Modeling Perceptual Organization in Abstract Art Using Eye Tracking Data

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ABSTRACT

The review of quantitative studies of Gestalt principle of proximity modelling perceptual organization showed insufficient evidence of its consistency in different contexts. Most of the methods mentioned the use of eye tracking as a viable alternative approach to quantify perceptual organization through clustering of gaze movements, specifically fixations of participants. The domain in which these studies are conducted includes the perception of artistic paintings. Subjectivity of visual perception may be explained by the differences in participants' gaze behaviors and art expertise. Based on their limitations, further research was seen to determine whether Gestalt grouping principles can neutralize subjectivity between experts and novices while viewing art. This study reveals novice and advance participant gaze clustering are likely equal, although having low adherence to the Gestalt grouping principle of proximity.

KEYWORDS

Gestalt theory, visual perception, eye tracking, abstract art

1 INTRODUCTION

Human beings have the innate capacity to generate groupings out of relevant structures from complex visual images without previous knowledge of its components [6]. This ability is known as *perceptual organization*. Perceptual organization occurs when disjoint objects are perceived as a single, unified whole [20]. Gestalt theory proposes that the perceptual process is *wholistic* and integrative, that human beings perceive wholes rather than the parts [3, 7, 14]. Max Wertheimer, one of Gestalt's founders, discovered several Gestalt laws of perceptual grouping that come into play in the perceptual process including the principle of proximity [6, 14, 21]. It was stated as the tendency of human beings to perceive closely grouped objects to be more related than distant objects.

Because of the subjective nature of perception, there were criticisms to the consistency of Gestalt grouping principles in various contexts. First, demonstrations of Gestalt theorists used stimuli with low naturalness or *ecological validity* to represent real-life objects [23]. Second, Gestaltists have not specified how perceptual organization can vary depending on differences, such as age, experience [11] and circumstance, among individuals. In the context of art appreciation, varying levels of art expertise between novice and expert can have an impact on the way the work is perceived [17, 19]. Experts tend to have a greater capability to detect patterns than novices [12]. For them, experience had strong significance in shaping human perceptual development concerning a cognitive aspect in perception [15, 18, 23]. Yet, Gestaltists denied the existence of the influence of past experiences and cognition in all perceptual experiences [9, 11].

Understanding how humans make use of vision to acquire specific information from an environment with visual noise is one of the difficulties cognitive sciences tries to solve [5, 8, 22]. In fact, questions regarding how the brain processes visual information [10] and how these are organized to make representations of faces, objects, and art [4] remains unanswered [23]. Although several theories of perception such as Gestalt theory [16] have been used to explain perceptual organization, these still lack quantitative models that are needed in various fields such as computer vision [1, 13]. Unless there are quantitative approaches to perceptual grouping, the challenge for computer vision research to efficiently understand features in the real world remains without finding how important visual information is organized.

One possible means of building these quantitative models is using eye tracking data. Pedreira and Quiroga's eye tracking study, *How Do We See Art*, attempts to bridge science and arts by quantifying how subjects view paintings [4]. This paper follows up on Pedreira and Quiroga's findings by analyzing subjects' gaze movement variability to determine the effect of their level of expertise in art on their gaze behaviors when viewing abstract art. Specifically, the paper uses Gestalt grouping principles to find whether these principles promote uniformity in visual perception and perceptual organization based on the compliance of subjects' gaze behaviors. In section 2, related work is described. The paper provides conclusion and future work in section 6.

2 RELATED WORK

2.1 Eye Tracking and Gestalt Principle of Proximity

An alternative method to quantify visual perception is through eye-tracking. In a bottom-up approach, eye gaze data can be used to validate the effects of the principle of proximity. Gaze movements identify informative details of a stimuli [27, 26] that report cognitive factors such as areas of interest relating to their attention. Thus, gaze movements can provide a general analysis of hypotheses and can evaluate the variability of individual gaze behaviors [28].

Alfred Yarbus states how human thought processes can be observed through their gaze behaviors from their perception of complex objects [28]. According to Yarbus, gaze movements accompany attention fixation (on stationary object's elements) [28]. These gaze movements may be in the form of voluntary or involuntary saccades measuring from a duration of at least 0.01 to 0.07 seconds depending on its amplitude of approximately 20 rotational degrees [29, 28]. These series of saccades change into different areas of fixation of the perceptual field to a feature element of perception [28]. Thus, fixation points derived from saccades can possibly present feature elements perceived as clusters or regions of interest as proposed by Gestaltists.

More recent studies specified a definite real-life context by viewing a more natural stimulus such as abstract and representational paintings. These studies used eye tracking as inputs to computational models clustering eye gaze data into regions of high interest or attention which may indicate a subject's compliance to basic image concepts and Gestalt grouping principles. Khushnood Naqshbandi et. al. studied application of automatic clustering models for eye gaze data [30]. These clustering algorithms operate similar, if not equal to, the principle of proximity. They used k-means and a density-based clustering algorithm, OPTICS, to cluster gaze points from a static stimulus before their classification. Although both performed well, their application of OPTICS gave higher success rates compared to k-means with proper hyperparameters [30]. The study used Seeing Machines FaceLAB 5 infrared cameras as gaze sensors, performed calibration and used three paintings as their stimuli [30].

2.2 Applications of Eye Tracking and Gestalt Theory on the Principle of Abstract Art

A domain in which methods quantifying perceptual organization can be tested is by studying how humans perceive art. Art history has had research on gaze movements since the sixth century [29]. In fact, psychological research on visual perception used gaze data based on artistic paintings as stimuli. The first eye tracking experiment was done by Guy Buswell in 1935 where he recorded eye tracking data from 200 individuals who viewed different paintings, drawings, and other works of art [29]. Even so, his results were not able to derive conclusions solely related to aesthetic sciences and psychology [29].

Raphael Rosenberg and Christoph Klein expressed similar findings from Buswell. Their conclusions emphasized a high regard for variation between individuals, especially between experts and novices [15]. Another eye tracking study by Carlos Pedreira and Rodrigo Quiran Quiroga attempts a more in-depth analysis of variations of participants' gaze movements by observing their compliance to art principles while viewing art [4]. Their findings show that participants' gaze behaviors behaved similarly while viewing the original version of Composition II in red, blue, and yellow and had varying gaze behaviors when viewing its modified version [4]. Pedreira and Quiroga's discussion concludes basic uniformity in their participants' gaze behaviors [4]. However, participants' prior knowledge of the artwork generated large variability in their results [4].

The high level of subjectivity observed in the method applied by the preceding studies may be explained by studying the function of art as discussed by Patrick Cavanaugh. According to Cavanaugh, the creation of art by artists makes the artist a practitioner of physics by representing real world elements into his or her artwork [31]. Like the function of the visual brain, the function of art allows us to search for "essential and enduring features of objects, surfaces, faces, situations, and so on, which allows us to acquire knowledge" [8]. To facilitate this acquisition of knowledge, artists allow the beholder of their art to view their creation from their own perspective through different techniques like abstraction.

Rudolf Arnheim discusses the concept of perceptual abstraction in art in his works [8]. According to Arnheim, children manifest abstraction in perception as a basic operation [33, 32]. To illustrate, he takes note of how children represent human faces as circles [32]. The use of this type of representation (of children) denotes an abstraction of the face as a round object.

Definitions of perceptual abstraction and current studies on abstract art generate questions of opposition. Do gaze movements (in a specific context such as abstract art) present uniformity based on principles at a minimum as demonstrated by Pedreira and Quiroga? Or do these present subjectivities between differences of individuals, especially experts and novices? Current work on Gestalt perceptual organization and eye tracking does not account for all contexts. Specifically, further research is needed to determine whether Gestalt accounts for all levels of expertise.

3 METHODS

3.1 Structure of the Study

In this study, the research design uses a triangulation research design model to analyze qualitative and quantitative data: pre-test questionnaire, post-test interview and eye-tracking data. The pre-test questionnaire is used to evaluate participants' art expertise and background, and to classify participants to novices and experts. An eye tracking experiment is conducted for both novice and expert groups to gather quantitative data on their gaze behavior while viewing digital abstract art. The post-test interview serves to validate quantitative comparison of novice and expert gaze behaviors including their fixation data and scanpath patterns, and to enhance comprehensive evaluation of the effects of proximity in their gaze behaviors. With this method, the chosen model shall answer the research questions: "how can Gestalt grouping principle of proximity be quantified in the context of abstract art?", and "to what extent does the level of expertise in art affect the Gestalt grouping principle of proximity when viewing abstract art?".

Before the actual testing, a pre-test is conducted to determine modifications in the materials used in the study. During the pre-test, the research protocol is performed as designed. Data gathered in the pre-test is used to test instruments and procedures and is not included in the final dataset. Finally, the research protocol is executed for actual testing based on modifications in the instruments and procedures based on the test data.

3.2 Selection of Stimuli

To select the appropriate set of non-representational abstract art, two classically or formally trained art studies experts proficient in art criticism are consulted. First, one expert is asked to aid in the selection of the stimuli based on two criteria. The abstract art print must exhibit both Gestalt proximity effects and art composition relationships which can also be analyzed by experts using any other formal criteria they may have while viewing art. To reduce bias in artistic styles, prints are chosen from varying artists but not limited to a specific period. Lastly, the second consultant shall verify and review the validity of the selected prints based on the criteria mentioned. Only six prints from the master list must be selected as part of the shortlist of the stimuli for the experiment. To guide, a formal document is provided to each consultant including the objectives of the study, the instructions for the selection of prints, and an informed consent form.

Figure 1: Sample art print “Untitled/5” by Antonio Lorenzo

To be able to determine areas of interest (*AOI*), consultants are asked to mark their expected clustered regions on each stimulus based on their evaluation of the abstract art prints. These shall be the bases to computationally determine groupings based on the principle of proximity. To do this, digital versions of the stimuli are resized to fit the dimensions of the screen. Each stimulus is assessed using a K-Means image clustering technique. Clusters formed from the algorithm are adjusted based on the validation of the consultants against their expected clustered regions.

3.3 Eye Tracking Experiment

The eye tracking study is performed remotely through Zoom Conferencing Tool as compromise to the situation caused by the 2019 N-Coronavirus. The room and environment of the remote participants must be well-lit, enclosed, and silent for the duration of the experiment. For this study, different integrated and standalone non-infrared webcams with varying resolution qualities are used under RealEye Eye Tracking Software to provide a higher accuracy rate regarding webcam differences. Each webcam must have at least 640 x 480 resolution (low-image granularity) at 720p and 30 FPS to meet the minimum requirements of RealEye. The eye tracking solution also requires running in Google Chrome web browser. This solution gathers data online and can be retrieved or exported by the researcher. Exported data includes raw gaze data, fixation duration, coordinates, and summaries of fixation data per stimulus.

Table 1: Participant Count per Educational Degree

Participant Degree	Count
Information Design, Art Management	8
Information Systems, Computer Science	4
Management, Economics	3
Legal, Political Science	4
Illustrator	1

20 participants composed of university graduates and college undergraduate students are asked to participate as volunteers for the study. Participants of the study were selected through convenience sampling and are male and female and are from 18 to 32 years old, with excellent visual acuity and good contrast sensitivity. Participants are asked to read and sign the informed consent form containing the purpose of the study, a description of the experiment and the rights of the participants to serve as a formal document of the communication between the researchers and the participants.

Participants who agree to carry on with the experiment are asked to answer a pre-test questionnaire which includes:

- Participant Demographic: Age, Sex, and Course
- Visual Acuity
- Background in Art Principles or Formal Education
- Background in Contemporary and Abstract Art Works

To protect their privacy, each participant was identified only based on their control number in the questionnaire. The questionnaire is adjusted specific to the academic expectations of a consultant art appreciation instructor in the university to evaluate art expertise of the participant. Aside from formal art background, participants’ knowledge in artistic principles and elements are further evaluated based on 12 multiple choice questions which consists of basic principles, and elements of art and design: Principles of Design (2), Principles of Art (5), Elements of Art (5). Additionally, participants are asked to provide a self-assessment of their perceived expertise and appreciation in art based on a Likert scale with weighted scores of 1 (Strongly disagree) to 5 (Strongly agree). Participants who correctly answered at least 10 out of 12 multiple choice questions and have scored at least a mean score of 4.0 in their self-assessment are considered as “experts”. Both criteria must be met to be considered as an expert. Participants who scored otherwise are considered as “novices”.

Each participant is informed of a free viewing of six abstract art in succession and has exactly 30 seconds viewing time per stimulus. For every participant, the viewing sequence of stimuli is randomized and is asynchronous. Once all art prints have been shown, participants are interviewed. The interview includes an evaluation of the participant’s familiarity of each abstract art shown, perceived aesthetic qualities of the art, perceived prominent areas of the art and their viewing criteria for each print. Participants are provided digital copies of the abstract art shown for their annotations during the demonstration. Furthermore, participants are asked regarding observance of the presence of Gestalt principle of proximity. Specifically, they are asked whether they were able to distinguish grouped components in each art print.

3.4 Scanpath Pairwise Distance Analyses

Participants' scanpath were compared against participants within each sample group and against each sample group to measure effects of art expertise using Eyenalysis. First, the denoised raw gazes eye tracking data from RealEye was transformed to retrieve the scanpath for each participant per art print viewed. The transformed data was a dataset consisting of a dictionary where each dictionary entry is a single named scanpath. A scanpath consists of a list of points. A point consists of a list of coordinates. This scanpath data was grouped per art print for analysis, and this was categorized based on participant sample group.

The transformed data was derived to determine the pairwise distance between the raw gazes of all participants against other participants. Specifically, the pairwise distances were calculated using the cross-compare function of the Eyenalysis Python Library to validate the statistical significance of intra and inter sample group scanpath similarities with respect to measuring the effects of art expertise. Eyenalysis is a modified Mannan linear distance method which compares fixation positions based on spatiotemporal similarity [24]. Since the original Mannan linear distance only maps each coordinate of a scanpath set to its nearest neighbor from another scanpath set without considering fixation order or sequence [24], Eyenalysis uses timestamp of each coordinate to measure similarity between sequences of fixation positions without considering the pre-defined areas of interest [24]. Similarity of scanpath is measured based on their distance measure. A scanpath with a distance measure D of 100 pixels are considered similar as proposed by the author of the algorithm, Sebastiaan Mathot [25]. The distance measure is given by the equation function [26]:

$$D(S,T) = \frac{\sum_{i=1}^{n} d_S^i + \sum_{j=1}^{n} d_T^j}{\max(n_S, n_T)}$$

where d is the distance calculated for each point in scanpath S and T. To determine variance within participant categories, participants' scanpath of each group are compared. Each participant's scanpath is compared against the scanpath of all participants within their group using Eyenalysis.

For both participant groups, standard deviation SD is computed using ANOVA for all stimuli to determine the spread of the distribution between scanpath within groups.

The pairwise distances of the sample groups were compared against each other using Welch's t-Test per art print to confirm there is no statistical significant difference between the gaze behavior of non-art participants and participants with formal background in art. Specifically, the test was used to determine the mean statistical difference of the gaze behavior of the sample groups in relation to the standard error of their mean using their gaze scan path pairwise distances, wherein the standard error of the mean demonstrates how far the sample mean of the data was likely to be within the true population mean. Welch's t-Test was determined to be the statistical test used due to unequal variances of the samples. The Brown-Forsythe test was used for validation for each art print t-Test result.

3.5 Implementation of Intersection Over Union of Convex Polygons of Gaze Clustering

Participant gaze clustering results were analyzed to measure the effect of the Gestalt grouping principle of proximity and to validate results of the scan path distance analysis. Density-based clustering algorithms, DBSCAN and OPTICS, were used to identify high-density regions of arbitrary shapes. Each participant gaze clustering was compared. Common clustering comparison methods, such as Adjusted Rand Indexing and Adjusted Mutual Information, Silhouette Coefficient, were identified as not suitable due to varying sample sizes of gaze points from each participant. Hence, the intersection over the union (IoU) of the convex polygons of the gaze cluster results were calculated to compare clustering results of each participant against each other. The results confirmed observations from the scan path pairwise distance analysis.

DBSCAN and OPTICS clustering models were used to analyze the gaze clustering of participant gazes to measure the effects of proximity using Scikit Learn machine learning libraries. The OPTICS model used the Minkowski distance metric wherein its parameters included minimum of 6 neighbor gaze points to define a core point and with minimum size of 0.5 gaze points to define a cluster. This was also tested using the DBSCAN cluster method, and compared against the initial Xi cluster method, with maximum distance between gaze points of 1.0 and 2.0 epsilon cuts performed separately. The epsilon cuts of the DBSCAN cluster method were defined through the K Nearest Neighbors (KNN) elbow method. OPTICS was finally used based on its performance and as it was relatively insensitive to parameter settings and can automatically adjust epsilon cuts with eps = infinity.

4.4.1 Implementation of Intersection over Union of Convex Polygons of Gaze Clustering. IoU scores were calculated for all possible comparisons of each participant within and outside their sample groups for each art print. Where IoU is calculated by the formula:

$$Area(Q1 \cup Q2) = Area(Q1) \cup Area(Q2) - Area(Q1 \cap Q2)$$
$$IoU = Area(Q1 \cap Q2) / Area(Q1 \cup Q2)$$

where Q1 is the gaze clustering set of the first participant and Q2 is the gaze clustering set of the second participants. IoU scores of 1 predicts that convex polygons exactly match, and scores of 0 predicts that convex polygons do not. IoU scores are interpreted as:

IoU > 0.5 is "decent"
IoU > 0.7 is "good"
IoU > 0.9 is "almost perfect"
IoU = 1 is "equal"

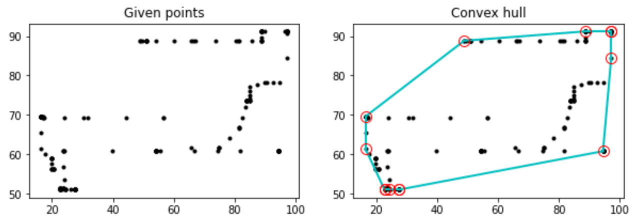

Figure 2: Formation of Convex Hull from Gaze Clusters

To obtain the IoU scores, convex polygons or convex hulls of the OPTICS gaze clusters were calculated using the SciPy Spatial Convex Hull Python Library. The library provides the vertices and the simplices in or to define the bounding box of the convex hull. This also provided the areas and volume of the convex polygons obtained for each cluster.

The IoU was calculated for each convex hull in a participant scan path against all convex hull of the second participant scan path to find its most similar cluster, since cluster count for each scan path varied. The IoU of the two most similar clusters from the first and second scan path was achieved by calculating the largest IoU score iteratively for each defined hull of the participants.

The average IoU scores of each participant were measured to achieve the average IoU score of the intra-group and inter-group comparisons to compare intra and inter group scores as the sample sizes of each group are unequal.

4 RESULTS

4.2 Pre-test Results

The revised research protocol was executed for the final study. The assessment test results are outlined below.

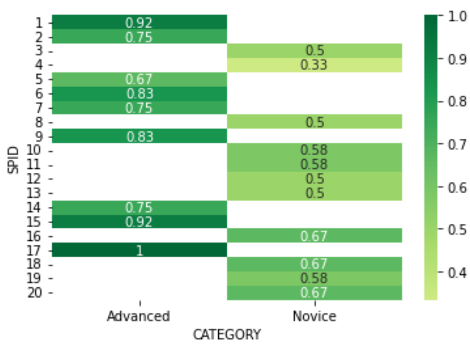

Figure 3: Participant Artistic Knowledge Assessment Average Scores

4.2.1 Assessment Test Section 1. Participants with formal educational background in arts or are currently art professionals had test scores greater than or equal to 67%. Overall, the art participant sample group attained an average of 82% test score.

Participants who had no formal background in arts obtained an average of 55% with the lowest test score of 33%. Only three out of eleven participants achieved test scores of 67% or above, however these participants failed to pass Section 2. To further validate, Section 2 results were analyzed to verify results of the first assessment test and to confirm the relationship between the sample groups.

4.2.2 Assessment Test Section 2. To demonstrate, the diverging stacked bar charts below illustrate the level of agreement of participants per their sampling categories.

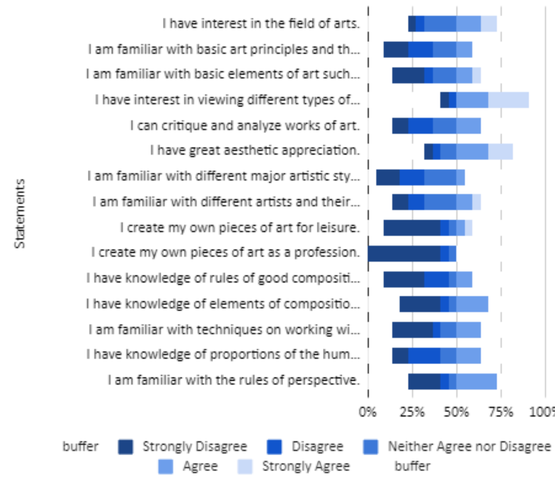

Figure 4: Level of Agreement of Novice Art Participants

Figure 4 shows lower perceived artistic familiarity, aesthetic appreciation, and fundamental knowledge on visual arts of participants with no formal background in arts. Although, nine out of eleven participants in the group agreed to have interest in viewing pieces of art. Similarly, the median for the group had a good perceived aesthetic appreciation.

Figure 5: Level of Agreement of Advanced Art Participants

Figure 5 shows higher perceived fundamental knowledge, aesthetic appreciation, and interest in arts of participants with formal education and profession in visual arts. However, 25-50% of these participants had neutral agreement on statements regarding their knowledge of basic art principles and elements of composition.

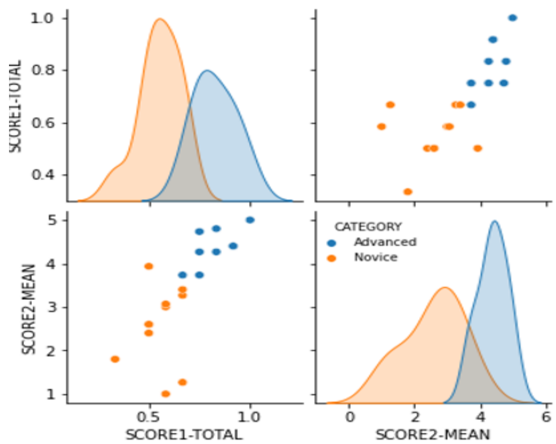

Figure 6: Participant Knowledge Assessment Pair Plot

Correlation analysis between participant category or sample group and their assessment tests showed novice participants with lower perceived artistic knowledge with respect to their section 1 assessment tests scores compared to participants with formal background in arts. Figure 6 shows symmetric unimodal distribution of participants with no background in arts and have relatively lower scores in section 1 of the assessment test compared to participants with formal background in arts.

To further analyze the difference between the groups' perceived interest and knowledge in visual arts, a Mann-Whitney U Test (MWU) was executed using the mean scores of each participant per group. This is to determine the difference between the participant groups regardless of direction with the null hypothesis stating no significant difference between the groups. Samples from both groups were combined with respect to their art background. The derived U Value from the test was 2 with a critical value of U 23 at the significance level of $p < 0.05$. The calculated z-score was -3.57076 at $p = 0.00036$. Given these, the result showed significant difference between advanced and novice groups at two-tailed significance level of $p < 0.05$. Hence, the sampling grouping of the participants was maintained after the assessment test as categorization for the eye tracking experiment results analysis with respect to Section 1 results. This was the final participant grouping used for the analysis of aggregated eye gaze data in the succeeding sections.

4.2.3 Eye Tracking Experiment Results. Several eye-tracking test data were exported from RealEye Dashboard – Gazes, Fixations, AOI-based exports, Facial Coding and Survey Results. Among three (3) gaze data exports, Denoised Raw Gazes export was used to ensure no additional interpolation of gazes within 50ms to 60Hz were applied to the dataset. The raw gaze data established recording of raw gazes every 30ms.

Exploratory data analysis was performed to validate the integrity of the exported data. 20 tests were completed overall for six stimuli, with 30 seconds viewing time (+/- 0.1 seconds) each. To validate the quality of each test, the test quality grades were studied for each tester and stimulus viewed. Stimulus results with less than a grade of 3 or "Good" were not included in the succeeding sections of the study to ensure quality of the eye tracking data analysis.

4.3 Scanpath Pairwise Analyses

The calculated pairwise distances for each sample group were analyzed per art print viewed. There are 45 pairwise distances for participants with no formal background in art with an average distance score of 0.47 pixels with standard deviation of 0.26, and only 28 pairwise distances for participants with formal background in part with an average distance score of 0.42 pixels and standard deviation of 0.11. The intra group scanpath distance analysis using Eyenalysis presents similarity of scanpath through relatively shorter pairwise distances for participants with formal background in art.

Table 2: Welch's' t-Test and Brown-Forsythe Test Results Matrix

item_id	t	p tTest	W	p BF	DOF
1	3.08	0.0031	7.78	0.0068	65.11
2	2.80	0.0084	12.37	0.0008	33.71
3	2.14	0.0359	3.40	0.0692	66.42
4	0.27	0.7903	0.002	0.9620	63.69
5	0.49	0.6228	3.72	0.5774	70.99
6	1.26	0.2115	6.85	0.0108	64.63

The overall analysis showed there was a statistically significant difference between the pairwise distances of non-art participants and participants with formal background in art *(N=153)*, for art print 1 and 2 only with at least $t = 2.54$, $p \leq .05$. This conformed with the initial IoU scores of the sample groups.

4.4 Measuring Effects of the Principle of Proximity

The researchers studied the average IoU scores for each art print to validate the sensitivity of the effects of the proximity principle with respect to the participants' eye tracking behavior segments which exhibits higher visual perceptual activity and lower cognitive processes. The effects of proximity were measured against different scanpath lengths from its maximum duration of 30 seconds.

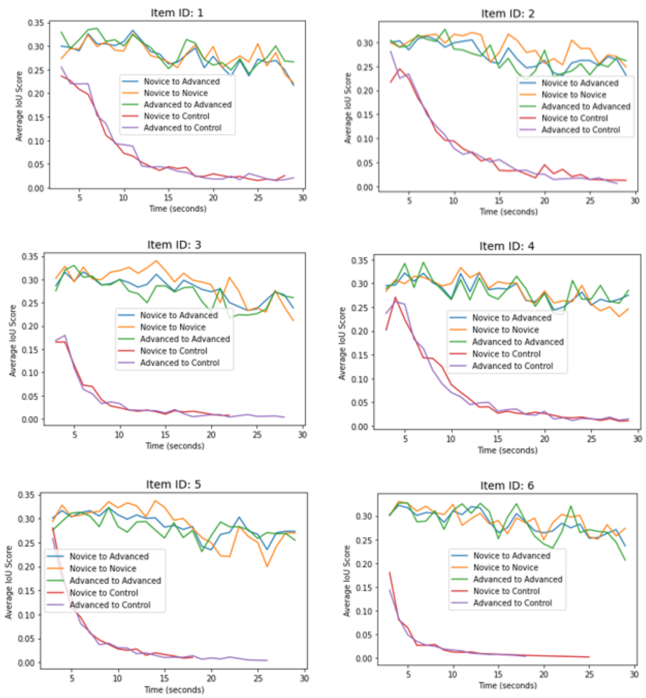

Figure 7: IoU Average Score Matrix over Time

The maximum average IoU scores of the participant groups were no more than 0.35 and did not meet a "decent" similarity score. Despite the low similarity score, the average IoU scores for each art print were higher in earlier time marks and showed a downward trend within the duration of 30 seconds. Although, the average IoU scores oscillated and did not show a consistent decline. There was also no significant difference between the average IoU scores when compared against the same and opposite sample groups. The average IoU score of participants with formal background in art were neither consistently better nor worse than participants with no formal background in art.

The average IoU scores of the controlled dataset based on the expected gaze clustering, defined with the consultant art expert, were also computed against the participant groups gaze clustering. The average IoU scores of "Novice to Control" and "Advanced to Control" were both lower than the average IoU scores of the sample groups and did not meet a "decent" similarity score. Like the comparison of average IoU scores of sample groups, the average IoU scores, when compared against the controlled dataset, were higher in the earlier time marks and showed a downward trend within the duration of 30 seconds. There was least oscillation observed when comparing against the average IoU scores with the controlled data set.

To quantify whether there exists a statistically significant difference between the mean values of the participant IoU scores per art print, a one-way ANOVA test was conducted. All art print items had an ANOVA test with p value < 0.05 except for art print item 5. This confirmed there was no significant difference of IoU scores of the sample groups. This presented both sample groups performed comparably when measured against the control gaze clustering with low similarity scores. This confirmed non-adherence of the sample groups to the Gestalt grouping principle of proximity.

The tests also presented significant differences when comparing the IoU scores of participants in the within their sample groups and IoU scores of participants in different sample groups with their performance against the control. This suggests clustering performance measured between the same and opposite sample groups are better than when measuring the sample groups' performances against the control.

5 CONCLUSION AND FUTURE WORKS

As discussed in Gestalt principles of visual perception, all humans can group similar elements through visual cues such as similarity, closure, and proximity. Criticisms of the Gestalt theory commonly discuss its potential lack of empirical research and focus on phenomenological methods [1, 13]. The result of this research helps in finding the differences of the effects of Gestalt Theory in specific cases and demographics especially in the field of arts. Given the level of subjectivity of visual perception in abstract art, this study can aid to confirm and provide a new direction to what is currently discussed in Gestalt research. This study has provided empirical evidence to show the presence of the Gestalt principle of proximity when viewing specific abstract arts, especially for non-art participants compared to participants with formal background in art.

The study leveraged gaze clustering analysis to measure the effects of the Gestalt principle of proximity between participants with advance or formal art, and novice or non-art backgrounds. Specifically, the gaze clustering algorithm explored was OPTICS to analyze the effects of proximity to participant gazes. Due to the variance in gaze point counts to measure gaze clustering similarity, convex hulls were calculated from the OPTICS clusters. The Intersection over Union (IoU) scores of the participants' gaze convex hulls and the expected clusters' convex hulls were studied to measure adherence to the Gestalt principle of proximity. To further confirm, scanpath pairwise distance analysis was performed to measure the similarity of scanpaths and validate the effects of participant art expertise.

Both novice and advance participant gaze clustering had low similarity scores against the expected gaze clusters. However, both novice and advanced similarity scores present likely equal performance to their adherence to the effects of the Gestalt Principle of Proximity. With respect to the effects of expertise, within group variances show likely equal similarity scores. The post-test interview indicated comparable perceived objects and observed clustering of the participants, especially for art print item 3, which yielded potential correlation to the similarity of the gaze clustering performance of the sample groups. Overall, the results presented limited effects of expertise when viewing abstract art but had low adherence to the Gestalt principle of proximity.

Through the proposed gaze clustering analysis methodology, the study invites further quantitative research on the effects of Gestalt principle of proximity in visual perception in arts and across various fields. Further investigation is needed to validate two potential directions of research: (1) considering use of non-abstract or non-art stimuli to measure the effects of the Gestalt principle of proximity and level of expertise in a domain relative to the chosen stimuli, and (2) evaluating alternative clustering algorithms to measure the effects of Gestalt principle of proximity. The findings in this study were specific in the domain of abstract art and limited to remote facilitation of eye tracking experiment brought by the effects of the COVID 19 pandemic. More accurate eye tracking instruments and validation through use of other abstract art as stimuli would be recommended to refine the findings of the study.

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