L$  are numbers of horizontal and vertical lines of length at least  $L$  (in our case  $L = 2$ ), and  $R$  is the sum of recurrences in the upper triangle of the recurrence plot.

6. Clustering coefficient can be defined as:

$$CLUST = 100 \frac{2CR}{N(N-1)}$$

where  $CR$  is the sum of clustered recurrences and  $N$  is the number of fixation in the sequence.

7. Center of recurrence mass measure (CORM) can be defined as:

$$CORM = 100 \frac{\sum_{i=1}^{N-1} \sum_{j=1}^N (j-i)r_{ij}}{R(N-1)}$$

where  $N$  is the number of fixation in the sequence,  $R$  is the sum of recurrences in the upper triangle of the recurrence plot, and  $r_{ij}$  takes a value of 1 if there is a recurrence between fixation  $i$  and  $j$ , and a value 0 in the case of no recurrence.

## REFERENCES

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- Krejtz, K., Szmidt, T., Duchowski, A. T., & Krejtz, I. (2014). Entropy-based statistical analysis of eye movement transitions. In P. Qvarfordt, & D. W. Hansen (Eds.), *ETRA '14: Proceedings of the symposium on eye tracking research and applications* (pp. 159–166). ACM. doi: 10.1145/2578153.2578168

## List of Paintings Used in the Study

No.	Title	Author
1.	Waiting by the Window (before 1935)	Carl Holsoe
2.	Rainy Day, Boston (1885)	Childe Hassam
3.	The Hiker above the Sea of Fog (1817)	Caspar David Friedrich
4.	The Bridesmaid (between 1883 and 1885)	James Tissot
5.	A Meeting on the Bridge (before 1924)	Emile Claus
6.	The Captain's Daughter (1873)	James Tissot
7.	At Dusk (Boston Common at Twilight) (between 1885 and 1886)	Childe Hassam
8.	The Kiss (1859)	Francesco Hayez
9.	The Wind (between 1849 and 1935)	Jean Beraud
10.	Paris, a Rainy Day (1877)	Gustave Caillebotte
11.	Woman of the Artist at a Window (1900)	Carl Holsoe
12.	Under the Roof of Blue Ionian Weather (between 1898 and 1901)	Lawrence Alma-Tadema
13.	Lady in a Garden (between 1852 and 1922)	Edmund Blair Leighton
14.	Souvenir de Mortefontaine (1864)	Jean-Baptiste-Camille Corot
15.	At Home (1864)	Julius Leblanc Stewart
16.	Lost In Dreams (1835)	Friedrich von Amerling
17.	Clamming (circa 1890)	Daniel Ridgway Knight
18.	Her Best Friend (1882)	Émile Munier, 1882
19.	Christina's World (1948)	Andrew Wyeth
20.	Reading the News (circa 1874)	James Tissot
21.	Two Children (1888-1889)	Eugene de Blaas
22.	Grossglockner (1857)	Marcus Pernhart
23.	Young Savoyard Eating Under a Door (1877)	Pascal Adolphe Jean Dagnan-Bouveret
24.	The Thorn (1886)	Charles West Cope
25.	Volga Boatmen (1870-1873)	Ilya Efimovich Repin
26.	Ophelia (1883)	Alexandre Cabanel
27.	Une averse (1887)	Childe Hassam
28.	Street In The Old Town (1873)	Alphonse de Neuville
29.	Le Désespéré (circa 1843)	Gustave Courbet
30.	The Black Brunswicker (1860)	John Everett Millais
31.	The Broken Pitcher (1891)	W i l l i a m - A d o l p h e Bouguereau
32.	Doctor (1891)	Luke Fildes
33.	A Special Moment (1874)	Emile Munier
34.	The Resting Sentinel (between 1859 and 1913)	Paul Joanovitch
35.	Unexpected visitors (1885)	Ilya Efimovich Repin
36.	Portrait of a Young Lady (1885)	Albert Edelfelt
37.	The Girl With The Pearl Earring (1665)	Johannes Vermeer
38.	Blowing Bubbles (between 1882 and 1966)	Bernard Pothast
39.	American Painting Auction (1934)	Daniel Greene
40.	Fur Traders Descending the Missouri (circa 1845)	George Caleb Bingham
41.	An Accident - Walters (1879)	Pascal Adolphe Jean Dagnan-Bouveret
42.	A Girl and her Duenna (between 1655 and 1660)	Bartolomé Esteban Murillo
43.	Discussing The Talmud (between 1854 and 1921)	Kaufmann Isidor
44.	The Sad Message (1838)	Peter Fendi
45.	An Interesting Story (1872)	James Tissot
46.	Out In The Cold ( before 1908)	Perrault Leon

No.	Title	Author
47.	Man in a Room (circa 1629)	Follower of Rembrandt
48.	The Spectators, 1877	Pascal Adolphe Jean Dagnan-Bouveret
49.	Negro with Parrots and Monkeys (1670)	David Klocker Ehrenstrahl
50.	Marriage (circa 1743)	William Hogarth
51.	The Bird Charmer (1873)	Perrault Leon Jean Basile
52.	Widowed and Fatherless (1888)	Thomas Benjamin Kennington
53.	The Calling of Saint Matthew (circa 1599-1600)	Michelangelo Merisi da Caravaggio
54.	Bonjour Monsieur Courbet (1854)	Gustave Courbet
55.	Ballet Class (1880-1881)	Edgar Degas
56.	Joseph Proudhon and His Children (1865)	Gustave Courbet
57.	Pelt Merchant of Cairo (1869)	Jean Léon Gérôme
58.	St John of Nepomuk Hearing the Confession of the Queen of Bohemia (1712)	Giuseppe Maria Crespi
59.	The Botanist (circa 1855)	Carl Spitzweg
60.	Automat (1927)	Edward Hopper
61.	Lady Maidservant Holding Letter (circa 1666-1667)	Johannes Vermeer
62.	The Return of the Prodigal Son (1669)	Rembrandt Harmenszoon van Rijn
63.	The Drinkers (1908)	Jean Béraud
64.	La Cuoca (after 1712)	Giuseppe Maria Crespi
65.	Cardsharps (circa 1594)	Michelangelo Merisi da Caravaggio
66.	Anna and the Blind Tobit (circa 1630)	Rembrandt Harmenszoon van Rijn
67.	Bouderie (Gustave Courtois in his Studio) (1880)	Pascal Adolphe Jean Dagnan-Bouveret
68.	Children at the River	Borrego Ruiz
69.	The Broken Jug (between 1833 and 1922)	Leon Bonnat
70.	Christus im Hause seiner Eltern (1850)	John Everett Millais
71.	The Promenade (1870)	Pierre-Auguste Renoir
72.	An Interesting Story (1863)	Eugen de Blaas
73.	The Death (1902)	Jacek Malczewski
74.	Dancer Posing for a Photographer (1875)	Degas Edgar
75.	The Fortune Teller (1760)	Gaspere Traversi
76.	The Fate (1920)	Alphonse Mucha
77.	Old Woman Frying Eggs (1618)	Diego Velázquez
78.	The Lock (1776)	Honoré Fragonard
79.	Old Man and a Child (after 1750)	Gaspere Traversi
80.	The Inn of Mother Anthony (1866)	Pierre-Auguste Renoir
81.	Portrait of M. and Mme. Auguste Manet (1860)	Édouard Manet
82.	The Dead Toreador (1865)	Édouard Manet
83.	Bretons Praying (1888)	Pascal Adolphe Jean Dagnan-Bouveret
84.	The Geographer (circa 1668)	Johannes Vermeer
85.	Hotel by A Railroad (1952)	Hopper Edward
86.	Polonia II (1914)	Jacek Malczewski
87.	The Grain Sifters (1854)	Gustave Courbet
88.	A Boor Asleep (first half of 17th century)	Adriaen Brouwer
89.	The Blue Boy (1770)	Thomas Gainsborough
90.	Potato Eaters (1885)	Vincent van Gogh
91.	Rebecca at the Well (circa 1740)	Giovanni Battista Piazzetta
92.	The Loveletter (circa 1669-1670)	Johannes Vermeer
93.	The Breakfast at Berneval (1898)	Pierre-Auguste Renoir

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No.	Title	Author
94.	Countess Mathieu de Noailles (1913)	Ignacio Zuloaga
95.	Absinthe (1876)	Degas Edgar
96.	The Lunch (1617)	Diego Velázquez
97.	The Box (1874)	Pierre-Auguste Renoir

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No.	Title	Author
98.	Luncheon in the Studio (1868)	Édouard Manet
99.	Malle Babbe (1869)	Gustave Courbet
100.	Peasant Boy at a Market (before 1754)	Giovanni Battista Piazzetta

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