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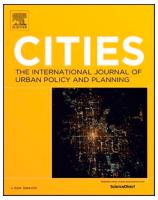

Opening alternative data imaginaries in urban studies: Unfolding COVID place attachments through Instagram photos and computational visual methods

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ABSTRACT

Planners, policy makers, and scholars are increasingly using social media data to study public life in cities. Yet, such projects tend to be limited by three commitments that shape the imaginaries of such data-driven urbanism, namely 1) bias towards textual social media; 2) fixation on geotag-ontologies; and 3) seeing the subjective nature of data as a bias. The consequence is that the potential of digital traces for renewing the empirical ground of digital urban studies is not fully realized. To open alternative imaginaries around data-driven urbanism, we provide a bibliometric review of these trends and suggest that social media images could be used to study place attachments and explore how people experience cities, bridging ethnographic research questions with the computational agenda. Second, to exemplify what can be gained from such a re-orientation of urban projects, we deliver a digital methods study of 39K Instagram posts from 2020 and explore how people in Denmark attached to different environments during the first nine months of COVID-19. The case demonstrates that we might open new empirical routes in urban studies by centering image data, moving beyond geotag-ontologies, and foregrounding the subjectivity of data as an analytical opportunity, rather than a problem.

1. Introduction

With the proliferation of online media, critical voices in the humanities and social sciences have argued that digital technologies alienate people from cities and places, producing a distracted and spatially disembodied relationship to urban environments (Luke, 2005; Shaw, 2015). In this view, technology produces a postmodern subject, or 'cyberflaneur', who is detached from the city. Others, however, have proposed that the pervasiveness of digital media in cities lead to new contexts for the production of public space (Wilken, 2008). Adding to that, scholars like Halegoua (2020) and Gatti et al. (2022) pose that digital media do not only constitute an integral part of how we experience urban life, but is central to how we embed ourselves in urban environments and create a sense of place and community. This became more visible than ever in 2020 when the COVID-19 pandemic put urban populations under quarantines and lockdowns, changing life in cities across the globe. Navigating new urban realities and everchanging restrictions, people took to social media to share their experiences of life during the pandemic (Hussain, 2020; Venegas-Vera et al., 2020). Gatti et al. for instance argue that when COVID-19 restrictions "(…) partially or totally hindered the opportunities for individuals to attend common places in their community and, more specifically, to keep in touch with their social meanings, these social media have represented reliable alternative strategies to do so" (2021, p. 41). In Italy, as an example, people started meeting on balconies and singing together in events orchestrated via social media (Antchak et al., 2022). Such events would not only change spatial practices in Italian cities: They went viral on social media and spread to other countries. Digital media's capacity for connecting people and embedding us in the city makes social media platforms an important arena to study when seeking to understand people's place attachment during COVID-19, and how such attachments were enacted and unfolding via social media.

Increased dependency on social media platforms for embedding ourselves in the urban environment in other words presents researchers with an opportunity to rethink how we study place attachments with digital media. Following the rise of Web 2.0 (O'Reilly, 2009), a growing number of scholars in fields like human geography, digital humanities, and urban studies have become interested in utilizing traces from online platforms to study urban public life. Especially influential has been the proposition that we can think of 'citizens as sensors' and the geo-tagged

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traces they leave behind as 'volunteered geographic information' (Goodchild, 2007). Leveraging such traces, the past decade has seen more and more scholarship exploring how social media data can be used to study cities (Moore & Rodgers, 2020; Schwartz & Hochman, 2014). Yet, as we will show, the *visual* data shared on such platforms remains at the margins of digital urban research. This is striking, since the proliferation of image-based platforms is creating increasingly visual cultures where citizens produce and share photos to negotiate their urban experiences (Manovich, 2020). Scholar likes Gatti and Procentese (2021) have for instance shown that platforms like Instagram can enhance people's ties to the community and its places. Photos, moreover, have certain characteristics that make them a unique source of insight, compared to textual and numerical data, when tackling urban issues. Photos are always taken *somewhere*, making them geographically and temporally anchored. As a consequence, user-generated images offer a chance to investigate the city from a 'situated' citizen perspective (Haraway, 1988). Images open for phenomenological inquiry that ties urban issues directly to the physical environment and grasps aspects of lived experience that may not be understood by words alone (Plunkett et al., 2013). Meanwhile, images shape the cultural politics of place-making, generating visibilities and (in)visibilities that frame how we are able, or made to see (Rose, 2016). In 2020, images of doughnuts from a particular shop in Copenhagen for instance started trending on Instagram. For six months this led to a never-ending line outside the shop. What places and moments are shared online thus do not only reflect those people's experiences, but also influence how others use the city. In this light, social media images provide a chance to ask questions about how cities are experienced, and how people attach to places (Stedman et al., 2013). But, as we show next, digital projects have far from fully leveraged this.

2. Visual studies between data science and ethnography

To review the literature at the intersection of urban studies, social media, and visual methods, we take a structured bibliometric. We searched the Scopus database for contributions that mention 'city', 'cities' or 'urban' in the title, abstract or keywords, combined with mentioning 'social media' and either 'visual', or 'photo' or 'image'. Executed in May 2021, this search string returned 738 results in total. Out of these, 311 papers are from the social sciences or humanities, published between 2011 and 2021. To get an overview of the content, we mapped the author keywords of the papers as a co-word network (Callon et al., 1991) connecting keywords (nodes) in a network graph whenever they co-appear in an article. After filtering out generic keywords,[1] we spatialized the network with a force-directed algorithm in Gephi (Bastian et al., 2009), which positions author keywords closer together, the more often they appear together in articles. Next, we sized nodes representing author keywords according to their frequency in articles. Using techniques from Visual Network Analysis (Jacomy, 2021) we identified clusters of keywords that often co-appear in the 311 articles, coloring nodes according to a modularity-based classification (Blondel et al., 2008). Finally, we produced the graph in Fig. 1 using Graph Recipes scripts (Jacomy & Thorsen, 2018).

There are two thematic regions to be observed in Fig. 1, indicated with a white line down the middle (authors' annotation). On the right side, the green, dark green, blue, light-blue, and yellow clusters constitute themes around 'big data', 'spatial analysis', 'GIS science' and keywords centered on geo-tagging and computational tools like 'machine learning', 'text mining' and 'computer vision'. Keywords like 'volunteered geographic information', 'smart city', 'smart cities' and 'urban planning' are also found here, along with two larger nodes,

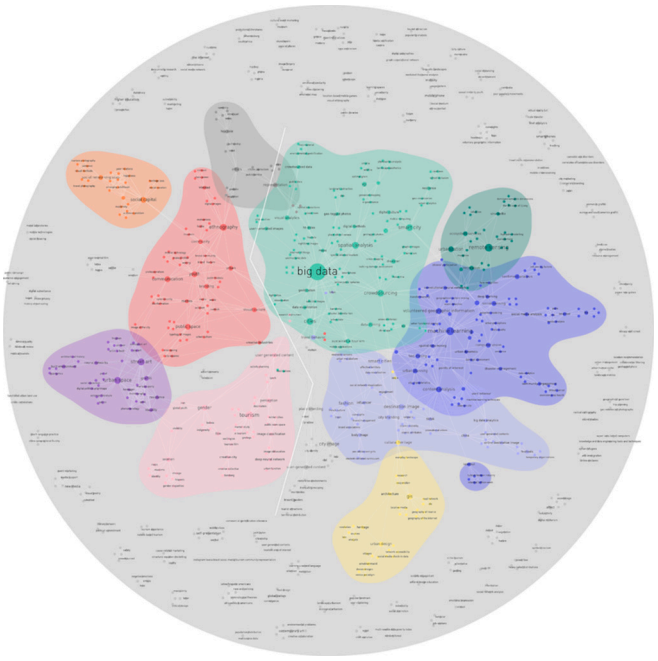

Fig. 1. Network graph visualizing co-occurrence of author keywords in the 311 Scopus articles. Spatialized with ForceAtlas2 in Gephi, sized according to occurrence of keywords in articles, and colored with Modularity Class algorithm. Illustrated with Graph Recipes. White line is an annotation by the authors.

'remote sensing' and 'social sensing', which frequently occur as author keywords in articles.

On the left side of the network, the red, pink, and purple clusters represent a different theme around 'ethnography' and keywords like 'community', 'perception', 'public space', 'social interaction', 'visibility', 'gender', 'women', 'gaze', and 'urban culture'. The lack of connections between nodes on the right and left side indicates a split in the literature, showing that author keywords from the two sides are rarely found in the same papers. This suggests that a methodological divide between *ethnographic* and *computational* approaches leads to differences in how social media data is used to study the city. On the left side, the ethnographic approach is connected to an interest in social, political, and cultural topics, as well as a subjectivity-oriented agenda, with author keywords like 'perception', 'phenomenology', 'motivation', and 'culture' being frequently used. On the right side, papers centering on computational methods tie social media data to author keywords about 'land use classification', 'event detection', 'destination image', 'city branding' and 'disaster management'. It is also noticeable that 'urban planning' is positioned in the computational cluster to the right, close to 'machine learning' and 'smart cities'. This indicates that most articles on urban planning also construe social media data as an opportunity for managing the city within the frame of a computational, big data paradigm, without including more ethnographic topics.

Such an epistemological split might seem like a logical consequence of the methods found on each side, one being inherently more qualitative and interpretative, and the other more quantitative. Meanwhile, we argue that there is no reason why the use of computational tools should exclusively lead to framing the city as a problem that can be quantified and measured in a remote sensing way. Instead, it is imperative to bridge the gap between the capacities of computational methods and ethnographic questions about urban culture, subjective experience, perception of urban issues, and so on. A similar point has been made recently by Madsen et al. (2022), who call for untangling data-driven urbanism from a dominating 'hard city sensing' paradigm and reframing digital data as a potential to study more humanities-led research interests. Similar calls have been made from the emerging sub-field of

[1] High-degree keywords removed to reveal thematic differences: 'Instagram', 'Twitter', 'Flickr', 'Facebook', 'photography', 'image', 'social media data', and 'social networks'. A raw version of the network is seen in Appendix A1.

computational anthropology (Munk et al., 2022).

So, what prevents us from advancing in that direction? Extending on the concept of sociotechnical imaginaries (Jasanoff & Kim, 2009), Rieder (2018) introduces the notion of 'big data imaginaries' to describe collectively held narratives, visions and epistemic commitments that shape the role of big data in society. Similarly, Markham (2021) uses the concept of 'discursive closure' to describe how "particular values and (infra)structures are naturalized, neutralized, and legitimated, closing off discussion of alternatives that might counter current hegemonic power" (p. 382). Learning from the network in Fig. 1, we can only wonder if the split into two observable islands, means that digital urban studies have already produced a kind of discursive closure around how social media data is envisioned to be of use. We can at least observe that the author keyword 'urban planning' is positioned in the computational side with little to no links to ethnographic-centered keywords on the other side. To unpack this, we next provide a review of empirical urban projects that use social media data as research materials. We identify three trends in this literature that shape the 'data imaginaries' of the field and limit potentials of using social media images to study lived experience.

2.1. Three commitments that shape data imaginaries in digital urbanism

Taking a broad lens, it has been problematized that urban social media projects are biased towards textual platforms like Twitter, Foursquare and Facebook, leaving visual platforms understudied. This has been emphasized by Highfield and Leaver (2016), Zasina (2018), and Davies et al. (2019), among others, who emphasize the need to include visual materials in digital urban studies. Such bias is also seen in Fig. 2, which shows the frequency of results from a bibliometric search on Scopus from May 2021 for social science and humanities projects that use data from any of the listed platforms to study cities. Fig. 3 compares this to numbers of active users in 2021 (Tankovska, 2021).

In Fig. 2, we see that few articles study visual platforms like Instagram, Flickr and YouTube, while almost no projects study TikTok, Pinterest and Snapchat. Fig. 3 further reveals that the high number of Twitter studies is disproportionate to the number of active Twitter users.

There can be multiple explanations for this preference for Twitter and textual data in social media studies, including easy APIs access, or more developed computational and algorithmic tools for processing text compared to images. No matter the reason, this over-commitment to textual data leaves visual platforms vastly understudied in the context of cities, even though visual data offers a rich source for exploring how citizens experience and perceive urban issues. Whereas a limitation of studying textual data includes that researchers can only grasp the parts of citizens' urban experiences that they explicitly express, images are able to capture qualities and aspects of the photographed environment or moment that citizens are not able to vocalize in words and offers planners a chance to study not just *where* in the city people go, but also *how* a given environment looks from the citizen perspective (Gubrium & Harper, 2016). In a digital reality where citizens increasingly use *visual* technologies to embed themselves in cities, as has been posed by scholars like Pink (2021) and Halegoua (2020), visual data constitute not just an opportunity, but an important site of study for research into how citizens make sense of and relate to urban space today.

In response to this, an emerging body of literature is starting to use social media images for studying cities. In this research, however, a second over-commitment can be observed, namely the tendency to focus on metadata of images as the main analytical unit. The literature is saturated with projects that use social media images to capture the whereabouts of users, relying on geotag and timestamp metadata to map spatial-temporal dynamics of city life, without looking into the visual content of the images. Examples range from studies of Flickr (Becker et al., 2015; Haider & Ali, 2018; Hollenstein & Purves, 2010; Li et al., 2013), Panoramio (García-Palomares et al., 2015), and Instagram (Boy & Uitermark, 2016, 2020; Domínguez et al., 2017; Mukhina et al., 2017), Weibo (Cai et al., 2017), to Getty Images (Currid & Williams, 2010). Such projects typically use image data to map the pulse of the city, identify urban hot spots, or detect urban events and clusters. An example is seen in Schwartz and Hochman (2014), who collect around 48K Instagram photos from Union Square, Bryant Park, and Madison Square Park in New York. While the image data could offer rich insight into how users experience these parks, the authors do not look at the images themselves, but mainly use geolocation and timestamp metadata to study spatial and temporal patterns of activity in the parks. Another example is a project by Quercia et al. (2015) who uses Flickr and Foursquare data to identify walkable streets in London. The authors map safety of streets from the logic that where there are higher numbers of photos posted at night, a street is safer to walk. This operationalization reduces the issue of safety to a quantifiable question about posting frequencies. While such projects are valuable in mapping geo-temporal dynamics of city life, they do not utilize the phenomenological richness of the images to qualify the issues being mapped. It for instance seems like a missed opportunity that images are not used in the Quercia

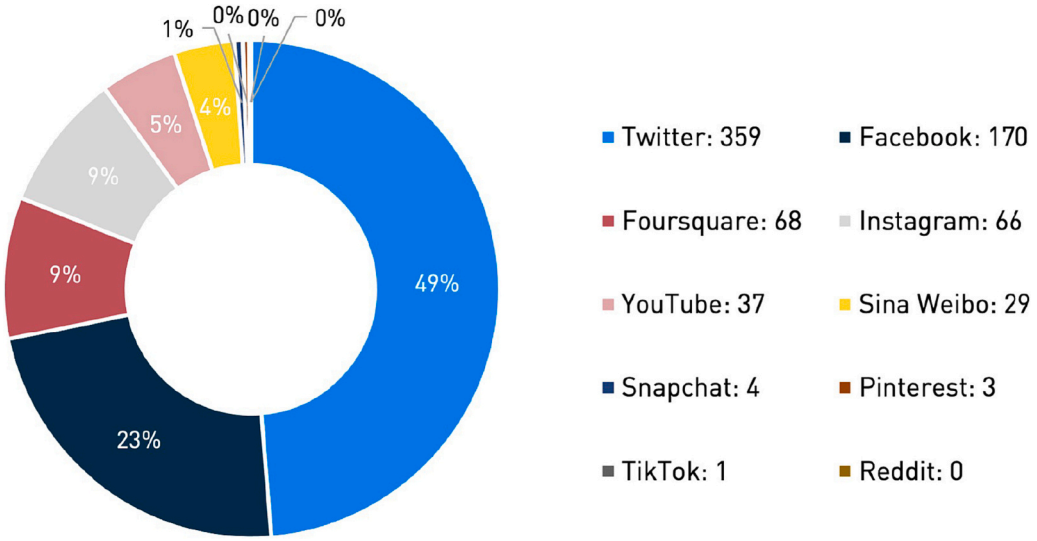

Fig. 2. Number of results on Scopus by May 2021 within social science and humanities when querying for 'cities' and 'data' in combination with one of the listed platforms in title, abstract or author keywords.

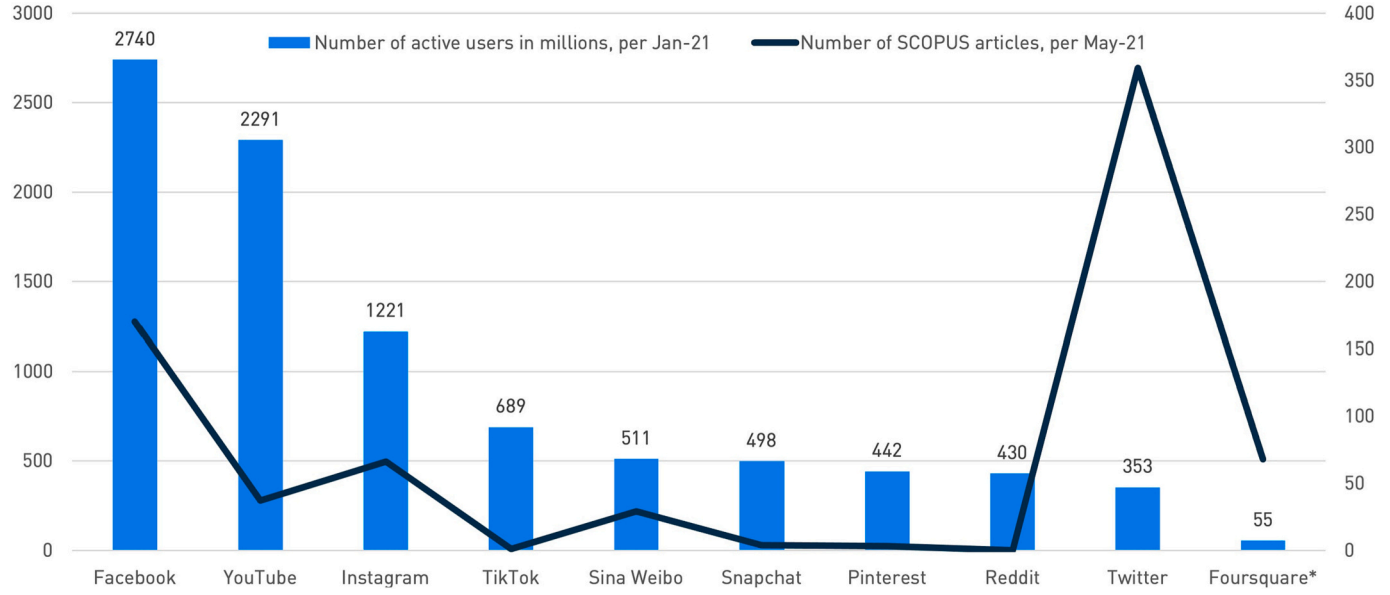

Fig. 3. Number of active users per platform (in millions) per Jan-2021 compared with May-2021 Scopus results in social science and humanities that mention cities, data, and each platform.

et al. (2015) study to examine how people experience safety and examine how urban space affects that experience. The commitment to the geotag is effectively limiting the research to *where* and *when* questions, leaving little space for *how*, *what*, and *why* inquiries. A similar critique is advanced by Crampton et al. (2013), and refined by Shelton (2017) who has argued that; "analysis of geotagged social media data over-privileges the single latitude/longitude coordinate pair attached to each individual data point, often leading to the kind of simplistic mappings and interpretations" (2017, p. 721). Since this review has shown that geotag-fixation continues to characterize many urban projects today, it is only appropriate to echo their call to go 'beyond the geotag', by centering the image content as the analytical point of interest.

Some urban projects are already doing this, as exemplified in for instance Li and Ratti (2018), Zasina (2018), and Zhang et al. (2019). Meanwhile, a third epistemic commitment can be identified in many of these projects, namely the tendency to use the images for 'remote sensing' and 'city forensic' purposes. Many of these projects construe the subjectivity behind the production of the images as a bug, not a feature. As an example, Cervone et al. (2017) uses Flickr and Twitter along with satellite images to do remote-sensing damage assessment of a flood in Boulder. Contrary to the geotag-projects this project actually uses the content of images analytically but interpret them as a form of objective sensor-like record of the city during the flood. They use social media images as a replacement where satellite footage is missing. A similar disinterest in the subjective nature of the data is also found in Doersch et al. (2012), who writes: "*The difficulty with Flickr and other consumer photo-sharing websites for geographical tasks is that there is a strong data bias towards famous landmarks. To correct for this bias and provide a more uniform sampling of the geographical space, we turn to GOOGLE STREET VIEW* (…). *This enables extraction of roughly fronto-parallel views of building facades and, to some extent,* ***avoids dealing with large variations of camera viewpoint***" [authors' emphasis]. Here differences in 'viewpoint', is seen as a weakness of the social media data, instead of an analytical opportunity to understand what citizen focus on, relate to, or emphasize as important. These projects are in other words interested in the *geographic*, rather than *experiential* topography of cities. They construe the user-generated photos as a form of sensor-like scanning of the streetscape, as also seen in Zhang et al. (2019) who use social media images and computer vision AI to compare the visual distinctiveness of cities. This leaves unexplored what we argue is a key quality of social media images; namely that they are semantically rich data inscribed with individuals' subjective needs, preferences, and perceptions.

As demonstrated, most of the existing work has only to a limited extent taken advantage of visual social media, because of 1) bias towards textual data (even when working with visual platforms), 2) over-committing to the ontology of geotags, and 3) interpreting subjective nature of social media as a bug, not a feature. A handful of projects, however, do not bind themselves to these commitments, but use social media images and their content to do Kevin Lynch-inspired cognitive mappings (Huang et al., 2021; Liu et al., 2016), understand what attracts people to certain places (Crandall et al., 2009; Gomez et al., 2019; Hu et al., 2015; Jayarajah & Misra, 2016; Rossi et al., 2018; Song et al., 2020), or map visual rhythms in the city (Hochman & Manovich, 2013). Graham and Gosling (2011) even use profile picture of people who visit bars and cafes to determine the ambience of these places. Such projects take steps to push data-driven urbanism in a different direction, producing alternative 'modes of knowing' cities (Kurgan & Brawley, 2019). In the following we advance this work through a case study that exemplifies how it is possible to reorient the digital agenda in urban studies in a way that; 1) centers visual data, 2) moves beyond geotag-ontologies to look at content of images, and 3) frames social media as analytical opportunity to study subjective, lived experience.

3. Materials and methods

3.1. Case study: #BareDanmark campaign on Instagram

In 2020, when the COVID-19 pandemic hit the world, the closing of national borders forced people in Denmark, as in many other places, to stay within the country for holidays and leisure time and explore places and experiences closer to home. To encourage an active public life and make visible what you can do within the country, tourist organization Dansk Kyst- og Naturturisme (DKNT) launched an Instagram campaign called #BareDanmark (in English: "just Denmark"), inviting people to share local experiences. The campaign launched May 28th when 100 influencers shared posts from around the country using the hashtag, inviting people to do the same.

At the end of 2020, we entered a research collaboration funded by the Danish Board of Business Development to analyze the #BareDanmark campaign. We report here the part of our analysis which explored the around 40.000 images that were shared in the first nine months of 2020, and use it to study how people in Denmark related to their

environment during COVID-19 from the first lockdown, through different phases of re-opening, and until the second wave and lockdown. In doing so, we build on Halegoua's 'Digital City' framework, as previously mentioned, which conceptualizes everyday digital interactions as placemaking activities that people employ to produce a sense of place. She argues that people today use digital media to "(…) shape emotional attachments with(in) urban environments by re-placeing the city as unique, desirable, familiar, or knowable through assorted digital media forms" (Halegoua, 2020, p. 5). Further, she proposes that locatable digital media offer people a sort of geospatial empowerment that aid their interpretation and experience of urban spaces, which is something a growing number of urban studies have begun showing interest to (Martí et al., 2017; Schwartz & Hochman, 2014). In the pandemic, this seems more true than ever with media like Instagram becoming a crucial way for people to produce a sense of place and negotiate attachments to their environment, while isolated (see also Gatti et al. (2021)).

Hashtag campaigns, like #BareDanmark, where users respond to a call for participation by a company or an organization, have been studied on Instagram before (Oh et al., 2016). Likewise, a shift from ad-hoc to calculated publics organized around a hashtag campaign has been theorized in media studies (Bruns & Burgess, 2015). On Twitter, for example, it is now well-documented that use practices around hashtags have developed and changed over time resulting in a need to distinguish between different types of hashtag events with different characteristics (Bruns et al., 2016). In relation to COVID-19, more specifically, the use of hashtag campaigns has also been prominent. Examples for instance include the Prospettive di Connesssioni Urbane project (Gatti et al., 2021) and the #Stayhome hashtag, as documented by Umar (2020), which was used as a social campaign in Makassar City to prevent spread of the pandemic, by persuading people to stay home. The #BareDanmark campaign studied here was organized by DKNT as a COVID-19 specific campaign and was not widely used as a hashtag prior to the campaign (although some usage can be observed, see Fig. 4). The choice to study this hashtag hereby provides both an analytical *limitation* and *advantage*, which shapes our results: Since the hashtag campaign is COVID-19 specific, there is no way to compare the #BareDanmark campaign during the pandemic with anything that came before it. This could have been possible if we had scraped Instagram data using a place-specific hashtag that was in use before the pandemic, as we have for instance done in a related project where we studied photos of Rømø on Instagram, comparing the summer of 2020 with photos from five preceding summers. Here it was the place-specific hashtag, #Rømø, that enabled collection of historic data. While use of place-specific hashtags is a data collection strategy taken in many Instagram studies, such strategies impose a different limitation, making the geographical location a constraint on the analysis by pre-determining *where* data is collected from. This closes down opportunity to discover that there might places beyond our a priori assumptions that matter to people. The #BareDanmark campaign, in contrast, opens possibility to explore what sort of environments people found valuable and meaningful to visit during 2020, which is the analytical interest in this study.

3.2. Data collection

Data was collected on October 20th 2020 and contains posts from January 1st 2020 to October 19th 2020. We used Instaloader (2020) to scrape 39.575 posts that tag #BareDanmark in their caption.

While some would argue that we should not collect data from platforms where APIs have been closed, this project subscribes to discussions about post-API research (Freelon, 2018; Perriam et al., 2019) and calls made by Ben-David (2020) to challenge the data colonialist powers of media platforms that increasingly privatize inherently public debates. Meanwhile, we made the distinction that only public posts were collected, meaning posts that were made publicly visible by both the user and the platform to anyone with an internet connection, without requiring login to Instagram. By design, no private data is thus collected. Even so, and guided by ethical standards in the field (Franzke et al., 2020) concerning personal identifiable information, data is anonymized in two steps; first by removing user-specific metadata, and second by blurring faces in pictures with '*deface*' (Drawitsch, 2021). Data is stored on protected servers and registered under GDPR at our university.

The dataset is produced by 5.807 unique users (Appendix B1) and

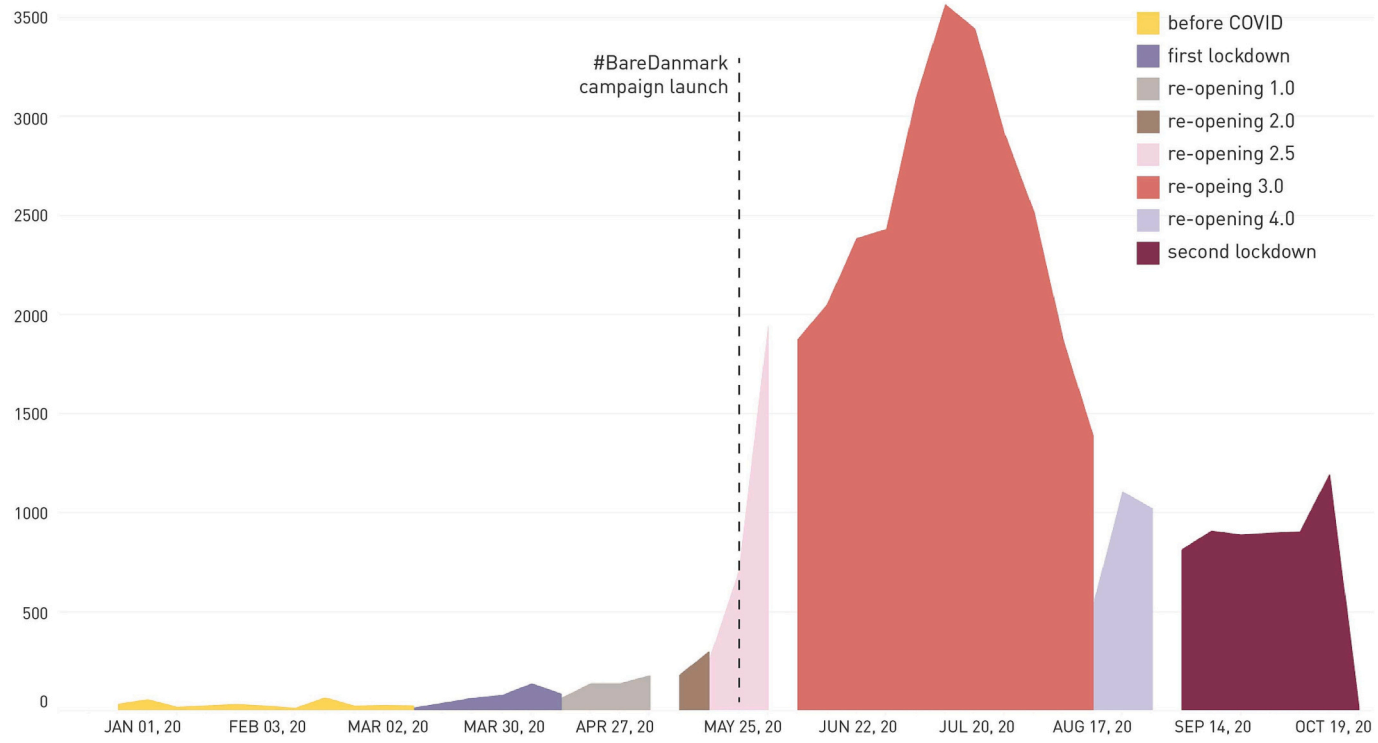

Fig. 4. Distribution of posts collected from #BareDanmark campaign, January 1st to October 19th 2020.

contains images from; before the pandemic; the first lockdown; different phases of re-opening; and on to the second COVID wave and re-closing of society. These periods and the distribution of image data collected is seen in Fig. 4. It should be noticed that 95 % of the posts are from after the campaign launch, while 5 % were posted before. Since these pre-launch posts are a part of what others see when looking at the hashtag, we keep them in the dataset.

3.3. Pre-processing

Geotags were not retrievable when scraping data from Instagram, due to restrictions on scraping. As such, a three-fold geocoding process was carried out which allowed us to geolocate 28.336 posts (about 75 % of the dataset). First, a script was used to open each post in a browser and pull post location name, if found. Using a geo-gazetteer from Geo names.org, the scraped location names were then translated into geo-location with latitude and longitude. Second, Google AI Landmark Detection was run on images that were yet unidentified, annotating locations for 772 additional posts. Third, a manual geocoding was carried out for the 10 most frequent location names pulled from Instagram which the geo-gazetteer could not translate into latitude and longitude. These are posted from 458 times and geocoding them manually thus ensured that locations often visited by users did indeed get geolocated. These elaborate steps taken to geocode the posts, however, provide another, more pragmatic, argument for pushing digital urban research beyond geotag-fixation, since it gets harder and harder to get data with good geographical metadata due to social platforms closing and restricting APIs (Perriam et al., 2019). While Instagram makes it difficult to scrape data with location, a platform like Twitter offers a relatively open API, but in our experience only has geolocation for around 8 % of results. A singular focus on geotags will thus often leave out majority of data, limiting results and increasing risk of misrepresenting the studied phenomenon. To annotate images according to their visual content, the 39.575 images were also processed with Google Vision AI, which was used to assign labels to each image that describe objects in the image. Each label comes with a confidence score from 0 to 1, which we used to remove labels with a confidence less than 70 %. Finally, data was annotated according to COVID phases (see Fig. 4 and Appendix C1).

4. Results

4.1. COVID and the end of wilderness

To explore what sort of environments were important during COVID-19, we first test what we might call the 'naive geotag-approach' by plotting the image metadata onto a map, as seen in Fig. 5, with a bar chart that shows a list of the most frequently posted-from locations. Fig. 5 shows that cities like Copenhagen, Aarhus, Odense, and Aalborg are among the most posted-from locations during COVID-19. This could indicate that these are the most visited or important places during the pandemic. But this is a case where overly focusing on the geotag could lead to a mis-conclusion.

If we deploy a computer vision strategy instead and study the content of images as annotated by image recognition, we can interrogate what types of environments are depicted and shift the attention from 'place' to 'space' in what we tentatively dub a *space typology* analysis. Qualitatively investigating all labels detected across the dataset more than 90 times by Google Vision AI, we source a list of labels, such as 'forest' or 'city' that describe the physical environment in the image. If 'beach' has for instance been identified by Google Vision Ai in an image, we assume that it depicts a beach as a type of space. Although we only examine labels with more than 70 % confidence score, this will not be accurate in all cases as there is always inaccuracies when depending on supervised image recognition (we return to this in 'Discussion'). But if combined with qualitative exploration, such space typology-annotation is a useful strategy for getting an overview of image content based on how certain space types re-occur within photos. Building a source-list that matches image labels to a space typology (see Appendix D1), we annotated the data in a non-exclusive exercise: If an image depicts both 'beach' and 'forest', it is annotated with both typologies, and we identify one or more space typologies in 78,64 % of all posts. Noticeably, we can identify a space typology in 9.401 of the 12.766 posts without geolocation. In Fig. 6, a tree map shows the frequency of space typologies identified in posts. Square sizes indicate frequency, and one of the most liked images of each typology exemplifies what it looks like. Fig. 6 shows that 'green' nature such as natural landscapes, cliffs, hills & highlands, meadow, forest, and grasslands is often depicted in image posts. In fact, we see that these natural environments are much more frequently depicted in

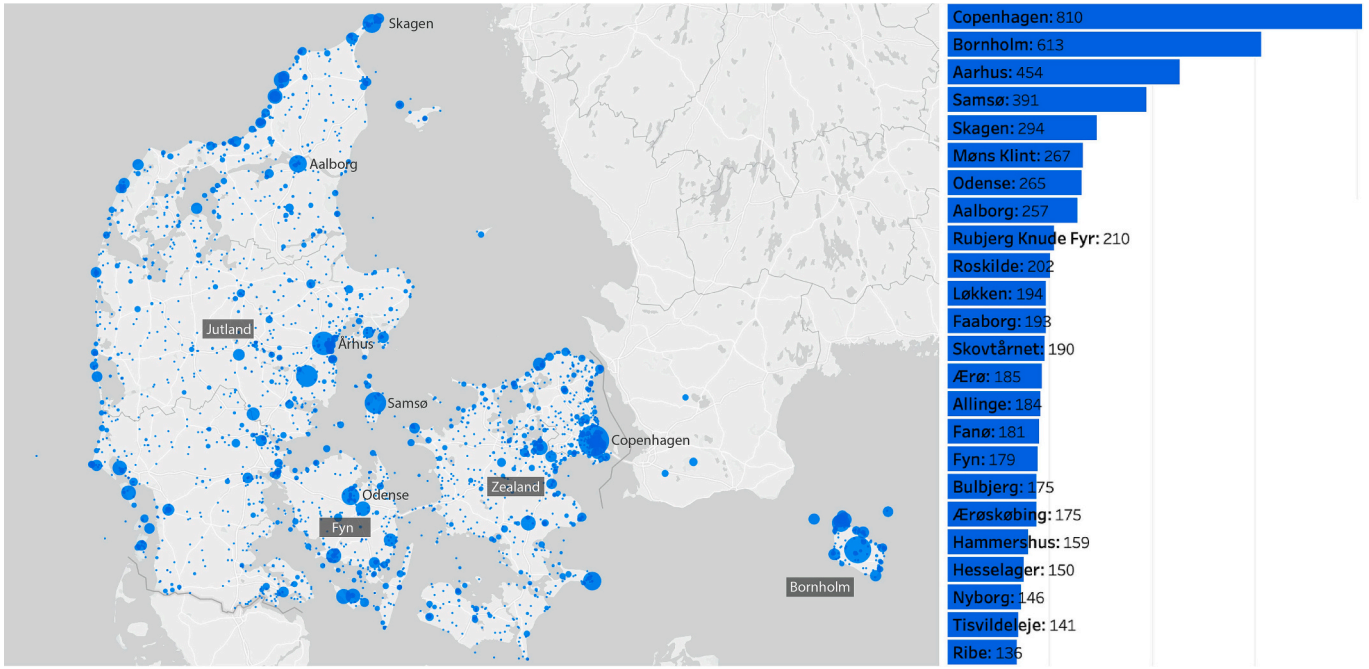

Fig. 5. Map of posted-from locations, sized by frequency (left) with bar chart of top 24 locations (right).

Fig. 6. Tree map showing distribution of identified space typologies within #BareDanmark image posts. Size of squares according to how frequent each space type is detected in the dataset.

#BareDanmark images than urban spaces such as cityscape, streetscape, and public spaces. When we center visual content, we can thus unsettle premature conclusions about place stemming from simplified geotag ontologies and use visual strategies to open for interrogating place attachments in alternative ways. And contrary to what the map in Fig. 5 might suggest, we discover that during COVID-19 people form strong attachments to natural environments, more than urban spaces.

This ties into other COVID-19 studies, which have shown that recreational use of green spaces increased during the pandemic, which has caused scholars to argue that nature plays a critical role a source of resilience during such a crisis (Samuelsson et al., 2020; Venter et al., 2020). In contrast to COVID studies from other countries, however, Fig. 6 reveals that in Denmark it is especially 'blue' natural environments like beaches, ocean & coast, rivers & lakes, and harbor, which are prominent in images. This indicates that proximity to water plays a big role during COVID-19, and taking a closer look we even discover that subsets of the image data depict urban environments in *connection* to water. We unpack this in Figs. 7 and 8 in montages of image examples of 'lighthouses', and 'bridges'. The images in Figs. 7 and 8 are from all over the country geographically, and temporally from different phases of the pandemic. Yet, they show consistent ways of visually framing the same types of spaces. This may be a consequence of the aesthetic vernaculars of platforms like Instagram (Manovich, 2019). But refining such simple interpretation, we might also suggest that these similarities in framing are more meaningful than just that.

Exemplified in Figs. 7 and 8, contributors to #BareDanmark capture photos of harbors and lighthouses as built structures that connect them nature: While the boardwalks and bridges in the 'bridges' photos are pointing visually out towards an endless horizon, the lighthouses point our gaze up towards the endless sky, framing nature as expansive and boundless. It is remarkable that people emphasize this sort of attachment to nature in a time where cities did the opposite and offered confinement and isolation. What this points to is perhaps a reflection of what Brenner & Scmid in their conceptualization of *planetary urbanism* has termed the 'end of wilderness', describing how the kind of urbanism we live in has become so expansive "that even spaces that lie well beyond the traditional city cores and suburban peripheries (…) have become integral parts of the worldwide urban fabric" (Brenner & Schmid, 2011, p. 12). Opposed to seeing this through a city-nature divide, which has been argued to be an artificial construct anyway (Latour, 1993), a planetary urbanism lens invites us to interpret the nature in these images as an extension of life in urban centers. This is also supported by literature on COVID-19, which has emphasized that the pandemic highlighted the importance of nature as an essential quality-of-life element in sustainable cities (Kleinschroth & Kowarik, 2020). While COVID research has shown that that the pandemic has had a negative impact on public mental health, increasing loneliness and social disconnection (Bil et al., 2021; Holaday et al., 2022), access to nature on the other hand has been documented to have a positive impact on mental health during this crisis and been proposed as a source of resilience (Samuelsson et al., 2020; Soga et al., 2021). If access to nature is a key to creating resilient cities during a crisis like COVID-19, the next question from a planning perspective becomes: Where are these spaces found?

4.2. Geospatial Mapping of Space Typologies

The previous section exemplified that we might discover a cohesiveness in photos that are temporally and geographically scattered by using image recognition to identify re-occurring space types, and qualitatively studying them to unpack how people frame these spaces. Relating this to the review, this is a concrete example of how it is possible to use computational methods in ethnographic explorations, when studying cities with visual social media data. We might also relate it to discussions by Massey (2005), who has proposed a relational ontology of 'place'. Extending this perspective, we can use the space typology approach to map photo locations as connected geographies based on visual similarities in the photo content. This is exemplified in Fig. 9.

In Fig. 9, Voronoi plots are used to indicate spatial density by creating web-like structure that visualizes proximity between photos of a particular space type, showing where people have shared photos of forests (top left), cliffs (top right), cityscapes (bottom left), public spaces (bottom right). In doing so, the maps take inspiration from the 'Soft City Sensing' approach (Madsen et al., 2022) and use geospatial granularity of data to draw bottom-up topologies. Instead of aggregating data within pre-defined spatial ontologies such as zip codes or municipalities, the plots suggest new borders and layouts based on what types of spaces are highlighted in the #BareDanmark campaign. This exemplifies that it is possible to leverage social media images to break with the trend identified in the review of using data in 'remote-sensing' and 'city forensic' ways. Photos are not used here as a proxy for objectively registering where there are beaches or forests in the country. Rather, the subjectivity of the data, being produced by citizens who highlight certain places they value, is used to unlock insights about their preferences and attachments to certain spaces. The green map for instance makes it clear that people find valuable forest-related experiences in higher proximity in central Jutland and North of Copenhagen. In contrast, the red map shows a different spatial pattern for cliff-related environments, which people find along the coast, especially around Northern and Western parts of Jutland and the island Bornholm. Further, the blue map in Fig. 9 shows that cityscape-images do not surprisingly have high proximity in the two biggest cities; Copenhagen and Århus. Yet, there are cityscape-images all around the country. Meanwhile, the yellow map shows that there is very far between Instagram users capturing images of public space outside of Copenhagen. In especially West and Mid Jutland, there

Fig. 7. Montage of 75 images of 'lighthouses' space typology.

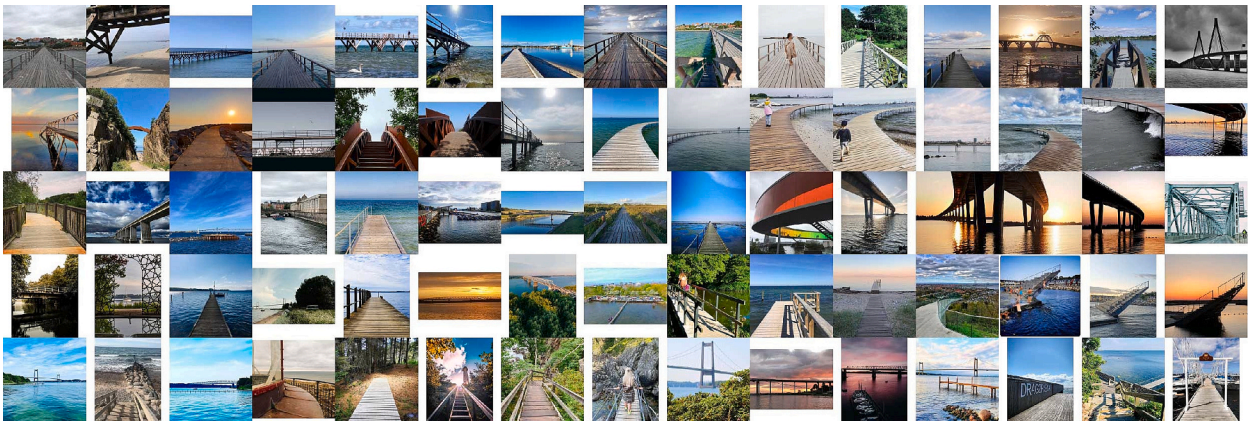

Fig. 8. Montage of 75 images of 'bridges' space typology.

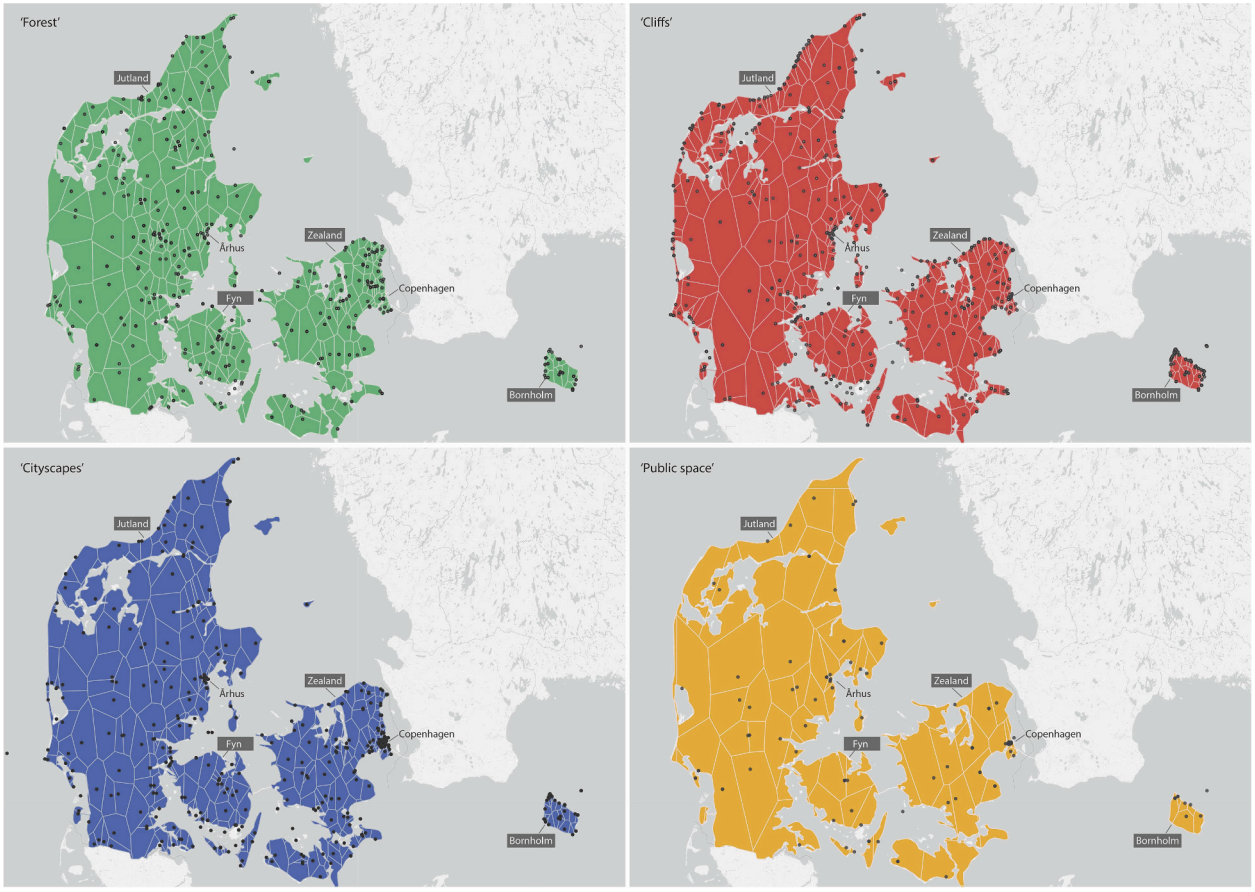

Fig. 9. Voronoi plots made in QGIS showing spatial density of photos across Denmark depicting particular space typologies. Top left: Forest. Top right: Cliffs. Bottom left: Cityscape. Bottom right: Public space.

are seemingly far in between any public spaces of value to people in the campaign. This suggest that the smaller Danish cities did not provide the same access to quality public spaces during COVID as the capitol. For planners, this could warrant further research into how public spaces in smaller cities were used during COVID. This is a pressing issue in planning, where studies outside Denmark have emphasized that COVID-19 revealed inequalities in access to good public spaces (Apostolopoulou & Liodaki, 2021; Kordshakeri & Fazeli, 2021).

To examine this qualitatively, Fig. 10 compares a handful of images annotated with 'public space' from Copenhagen and smaller towns, unpacking our idea of what sort of 'public space' is of value to the Instagram users, and why these are more often found in the capital: In Copenhagen, we see people in the photos, gathered in plazas, parks, or along the waterfront, where bike lanes or swimming decks invite for activity and coffee stands and street food attracts people to spend time. In contrast, the images from smaller towns like Grenå, Ebeltoft, and Næstved show empty public spaces with no benches, shops, or bike lanes. People are mainly visible in spaces designed for play, where kids and families are using the space actively. This sort of analysis could help planners and policy makers identify where interventions are needed to increase quality of public space and can help qualify how different design and programming of the environment activates a space, which is

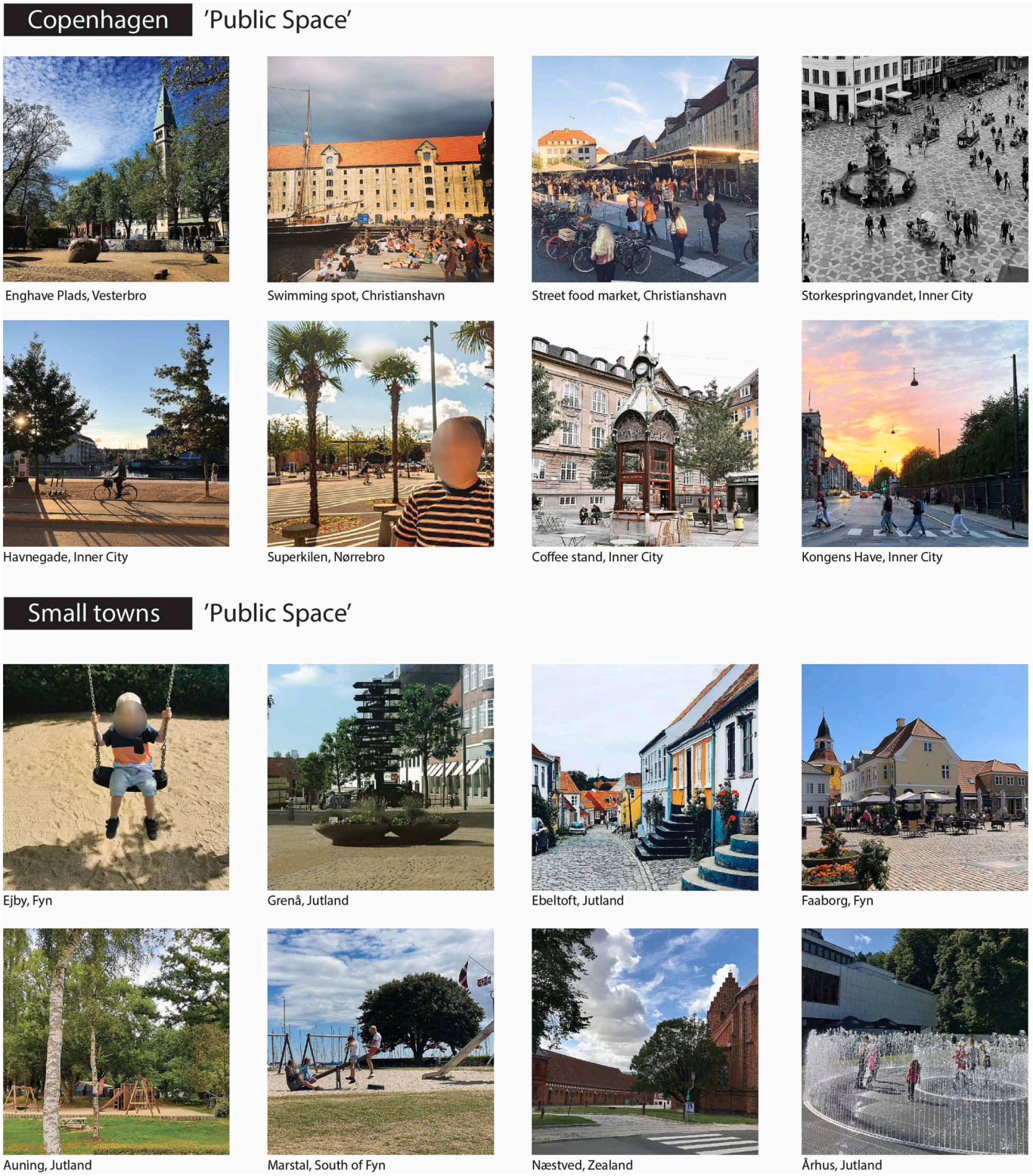

Fig. 10. Selection of images from Copenhagen (top) and small towns (bottom), depicting the 'public space' typology.

a recurring question in planning. This demonstrates how we can problematize the city in new ways, when we move beyond the geotag and use image content to see cities through the eyes of its users.

4.3. Perceptions of Nature in Cities

To examine representations of urban spaces further, we zoom in on images from the two most posted-from cities; Copenhagen (2243 images) and Århus (851). Producing an overview of the content of images, we map them as a network graph, based on visual similarity detected in images.

To do so, we combined the image labelling done with Google Vision AI with Visual Network Analysis and built an image-network for each city in which images are connected if they have three or more image

labels in common (see also Thorsen and Astrupgaard (2021), Ren and Munk (2019), and Omena et al. (2021)). The more labels are shared between two images, meaning the same visual motifs are depicted in both, the stronger the connection and the closer images are positioned in the network when spatialized with ForceAtlas2. This creates a network that positions images based on visual similarity. Images are sized according to number of likes, and we use custom Graph Recipes scripts to draw clusters identified with Gephi's Modularity Class algorithm (Blondel et al., 2008). Fig. 12 shows a network graph of all 851 photos from Århus, plotted in clusters of visual similarity. To increase readability of the graph, Fig. 11 shows a network graph of 1233 photos from Copenhagen, filtered so we only see photos with more than 20 likes and at least one comment, indicating that these photos are more interacted with by users.

Looking at Fig. 12, we find a medium-sized cluster of images from Århus that depicts the urban environment, with especially several photos of ARoS Aarhus Art Museum, which re-opens in 'phase 2.5' of the pandemic. In comparison, the network of Copenhagen images in Fig. 11 shows three big clusters of images depicting the urban environment with photos of buildings, architecture, landmarks, streets, and facades and a lot of aerial drone photos. As a city, Copenhagen thus seems to offer a wider array of architecture and streetscapes that people find interesting enough to share online, supporting the previous exploration that there is more 'public space' imagery from Copenhagen, than other cities in the country. In both networks, however, we also see big clusters of images depicting urban nature, indicating that people find meaningful nature not only *outside* urban centers, but also within these two cities. While in Århus, Fig. 12, we see a mix of forest and ocean photos, the Copenhagen network contains several big clusters of images related to waterfront, harbor, canals, boats, and horizon over the water. This might suggest that in Copenhagen, there is more access to 'blue', than 'green' nature, while in Århus, people highlighting both 'green' and 'blue' nature in photos. This ties into debates among both planners, and policy makers about the role of nature in urban societies, and discussions about how such 'nature' is envisioned. While nature is generally considered "good" (Angelo, 2021) and the reconciliation of nature and urban space is considered among the smart solutions to complex issues created by urban growth, it has also been highlighted in the NATURPRADI project that "(…) there is no agreement on the imaginaries and technical practices that should be included into the new urban nature" (Ricci et al., 2017, p. 2).

Unpacking the imaginary of what is indeed perceived by people as valuable urban nature, Fig. 13 shows a set of images of nature from Copenhagen. These validate previous indications that water is important, and qualifies how these environments are framed: We see that waterfront is used for swimming, sitting, walking, and sailing, with harbors, bridges, and boardwalks visible in most frames. While urban nature is often imagined as a green world, against a grey one, our analysis thus show that in Copenhagen 'blue' nature dominates perceptions of what are valuable spaces in the city.

Through studying online representations of urban environments during COVID-19, the computational and visual approach hereby opens for detailed exploration of *how* urban nature is perceived in online debates. But does a city like Copenhagen provide equal access to such nature everywhere? In Fig. 14, we filter all images taken within Copenhagen and show only the 911 photos of either blue or green natural environments. The left map renders each of the nature-related photos as a pie chart showing the distribution of space typologies identified within them. Colored thematically, red colors show space types related to built environment, green colors are used for nature-related space typologies, blue shades for water-related, and orange for bridges, harbors, and towers. From this we see that urban natural elements are not only found in the outskirts but that the city center is overflown with images of blue and green nature, often mixed with urban elements as indicated by red color in the pie charts. The map to the right in Fig. 14 draws K-means clusters around areas with high density of photographs with green or blue nature in them. It suggests that blue and green spaces are especially documented in 'Indre By' (Inner City) and along the waterfront of the city.

Meanwhile, it also reveals that the neighborhoods labelled Nørrebro, Vestebro-Kongens Enghave, Bispebjerg, Vanløse, Brønshøj-Husum seemingly are 'nature-less zones' with neither green nor blue environments that people find valuable enough to share in the #BareDanmark campaign.

Considering what implications this analysis can have for post-pandemic urbanism, we suggest that this could help planners and policy makers put (in)equal access to nature and public space on the agenda, inspired by how the NATURPRADI project uses digital methods to inform urban policy (Ricci et al., 2017). Using visual social media in a computational methodology to investigate how people experience their environment can provide tangible insights into where initiatives or interventions are needed, and qualify what people perceive as good or valuable spaces. This can add important nuances to debates about urban nature that often pitch nature as an idealized green world against a concrete one, by empirically unfolding what sort of nature people photograph (Ricci et al., 2017). Having data-intensive methods to put such topics on the agenda can also make a difference, seeing that few planning studies have focused on inequality in access to public spaces and urban nature in face of the pandemic. In reviews of COVID-19 planning efforts (Martínez & Short, 2021; Sharifi & Khavarian-Garmsir, 2020), planning features primarily as a component of pandemic control or as a practice that could learn from the pandemic in relation to environmental issues. As discussed by Acuto et al. (2020), few planning responses addressed the pandemic as "a window of urban opportunity" (p. 978) for attending to the urban inequalities that underpin the pandemic specifically, and urban societies in general. By rethinking the empirical ground of data-driven urbanism, the digital-visual methodology used here could inform future efforts to plan equitable sustainable cities, by giving tools to study how people experience cities in a crisis like the pandemic.

5. Discussion

As a methodological contribution, this project's use of social media images raises at least two important questions that demand further reflection. One regards the kind of *participation* we make possible for the people we are studying when we collect social media data. Another regards the way visual computational technologies *frame* what we see (and do not see) in image dataset.

When we collect digital traces left by people as a biproduct of online activity (so-called exhaust data (Kitchin, 2014)), we put several limitations on what sort of participation is possible. For one, we are only able to study the parts of the urban population that are indeed using social media, and there are consequently many people that we leave out when using social media data as a stand-alone source to study cities. Social media data is "pre-filtered to a very specific group of users", as Schwartz and Hochman (2014) write, limiting participation to people who own mobile phones, possess a certain digital and visual literacy, and general ability to use a camera. This has data ableist consequences for who are able to render themselves visible through this sort of data (Charitsis & Lehtiniemi, 2022). Adding to that, the methodology allows for only passive forms of participation, and often produce a distant relationship between researcher and researched. Rather than 'listening in' on what people are debating, the question is if we could involve them further? To do so, we would need to reframe social media analysis from a one-way extractive endeavor to a two-way relationship where data is being as elicitation devices and fed back to people for continued interpretation. While there have been experiments with this (Madsen & Munk, 2019), GDPR and protection of privacy often makes it difficult to follow up with social media users. Alternatively, more active forms of participation centered around visual data could come from methodologies like photovoice, participatory map-making, and other modes of visual

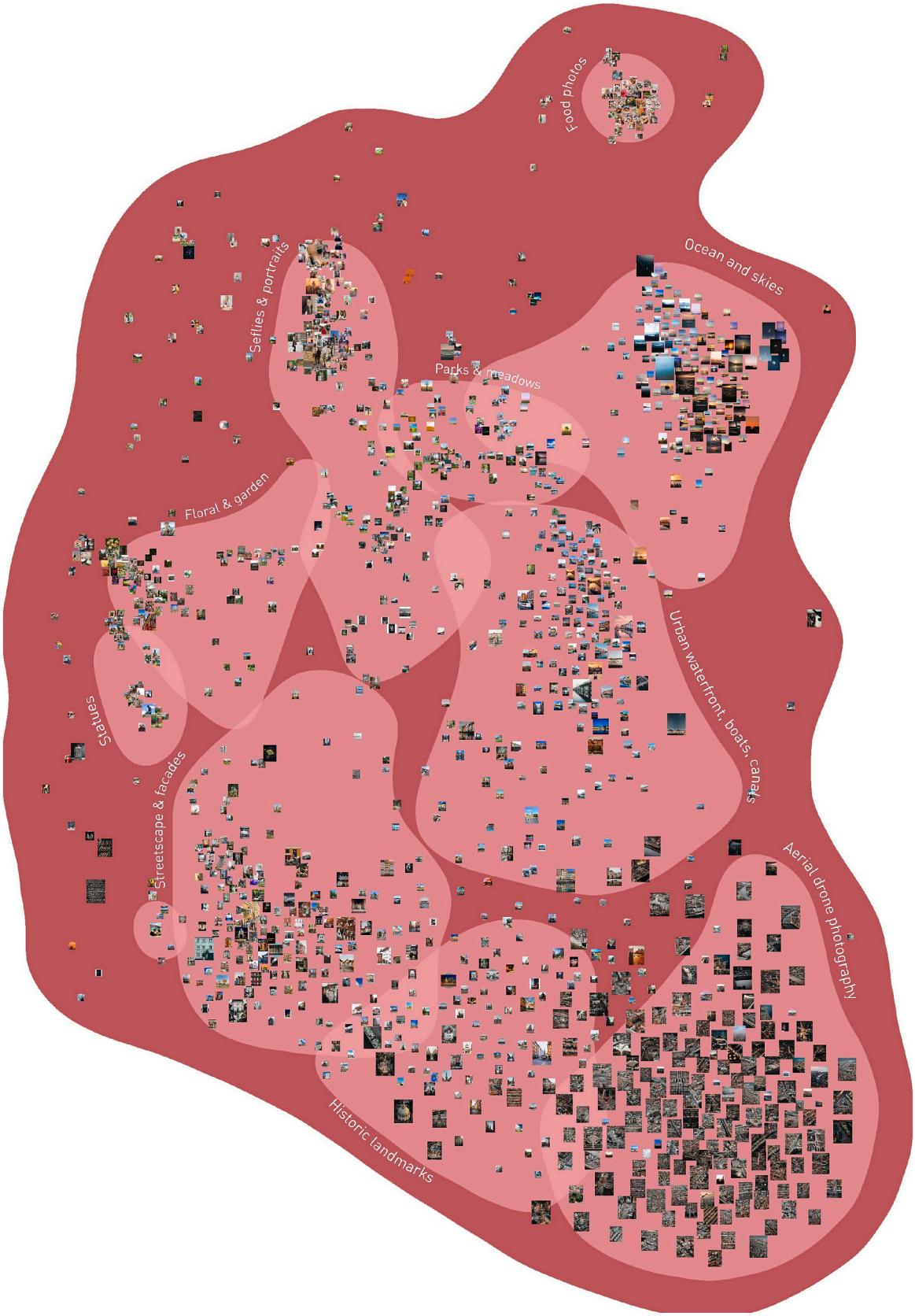

Fig. 11. Image network for Copenhagen: 1233 images, sized according to likes and connected if they share three or more object labels. Spatialized in Gephi with ForceAtlas2. Modularity Class algorithm cluster detection.

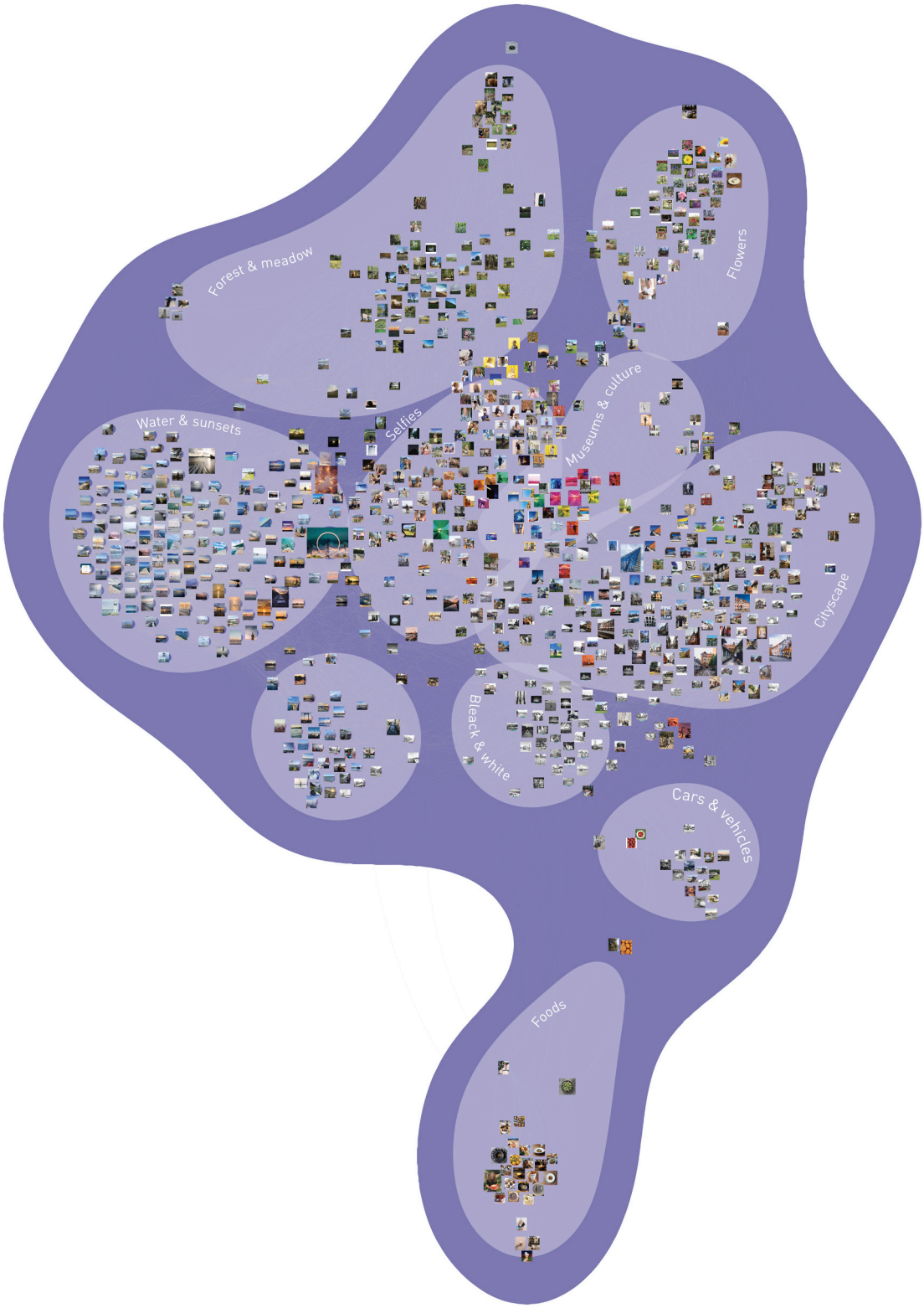

Fig. 12. Image network for Århus: 851 images, sized according to likes and connected if images share three or more object labels. Spatialized in Gephi with ForceAtlas2. Modularity Class algorithm cluster detection.

anthropology (Gubrium & Harper, 2016). Advantages of such methods include that visual materials can be sourced directly as primary material from participants in response to a prompt, and that a closer relationship between researcher and participant makes it possible to have workshops with participants to contextualize data. Finally, while social platforms are efficient at revealing what people value in cities, their aesthetic vernaculars and like-economy make them less efficient at inviting people to share the ugly, the problematic, or negative attachments (Gerlitz & Helmond, 2013; Manovich, 2019), which other visual methodologies like photovoice are efficient at unpacking (Wang & Burris, 1997).

The second, but related, point of discussion regards the layers of mediation introduced by computational analysis of images. Supervised

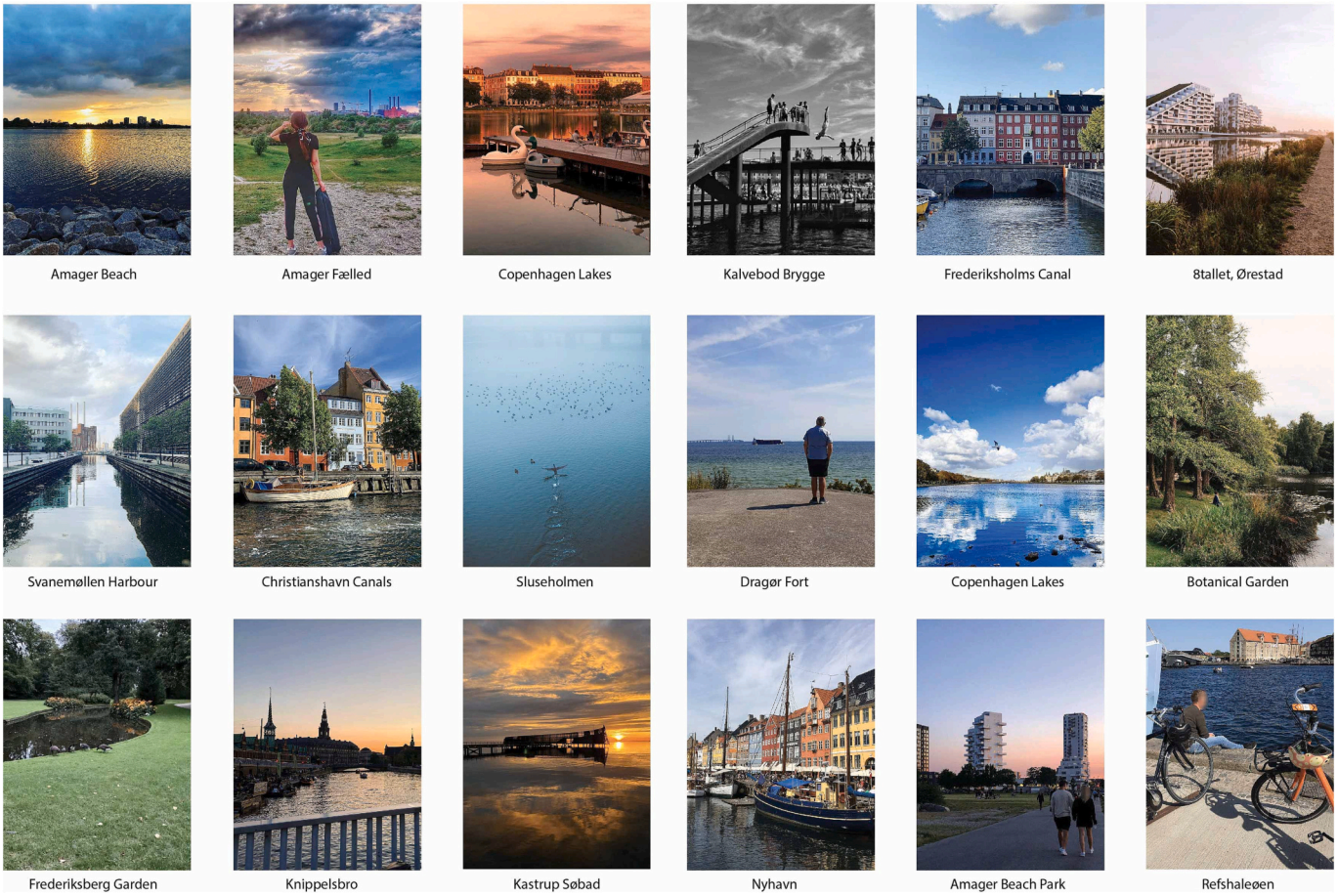

Fig. 13. Selection of images from Copenhagen showing urban nature.

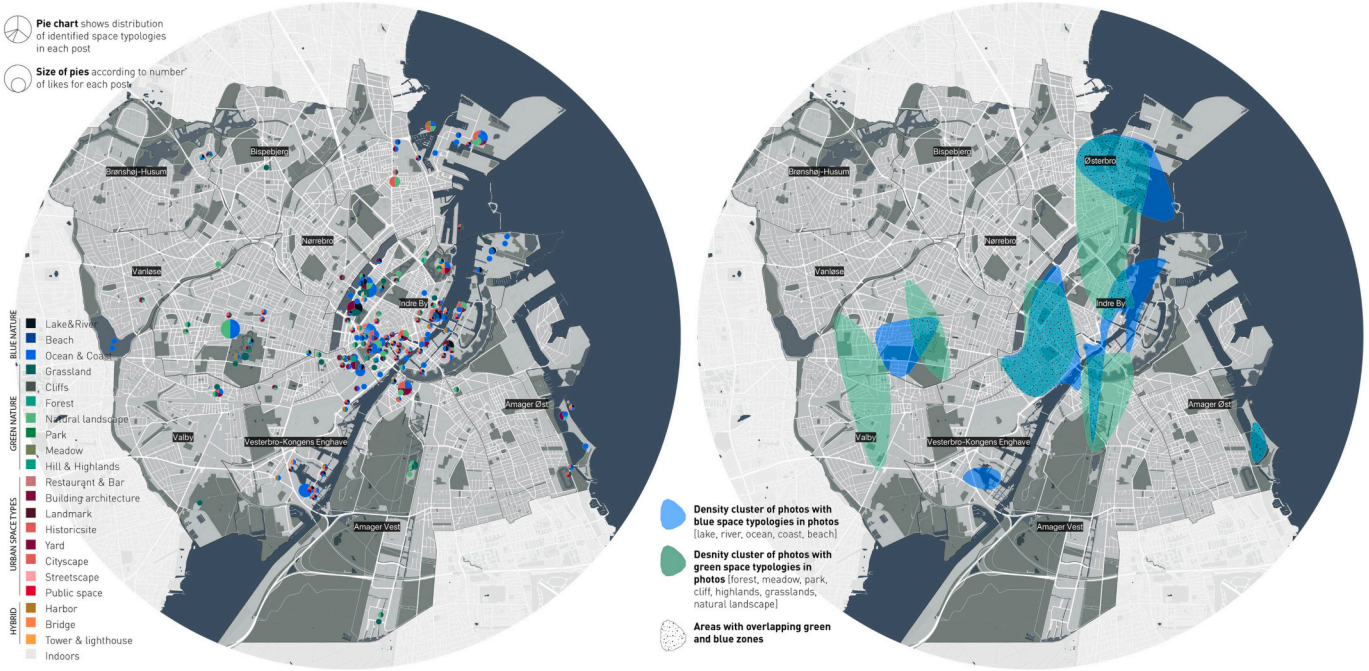

Fig. 14. Left: Map of 911 images in Copenhagen that depicts nature, rendered as pie charts that show the distribution of space typologies identified in the images via their visual content. Right: Map showing clusters with a high spatial density of images of depicting parks and other natural spaces (green) or water (blue). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

machine learning models for computer vision, like the one used to annotate our images, are inherently biased by the datasets they were trained on. While we can perhaps accept random mistakes, it becomes a problem of a different sort when the algorithm has systematic biases around for instance race and gender, as has been documented again and again (Buolamwini & Gebru, 2018; Crawford, 2016; Lambrecht & Tucker, 2017; Mintz & Silva, 2019; Raji et al., 2020). Yet, with the best-performing supervised computer vision available being proprietary (such as Clarifai, Google Vision Ai, and IBM Watson), we often depend on algorithms that are black boxed in engineering and training data, which leaves us in the dark with respect to how they shape our results. While this calls for more research on biases in relation to urban research, the use of computer vision also warrants discussion at the epistemological level: Visual technologies have historically introduced new modes of knowing (Cosgrove & Cosgrove, 2003; Halpern, 2015), and acted as "epistemology engines" in framing certain ways of seeing the world (Ihde, 2000). To understand what this means for urban studies, we need what Agre (1997) called a "critical technical practice". This could begin by asking: Where does computer vision guide our attention?

To explore this empirically, we carried out a small experiment seen in Fig. 15, which inverts the object-detection of computer vision image labelling by 'clipping out' the boxes of identified objects in a test image from New York. It shows that when we use supervised models to label photos, we effectively turn images into dissectible objects, and raises the question: What do these objects mean to us as stand-alone analytical entities, when we only focus on them and leave everything else out, as seen in the bottom-right of Fig. 15? If we obscure the detected objects and look at what is left (top of figure), it becomes evident how the AI-led gaze leads us to overlook what should matter most to urban planners and scholars; namely the environment in which human and non-human entities are situated. Computer vision thus opens for certain explorations of data, while omitting others. Tools that scale up such experiments by turning computer vision from instrument into object of investigation could encourage more scholars to engage in visual research, rather than stay away out of fear of how algorithms shape the results. A more sophisticated use could also come from training AI models specific to the built environment from datasets like Cityscapes, or from advances in unsupervised vision AI (Gordon, 2022; Hamilton et al., 2022). Models like STEGO or PixPlot's UMAP-model for instance offer a context-specific labelling of images, without depending on human-coded training data. Indeed, this is where one could imagine participatory experiments: Unsupervised image classification does not tell us what is in an image, but only informs how certain images appear similar to, or different from, other images, producing more questions, than answers (e.g. how is this

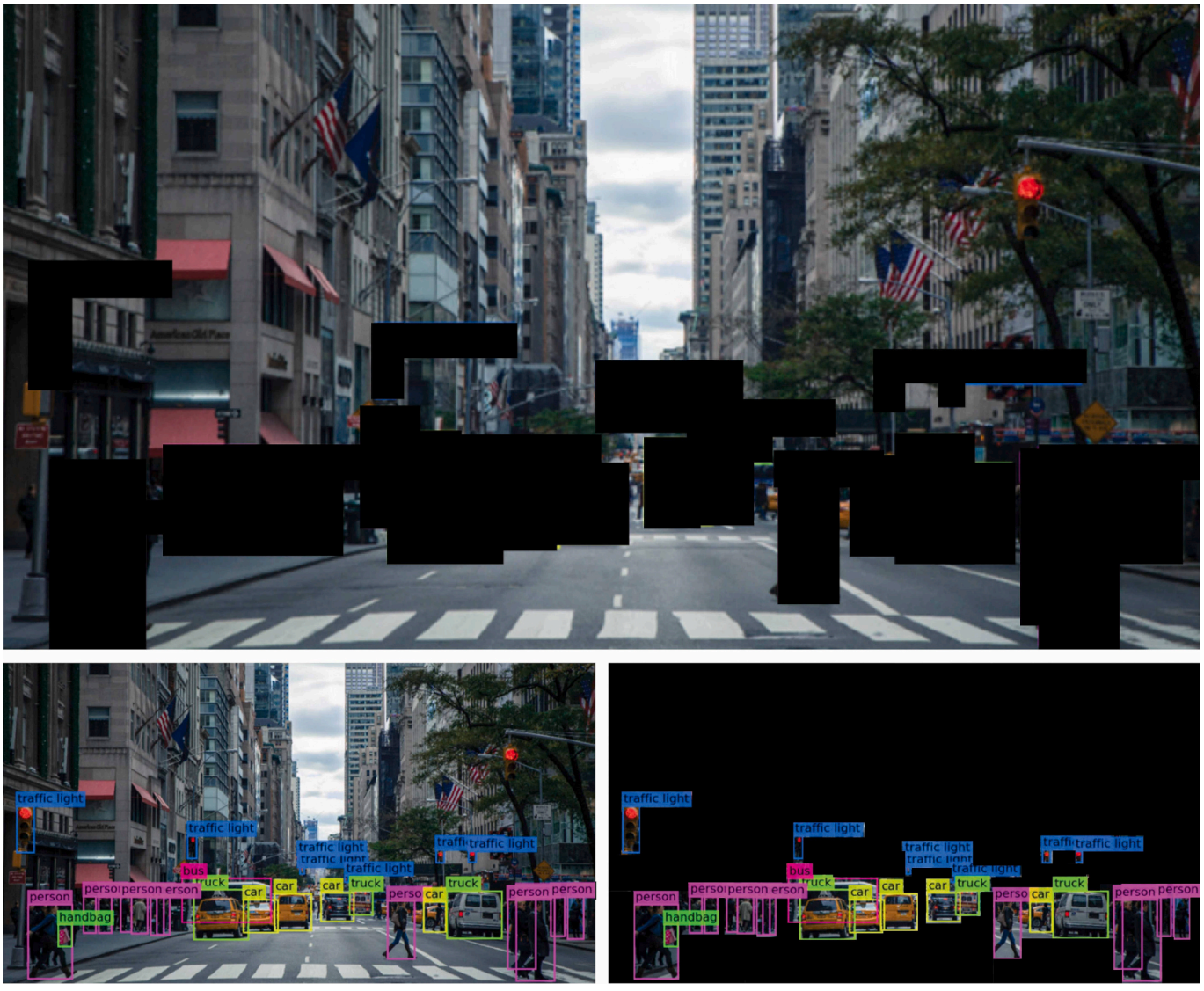

Fig. 15. Illustration of an image of New York annotated with AI (bottom left), directing analytical attention towards discrete larger objects (right). If we subvert this (top) we see everything omitted by the AI gaze.

group of images different from that group?). An unsupervised model might hereby generate elicitation devices that urban communities could be asked to make sense of in conversations that could unfold their relationships to the city.

6. Conclusion

With a bibliometric study, this paper has first reviewed projects in humanities and social science that use social media data to study cities, showing that the data imaginary of the field is dominated by 1) bias towards textual data, 2) fixation on geotag-ontologies as main analytical unit, and 3) frames of the subjective nature of social media data as a bias, not an analytical opportunity. To open alternative imaginaries in urban studies around what research agendas are possible with social media data, we have proposed a way to flip the script on these three methodological commitments by a) focusing digital urban analysis on visual data, b) going beyond the geotag and making use of the content of images in quali-quantitative ways, and c) re-framing the subjective nature of data as an analytical opportunity for studying lived experience and place attachments. Second, we have demonstrated applied strategies for opening such empirical routes in digital urban research through a case study of the #BareDanmark Instagram campaign, where computational analysis of 39K images was used to study place attachments during the first nine months of COVID-19. While a simple geo-tag mapping of the data would suggest that Danish cities are the most important environments during COVID, we have showed how centering visual content enables us to unsettle premature conclusions about place that stem from just looking at the geotag. Instead, our 'space typology' analysis demonstrated how visual social media data affords alternative opportunities for studying place attachments. Through this we learned that most campaign images depict natural environments, with emphasis on the water and coastline with beaches, harbors, lighthouses and so on providing an important refuge for people during COVID. While cities like Århus and Copenhagen are frequently posted-from locations, a visual analysis of images enabled us to discover that within these cities, photos of parks and waterfronts proliferate in the #BareDanmark campaign, revealing that people built strong place attachments to nature both inside and outside urban centers during the pandemic. Compared to existing studies that use textual social media data or mobile phone sensor data, the advantage of the visual approach is that we are not only able to identify *where* citizens post from, but to explore and qualify what these environments look like via the visual content of images. A qualitative exploration of nature-related images within Copenhagen for instance enabled us to go beyond the simple observation that people often post images from the waterfront, by visually examining the qualities of waterfront spaces and how they are used (for biking, swimming, and so on). Additionally, the analysis showed that access to valuable nature, according to Instagram users, does not appear equal across the city of Copenhagen. Such insights could inform efforts to plan more resilient and equitable cities and to identify places in need of planning or policy interventions.

Declaration of competing interest

There are no competing interests to declare.

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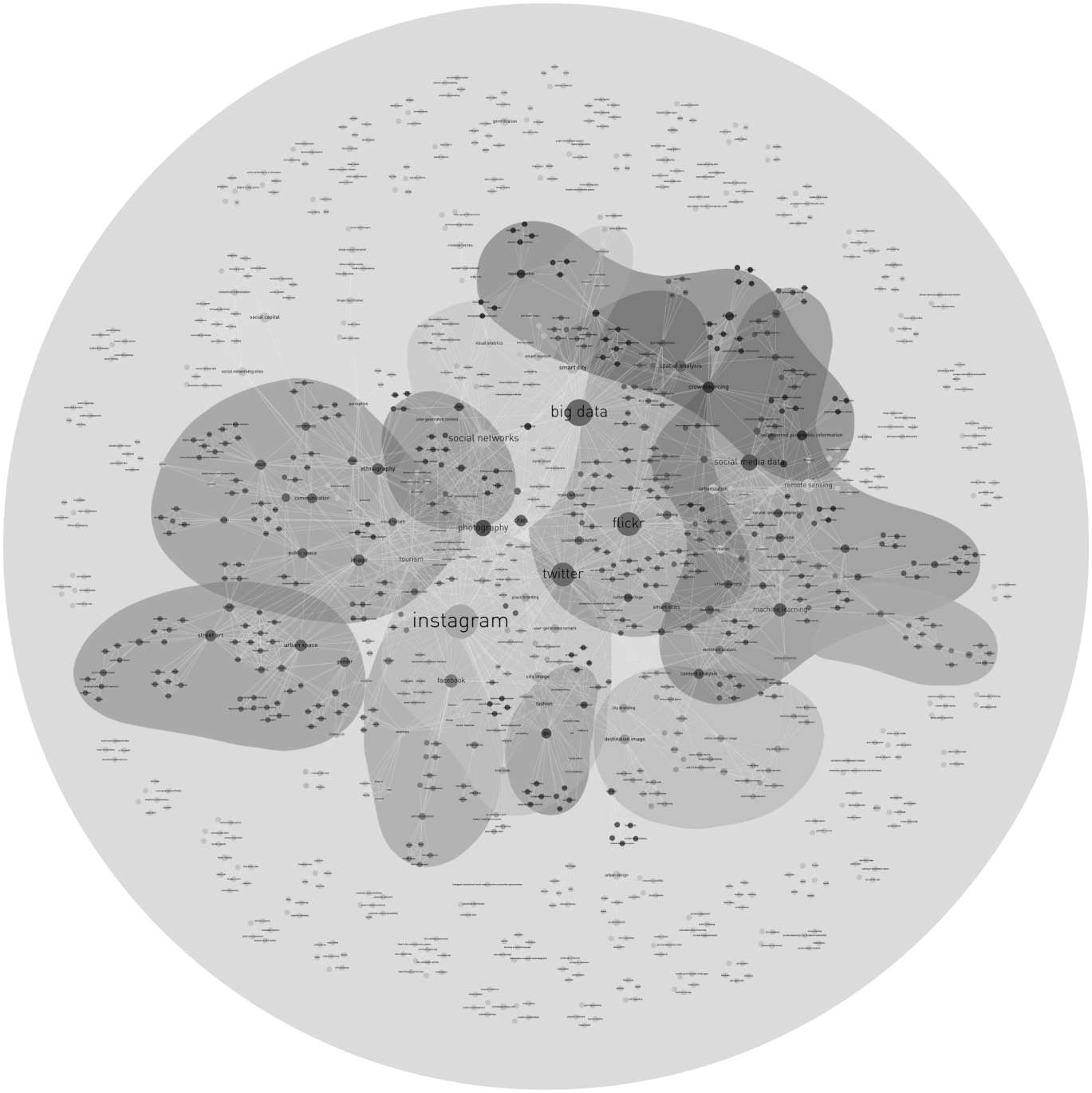
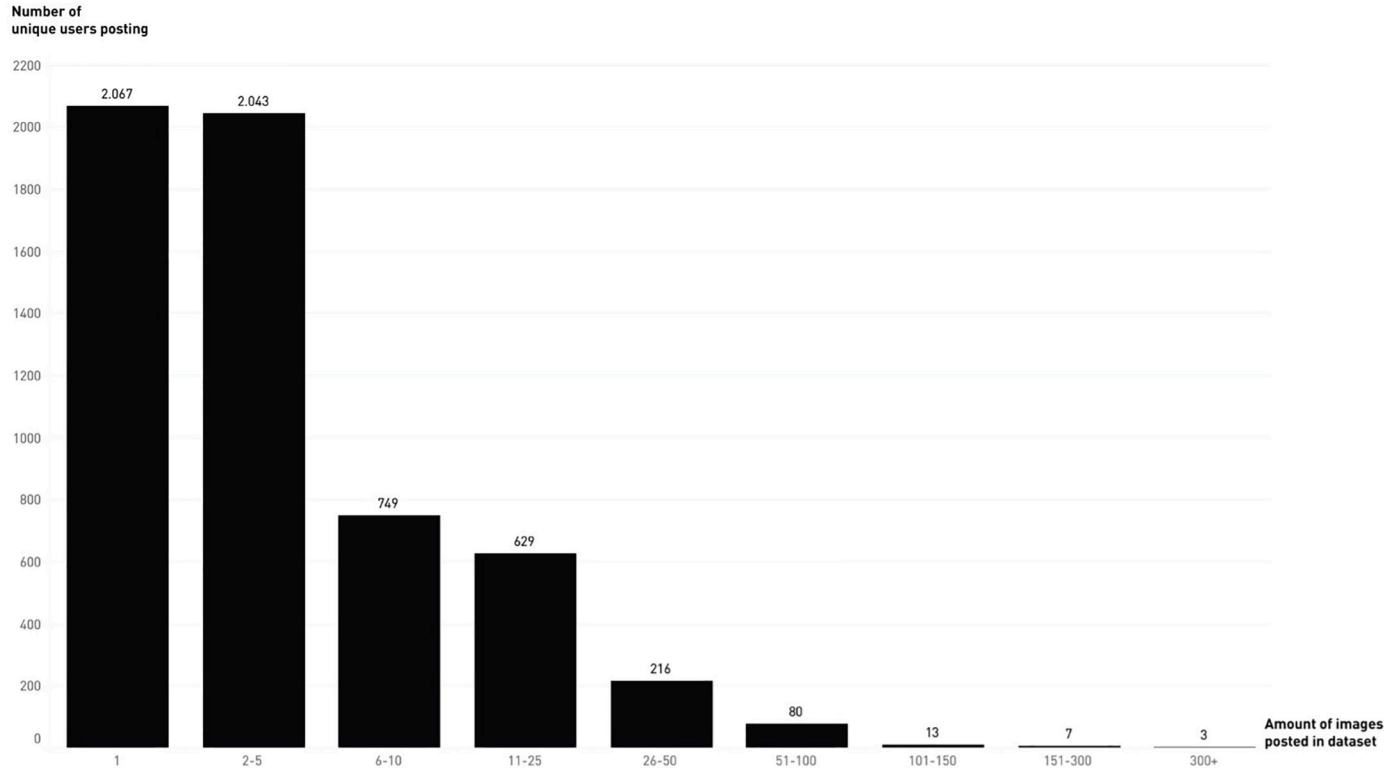
Data statement

The dataset contains personally identifiable information about Instagram users. It is collected within the EU and registered under GDPR. Therefore, the data is considered unsuitable to post.

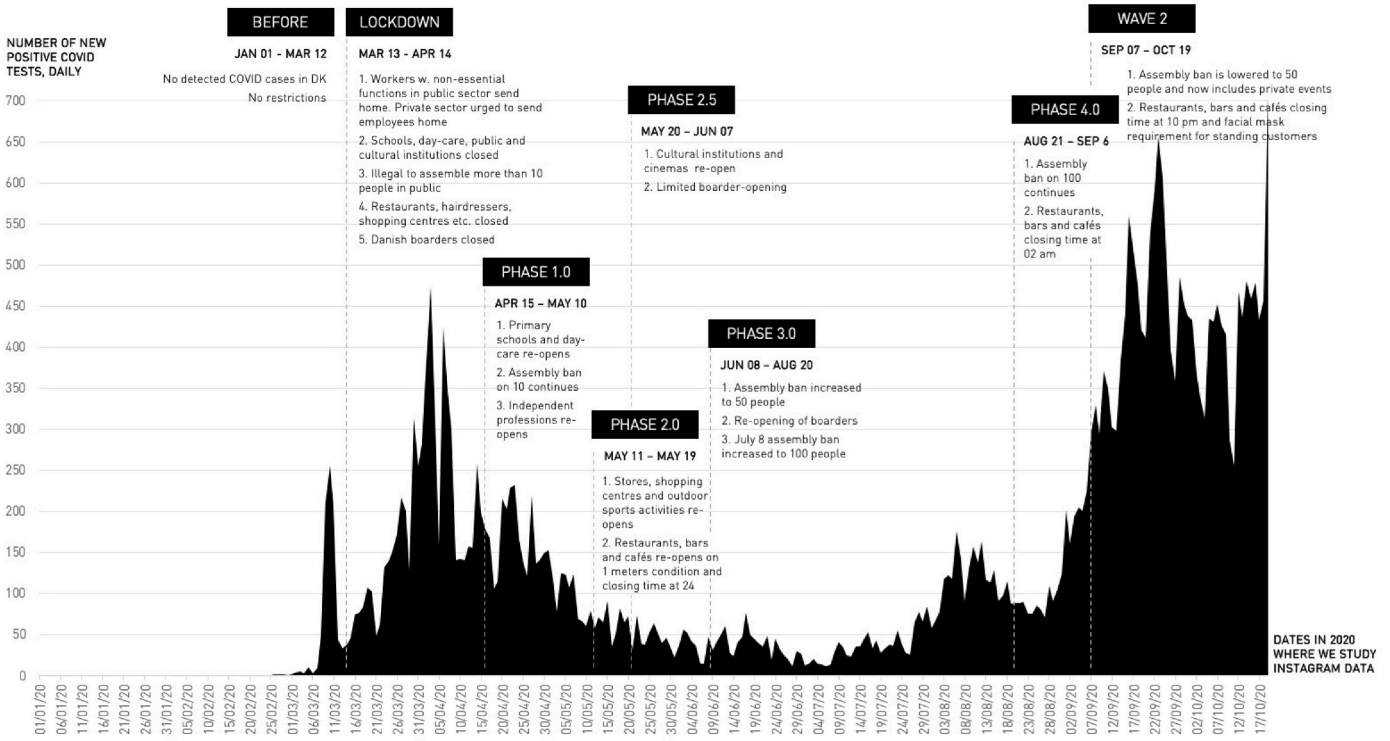
Appendix A



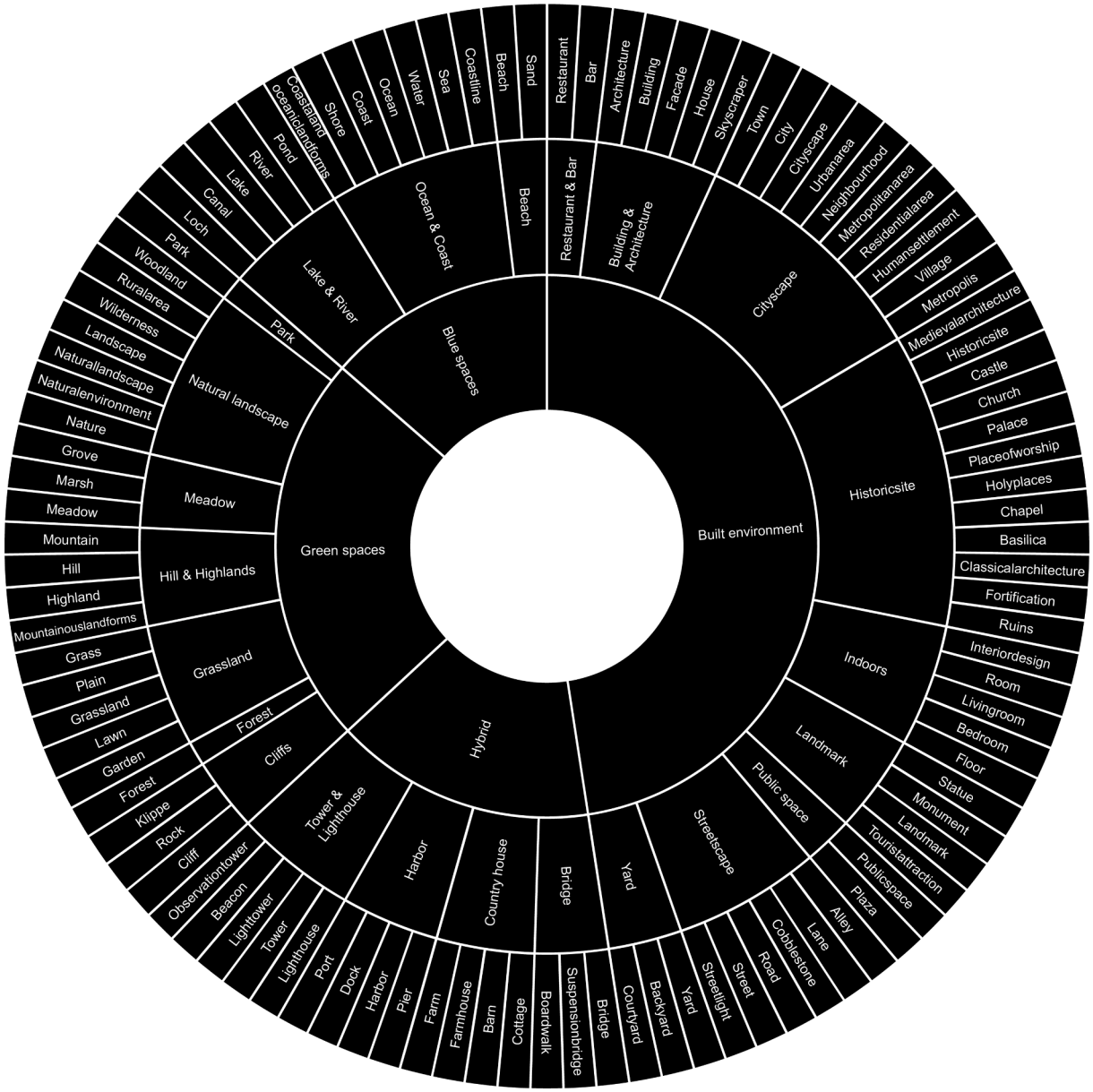
Appendix A1. Network graph visualizing co-occurrence of author keywords in 311 SCOPUS articles that result from a search for visual, social media and city projects. Before selected big nodes are removed.



Appendix B1. Number of posts per user with 5.807 unique users in total (right).



Appendix C1. Overview of COVID phases in Denmark: Official dates, key changes in restrictions mapped on top of trend line of the registered number of new positive COVID tests daily (Statens Serum Institut, 2022).



Appendix D1. List of Google Vision image labels (outer ring) used to annotate space typologies (middle ring) classified as built environment, or blue, green, or hybrid spaces (inner ring).

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