Graph Drawing Contest Report

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Abstract. This report describes the 29th Annual Graph Drawing Contest, held in conjunction with the 30th International Symposium on Graph Drawing and Network Visualization (GD'22) in Tokyo, Japan. Due to the continuing global COVID-19 pandemic, the conference and thus also the contest was held in a hybrid format, with both on-site and online participants. The mission of the Graph Drawing Contest is to monitor and challenge the current state of the art in graph-drawing technology.

1 Introduction

Following the tradition of the past years, the Graph Drawing Contest was divided into two parts: the *creative topics* and the *live challenge*.

Creative topics were comprised by two data sets. The first data set was the *Opera Network*: The data represent a collection of opera performances that took place across Europe between 1775 and 1833. The second data set showed a an *Aesthetic Experience Network*: The data set represents 8 networks that model an aesthetic experience of the viewers when observing artworks. The data sets were published about half a year in advance, and contestants submitted their visualizations before the conference started.

The live challenge took place during the conference in a format similar to a typical programming contest. Teams were presented with a collection of *challenge graphs* and had one hour to submit their highest scoring drawings. This year's topic was similar to last year's: minimize edge-length ratio in a planar polyline drawing graph with vertex locations restricted to a grid and a maximum number of bends per edge allowed.

Overall, we received 26 submissions: 9 submissions for the creative topics and 17 submissions for the live challenge (10 manual and 7 automatic).

2 Creative Topics

The general goal of the creative topics was to model each data set as a graph and visualize it with complete artistic freedom, and with the aim of communicating

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as much information as possible from the provided data in the most readable and clear way.

We received 8 submissions for the first topic, and 1 for the second. Submissions were evaluated according to four criteria:

(i) Readability and clarity of the visualization,
(ii) aesthetic quality,
(iii) novelty of the visualization concept, and
(iv) design quality.

We noticed overall that it is a complex combination of several aspects that make a submission stand out. These aspects include but are not limited to the understanding of the structure of the data, investigation of the additional data sources, applying intuitive and powerful data visual metaphors, careful design choices, combining automatically created visualizations with post-processing by hand, as well as keeping the visualization, especially the text labels, readable. For each topic, we selected the top five submissions before the conference, which were printed on large poster boards and presented at the Graph Drawing Symposium. We also made all the submissions available on the contest website in the form of a virtual poster exhibition. During the conference, we presented these submissions and announced the winners. For a complete list of submissions, refer to http://www.graphdrawing.org/gdcontest/contest2022/results.html. Eight of the submissions were accompanied by an online tool, which are linked on the web page.

2.1 Opera Networks

The data represents a collection of opera performances that took place across Europe between 1775 and 1833.

Each row corresponds to a performance and contains the following information:

- The performance title (`title`)
- The librettist's name (`libertist`)
- The composer's name (`composer`)
- The performance year (`performance_year`)
- The city in which the performance tool place (`placename`)
- `rism_id` - unique identifier corresponding to the performance that gives a possibility to extract more information about the performance from RISM database

The data was extracted from the RISM database[1] and was offered by Frans Wiering[2] – professor of Utrecht University studying Musicology.

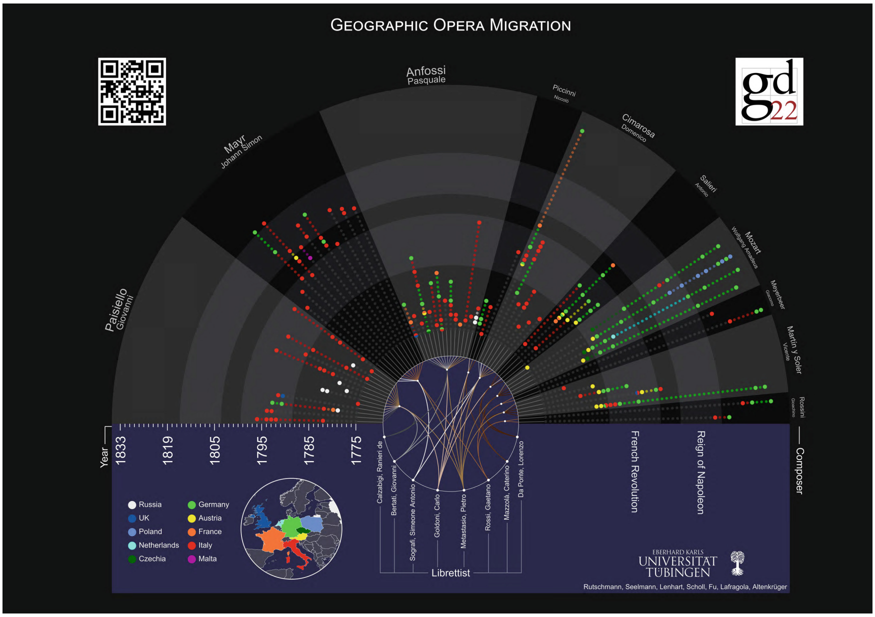
[1] https://opac.rism.info/main-menu-/kachelmenu/help.
[2] https://www.uu.nl/medewerkers/FWiering.

There are several possibilities on how a network can be extracted from this data. We left it to the participants to decide how and whether to model this data set as a network. The possible research questions that can drive this modeling were pointed by Frans Wiering and are as follows:

– How performances travelled geographically and in time?
– How Italian/Viennese operas travelled to Europe?
– Which operas stayed at same place and which went over Europe?
– Are there patterns in collaborations among composers and libertists, also over time?

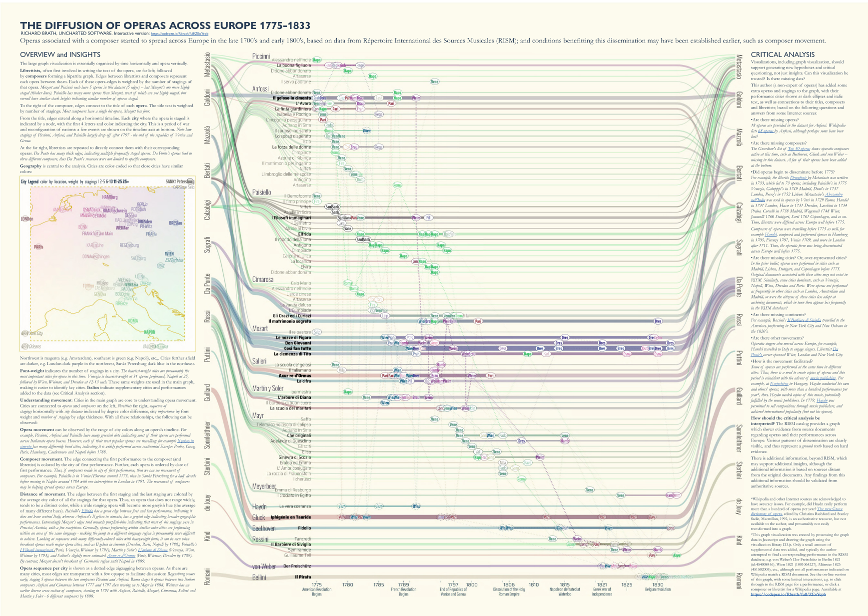
3rd Place: Joshua Rutschmann, Marc Seelmann, Patrizia Lenhart, Tim Scholl, Mike Fu, Vincent Lafragola, and Sarah Altenkrüger (Universität Tübingen). The contest committee likes this layout for its simplicity and easy readability of the data captured by the visualization. Representing the composer to librettist relations via a small graph is a choice that nicely inserts this information into the visualization without adding a lot of visual complexity. Also, the choice of laying out the visualization in the style of an opera seating arrangement leads to a pleasingly looking picture that invites exploration of the data. Clustering the geographic information by countries is a good choice, though the colors do not necessarily support the easy identification of geographic areas. The provided online tool adds the missing information like opera names as easy-to-read hover items.

Tool: http://operanetwork.cs.uni-tuebingen.de/



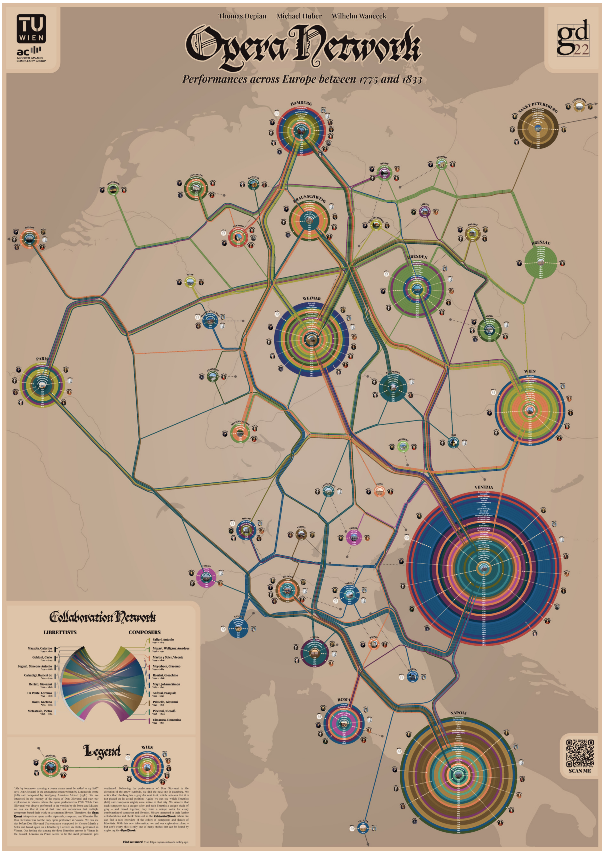
2nd Place: Richard Brath (Uncharted Software). The committee finds this visualization to be not only pleasant to look at, but also provoking to explore the data. It allows for an easy exploration and analysis of many aspects of the data. Most notably, the south-to-north pattern of the operas over time is very clearly visible, achieved via the color-scheme and the choice of layout. Also, the choice of repeating librettists at both sides of the visualization supports well the tracking of composer-librettist and opera-librettist relations which otherwise might have been hard to follow. However, finding all occurrences of a single location is somewhat difficult: the lines connecting them are hard to follow due to the majority being near vertical and the color scheme is a bit too subtle for this purpose.

Tool: https://codepen.io/Rbrath/full/ZEoYepb



Winner: Thomas Depian, Michael Huber, and Wilhelm Wanecek (TU Wien). The committee finds this visualization to be mesmerizing and beautiful to look at. At the same time it also well supports analyzing and answering most questions posted with the challenge. The well thought-out space-central view makes locating the opera-city relation straightforward and the metro-style layout provides a familiar way of tracing the movement of an opera over time. The legend explains the visualization in a good fashion and the small bundled graph supports well the identification of composer-librettist relations. The committee also appreciates that various algorithmic tools were used to create this drawing. Finally, the online version of this visualization adds the ability to highlight the path any opera took through time and space. The only downside is that the temporal information is more difficult to assess and compare between cities.

Tool: https://opera-network.netlify.app

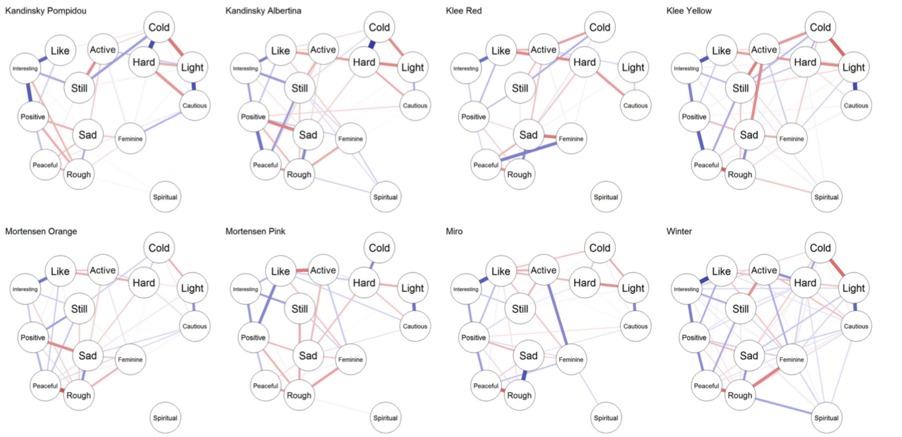


> In our Opera Network, we grouped performances by their operas, which we identified by the triple title, composer, and librettist. On a map of Europe, cities comprised of concentric rings, each representing a performance, were positioned close to their actual location using a force-based layout. Then, performances within the same group were chronologically connected on directed paths running along the edges of a generalized Voronoi diagram. For this, the crossing-optimal path bundling algorithm by Pupyrev et al. (2016) was used, followed by optimizations to make the paths more homogeneous. Finally, we assigned colors by mixing a base color for each composer with a shade of grey for each librettist, visualized with the composer-librettist collaborations in a chord diagram. On top, to make the data exploration easier, our interactive version allows highlighting the paths of performances individually or by composer/librettist.
>
> *Thomas Depian*

2.2 Aesthetic Experience Network

The data set represents 8 networks that model an aesthetic experience of the viewers when observing artworks. The analyzed artworks are 8 paintings by Klee, Kandinsky, Mortensen, Miro and Winter:

Artist	**Title**	**Year**
Paul Klee	Zeichen in Gelb / Sign in Yellow	1937
Paul Klee	Blick aus Rot / Be aware of Red	1937
Wassily Kandinsky	Regungen / Impulses	1928
Wassily Kandinsky	Untitled	1934
Richard Mortensen	velsesstykker / Mortensen Pink	1922
Richard Mortensen	velsesstykker / Mortensen Orange	1922
Joan Mirò	Untitled	1961
Fritz Winter	Siebdruck 6 / Silkscreen 6	1950



Each of the 14 nodes represents one of the two polarities of an aesthetic effect: (i) positive – negative; (ii) active – passive; (iii) still – lively; (iv) sad – happy; (v) peaceful – aggressive; (vi) hard – soft; (vii) cold – warm; (viii) light – heavy; (ix) rough – smooth; (x) spiritual – bodily; (xi) feminine – masculine; (xii) cautious – intrusive; (xiii) like – dislike; (xiv) interesting – uninteresting.

The edges are weighted by conditional dependence relations among aesthetic effects: If two aesthetic effects are connected in the resulting graph, they are dependent after controlling for all other symptoms. Thus, a negative dependency between A and B indicates a positive dependency between A and the opposite of B. This data is a result of the research presented in the paper *Associating With Art: A Network Model of Aesthetic Effects* by Specker et al. [1] and the full set of collected data is available online[3]. When sharing the data for the challenge, the authors of the paper said they are curious "how to visualize this data set for an art historical audience or other audience that does not know about network theory."

[3] https://osf.io/zqxbm/.

Winner: Axel Kuckuk, Henry Förster, and Sarah Gester (Universität Tübingen). The contest committee liked that the layout is easy to read and clearly displays the individual as well as the aggregated data. Taking a rather minimalistic approach with well-separated sub-figures, the authors create a visualization that conveys well the overall data at a glance for each piece of art. The committee also liked the meta-level of representing this particular data set about art again as a piece or as pieces of art hanging in an exhibition.

> "The latest work by the artist trio Kuckuk, Förster and Gerster, who are renowned for creatively exploring how humans influence data and vice-versa, was also unveiled at the conference. The series of paintings titled "Aesthetic Experiences" showcases correlations of different aesthetic effects experienced by the audience of classic abstract art pieces in the shape of heatmaps. "In the design, we strived to present the data in a clear and minimalistic way, omitting numbers for the most part to encourage a playful and courious interaction with the data, searching for differences and similarities between the networks.", Kuckuk said. Acclaimed experts appeared ecstatic following the unveiling of this marvellous piece of art. As graph drawing expert Kindermann put it: "Readability is fine". His further statement "How they obtained the ordering isn't immediately clear." is courtesy to the unusually creative thought process of the artists."
>
> *Henry Förster*

3 Live Challenge

The live challenge took place during the conference and lasted exactly one hour. During this hour, local participants of the conference could take part in the manual category (in which they could attempt to draw the graphs using a supplied tool: http://graphdrawing.org/gdcontest/tool/), or in the automatic category (in which they could use their own software to draw the graphs). Because of the global COVID-19 pandemic, we allowed everybody in both categories to participate remotely. To coordinate the contest, give a brief introduction, answering questions, and giving participants the possibility to form teams, we were kindly provided with both a room in the conference building, and a the Zoom stream for the conference; furthermore, participants could also meet and follow the contest via a dedicated room in gather.town.

The challenge focused on minimizing the planar polyline edge-length ratio on a fixed grid. The *planar edge-length ratio* of a straight-line drawing is defined as the ratio between the length of longest edge and minimal Euclidean distance between two neighboring vertices. This slightly changed from last year to allow for better scores to more correspond to nicer drawings. There has been recent attention to this topic with several publications. The *planar polyline edge-length ratio* is a generalization of the planar edge-length ratio where edges do not have to be straight-line segments, but can be polylines with a maximum number of bends per edge defined by the input.

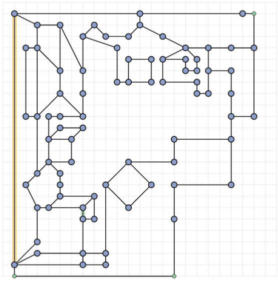
The input graphs were planar undirected graphs. For the manual category, each graph came already with a planar drawing.

The results were judged solely with respect to the edge-length ratio; other aesthetic criteria were not taken into account. This allows an objective way to evaluate each drawing.

3.1 The Graphs

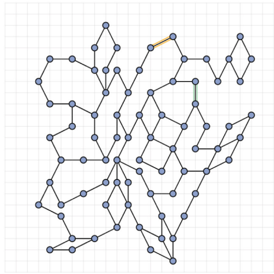
In the manual category, participants were presented with six graphs. These were arranged from small to large and chosen to contain different types of graph structures. In the automatic category, participants had to draw the same six graphs as in the manual category, and in addition another seven larger graphs. Again, the graphs were constructed to have different structure.

For illustration, we include the third graph, which was given a seemingly random graph with initial ratio 22, but that can be drawn with uniform edge lengths, except for one edge. The best manual solution we received (by team *kuneri nashi*), and the best automatic solution we received (by team *OMEGA*) are given below.

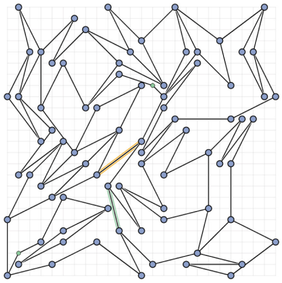


Provided drawing

edge-length ratio 22



Best manual solution
kuneri nashi
edge-length ratio 1.12



Best automatic solution
OMEGA
edge-length ratio 1.21

For the complete set of graphs and submissions, refer to the contest website at http://www.graphdrawing.org/gdcontest/contest2022/results.html. The graphs are still available for exploration and solving Graph Drawing Contest Submission System: https://graphdrawingcontest.appspot.com.

Similarly to the past years, the committee observed that manual (human) drawings of graphs often display a deeper understanding of the underlying graph structure than automatic and therefore gain in readability. However, excepting the instance above, the automatic techniques by *OMEGA* managed to outperform the manual solutions when measured purely on edge-length ratio. For the larger graphs, we gave ample space to ensure that finding some embedding would be feasible in the given time. This allowed for most techniques to solve most instances. However, the fourth instance of the larger graphs was still restricted in grid size, though it was given an initial embedding. Nonetheless, only *OMEGA* managed to roughly halve the initial edge-length ratio, suggesting that working in such a confined space is still challenging, even with a given embedding.

3.2 Results: Manual Category

Below we present the full list of scores for all teams. The numbers listed are the edge-length ratios of the drawings; the horizontal bars visualize the corresponding scores.

graph	1	2	3	4	5	6
Final Exam	1.78	2.23	8.54	5.0	4.85	8.27
Minimal is criminal	1.2	1.96	6.08	2.82	2.77	10.57
M. Gronemann Memorial T.	1.08	1.66	2.51	2.23	2.45	2.3
OneLayoutToRuleThemAll	2.23	2.28	4.03	5.09	4.8	4.03
kuneri nashi	1.07	1.71	1.11	3.16	5.0	1.92
Yoshio Okamoto	1.41	2.23	10.0	10.52	9.26	5.99
Good luck	1.5	2.21	2.76	4.0	4.25	2.4
New keyboard, who dis?	1.41	2.82	2.69	3.16	2.16	2.38
Greedy Unicorns	1.2	1.8	7.0	6.32	5.39	4.46

Third place: **New keyboard, who dis?**, consisting of Anaís Villedieu, Jules Wulms, and Soeren Nickel.
Second place: **kuneri nashi**, consisting of Felix Klesen and Johannes Zink
Winner: **Martin Gronemann Memorial Team**, consisting of Fouli Argyriou and Henry Förster.

> “Since the formation of our contest team in 2019, it was the first time we had to compete without Martin Gronemann. So with heavy heart only the two of us kept going with the contest as Martin has untimely passed on in life after leaving academia. As we know he would be proud of us, we followed first of all the basic rule that is independent of the problem to be solved as Martin taught us: ”So at the beginning submit all instances right away with their initial layout to ensure that at the end we have a feasible entry for every instance (also, it puts pressure on the competitors right away).” For the particular problem of this year’s contest, we realized that bends were completely useless. So, when drawing one of the graphs, as a first step we deleted all bends. Then, we reintroduced planarity before shortening the longest edge (or very rarely elongating the shortest one). As a result, we achieved an edge length ratio of less than 3 in all contest graphs, or as Martin put it ”Ihr habt aber auch nen geilen Job gemacht wenn ich mir die Punkte anschaue”.”
> *Fouli Argyriou and Henry Förster*

3.3 Results: Automatic Category

In the following we present the full list of scores for all teams that participated in the automatic category. The numbers listed are the edge-length ratios of the drawings; the horizontal bars visualize the corresponding scores.

graph	1	2	3	4	5	6	7	8	9	10	11	12	13
el_ratio	1.58	2.0	5.61	4.24	5.14	3.65	10.6	67.13	69.0		58.48		480.0
HopingFor2DigitRatios	1.41	1.68	9.06	3.0	5.0	4.64	15.22	208.72	94.9	158.47	58.47	146.12	687.25
Golden Ratio	1.58	1.89	6.01	7.3	4.19	5.09	46.09	68.0	123.0	158.47	42.48	234.05	932.0
OMEGA	1.02	1.41	1.21	2.0	1.26	1.04	4.46	36.77	8.91	70.0	105.76	3.98	97.66
TUW-ELR1	1.11	1.68	3.16	2.82	2.17	3.25	44.57	152.58	219.61	158.47	129.87	122.56	879.75
Wo ECTS?	1.11	3.16	4.47	3.16	8.24	4.16	34.01	695.08	845.0		177.49	290.0	1760.0

Third place: **Golden Ratio**, consisting of Andreas Krystallidis, Leonid Darovskikh, and Manuel Bacher.
Second place: **TUW-ELR1**, consisting of lexander Dobler, Oliver Pilizar, and Sebastian Uhl.
Winner: **OMEGA**, consisting of Laurent Moalic, Dominique Schmitt, and Julien Bianchetti.

> "Our team comes from the University of Haute-Alsace in Mulhouse (France). Julien is a Master's student in Computer Science, Laurent a researcher in Combinatorial Optimization, and Dominique a researcher in Computational Geometry. Our algorithm uses the OGDF library to first construct a planar straight-line drawing of the graph, whose external face is its largest face. The graph is then shrinked (if needed) to fit in the given grid. This is done by a simulated annealing algorithm, which attracts the nodes towards the centroid of the graph. Finally, the nodes are moved in random order with the aim to shorten the edges whose length is closer to the longest edge than to the shortest one, and to lengthen the other edges. Bends are added randomly and treated as nodes, except that they are allowed to overlap their two neighbors, in which case they are removed. Again, a simulated annealing approach is used to avoid falling in a local optimum. The algorithm was run simultaneously on all thirteen graphs of the competition on a laptop computer with a 12-core 2.7GHz processor. It worked well with all graphs except graphs 10 and 11. For graph 10, it did not succeed in fitting the generated drawing in the grid. Now, since graph 10 was given with coordinates, we had just to run the ratio-optimization phase on the given graph. Graph 11 was given with a grid that was too large for our algorithm. So we treated graph 11 with a slower version of the algorithm, which still achieved a ratio of 8 in about 10 minutes. Unfortunately, we submitted the wrong solution at the competition (the initial drawing rather than the improved one). Our algorithm also achieves good results on last year's competition by a straightforward adaptation of the edge-length computation."
> *Laurent Moalic, Dominique Schmitt, and Julien Bianchetti*

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http://www.graphdrawing.org/gdcontest/contest2022/results.html

Reference

1. Specker, E., Fried, E.I., Rosenberg, R., Leder, H.: Associating with art: a network model of aesthetic effects. Collabra Psychol. **7**(1), 24085 (2021)