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Instruction vs. emergence on r/place: Understanding the growth and control of evolving artifacts in mass collaboration

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ABSTRACT

In April 2017, Reddit hosted an online social experiment in mass collaboration that consisted of placing graphical (1-pixel) tiles on a 1000 by 1000-pixel canvas. A simple design rule instructed each person to place one tile at any location but then had to wait 5 min to act again. One of the authors participated in the experiment as a participant observer. We wanted to understand the process of going from nothing to complex visual artifacts, and to compare instruction (rules) and emergence as two mechanisms for controlling complexity (top down vs. bottom up). We used a mixed methods approach for data collection and analysis. After 72 h, most of the visual artifacts were recognizable, but at a more detailed level, many of them had extraneous objects within that diverged from the overall design. We examined in detail one visual artifact (Mona Lisa painting with the Swiss flag) and its related discussion board and suggest a conceptual framework for the analysis of the evolution. The framework takes inspiration from two metaphors of human intervention in natural evolution (plant growth and a disturbed anthill). At the end, we apply the framework to other objects on the canvas and discuss the tradeoff between instruction and emergence.

1. Introduction

Place (known by its participants as "r/place") was a social experiment (Asarch, 2017) directed by the social media site Reddit on April 1st, 2017 and ended three days later. The following message introduced r/place: "There is an empty canvas. You may place a tile upon it, but you must wait to place another. Individually you can create something. Together you can create something more" (Reddit, 2017a). Apart from a link to the canvas and a list of four general r/place rules (be creative, be civil, follow sitewide rules, and do not post personal information; Reddit, 2017b), there were no further instructions.

r/place consisted of a virtual canvas of 1000 by 1000 "tiles" or pixels. Initially, all one million tiles were white. However, anyone with an existing Reddit account could place (sic) a tile of any of the available 16 colors anywhere on the canvas. As the users placed their tiles, the canvas was "painted," but there was a technical restriction: Once a tile was placed, the user placing it was unable to place another for five (or periodically up to 20) minutes. During that period, the tiles could be replaced by anyone with a valid account, and the canvas was updated synchronously. Although not stated as r/place rules, these technical restrictions made up the framework of what a user could and could not do on r/place.

Despite Reddit not describing a purpose for the experiment, within the first day of the experiment, Reddit users had organized into communities that collaborated on creating and maintaining images or regions on the canvas. Country flags, video game characters, and sports team logos were some of the images people worked together to create. As more groups joined and claimed parts of the virtual territory, social organization began to emerge with different communities represented by Reddit discussion forums. In preliminary observations, we found the users participating in several types of interaction, including conflict, negotiation, persuasion, and coordination in an overall effort to argue and deliberate. However, during the second half of the experiment, the process of replacing tiles was a constant "battle" to further develop and maintain the images agreed upon within the groups as the discussions evolved as new members joined. Therefore, many images were distorted or skewed (partly overridden by extraneous objects) because of creativity, destruction, and compromise. The idea that creativity and evolution are key components of end-user development has been explored in previous work (Giaccardi & Fischer, 2008) but not in the context of mass collaboration with evolution and emergence as conceptual framework, which we examine in this study.

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Reddit ended the event without warning 72 h after it started. When the event was ended, 90,000 users were viewing it (Weinberger, 2017). Fig. 1 shows what the final canvas looked like. According to Reddit, more than one million user accounts were involved in placing a total of around 16.5 million tiles (Wardle & Bassett, 2017). The r/place Atlas (Rytz, 2017) identified almost 1500 different objects and phenomena on the canvas. The arguably best way to understand r/place is by viewing its evolution in animated form (see egeesin, 2017).

Quantitative methods in visual artifact analysis can identify the boundary of artwork and on a general level, predict users' collaboration on the artwork as it evolves (Rappaz et al., 2018, pp. 261–269). However, quantitative methods cannot identify whether the visual images were the result of collaboration or conflict, or whether the participants in the discussion forums cooperated or disagreed. To explore these perspectives, we used qualitative methods. Following Andersen and Mørch (2016) who combined quantitative and qualitative methods, we applied a mixed methods approach.

The aim of this study is to understand the r/place event through the evolution of two types of objects, visual artifacts and social artifacts, which change continuously over 72 h. We selected the Mona Lisa for in-depth analysis. The Mona Lisa was a visual object that appeared after around 23 h, following a single user's suggestion that included a simplified, visual model of Leonardo da Vinci's famous Mona Lisa painting. The rest of the paper we have organized as follows. In Section 2 (Related Work), we present a review of previous research. In Section 3, we develop a conceptual framework for analyzing the observed phenomena, which we use in the analysis, and we present the research questions. In Section 4, we present the research methods. In Section 5, we show data excerpts and analyze them. In Section 6, we discuss the

results and compare them the results reported in related work. Finally, in Section 7, we summarize this research and provide implications.

2. Related work

2.1. Complex systems

Complex systems are systems composed of many parts that interact in many ways, which result in a large variety of phenomena, such as self-organization (Kauffman, 1993), collaboration (Mason & Watts, 2012; Newman, 2001; Tapscott & Williams, 2008), and collective intelligence (Engel et al., 2015, pp. 3769–3778). A common behavior in complex systems is collective action coordinated locally without centralized planning (Thurner, Hanel, & Klimek, 2018) but involving the process of emergence (Holland, 1998; Sawyer, 2005). Complex systems are described and visualized in different ways, such as by levels of abstraction or weakly connected sub-systems. For example, psychology treated as a complex system would include neuronal, cognitive, intra-personal, interpersonal, and cultural levels (Jacobsen et al., 2016). By adopting a complex systems perspective, researchers aim to find quantifiable answers to broad (cross-disciplinary) questions, such as how humans learn, how to improve remote team performance (Engel et al., 2015, pp. 3769–3778), and how to conceptualize educational research (Jacobson et al., 2016). However, spanning a wide bridge is sometimes prone to failure (Bruer, 1997) because the constituent sub-disciplines might not be compatible with a common framework (e.g., neuroscience and cultural psychology). In this case study, we adopt the notion of emergence but limit the analysis to three levels (see Section 3). We study the development of two types of artifacts on these levels, and we
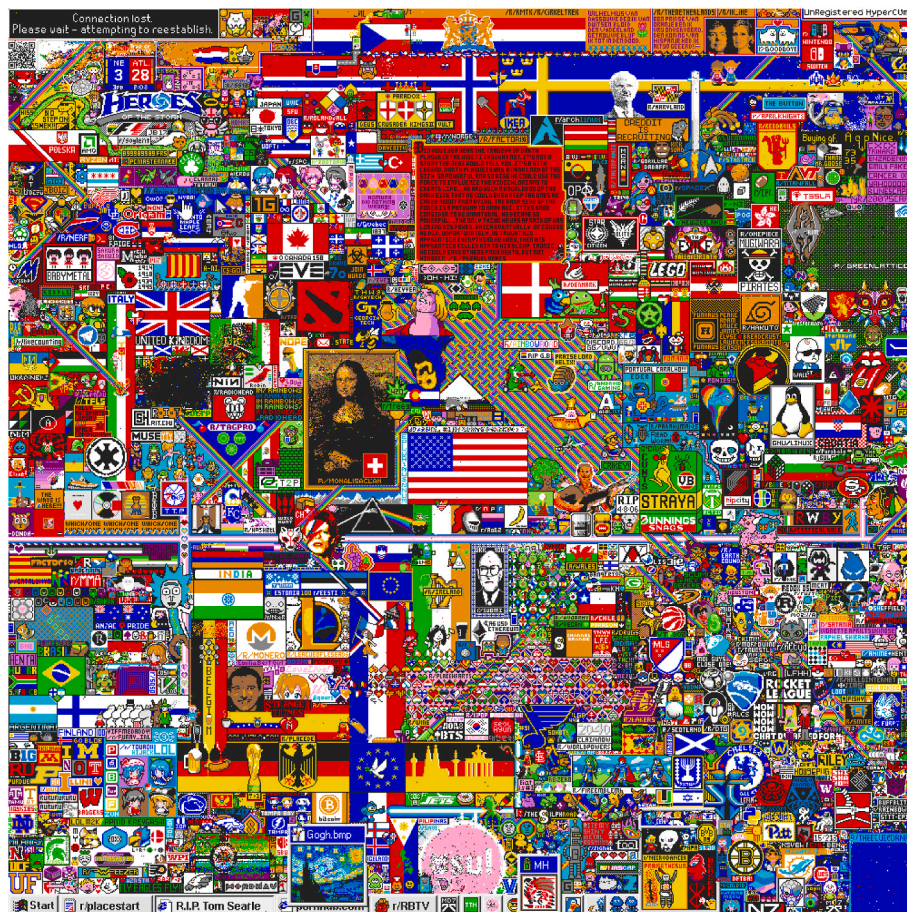

Fig. 1. Final r/place canvas (N1c0o., 2017). In total, there are around 1500 objects on the canvas. We selected one for in-depth analysis, the Mona Lisa with the Swiss flag.

compare the relative merits of instruction and emergence for guiding the activity.

2.2. r/Place studies

r/place as a complex system was the focus of a study reported by Rappaz et al. (2018, pp. 261–269). The authors developed a generic method for inferring collaboration patterns from observable user actions on r/place, according to the proximity of users' actions (mouse clicks) on the canvas. The authors found the activity was distributed unevenly across the canvas and increased in intensity and focus over the course of the experiment, rising abruptly on the second day to about two to four clicks per user per hour. This is, to some degree, in line with the findings we present below. At the same time, the percentage of unused space on the canvas dropped asymptomatically from an empty canvas to zero empty space in about half the time (all pixels colored). The authors explained the unexpected rise in activity from day 2 as due to external factors, such as publicity about the r/place event attracting more people (Rappaz et al., 2018, pp. 261–269). We show another factor: Users of neighboring regions expand their territory, as unused space became scarce. We show that collaboration and creative destruction were emergent phenomena on r/place. Creative destruction occurred when an extraneous object was inserted in a picture and led to vigorous local activity to minimize deterioration and preserve the original design, or update it, if removing the object was not an option. We refer to the result of this behavior as integrated, skewed artwork.

2.3. Meaning making

Meaning making in small-group collaboration is typically explored in computer-supported collaborative learning (CSCL) and computer-supported cooperative work (CSCW) research. Stahl (2003) distinguished between meaning making (group level) and users' interpretation (individual level). Meaning is shared and exists in an intersubjective world, whereas interpretation is about individual understanding and expression of (own) meaning (Stahl, 2003). These two levels inspired two of the levels in our conceptual framework.

A group of people in a large community must learn to collaborate in small groups before they can collaborate successfully in larger aggregates and nested organizational structures (Forte et al., 2012, pp. 417–426), as participation depends on meaningful interactions to advance, and individuals must follow the norms of the community to be heard (Tapscott & Williams, 2008). Some of the challenges regarding mass collaboration, and specifically, peer production, are that there is a lack of shared culture, plenty of conflict (Kittur et al., 2007, pp. 453–462), and difficulty protecting intellectual property (Boudreau & Lakhani, 2013). Two of these challenges (lack of shared culture and conflict) were present, and to some extent, a driver of activity in the communities we observed.

Fischer et al. (1994) argued that complex and successful software systems need to evolve by collaborative design in which end users and professional developers can work together. Shared understanding is aided by visual representations and domain-oriented user interfaces, which helps externalize ideas talked about in online communities. The combination of visual representations and design communication in online settings applies to the present case in the visual and social artifacts that had to be coordinated. This is our primary level for analysis, as a mixed method approach, where the qualitative method is the primary method. This approach differs from other studies on the field of mass collaboration, which mainly used only quantitative methods. The rationale for our choice is to provide a broad description of what happened during the 72 h.

2.4. Virtual social networks

Quinio and Marciniak (2013) contended that virtual worlds, online games, and social media could be viewed through the same lens termed *virtual social networks*. Viewing r/place through this common lens may provide a helpful perspective to understand the unfolding events, by comparing this network with other, similar types of networks.

r/place is similar to massive multiplayer online games or virtual three-dimensional (3D) worlds, such as World of Warcraft (WoW) and Minecraft. The similarities include a large number of "players," a virtual game space, and a set of rules that define the gameplay. In World of Warcraft, all players belong to one of two factions traditionally linked to different ethics (one is "good"; the other is "evil"), which, to some degree, affect how the players act in the game (Orr, Ross, & Orr, 2012). Unlike WoW, the factions of r/place were an emergent, and not a technical, feature or "rule" (see Section 6.2.2). WoW does not allow users to build or create visual artifacts. Instead, the game emphasizes collaboration and the creation of social "guilds" to win battles against common enemies (Nardi & Harris, 2006, pp. 149–158). Although r/place consisted of a two-dimensional (2D) canvas, many of the same affordances are offered in three dimensions in the virtual block building game Minecraft (Mørch, Mifsud, & Eie, 2019).

Another virtual social network is an article network. Collaborators in peer production systems such as Wikipedia engage in multiple networks to create and edit articles ("article network") and discuss them ("social networks"). In the article network, individual articles are nodes, and the connections between them are edges. This article network can be modeled as two (dual) mode networks of people mediated by articles (Borgatti, Everett, & Johnson, 2013). The equivalent single-mode social network is a network of relations among discussants. In the r/place case study, the "article network" was a network of pixels of a graphical region on the r/place canvas. Thus, we put visual artifacts in the foreground, whereas on Wikipedia, textual artifacts are in the foreground.

For visualizing Wikipedia activity, previous researchers have proposed techniques, such as chromograms to characterize editing patterns of very long textual sequences (Wattenberg, Vidgas, & Hollenbach, 2007, pp. 272–287) and history flow visualization of patterns of cooperation and conflict (Viégas, Wattenberg, & Dave, 2004, pp. 575–582). Compared to previous work, r/place was unique by offering a visual artifact as the primary interface, which may influence the way people interact in the online community, making it a novel context for understanding mass collaboration. Another peculiarity is that most Reddit users (97%) are active in a single community (Buntain & Golbeck, 2014, pp. 615–620) and do less cross posting than users on other social media sites. The communities or factions of r/place can be considered communities of interest, meaning they consist of heterogeneous groups of people who shared an interest in solving complex problems (Fischer, 2001). The heterogeneity of the communities provides opportunities for creativity "by transcending individual perspectives" (Fischer, 2001, p. 11). As opposed to Wikipedia, "most of Reddit cares more about what is interesting, than what is correct" (frogger2504, 2013). On r/place, there was little explicit right or wrong, but ample possibilities for communities to be creative and to find interesting solutions.

2.5. Mixed methods with social network analysis

Researchers have combined social network analysis (SNA) with other methods, both qualitative and quantitative, in several different ways, and SNA may provide a way to eliminate shortcomings in the individual methods when they are applied in isolation (Mørch, Andersen, Kaliisa, & Litherland, 2020). For example, Andersen and Mørch (2016) combined tags of structural social network data from an online discussion forum with the qualitative content of the discussion to provide a deeper (historical) understanding of the context and participants. There are also examples of SNA being used as a tool to "zoom in" (i.e. identify) parts of discussions to investigate in further detail (Fugelli, Lahn, & Mørch, 2013; Mørch, Andersen, Kaliisa, & Litherland, 2020). In this work, we adopted both methods. For example, Fugelli, Lahn, and Mørch (2013) used SNA in combination with interaction analysis to understand the

evolution of intersubjectivity in an open source software development community and created an early version of a process model for mixed methods research. This consisted of three steps: 1) identify regions in the network that are interesting from the point of view of intersubjectivity, 2) identify meaning-making processes in the selected regions, and 3) identify the mechanisms that trigger the meaning-making process. This work was inspired by (Fugelli, Lahn, and Mørch (2013)) research; we developed it further for mass collaboration and using a new theoretical framework. However, we did not yet find whether comparable methods exist for combining SNA with visual artifacts. As we discuss later, r/place participants created direct connections between the visual and social artifacts.

In sum, the related work shows some of the many facets of studying complex systems and ways to reduce complexity by focusing on certain objects and levels of abstraction. We identified a gap in the previous research on online activities that are not goal-oriented in the outset (unlike e.g. Wikipedia and computer games), but where the meaning and goals of the activity partly emerge from the actions and interactions of the users, which we addressed in this article.

3. Conceptual framework

The intense three-day effort to create 1500 different objects on a canvas the size of a small computer screen suggests a conceptual framework that considers evolutionary growth and complexity control. Evolution and emergence are the basic concepts we use to analyze the observed phenomena, originating in biology with applications in social sciences (Mead, 1932, 1934) and history of technology (Basalla, 1988). We refer to the evolution of artifacts.

3.1. Evolving artifacts

Herbert Simon (1996) coined the notion of "evolving artifact." He distinguished normative and descriptive representations in relation to artifacts: "artificial things are often discussed, particularly when they are being designed, in terms of imperatives as well as descriptives" (Simon, 1996, p. 28). In the case we report, the imperatives are the rules and restrictions of r/place, and the descriptives are the discussions in Reddit forums about developing r/place canvas picture regions and emergent properties and behavior. Furthermore, Simon said that complex systems would evolve from simple systems much more rapidly if there were stable intermediate forms that contain and hide smaller units, thus allowing analysis of a complex system by choosing the level of abstraction and designing the system by detailing subassemblies (Simon, 1996).

A process model for evolving artifacts is Seeding, Evolutionary growth, Reseeding (SER) proposed by Fischer and Ostwald (2002). It defines two levels of abstraction inspired by two types of organism evolution, ontogenetic (individual; lifespan) and phylogenetic (species; long term). The model postulates that for artifacts to evolve over a sustained period they must continually alternate between periods of adaptation by end users (evolutionary growth) and periods of deliberate restructuring and enhancement (reseeding), involving users in collaboration with designers (Fischer & Ostwald, 2002). At first sight, the present case study can be characterized as continuous evolutionary growth: The duration of the experiment was relatively short (72 h), and designers were not involved in periods of reseeding (e.g., cleaning up or updating the canvas daily). However, we also observed major changes occurring on the canvas, often initiated in the discussion forums by a group of participants. We refer to these periods as growth control.

Building on Fischer and Ostwald's work of evolutionary growth and reseeding, Mørch (2003, 2011) suggested tools for modifying applications at three levels—customization, integration, and extension. These levels provide a gradual transition to the computational complexity of a computer application via increased flexibility for each level. We developed a three-level conceptual framework for this case study, and we

named the levels after the ways r/place users and the designers participated in the experiment (creativity, group interaction, and instructions).

3.2. Emergence

Evolving artifacts help us understand the growth of complexity, but evolution does not provide the means for controlling the complexity. For the latter, we use emergence in addition to rules as developed by scholars in social sciences. Emergence is a process of obtaining information from the many parts and interactions from within a system and unknown or unplanned before the activity to identify patterns of parts and interactions, rather than the parts or interactions in isolation (Holland, 1998; Sawyer, 2005). Before we discuss the theory of emergence, we provide three examples, the latter two serving as metaphors for the evolutionary growth and control on r/place.

The first, classic, example of emergence is a bird flock revealing a V-shape from a distance. The V-shape is a property of the whole flock and cannot be reduced to a sum of individual birds in flight because each bird's behavior is quite simple. The second example as a control mechanism is the growth of the stem of a flowering plant or a fruit tree. The buds of the plant's leaves and flowers might transform into a thin stem at the end of the growing season. The relatively short-lived plant organs (flower and leaf) thus extend their lifespan into a more durable structure, supporting and directing future leaf and flower budding (Mørch, 2003). The third example is an anthill, a complex system that compares with human societies on a small scale (Moffett, 2019). The anthill is fragile, as external objects ranging from broken branches of a nearby tree to the remains of small animals to a human footstep can disturb the hill. The disruption will delay the ants' nest-building activity, replacing it with combatting and restoration. The external object will eventually dissolve into the hill or be integrated (worked around). As long as the internal structure and operation is intact or minimally disturbed, the anthill will survive, and even flourish, despite imperfections. The three metaphors can help the reader to understand our conceptual framework and the observed r/place behavior without needing further knowledge of the theory of evolving artifacts and emergence.

Emergence as a control mechanism in evolution in social science was (to the best of our knowledge) first suggested by George Herbert Mead (1932), who developed a theory of communication based on temporality and emergence. Communication, according to Mead, is a continual process of adaptation to novel social situations, but disrupted at certain intervals by reconstruction. The role of reconstruction is to create a temporal context for communication, referred to as structural context (Mead, 1932). The structural context describes the events leading up and following the present situation at a more general level (e.g. a visual image) than the complexity of the present situation (actual growth). The structural context is an emergent dynamic entity, often visual, that stands in a dialectical relationship with the actions and interactions taking place in the present. Thus, emergence defines the relation between two objects evolving on different time scales, structural context, and actions in the moment, which is characterized by a tension, in which the object at the higher level changes at a slower pace than the actions and interactions the object represents, and thus, serves as a control mechanism in adaptation (Mead, 1932).

The framework we used is shown in Table 1. It was partly inspired by the two metaphors described above (plant/tree growth and anthill disturbed) and Mead's (1932) and Stahl's (2003) theories of communication. We use the framework to analyze mass collaboration of visual artifacts and social artifacts (textual communication) as they evolve together, change on different levels of abstraction, and are supported by different research methods (qualitative and quantitative). We use the framework to analyze the phenomena we observed on r/place. The final version of the model with dependency relations is presented in Section 6.

We analyze r/place activity as two simultaneously evolving systems

Table 1
Artifacts and levels of abstraction.

Level (*human intervention*)	Canvas (visual artifact)	Communication (social artifact)	Actors (*rate of change*; focus of our analysis; research method)
Structure (*instruction*)	r/place rules; *emergent*: tile placement structure and visual patterns	r/place rules; *emergent*: social structure and common attitude	All participants (*days*; emergent structure vs. instruction; quantitative)
Meaning (*group interaction*)	Seeing an image evolve; design by visual composition	Discussion (debate, negotiation, persuasion); voting posts up/down	Small group (*hours*; recognizable images and multiple attitudes from cooperation to conflict; qualitative)
User action (*creativity*)	Placing or replacing a tile in a certain color	Written utterance in forum	Individual (*minutes*; clicks and utterances; quantitative/qualitative)

(visual and social artifacts), partly independent (on each level, the artifacts follow unique trajectories requiring separate methods for analysis and design) and partly interdependent (e.g., visual artifacts and social artifacts influence each other; emergence is a relationship between two vertical levels, etc.). The framework allows us to distinguish collaborative and non-collaborative (e.g. destructive; anti-social) behavior on r/place.

We ask the following research questions:

RQ1: How did a specific visual artifact of the r/place canvas and its related social artifact evolve?

RQ2: How do the relative merits of emergence and instruction compare as two mechanisms for controlling the complexity of evolving artifacts?

The first research question investigates the specific evolution of the Mona Lisa picture and discussion, and is descriptive. The second research question investigates how emergence and instruction formed this evolution. Both perspectives are important, as the complexity of the event makes it an interesting case to describe, and understanding what happened paves the way for understanding why.

4. Methods

4.1. Rationale for the mixed methods approach

To capture and analyze data at different levels of abstraction, we chose a mixed methods approach (Lund, 2012) to combine quantitative and qualitative analyses. Based on the framework in Table 1, we used quantitative analysis to compute the structural properties of the activities and qualitative analysis to identify the shared meaning in group interactions and visual artifacts. For the quantitative analyses, we used SNA and analysis of tile placement by users and over time, and for the qualitative analyses, we used interaction analysis (IA) and a content analysis of the evolving visual artifacts. SNA is an established method in social science (Borgatti et al., 2013; De Nooy, Mrvar, & Batagelj, 2018). IA is an interdisciplinary method for investigating the interaction of human beings with each other and with the objects in their environments, including digital objects (Jordan & Henderson, 1995). IA involves verbal and non-verbal communication in face-to-face and online conversation as data.

4.2. Data collection and selection

We collected data from February 2018 to April 2019, as the data remained accessible online. Studying the r/place atlas, we found that more than 800 communities were involved in making more than 1500 objects on the r/place canvas. We used Kozinets' (2015) seven criteria for selecting online ethnographic field sites to narrow down the number of relevant communities and objects. We also added a language criterion (English) for practical reasons and required the visual artifact of choice to be recognizable by the general public, as some were more obscure than others. Based on these criteria, we selected the Mona Lisa image and the Mona Lisa Clan community as the main field sites and focal points for in-depth analysis.

4.2.1. Quantitative data

The quantitative consists of two different, but related data sets based on the visual and social artifacts. The social network data and the r/place data set.

Social network data: We used a script to collect the social network data, which extracted metadata from public JSON files related to the most important (top) posts in the selected community. We included the first three levels of comments based on Weninger, Zhu, and Han (2013, pp. 579–583) Reddit research, which indicated that more deeply nested comments are less relevant. Only posts and comments made during the three days of the experiment were included. Other scientists (Buntain & Golbeck, 2014, pp. 615–620; Del Valle, Gruzd, Kumar, & Gilbert, 2020) have applied a similar approach to select data on Reddit. Posts and comments that we identified as written by bots or anonymous (deleted) users (and replies following them) were not included. A second script formatted the data into the .NET format required by Pajek, a software package for social network analysis (De Nooy et al., 2018). Following Andersen and Mørch (2016), we did not include posts that were not responded to, as the presence of interaction requires a minimum of one post and reply sequence. The sample included 161 unique users and 361 comments on 72 posts. Note that Reddit allows people to own an unlimited number of accounts; thus, the number of users should not be confused with the number of distinct people involved, a number we did not have.

We chose weighted all degree (WAD) centrality as the primary structural property of the Mona Lisa social network. WAD is a measure of a social network computed by SNA software, in this case Pajek (De Nooy et al., 2018). WAD measures the weighted number of ties for each node in the network, that is, the number of interactions, posts and comments (output degree), and replies (input degree), the user has had with other users in the Mona Lisa Clan (Mrvar & Batagelj, 2020). Weighted degree centrality represents a count of interactions similar to the count of placed tiles on the canvas. Based on the input and output values (see Table 4) we can determine whether users were active/inactive and/or gregarious/popular. Other centrality measures, such as closeness and betweenness centrality (Freeman, 1979), typically used to describe the flow of information and distribution of power within a network (Andersen & Mørch, 2016; Borgatti et al., 2013), are also relevant, but outside the scope of this work.

To compute the network value for this node measure, we calculated the WAD values for all the users, summarized the values, and divided by the number of users, obtaining the average number of interactions per user (average weighted all degree, AWAD) of the community during the four phases.

The r/place data set: The official r/place data set (Reddit, 2017c) is openly accessible and includes data on all 16.5 million placed tiles, including timestamps of when the tiles were placed on canvas, their x and y coordinates, colors, and all contributors' hashed usernames. We based the analysis on the tiles with x-coordinates within the range 325–429 and y-coordinates within the range 375–529, as this rectangle comprised what would become the Mona Lisa region (including the frame). A total of 76,774 distinct users placed a total 243,103 tiles in this region.

4.2.2. Qualitative data

We selected 10 posts from the Mona Lisa Clan and studied them in further detail using interaction analysis (Jordan & Henderson, 1995). We selected these posts because the SNA revealed that the most important users were active in the conversations. This reduction of data was necessary because the forum had a large number of posts and studying them all was not feasible. However, it was sometimes necessary to view the animated version of the canvas and to read other discussion threads to understand the broader social context of the utterances in the selected posts. The latter strategy allowed us to follow the evolution of a visual artifact (the Mona Lisa picture) from beginning to end to see how the different parts emerged and interacted, and when the users were most active. We also identified toggle shifts between the Mona Lisa picture and the discussions in the Mona Lisa Clan. Finally, it was necessary to identify interactions with surrounding pictures and the discussion threads of embedded images within the Mona Lisa region. Hence, snapshots of the visual artifact itself is also part of our qualitative data.

4.3. Ethical considerations

The study is based on the publicly open r/place data set and discussion forum Mona Lisa Clan on Reddit. Its open access increases reliability at the expense of privacy. However, publishing personal information is strictly prohibited on Reddit (Reddit, 2017d), and generally, the rule seems to be followed. Even if Reddit users are aware of their posts and comments being public (openly accessible on the web), they might not agree to their contributions being taken off Reddit and used for other purposes, including research. To inform all participants of the study, we sent a post to the r/placenostalgia forum with general information about the study. In addition, all quoted participants received a personal message on Reddit, including an information letter about the research and how to opt out. No participants chose to withdraw. The research is approved by the Norwegian Center for Research Data.

In sum, we applied a mixed methods approach because our research in mass collaboration considers three independent levels of a complex system: user action, group interaction, and their structural context.

5. Data and analysis

We present and analyze the data according to a mixed methods strategy: 1) quantitative data and 2) qualitative data (enriched). We start with the visual artifact (the Mona Lisa picture) and then the social

artifact (the Mona Lisa Clan). We reproduce four visual images and three interaction excerpts.

5.1. Visual artifact

We present the visual artifact data on two levels: the visual structure and visual composition.

5.1.1. Visual structure

Fig. 2 shows a visualization of the amount of activity (frequency of tile placement) in the Mona Lisa region during the 72-h lifetime of r/place, based on data extracted from the r/place data set. Each color corresponds to the color placed on the canvas. The length of a colored bar shows the number of pixels of that color placed in the region during a given 1-h period. The tile placement graph was not accessible to the participants during the r/place event. We created the graph as a research tool.

We roughly divided the 72 h of the Mona Lisa region into four phases of 18 h each, based on the visual Mona Lisa data and metadata in Fig. 2. During the first phase, the Mona Lisa did not exist in pictorial form. During this phase, 8.5% of the color tiles in the region were placed. The second phase was the main construction phase (the picture was recognizable as the famous painting); 36.3% of all color tiles were placed. The third phase was the refining phase (29.5% of tiles). The fourth and final phase consisted of maintaining the image against vandalism as no new visual objects were added or removed (25.8%).

The distribution of users' actions is shown in Table 2, the average number of tile replacements per user during the four phases. The number of actions doubled from phase 1 to phase 2 and remained steady at about 3 ± clicks per user during phases 2 and 3 with a slight decrease in phase 4. The increase in activity from phase 2 to 3 did not follow the same pattern as shown in Fig. 2. A reason for the discrepancy is that user actions focused on smaller parts during refinement and maintenance.

Table 2
Mona Lisa visual structural properties.

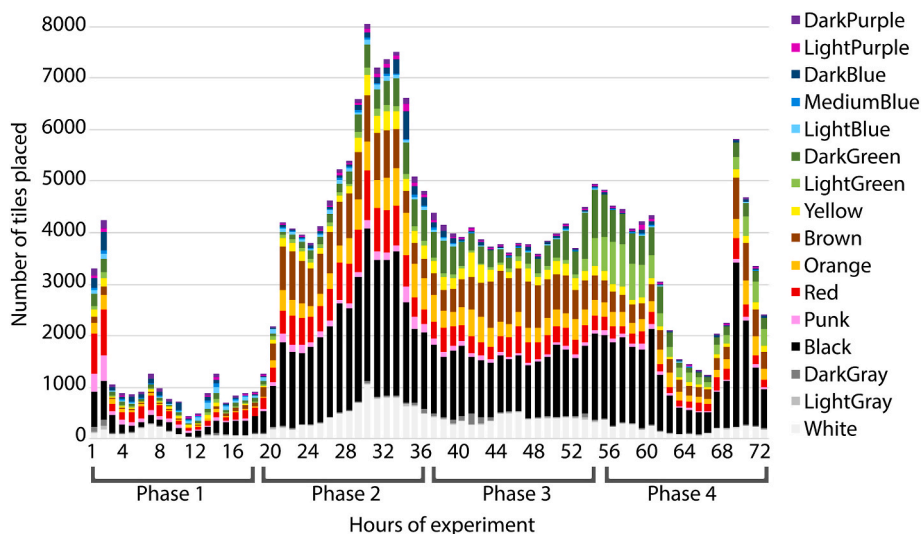| Phase	Tiles	Users	Average number of tiles per user
1	20,579	13,580	1.52
2	88,178	29,702	2.97
3	71,720	21,902	3.27
4	62,626	23,578	2.66

Fig. 2. Tile placement graph: Number of tiles placed by color per hour in the Mona Lisa region.

5.1.2. Visual composition

The images shown in Fig. 3 are four snapshots of the Mona Lisa region and the closest surroundings, as they appeared to the participants of r/place at four moments in time (approximately t = 23, 27, 32, and 47 h). The snapshots represent pivotal moments we identified in the development of the visual Mona Lisa image, and all four took place within the two most active phases of development according to the graph in Fig. 2 (phases 2 and 3). For the final version (t = 72 h), see Fig. 1. Snapshots were extracted from egeesin (2017).

Fig. 3(a)–(d) depict how the Mona Lisa first appears (a) and how her visual surroundings evolve along with her, including claiming and framing-out space (b). In snapshot (c), the full Mona Lisa picture takes shape, and the r/monalisaclan URL tag has appeared (see bottom of picture). In the last snapshot (d), a frame has been added, and the rainbow pattern crossing over the lower right corner has been integrated in the frame. While the Swiss flag and rainbow pattern were present throughout the development, other objects were overwritten, including the pineapple and the leaf to the right of the Mona Lisa's face. Why this visual composition, manifested as mergers and expansions of regional territory, occurred, we cannot determine with the visual artifact analysis alone.

5.2. Social artifact

We present the social artifact analysis on two levels: the social structure and social interaction.

5.2.1. Social structure

The Mona Lisa Clan opened at about 23 h. At this time, the Mona Lisa image had been recognizable for some time, and further work required coordinating the completion of the image and gaining higher authenticity.

Almost all nodes (97.5%) were connected to the main Mona Lisa Clan network of interactions. Table 3 shows the AWAD centrality of the whole network during the different phases of evolution.

As the Mona Lisa Clan did not exist until the second phase, no data for phase 1 is available. Overall, each user in the Mona Lisa Clan had three to four interactions during each phase, on average (Table 3). The average WAD centrality of the network increased from the second to the third phase, meaning the average user was involved in a higher number of interactions when entering phase 3. The changes were not in proportion to the changes happening on the visual Mona Lisa, which had higher activity in phase 2 than in phase 3 (Fig. 2). However, the changes in AWAD is in line with the number of tiles placed per user (Table 2). The average degree value declined during the last phase (3.95–3.80), which was also the case of the activity happening on the canvas. An interesting result is that involvement in developing the Mona Lisa picture during phases 2 through 4 (Fig. 2, Table 2) decreased more than the Mona Lisa Clan activity, which had fairly constant activity until the end.

Table 3
Mona Lisa Clan network structural properties.

Phase	Nodes	Edges	Average weighted all degree (AWAD)
1	n/a	n/a	n/a
2	76	103	2.87
3	133	224	3.95
4	161	265	3.80

The users shown in Table 4 were involved in the highest number of interactions in the Mona Lisa Clan, by writing many posts and/or comments (high OutDegree) and/or receiving many replies (high InDegree). Identifying these users provided a rationale for selecting potentially important posts to investigate further. User 341 stands out in this list because they were relatively inactive, yet their low number of interactions produced many responses, indicating importance based on popularity and perhaps quality.

5.2.2. Social interaction

For the group interaction level, we present three excerpts from the Mona Lisa Clan discussion forum. We selected the excerpts based on the following criteria: They involved one or more important users (Table 4), and they connected to the development of the Mona Lisa picture (references to sub-components). We present the excerpts chronologically, based on the post timestamp. The first turns in each post were written within a 6-h timeframe (27–32 h), all within the 2nd phase of the development; see Figs. 2 and 3b-c for reference. We assigned each user in the excerpt an identification (ID) number, followed by their WAD centrality in boldface (structural properties). This allowed us as researchers to get an indication of how active and influential or popular each user was, but this information was not available to the users themselves.

Extract 1: *Interactions Between Communities.* This extract shows a post made by user 1221 representing the Swiss flag community (r/Swiss-NeutralityZone). The post was written at about 27 h.

User 1221 had a relatively low WAD (4) and did not participate in any later interactions in our selected posts. However, the request was

Table 4
Top five most important users in the Mona Lisa Clan according to weighted all degree (WAD) centrality (ignoring interactions with bots and deleted users). Column 5 is the sum of columns 3 (weighted input degree) and 4 (weighted output degree).

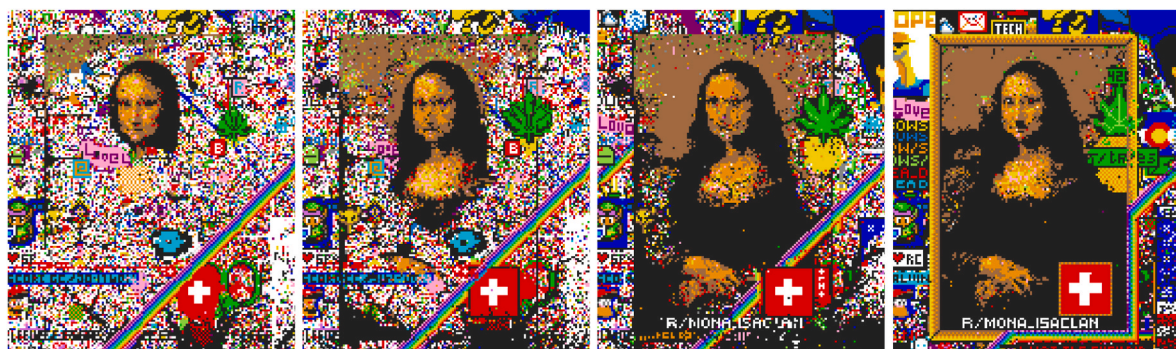| Importance	Actor	WID	WOD	WAD
1	User 1137	22	13	35
2	User 341	31	3	34
3	User 286	10	19	29
4	User 1174	13	14	27
5	User 1152	12	12	24

Fig. 3. Evolving visual artifacts (left to right): a) Mona Lisa appearing (t = 23 h), b) Mona Lisa, leaf, and Swiss flag growing and becoming more recognizable (t = 27 h), c) Mona Lisa Clan tag is made (t = 32 h), d) the frame is made and overwrites pineapple and leaf to the right of the Mona Lisa's face (t = 47 h).

Table 5

Interactions between representatives from two communities (r/monalisaclan and r/SwissNeutralityZone).

Turn	Actor (WAD)	Content
1.1	User 1221 (**4**)	Hello from/r/SwissNeutralityZone. We support your project. Respect our neutrality and we will help you build your Mona Lisa.
1.2	User 1158 (**4**)	We can work with the Swiss, but I fear you're getting consumed by the black hole:(
1.3	User 1152 (**24**)	Here you go: [link to image of the Mona Lisa with Swiss flag] That's the new design for us
1.4	User 1224 (**1**)	If you're interested, we could use some help completing it! You can view the contributing info [link] or join the Discord channel [link]

clear: Do not overwrite the Swiss flag. User 1158 (the first user to propose creating the Mona Lisa) was concerned about a third faction, "the black hole," whose members overwrote any and all visual objects in their path with all black tiles. The influential user 1152 (WAD = 24) accepted the initial request within 40 min and linked to an image of the Mona Lisa design, which included the Swiss flag. User 1224 welcomed the Swiss representative to join forces in developing the Mona Lisa.

Extract 2: *Social and Visual Integration*. In this extract, the most important user (1137, WAD = 35) suggests that they incorporate the r/monalisaclan tag (URL) in the Mona Lisa image. The post was written at about 30 h.

User 1137 suggested writing an URL tag to recruit more people to the Mona Lisa Clan to help with the coordination work of creating the image. Less than 2 h later, user 292 (WAD = 1) replied that it worked and that they were there because of the tag. Users 1138 (WAD = 11) and 1202 (WAD = 1) did the same. Users 1200 and 1201 discussed the design of the letters at the pixel level. In snapshot (c) in Fig. 3, the L in "clan" is three pixels wide. In the next snapshot, it is four pixels wide, and the letters have been moved so they are distributed as user 1200 suggested in turn 2.4.

Extract 3: *Cooperation and Conflict*. The post in Extract 3 starts with an important user (WAD = 34) representing the Rainbow Road community (a community with territory that borders the Mona Lisa) suggesting giving the Mona Lisa a frame and at the same time, providing a solution to the design problem of the rainbow pattern crossing over the lower right corner of the Mona Lisa. The suggestion includes a visual design. The post was written at about 32 h when the activity on the canvas in the Mona Lisa region was highest (Fig. 2).

Members of a third community, "r/trees," were not pleased with the suggested frame, as it crossed over (and therefore, would destroy) their pineapple and leaf objects, located to the right of the Mona Lisa's face. r/trees is a forum for discussing recreational cannabis use that has a

Table 6

Social and visual integration.

Turn	Actor (WAD)	Content
2.1	User 1137 (**35**)	Let's get "r/monalisaclan" written! Hopefully everything else will come together more easily when we have more recruits. Use this as a guide: [link to image showing where to write the tag]
2.2	User 292 (**1**)	Looks like it worked. That's how I found you guys!
2.3	User 1201 (**2**)	Shift the last three letters one pixel to the left pls.
2.4	User 1200 (**3**)	No, shift "ISAC" to the right one pixel. Going off the official guide, the "L"s should be four pixels wide, but currently they're only three.
2.5	User 1138 (**11**)	Mona minion reporting in!
2.6	User 1202 (**1**)	I came here from seeing this on the picture! Let's get painting, fellow Da Vincis!

Table 7

Cooperation and conflict.

Turn	Actor (WAD)	Content
3.1	User 341 (**34**)	hello from rainbowroad, LET'S GIVE THE MONA LISA A FRAME, and incorporate the rainbow!!!!!!!! [link to image with visual representation of frame with rainbow]
3.2	User 1131 (**8**)	Please go around the pot leaf and pineapple. Leave us stoners be./r/trees want to leave their mark too. We set it up at 420/420, and there it will stay.
3.3	User 286 (**29**)	I like the idea and I get it, 420,420, but don't you guys think that was a bit inconsiderate?
3.4	User 1132 (**3**)	I agree, it is inconsiderate for someone to put their artwork over another's, especially when they were there first.
3.5	User 286 (**29**)	They could have put that pineapple anywhere and it would've been fine if it was just overlapping a bit like the hornets up top, but they made it way too intrusive.
3.6	User 1133 (**7**)	Our pineapple was in unclaimed territory first? Then r/monalisaclan proceeded to square out their picture and completely wipe out our pineapple, tag and leaf overnight.
3.7	User 1131 (**8**)	(answering turn 3.3) Nope. It's our holy right to set it up at 420, 420.
3.8	User 286 (**29**)	No it's not. You guys are just being hard-headed.

special relationship with the number 420, which is why they wanted to place their artwork over the tile with the coordinates x = 420, y = 420. This tile happened to be within the Mona Lisa region. User 1131 (WAD = 8) asked whether the frame could go around the leaf and pineapple objects, but the influential user 286 (WAD = 29) in the Mona Lisa Clan refused. In Fig. 3(d), the pineapple and the leaf are overwritten, but in the final version of the canvas (Fig. 1), they have reappeared over the frame.

6. Discussion

We organized the discussion to address the research questions, and we make use of the conceptual framework and related work to generalize the results.

6.1. How did a specific visual artifact of the r/place canvas (Mona Lisa picture) and its related social artifact (Mona Lisa Clan) evolve?

The two artifacts changed in a similar way, with the addition or replacement of parts of an existing object (visual region and discussion). The decision of what to add or replace was (for the most part) made at the group interaction (meaning) level, whereas actions were carried out on the user action level (Table 1). Ordinary users indirectly affected the structure of the evolving artifacts as more color tiles were added to the canvas, and new users entered the discussion forum (i.e., the structural properties were updated). r/place is an example of mass collaboration (Tapscott & Williams, 2008; Whittaker et al., 1998, pp. 257–264) where two levels of abstraction were commonly distinguished, small group conversation and a higher level consisting of a network of many weak ties as a result of specialization into factions of shared interests (Fischer, 2001). In addition, we draw on the micro-level of user actions of placing tiles and issuing utterances, which is the most basic level of participating on r/place (Rappaz et al., 2018, pp. 261–269). According to Rappaz et al. (2018, pp. 261–269), the user actions or the visual artifact became more focused over time, and as more communities integrated URL tags, there is reason to assume that social interaction also became more focused, but this can be further explored with social network analysis across communities.

A common trait of the three excerpts (and many of the top posts in general) is that they included "blueprints." In excerpt 2, we can see the users discussing changes in the design of the URL tag template. The original blueprint was realized first, but later, the discussed changes were transferred to the canvas. These blueprints represent a higher-level

representation (a kind of visual model or overall design) of the visual artifact that changes at a slower rate than meaning (visual composition) and user actions, same as the AWAD centrality of the network (see Section 6.1.2). We refer to the blueprints as visual patterns below.

The two artifacts differed the most at the structural level and the rules; the social artifact did not have the same restrictions on activity and space as the visual artifact. However, the sitewide rules applied to both visual and social artifacts. The emergent properties at this level had some variation, as we discuss below.

6.1.1. Evolution of a visual artifact

We identified different phases of high and low activity in the development of the Mona Lisa picture (Fig. 3). High activity was associated with initiation, object recognition, and maintenance (including combating vandalism). At the structural level, the tile placement activity per user changed from 1.50 to 2.66 with peaks in between at 2.97 and 3.27 (Table 2). In other words, the activity was stable at about two to three mouse clicks per user during the four phases. Fig. 3 shows how the Mona Lisa Clan members completed Mona Lisa's facial region first, followed by her hands—the famous painting's most distinguishing features. As we discuss later, being recognizable to other communities was important for the visual objects to "survive" on the canvas. Not until most of the Mona Lisa was drawn based on the initial blueprint did the community start to work with (and against) the extraneous objects and to integrate the URL tag. The tile placement activity moved from simply copying the visual model to updating the model itself based on activity in neighboring visual objects. As the Mona Lisa became recognizable, activity also shifted to a protective mode, where users placed tiles to protect the Mona Lisa against vandalism. Being recognizable was both a blessing and a curse in this sense, as it attracted both supporters and challengers. As the experiment ended without warning, the users did not know how much time they had to complete their projects. Although the Mona Lisa image can be seen as a moderately successful project from the Mona Lisa Clan perspective, there are examples of other objects whose stakeholders were not in agreement at the 72-h mark. Not to mention that some visual objects were, in fact, overwritten by the Mona Lisa. From their supporters' perspective, the Mona Lisa may have been disastrous.

6.1.2. Evolution of a social artifact

The AWAD is the most general measure for the evolution of the Mona Lisa Clan. It gives a count for the average number of interactions each user was involved in the discussion forum. This value started at 2.87 in phase 2, increased to 3.95 in phase 3, and decreased slightly to 3.80 in phase 4. Thus, it gradually changed from 2.87 to 3.80 over the 72 h, on average. In other words, the number of interactions per actor remained steady over the three days. However, some participants were very active (see Table 4, WAD values), and many participated with only one or two postings.

At the meaning level, we analyzed group interaction in terms of meaningful units of conversation (excerpts). The excerpts are dialogs about coordination of the development of the visual artifact and include examples of cooperation, conflict, negotiation, persuasion, and decision-making. The dialogs were of two types: convergent or divergent. Convergent dialogs had a common point of reference in a visual object or another discussion thread and seemed to be aimed at finding a point of resolution for including the (foreign) object. Divergent dialogs took longer to reach closure or consensus or decisions on actions, and they tended to be less cooperative and more anti-social. Markers have been suggested to tag Wikipedia articles that have a high level of conflict to alleviate discussants from excessive work (Kittur et al., 2007, pp. 453–462). This is a feature that r/place could have benefited from, to short circuit divergent conversation. High-WAD users seemed to have more decision-making power. As we see in the excerpts, (e.g., user 1137 in Extract 2 and user 286 in Extract 3), the high (weight > 20) WAD users had the power to allow and/or stop suggestions from being acted

on, but the causal relationship between WAD or power and user action remains unclear. This relationship compares with Andersen and Mørch (2016) who found that actors who have high status (measured by centrality values) and important roles were more likely to be listened to in the discussion forum of a customer engagement platform. As success on the r/place to a degree was dependent on engaging users to work together, WAD can instead be seen as a measure of the amount of engagement a user has produced directly (through posts/comments) or indirectly, by receiving many replies. Some types of posts may be more suitable to spark engagement, for example by linking to visual models (e. g. turns 1.3, 2.1, and 3.1), or by addressing controversial topics (e.g. user 286). User 341 remains an interesting example of how it was possible to make an acceptable suggestion even as a relatively inactive (WOD = 3) user. Their low output degree also strengthens their claim that they are coming "from rainbowroad" (turn 3.1), hence not identifying as a member of the Mona Lisa Clan.

6.1.3. Interdependency of visual and social artifacts

In the beginning, there was no interaction between the visual artifact and the social artifact, because the Mona Lisa Clan did not appear until about 23 h. From that time on, the Mona Lisa Clan members began vigorously coordinating the picture development toward a solution they could agree on with other factions, based on negotiation and persuasion, ranging from cooperation to conflict. For the Mona Lisa picture, the tag object (an URL) created a close coupling between the corresponding visual and social artifacts. For the Mona Lisa Clan, discussions referring to the sub-components (visual objects) of the Mona Lisa picture that belonged to other communities (r/trees, r/SwissNeutralityZone, etc.) further increased interdependence.

Many visual artifacts have URLs (tags) that link to a social artifact (discussion thread). In the Mona Lisa, this happened because members wanted to recruit new people to their community and to coordinate work (e.g., see Extract 2). The URL created a communication path with other communities. We saw indications that other factions might have had the same reasoning, based on viewing other parts of the canvas, where there are several examples of integrated visual objects. However, we did not find any discussion forums that were mutually integrated, where members of two or more communities were working together on equal terms. Instead, the discussion forums seemed to be connected by the use of diplomats who visited other communities (such as users 1221, 341, 1131, and 1133). While Rappaz et al. (2018, pp. 261–269) equated user activity with community affiliation ("belonging"), the present result provides contradictory evidence. In Turn 1.1, user 1221, although clearly identifying as a member of the Swiss flag community, proposed to help create the Mona Lisa. Therefore, community affiliation cannot be identified with quantitative measures alone.

The participants organized work, not only on a broader conceptual level, as in Extract 3, but also on the refinement of objects down to the single pixel level (Extract 2). This provides an example of the usefulness of a complex (leveled) framework for analysis that considers the social and visual artifacts (Table 1).

The interactions between the visual and social artifacts have anchor points in intermediate building blocks, that is, meaningful units in social artifacts and recognizable sub-components in visual artifacts, which compare with stable intermediate forms (SIFs; Simon, 1996). Examples of SIFs in social artifacts are posts and comments by important actors, as they are responded to or sent to a larger number of participants and therefore kept in circulation for a longer time. Interdependence at this level is established by intersubjectivity, according to Stahl (2003) who stated meaning is shared and exists in an intersubjective world (Fugelli, Lahn, & Mørch, 2013), whereas interpretation is about individual understanding and expression.

6.2. How do the relative merits of emergence and instruction compare as two mechanisms for controlling the complexity of evolving artifacts?

6.2.1. Emergence of structure

Previous researchers have shown that collaboration patterns emerged on r/place, as user actions became more focused over time on specific areas on the canvas. That is, subsequent mouse clicks were closer to each other over time (Rappaz et al., 2018, pp. 261–269), implying the users worked on smaller parts of the picture (to make, remove, and integrate objects into the larger image). Rappaz et al. (2008, pp. 261–269) also found that user activity became higher from the second day, which they explained by increased interest in the r/place event, attracting more participants.

However, from day 2, the rate of growth of the overall picture did not change in the same proportion as the user actions. This is because the Mona Lisa community had to change their focus from refining the canvas to combating malicious attacks from neighboring clans who disagreed about the importance of the artwork. We found that when we analyzed the user actions at the meaning level, the objects had multiple origins. In addition, the process was not always collaborative but sometimes conflict laden. Growth of the images was regulated by the number of smaller objects within an image that diverged from the original idea (i.e., the blueprint or visual model), which was partially influenced by discussions. For example, in turn 1.3 an influential user linked to an updated design of the Mona Lisa accepting the Swiss flag as an extraneous object. The size of the visual and social artifacts determined their ability to dominate and remain on the canvas without risk of being wiped out.

Visual patterns: The visual composition activity was focused and goal oriented, but there were different goals. The Mona Lisa image was partially distorted from the original painting because of three extraneous elements (the Swiss flag, the rainbow pattern, and the pineapple and the leaf). We conjecture that the distortions represent a process of updating the underlying visual pattern (blueprint), which was paralleled in the discussions by influential users promoting or confirming the new pattern and supported by serendipitous utterances such as the following: "Use this as a guide" (Extract 2, turn 2.1, user 1137, WAD = 35) and "That's the new design for us" (Extract 1, turn 1.4, user 1152, WAD = 24). The interactions could also mean some sort of negotiation of a shared visual identity between the different stakeholders. However, a possible objection is that the r/trees community had a reason for the placement of the image, which we did not observe in the other communities.

The Mona Lisa was placed in a relatively "empty" space on the canvas, but the Swiss flag, rainbow, and leaf were identifiable as objects in this area early as discussed in Extract 3. More obscure objects were overwritten. From this, we infer that once a visual object was recognizable, it had a better chance of survival and being integrated with other designs outside their own, which seemed to be a shared understanding between the communities in this area. We refer to the overall visual pattern of r/place as *integrated, skewed artwork*. By integration we mean artwork with a visual URL tag to a social artifact.

Social structure and common attitude: Social structure was more easily gleaned from the data as it was captured with SNA software, including WAD centrality for individual actors, and AWAD for the whole network during the different phases of evolution. The best measure we have for social structure is the value of the AWAD, which was around three to four interactions per user, on average (Table 3). This means that the social structure is quite stable, providing contrast to the multiple attitudes from cooperation to conflict observed on the meaning level. According to Fischer (2001), the multiple attitudes must be transcended, and Mead called the generalization of multiple attitudes for common attitude or 'generalized other.' According to Mead (1934), generalized other is the shared notion that a person has of the common expectations that others have about actions and interactions within a particular society. This "brings the attitude of all participants together to form a symbolized unity: This unity is the 'generalized other'" (p. 151). The

different attitudes we observed on r/place through interaction analyses were multiple social perspectives, e.g., artwork (alien object) advocator, negotiating toward acceptance, and negotiating toward rejection. A common notion to bring them together, as symbolized unity, was persuasive social perspectives according to r/place rules and actor/clan weights. For simplicity, abbreviated as *persuasive social perspectives* in Fig. 5.

6.2.2. Emergence of meaning

We observed two kinds of emergent behavior at the meaning level: recognizable artwork on the r/place canvas and multiple attitudes in the discussion forums.

Recognizable artwork: In Fig. 3(a), most of what would become the Mona Lisa region is covered in randomly colored pixels on a white background, with a few objects that can be recognized as something other than "chaos." In the first phase, a new behavior of users testing out the technology emerged, and a few users started to make small and simple objects. In the second phase, recognizable objects emerged, and there was a slow shift from seemingly random user activity to meaning making and structure. In the same way, the discussions became more focused as the communities created designated forums in which to plan their artwork. Finally, the communities started discussing and creating visual objects across the regions, either interfering or merging with others. The behaviors not only changed during the three days but also became more complex and interdependent.

Multiple attitudes: Unlike World of Warcraft, where the two factions are part of the game's design (Orr et al., 2012), the community of r/place was a conglomerate of multiple attitudes organized into factions. The different factions had different approaches (or ethics) for developing and maintaining their visual artifacts and objects. For example, the black hole members "consumed" other images with black tiles, the rainbow road members integrated their rainbow pattern with other images, and the Mona Lisa Clan accepts compromises to allow their object to resemble the "real" Mona Lisa as much as possible. Whether the Mona Lisa Clan accepted the compromises or not was determined by the "weight" or importance (by the users) of the foreign objects. Discussion threads and communities with many divergent paths because of discussants representing different visual objects with a stake in the region had the effect of skewing the picture in a unique way. If the conversation was cooperative, a new sub-component could be accepted as a part of the main picture. If the conversation was conflict-oriented, it could be deleted, especially when the stakeholder was a smaller community. Overwritten objects were sometimes allowed to reappear at a later stage, as we observed with the pineapple and the leaf in the Mona Lisa region (see Extract 3, Figs. 1, and Fig. 3). In other situations, decisions about what to include and exclude of another community's visual image were handled by negotiation, or objects were overwritten without any discussion at all. In Fig. 3, we observe several small objects that were reclaimed by the Mona Lisa. The boundary between creative evolution and vandalism was not clear but a tradeoff to be negotiated (Giaccardi & Fischer, 2008) and a question of attitude.

6.2.3. Toward generalization

Fig. 4 shows examples of distorted images that resemble the Mona Lisa visual structure (partly cluttered by a broad mix of different objects, including URL tags, recognizable images, etc.). For instance, we point to the integration between the Belgian and German flags with beer and sausage, and the compromise between France and Germany of creating a "neutral" European Union (EU) region with a peace dove in a disputed area between them. Several of the regions include URL tags, such as r/placede, r/wine, and r/monero. This suggests that processes similar to that of the Mona Lisa also emerged elsewhere on the canvas.

6.2.4. Comparison of emergence and r/place instructions and rules as control mechanism

The predefined size of the virtual canvas meant that space was a

Fig. 4. Creative evolution or vandalism? Canvas region x = [187−557], y = [696−892] shows examples of skewed visual artifacts and tags to integrate them with social artifacts, and resembles emergent structures recognized in the Mona Lisa.
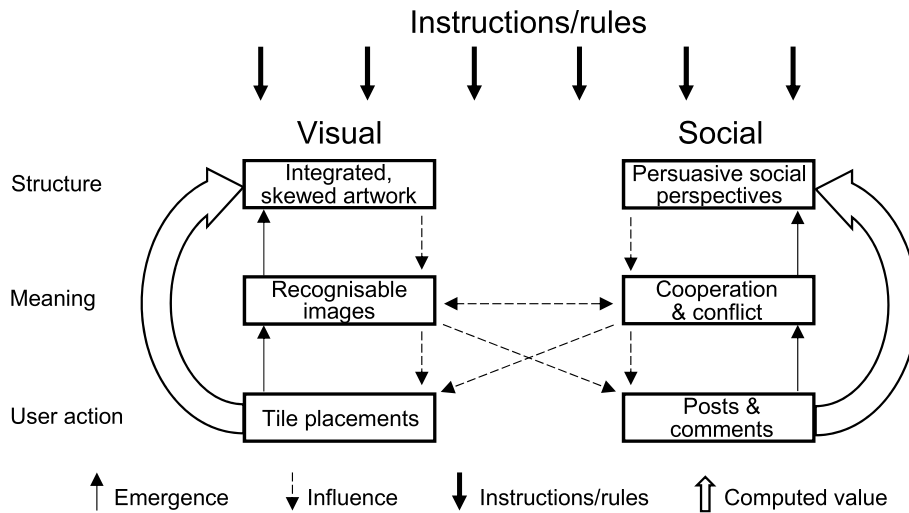

Fig. 5. The relations between the three levels of abstraction, and visual and social artifacts. The computed values of the visual artifact are the average tiles per user in the range = 1.51–3.27, and the computed values of the social artifact is the AWAD in the range = 2.87–3.95.

limited resource. The participants had to find ways to deal with this issue. We believe that the emergence of distortion and the integration of the visual artifacts were partly caused by this limitation. Limited resources gave the participants creative and collaborative opportunities that may not have appeared otherwise, although the first rule of r/place encouraged participants to be creative. Similarly, to an anthill, when an extraneous object suddenly appeared, the workforce instantly recognized the threat and reorganized (building came to a halt, restoration and maintenance became priorities, battle agents are put to the forefront, and so forth). These were behaviors of the intermediate level that seemed to emerge as an indirect consequence of the mass collaboration set in motion by the r/place rules and restrictions with the net effect of controlling growth.

Rules are examples of normative representations applicable to artifacts, whereas emergence (as an object) is a descriptive representation. The distinction between normative and descriptive representations in relation to artifacts was made by Simon (1996). Furthermore, the rules of r/place were top down, and emergence worked bottom-up. The former was created by developers and the latter (indirectly) by end users (Fig. 5). If the developers had been allowed or encouraged to redesign or adapt the rule set during the course of the experiment, the process would have resembled evolutionary growth that is periodically updated by

restructuring as suggested by Fischer and Ostwald (2002). However, no such restructuring occurred on r/place, except for short periods where the tile placement time limit was slightly longer. We speculate about the consequences in the final section as a tradeoff of two forces that must be balanced (combined in appropriate proportions).

The artifacts on the r/place canvas evolved through user actions and group interaction influenced by the co-concurrent activity of the visual and social artifacts. Overall, the activity was regulated by two control mechanisms (top down by instruction or rules and bottom up by emergence). The computed values were user actions and examples we obtained by tile placement graph analysis and social network analysis. They were the output of the research tools, whereas influence and emergent phenomena were researchers' interpretations of the actions and interactions.

In Table 8, we see that, on the one hand, the instructions for the users were vague and do not account for the complexity of the results, neither visually nor socially. On the other hand, some of the rules being open-ended may have led to unanticipated consequences. Although presented as a top down mechanism, we may also consider the instructions of r/place the foundation that enabled the emergence. Hence, the two factors of controlling complexity are not necessarily in opposition, but define a dynamic but define a dynamic relation.

Table 8
Emergence and rules control the complexity of evolving artifacts at the meaning and structure levels.

	Visual artifact		Social artifact	
	Meaning	Structure	Meaning	Structure
Instruction/ rules	Be creative	Tile placement restrictions (5-min rule)	'Together you can create something more'	Be civil; do not post personal information; follow site-wide rules
Emergence	From random clicks to individual, and later interconnected, objects	Stable, controlled by other emergent objects and the flexibility of underlying visual patterns (blueprints)	Developing discussion threads, recruiting members, and becoming a member; interacting and competing with other groups	Stable, controlled by influential users; organized in factions with diplomats and communities of interest that depend on influx of new users to remain stable

7. Conclusions and suggestions for further work

The results indicate an approach for examining social interaction in online communities as a dialectic process. This process is triggered by artifacts changing at different levels of abstraction according to different time scales. The levels achieve two important tasks of evolution: pre-serve history (the higher level captures the history of the lower level in a more durable form) and control complexity (the higher level controls the rate of growth of the lower). The connection between two different levels of the same artifact is defined by object transformation: An object appearing on one level may reappear on a higher level in a different form. This is a biologically inspired metaphor of reconstruction first used (to the best of our knowledge) for analyzing symbolic communication in face-to-face settings (Mead, 1932, 1934). We adapted the framework for online communication and applied it to r/place with two types of artifacts (visual and social). The analysis identified four types of relations among the artifacts: instructions/rules, influence, emergence, and computed values. Influence defines a relation between the artifacts on the user action and meaning levels, between social and visual arti-facts, and from a higher level to the lower level of the same type (Fig. 5). Emergence puts into motion history, control and reconstruction pro-cesses between two connected levels as described above, and computed values are the output of SNA and tile placement graph analysis (struc-tural properties) of user actions of social and visual artifacts, respectively.

We also compared emergence to rules or instructions as a bottom-up vs. top-down control mechanism. r/place has a set of rules making it different from other mass collaboration sites (72-h duration; 1000- by 1000-pixel canvas, bottom-up process, etc.). We argue the restrictions of r/place allowed for certain types of emergence, and in turn, this emer-gence could have influenced developers to change the restrictions. The term 'restrictions' should not be understood inherently negative in this context, as our results showed that the constraints were important cat-alysts for creative collaboration. On the other hand, restrictions can of course be inhibiting (or overly unrestrictive), to the point where user actions and meaning making are too limited (or too unlimited) for stable structures to emerge.

There are advantages of constrained settings for research purposes. r/place was a social experiment as advocated by Reddit (Asarch, 2017), and researchers could, in a short time, study a mass collaboration pro-cess from beginning to end. We suggest the analogy of the biological "fruit fly experiment." A fruit fly experiment captures realistic complexity on a small scale (simple reproduction cycle; observable with

ordinary tools; inexpensive to maintain, etc.). If researchers are allowed to vary the initial conditions, in this case such as the "5-min rule" or the size of the canvas, hypotheses about, for example, design activity, learning behavior, and social organization in mass collaboration can be tested out in a matter of days or months. The idea of changing conditions affecting behavior is in line with Sawyer (2005), who argued that emergence is sensitive to boundary conditions.

7.1. Limitations

The methods we used for the structural analysis of the evolving ar-tifacts (tile placement graph and social network analysis) could not capture naturally emergent structural contexts s, that is, the dynamics of structural changes, with the snapshot diagrams we show. Although the changes appeared slowly and with average values as good approxima-tions, it would be even better to see the dynamics of the degree centrality for the whole network and for selected participants as the activity un-folds during significant (meaningful) events.

7.2. Future work

As future work, we make the following recommendations. Tools developed and/or used by scientists to study social media like Reddit can potentially enhance the user experience on other social media and in other settings, such as workplaces and educational institutions. Other researchers can use the conceptual framework we developed in new settings. It considers modification of artifacts at different levels, and is original in treating emergence as a bottom-up control mechanism that is comparable with (top-down) rules and instructions.

We suggest graphical and verbal feedback with the value-added in-formation we used in the interaction analysis can inform end users' further actions. Researchers could investigate which output displays would help end users make sense of emergent information without having to analyze tile placement graphs and SNA measures. Researchers could also investigate the tradeoff between emergence and instruction as a control mechanism for coordinating social interaction in challenging environments (e.g., Covid-19; e-scooters in Europe). Scholars could develop tools for analyzing the structure of meaningful units (e.g., se-mantic analysis of debate to detect conflict and cooperation, along the ideas proposed by Andersen and Mørch (2016) and tools for analyzing political debates to reveal gaps in argument and decision making by stakeholders deliberately or accidently ignoring significant historical information.) Natural language processing could contribute towards this aim, not unlike the method proposed by Mørch, Andersen, Kaliisa, and Litherland (2020) in a learning analytics context. Researchers could examine interfaces that inform the users of a community when an evolving image is recognized as a known picture, and to identify and report visual subcomponents created by users outside the community. Finally, researchers could also create tools for measuring and displaying an online community's common attitude, and explore how changing the constraints or initial conditions (e.g., r/place rules and restrictions) in collaborative tools affects the outcomes of collaborative work. In all, there are myriad of contexts where understanding the merits of in-struction and emergence is relevant and useful to clarify.

Author contribution

Kristina T. Litherland: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Visualization, Project administration. Anders I. Mørch: Conceptualization, Methodology, Formal analysis, Investigation, Writing – review & editing, Supervision, Project administration.

Declaration of competing interest

The authors certify that they have NO affiliations with or

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2021.106845.

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