App ecosystem analysis

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Mobile “apps” (short for applications) are typically defined as software designed to run on a mobile device, such as a smartphone or a tablet. They are commonly considered a type of “mundane software,” not only because they support users’ everyday practices but also because they insinuate themselves into our daily routines and habits.[1] For users, apps seem like bounded software objects: they can be dragged around on the homescreen grid, grouped into thematic folders, and activated by pressing their typical, rounded-edge icons. From app “stores” to users’ mobile devices, apps are transmitted as software packages through seamless and highly-automated downloading, updating, and purchase procedures.[2]

However, this bounded and wireless appearance of these apps is only part of the story; it hides the fact that apps, perhaps more than any other type of software application, are dependent upon myriad remote software services, systems, and objects without the user even knowing when, how, or where connections are made. Zittrain and Gerlitz et al. have called attention to the political economy of apps by stressing their relationality and contingency,[3] pointing to the emerging power dynamics between (developers of) apps and the powerful platforms to which they are connected (or "tethered," as Zittrain suggests).

It is relevant to note that contemporary apps are not only built for smartphones or tablets anymore. Google (Alphabet) has developed several versions of the Android operating system (OS) for specific use cases, including Android Wear OS for smartwatches, Android TV for smart televisions, Android Things for “internet of things” devices (deprecated in 2021), and Android Auto and Automotive OS for cars, all of which run Android apps.[4] In short, the cultural and economic significance of apps today exceeds their use on smartphones or tablets alone.

Despite their undeniable significance, apps pose serious challenges for empirical media research. The purpose of this chapter is to outline ways forward, based on some of our own previous methodological experiments and research projects as part of the App Studies Initiative.[5] We cover examples from previous research projects and “sprints” (1) on thematic app collections (an approach we named *apps “for that”*), (2) on the app ecosystems that have formed around social media platforms (named *apps “for” apps*), and (3) on the ecosystems of third-party apps and services embedded within particular apps (named *apps in apps*). These three approaches should help critical app (and platform) researchers, as well as students, to move forward with the

empirical study of what are called the “ecosystems” of apps. That is, they should help researchers and students make, analyse, visualise, and interpret *collections* of apps, as well as uncover the (sometimes hidden) relations that form between and around apps and different types of software platforms they are linked to.[6] In short, this chapter presents a methodological outlook, including methods and resources for doing app ecosystem analysis.

The presented approaches for doing app ecosystem analysis are important not only to describe and study the “appification” of social and cultural issues, but also address concerns around the power of mobile platforms and app stores, “datafication” in the mobile ecosystem,[7] and the political economy of mobile communication.[8] Additionally, the approaches help to grapple with the many layers and interrelated components of the contemporary mobile ecosystem, including mobile devices, platforms or OSs, app stores, developer tools, and a variety of in-app software services to authenticate, compute, advertise, load content, track, pay, and more. Furthermore, specific relationships can be analysed to learn how particular apps are governed and shaped by the larger ecosystems they are part of, as well as how these larger ecosystems solidify infrastructural control and power in the hands of “infrastructural platforms" like Google and Meta.[9]

App Studies, an ecological perspective

The empirical approach to app ecosystem analysis draws from earlier methodological studies by Dieter et al., which identified four distinct “entry points” for App Studies: the app *interface*, the app *store*, the app’s software *package*, and the app’s network *connectivity*.[10] These four entry points demonstrate that apps are multifaceted objects that may be approached from different sides and that are shaped by the multiple techno-commercial environments they reside in. These entry points, especially the app store, also help us get started on app ecosystem analysis.

To grapple with the fundamental relationality of apps, Media and Communication Studies researchers have developed “ecological” and “infrastructural” perspectives on apps. Within app ecosystems, Lai and Flensburg suggest, “powerful companies figure as ‘invasive species’, where value is generated and control is exercised through the ownership of six types of critical infrastructural resources that support app-based communication, namely (1) devices, (2) operating systems, (3) app stores, (4) apps, (5) third-party trackers, and (6) data accesses”.[11] Similarly, Gerlitz et al. distinguished six distinct layers of the “app/infrastructure stack”, which also models these critical infrastructural resources of apps and the relations between them.[12]

This complex network of relations between apps, platforms, developers, and other interrelated components is referred to as the “mobile app ecosystem”.[13] In a restrictive sense, this “ecosystem” is composed of a core platform, its actors (the platform owner, third-party app developers, and users), and the apps developed on that platform.[14] A more open understanding

also includes advertisers, content providers, and other related actors as part of the "ecosystem".[15] This broader understanding borrows the ecosystem metaphor from the natural sciences to consider the relations, interactions, and dynamics among platforms, apps, their developers and end-users, and other stakeholders in a software-based environment. As such, it is an inherently relational perspective that explores how apps are always embedded in and shaped by their larger environments, which are inhabited by many different actors.

To study these larger environments, others analysed how platforms "technically integrate themselves into the fabric of the mobile ecosystem", providing valuable insights into the formation of platform monopolies and processes of datafication in the mobile ecosystem.[16] Pybus and Coté propose a "microscopic perspective on the technical objects that comprise application infrastructure".[17] By putting mobile apps under the microscope, they suggest, one can observe "digital parasitic relations", "invasive species", and study heterogeneous relations and power dynamics within app ecosystems.[18]

The ecological perspective on apps builds upon related work in Internet Studies preceding the age of apps. For example, critical research on web tracking (where website operators and third parties collect, store, and share information about visitors' activities via web cookies, fingerprinting, and other methods) has shown how online environments have become increasingly "inhabited and shaped by third parties such as social media platforms, advertisers, analytics companies, and content-delivery networks, embedding the website in various technological and commercial relations with these actors" and that this "website ecosystem" can empirically be detected and (re)constructed from the website's source code.[19] Recent studies have traced the global networks between and around these advertisers, analytics companies, and other powerful industry players and data intermediaries, and their software tools, which together form the complex digital advertising ecosystem.[20]

The sections that follow present three ways of doing app ecosystem analysis. They discuss examples from previous research projects that rely on the ecological perspective on apps. Specifically, they explain how one might build collections of apps and use them to study the culture and economy of apps, as well as reflect on how these cultures and economies of apps have been shaped by various platform interventions.

Three ways of doing app ecosystem analysis

Apps "for that": analysing thematic app collections

To begin, apps can be part of algorithmic or editorial app collections that are built and marketed as solutions to particular problems or issues. This first approach we named *apps "for that"*. Apple famously used the phrase "There's an app for that" after the launch of the iPhone in 2008; today, we can look at these millions of apps and ask: what kind of apps are there *"for that"*?

Consider the apps that emerged to fight the coronavirus (COVID-19) pandemic crisis in 2020 as a form of "techno-solutionism",[21] and the concerns they raised around citizens' data privacy and security. Critics also pointed to the role of app stores, which acted as powerful gatekeepers in the way that apps figured in the pandemic response.[22] Particular attention was paid to Google Play (for Android apps) and Apple's App Store (for iOS apps), as the dominant stores worldwide in terms of number of users and apps. Alternative app stores for Android apps exist, such as Amazon's AppStore and those aimed at the Chinese market, including Huawei's AppGallery and Tencent's MyApp. One aspect of Google and Apple's dominance comes from the tight coupling of the underlying software and hardware platforms (i.e., Android and iOS) to the app stores. They provide the necessary infrastructure for app development while gaining infrastructural control over their app ecosystems.[23]

App stores like these have become powerful gatekeepers because they function as the central intermediaries between developers and consumers of apps. App developers (who include individual developers, businesses, international organisations, and governments) make use of app stores to distribute, market, and monetise the apps they build, while consumers use app stores to discover, purchase, download, and automatically update their apps. App stores thus operate as marketplaces where apps and in-app commodities are marketed. However, because of their global reach and scale, app stores also provide affordances for social and cultural research; that is, app stores reflect larger social and cultural phenomena and dynamics, as well as the development practices of the actors (third parties) behind those millions of apps.

As Lupton suggested, apps are "sociocultural artefacts" and "the products of human decision-making, underpinned by tacit assumptions, norms and discourses already circulating in the social and cultural contexts in which they are generated, marketed and used".[24] Similarly, Hasinoff and Bivens considered how "app developers' design choices reflect existing cultural norms, assumptions, and ideologies".[25] Consequently, one might repurpose the affordances of app stores for social and cultural analysis and to study app development practices.[26]

For an exploratory study of COVID-19 apps in mid-2020,[27] we ran a number of search queries to find apps emerging in response to the pandemic crisis. We hypothesised there would be more than just digital contact-tracing apps, which received all the attention. Notably, search queries like [COVID-19] and [coronavirus] in Google Play returned only those apps that were targeted to our own locations—the Netherlands, the United Kingdom, and Germany—from where we did the searches.

This localisation, it turned out, was Google's attempt to control what Rogers calls "serious queries", or keywords that return official information.[28] In this case, search queries were editorially moderated by Google to ensure consumers find and install *the right* COVID-19 apps.[29] We then also tried queries using intentionally misspelled keywords, such as [COVD-19] and [coronna], which returned all apps previously hidden through our correctly-spelled searches.

In a second iteration of this study, we designed a more systematic method. This time, we queried both app stores for a list of (both correctly spelled and misspelled) search queries in all

supported “locations” (Google Play) and “countries or regions” (App Store) using our custom-built and openly available app store scrapers.[30] With this tool, we systematically collected the titles and details of the 410 Android and 253 iOS unique apps that matched our search queries (and whether they surfaced in the correctly spelled or misspelled collection). These app details included lengthy descriptions, screenshots, release dates, statistics, and developer information.

After careful inspection and comparison of the Android and iOS apps, one notable finding was how many apps were exclusive to one store (instead of existing in both). While the 136 apps present in both stores were predominantly made by governments, about 70% of the government-made Android apps did not have an iOS equivalent. Consequently, it makes a difference whether one uses Android or iOS for app-based governmental services.

The subsequent analysis focused on the types of actors and responses (or solutions) they were building, based on a collaborative coding of the apps into categories, and the distinct composition of actors and response types across countries. Throughout, we reflected on the role of app stores in shaping these app collections and intermediating the relationships between health organisations, governments, and citizens worldwide. Importantly, we showed how platforms used the pandemic to further entrench their global infrastructure into governmental and digital health apps.

This first project illustrates how one might make use of app stores’ information and built-in capabilities to demarcate collections of apps (i.e., corpora) *for us* based on the search queries we design.[31] Carefully-designed search queries help us find and create meaningful collections of apps for specific research interests, such as taking inventory of the range of app solutions on offer for a selected problem or issue. The approach can similarly be used to study other issues, such as (apps built for) mental health, sustainability, climate change, and privacy.[32]

Additionally, the approach enables comparative analyses of apps and issues between different stores (e.g., between Google Play and Apple’s App Store, or one of the Chinese stores) and between different countries or regions (e.g., between the USA, Germany, and Japan). Furthermore, the approach can be used for longitudinal analyses of changes in the composition of app collections, of particular apps, or of the evolution of the ecosystem as a whole.[33] Analysts might bring their own source lists or use lists created by experts to derive, evaluate, or enlarge their corpus of apps. Regardless of the type of app collection, one can then analyse the features of the apps included through labelling or categorising the apps, their functions, or the solutions they put forward, and the emerging discourses of these solutions.[34]

Sometimes, however, there are *no apps “for that”* and this may become the focus of study instead. For example, what happens when users search for content that is not just moderated (as in the case of COVID-19 apps) but explicitly banned under the developer guidelines or distribution agreement? In other words, what do app stores offer as search results and recommendations when one queries for objectionable content? In one of our previous projects, Google Play was queried for the regional language equivalents of [porn] and [pornography]

across multiple countries to find out what kind of results Google Play would serve instead.[35] Participants in our project identified three types of app results, including "porn inhibitors" (including games, social media, dating apps, VPN services, and chats), under-the-radar "porn facilitators" (including live chat apps, soft porn apps, and clickbait), as well as "anti-porn" results (including porn blockers and Christian apps against masturbation and porn addiction). This anti-approach may also be used to analyse search results for other controversial, banned, or otherwise objectionable content queries.

Apps "for" apps: analysing social media app ecosystems

Next, individual apps may also be part of larger collections of apps that are all developed "on top" of or "for" a platform, such as apps built "for" Instagram or "on top" of Twitter's Developer Platform. As such, this second approach we named *apps "for" apps*. This approach considers how apps relate to the use and developer cultures of platforms. As in the previous approach, these apps "for" apps are typically developed by third parties and distributed and marketed via the popular app stores to reach consumers worldwide.

Once again, the app stores served as our key "entry point" to demarcate app collections. We searched for the names of popular social media apps, including [Instagram], [Snapchat], [Facebook], and [Twitter].[36] We then enlarged our initial corpus with thousands of additional apps that were given as recommendations on the app details pages. The entire corpus was analysed to determine what types of apps and functions were built "for" these apps (again based on collaborative coding), as well as how these functions were implemented (based on an analysis of the app's code and resources). This provided a unique view of apps' claimed functionality on the one hand (from the app descriptions) and the actual implementation on the other hand (from the app code).

The first analysis served to explore the functions and user practices these apps were complementing to the core platform, which the platforms themselves were not offering (or had not anticipated). We found countless examples of complementary functions and use cases, including image and video content editors and downloaders, custom camera lenses and filters, emoji keyboards, and tools to monitor or grow friends, followers or likes. Additionally, there were apps that targeted the distinctive (missing) features of a platform, such as "no crop" and "regramming" apps for Instagram, Snap and Story replay apps for Snapchat, or Tweet-editing apps for Twitter. These third-party apps may support functionality that is disallowed according to the app stores' guidelines or the social media platforms' terms and policies. Conversely, when successful, functions suggested by third-party apps are frequently copied by the core platform.

The second analysis surfaced the embedded APIs and software development kits (SDKs) used for building apps on top of a platform. These included those not officially supported by the platform owners, which app developers were using as workarounds to the limitations and

restrictions of the official APIs and SDKs. Apps typically require API connections (e.g., via SDKs) to access a platform's data or functions and therefore function as a means of infrastructural control for the platform owner. We found a third of the Android apps "for" Facebook used its official SDK, while only one in six apps "for" Twitter featured its Twitter Kit. Not all platforms provide APIs, and when they do, they may be available to businesses only (e.g., Snapchat's Marketing APIs and Lens Studio). We also found that developers were using platforms' mobile sites to build "lite" or lightweight alternatives to the official app clients of Facebook and Twitter to address consumers with limited data plans, battery or device capacity, or network connectivity.

The two analyses show how developers build apps "for" other apps and "on top" of platforms' APIs and SDKs. In doing so, these apps are subject to the terms and policies and "API governance" of the core platform "for" which they were built. Additionally, they are subject to the review guidelines and governance mechanisms of the app stores they reside in. Apps "for" apps are thus connected to not one but two (or more) different platforms. These layered governance relationships complicate matters for researchers and developers alike, and therefore may constitute key points of contestation where the politics of platforms are manifested.[37] For example, in October 2022, Meta had over 400 malicious Android and iOS apps removed from Google Play and Apple's App Store, which had abused Facebook's SDKs to steal login information.[38] Many of these apps were disguised as apps "for apps", like the ones we found in our study, including photo editors and utility apps. Meta reported their findings to Apple and Google, requesting these malicious apps to be removed.

This second approach helps to surface how (social media) platforms foster their "developer community" and what kind of user cultures developers envision for platforms. Third-party developers play a vital role in the creation and early adoption of new functions, user practices, and forms of cultural production beyond those already supported by core platforms.

Apps in apps: analysing "in-app" ecosystems

Finally, apps are frequently inhabited by myriad third-party "in-app" apps and services. This third approach we named *apps in (or inside) apps*. Many apps include software libraries of apps and services created and provided by third parties in their package code.[39] These include "in-app" payment services, developer tools, cloud computing and storage services, content delivery networks, advertising networks, analytics, social login and authentication systems, and more. This approach looks at apps as "inhabited" by third parties and surfaces the relations between apps and the different types of infrastructure they need or use from third parties.

Similar to studies of "tracking" on the web that made use of the Ghostery browser extension,[40] one might detect and analyse the types of third-party apps and services embedded within particular collections of apps. Again, app stores may be used to demarcate collections of

apps. For example, we made thematic collections of Android apps related to sensitive health information, including [addiction], [depression], [pregnancy], [std], and [stress], as well as collections based on store-defined categories, such as "Games" and "Dating".[41] We then scanned the apps in these collections for embedded software libraries (i.e., apps and services) using tools like AppInspect or εxodus,[42] or a commercial service like AppBrain (which labels libraries as "ad networks", "social libraries", or "development tools").[43] Both εxodus and AppBrain offer reports from previous app inspections, so one merely needs to search for the names of apps to get lists of "trackers" (through code signatures) and "permissions" (through an app's manifest files, included in its software package) found in these apps.[44] One then needs to collect the information in one place (e.g., in a spreadsheet) for additional analysis, comparison, or interpretation. Together, these embedded software libraries (including "trackers") and permissions are the central mechanisms of datafication in the mobile ecosystem.[45] Tech-savvy researchers may use a complementary tool like AppTraffic or Wireshark to capture, inspect, and playback the data traffic flows from and to apps.[46]

In our aforementioned study of COVID-19 apps, it was striking to find many third-party services in government-made apps, including advertising and analytics services in the apps of some countries. Lai and Flensburg described the actors behind these "in-app" services as "invasive species" that "grow quickly and spread aggressively",[47] while Blanke and Pybus describe them as "services assemblages" to foreground the process by which platform companies have "broken apart into services and reassembled into new products".[48] Particular apps may provide glimpses of the larger platform ecosystem because they are inhabited by larger infrastructural platforms like Google and Meta.

The presence of apps and services inside apps leads to cascades of networked terms and policies for users and developers, further complicating governance relationships and blurring the boundaries between platform ecosystems. For example, we scanned the top-ten most-used Android apps to identify embedded software libraries and collected the terms and policies for all third-party services they relied on.[49] We found as many as 66 different services, each with one or more policies attached to it. With a median of seventeen embedded software libraries in our study of COVID-19 apps, both developers and users of apps face an overwhelming number of terms and policies in everyday life and practice. These policies may be difficult to read, revised regularly, and reference additional terms and policies. As such, the governance of particular apps may be layered and distributed across third-party services, while governance by app stores is centralised.

Additionally, this third approach calls attention to the emergence of so-called "super apps" (typically exemplified by WeChat, QQ, and LINE), where users can install "mini apps", "mini-programs", or "sub-applications" from within the super app.[50] This installation process bypasses the app store as the means of app distribution. Consequently, "super apps" may be inhabited by an entire ecosystem of third-party apps and services custom-built for the super app. While this business and development model is most prevalent in Southeast Asia and Africa, it is

also a broader trend that warrants further exploration. Therefore, we began exploring the emergence and evolution of different types of "super apps" and how they differ from other app ecosystems.[51]

The culture and economy of apps

These three ways of doing app ecosystem analysis, each illustrated with different examples from research projects we have been able to conduct so far, provide methods and resources that help researchers and students explore the cultural and economic significance of apps in terms of the ecosystems they inhabit and help constitute. This ecological perspective on apps helps to foreground the actors, their relations, and resources they share, and enables conceptual and empirical contributions to the field of App Studies.

The three ways of doing app ecosystem analysis offer complementary research opportunities. The first approach, which we labelled *apps "for that"*, enables the analysis of thematic app collections that may be demarcated with the built-in techniques of app stores. As such, this approach enables the analysis of app collections demarcated with the help of app stores and provides a basis for a critique of "techno-solutionism" in relation to apps. The second approach, *apps "for" apps*, lets researchers build and analyse app collections that emerge around particular (social media or other popular digital) platforms. These apps may be built "on top" of the platforms' official APIs and SDKs, or they may be complementary or related to the platforms' functionality and affordances in other ways. The third approach, *apps in apps*, inspects the third-party apps and services inhabiting particular apps or app collections, as well as the internal ecosystems of apps that live inside "super apps".

Based on the referenced examples and projects, ecological perspectives on apps seem valuable for at least several reasons. To begin, it draws attention to apps that are in many ways designed to become habitual and fade into the invisible background of everyday life and practice. The approaches help to understand how apps perform, create value, and support users' practices within environments of use that are governed by digital platforms and different third parties. This perspective broadens the scope of interpretative studies focused on single apps, or aspects of apps, to the larger ecosystems or collections of apps around particular social and cultural phenomena. As such, it provides a useful methodological outlook for the study of "appification" (how apps figure in different social, cultural, economic, or political processes),[52] "datafication" in the mobile ecosystem (whereby many aspects of our daily and private life have been turned into data through apps),[53] and how governance and power manifest themselves in this ecosystem.[54]

Additionally, ecological perspectives surface the external actors, relations, and resources shared by different apps (including infrastructure). The approaches all encourage an empirical

outlook to help describe and study ecosystems *as they are*, as they *are emerging*, or as they *have evolved*. The framework of "ecosystems" and ecological thinking are useful and valuable to appreciate the variety of actors, interactions, and resources shared among them, as well as the diversity, nestedness, and resilience of the mobile app ecosystem as a whole.[55]

Furthermore, an ecological perspective reveals the layered governance relationships and power dynamics that manifest themselves in the mobile ecosystem. The approaches reveal how complicated governance relationships can be for consumers and developers of apps, as well as how powerful infrastructural control by means of APIs, SDKs, and other developer tools may be. Dynamics like these do not only play out between platform owners and third-party app developers or users, but also between platform owners and app stores.

Finally, the advancement of "super apps," "mini programs," or "mini apps," and other nested app forms and business models invites further critical (conceptual and empirical) reflections on the new types of app ecosystems they help constitute. These alternative ecosystems will be characterised by different forms of governance and regulation, for instance. Despite the differences, the three ways forward outlined in this chapter provide starting points, methods, and resources that may be used or adapted to study emerging and alternative app ecosystems. It is our hope that the approaches and resources collected in this chapter will guide and inspire further studies that explore the culture and economy of apps, and app ecosystems in particular—now that there is a method for that.

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