A Study on Icon Arrangement by Smartphone Users

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ABSTRACT

The number of available mobile applications is steadily increasing. People have rapidly adopted application stores as means to customize their devices with various functionalities that go beyond communication. Understanding the principles of mobile application usage is crucial for supporting users within this new ecosystem. In this paper, we investigate how people organize applications they have installed on their devices. We asked more than 130 participants for their habits for icon arrangement and collected more than 1,400 screenshots of their devices' menus to further ground our findings. Based on this data we can distinguish five different concepts for arranging icons on smartphone menus, e.g. based on application usage frequency and applications' functional relatedness. Additionally, we investigated how these concepts emerge in relation to frequency of application installations, removals and icon rearrangements, as well as users' experience levels. Finally we discuss implications for the design of smartphone launchers, and highlight differences to icon arrangement on stationary computers.

ACM Classification Keywords

H.5.2 User Interfaces: Interaction styles, Screen Design.

Author Keywords

Mobile applications; icon arrangement; user behavior.

INTRODUCTION

Mobile phones have evolved from single- to multi-purpose devices. Today, there exist a huge number and great variety of functional add-ons that support users in different activities, e.g. banking, navigating, playing games, taking notes, or sightseeing. People can easily alter the purpose of their devices by adding new functionalities, called *apps*. A smartphone can easily be transformed from a phone to a camera, sketchbook, bus schedule, musical instrument, or dictionary. This functional customization is supported by application stores like *Apple's AppStore* or *Google Play Market*. They provide new means for developers to distribute their apps, and an easy way for end-users to install new applications. Such stores have recently become very popular. As a result, the number of available applications is steadily increasing. Currently, there are more than 650,000 apps available for Apple's iPhone and more than 513,000 apps for the Android platform.[1] The number of app downloads is anticipated to surpass 45.6 billion in 2012.[2] Users leverage this functional richness through our smartphones' app launcher menus. Despite the launchers' importance and heavy usage, so far it is poorly understood how users employ them.

Figure 1. Screenshots of iPhone launcher showing page with icons of nine apps and four folders (left), and a folder as a submenu (right).

Once installed, a new app resides on the user's device and is available for instant usage. Icon-based menus that are arranged in a grid layout, as shown in Figure 1, became common. These menus help people to organize, find and use their apps. However, since the screen size of mobile devices is limited, at some point the user has to decide on how to organize the icons. Current smartphones may be able to show up to about 24 icons at once. Icons that do not fit on the screen can either be put on a new page to be reached by scrolling, or they can be organized hierarchically into folders to be reached by navigating. While there are intuitions and beliefs on how people manage their apps, there is little published research on the topic. As a result, so far we are not able to comprehensively support this decision process. Important questions remain unanswered, for instance: Do people have certain concepts for arranging icons? If so, what are these concepts and how are they applied? How can we exploit the effort people put into maintaining their launchers?

One major design goal for menus is to adapt them to the users' tasks [18]. This is of particular interest for mobile menus, since the tasks of mobile users [1] and the apps they use [5, 8] are perpetually changing, and the design of context-aware menus is a topic of current research (cf. [4, 13, 22, 26]). However, in contrast to pre-designed menus, smartphone launch-

[1] List of digital distribution platforms http://is.gd/pzjWb6
[2] http://www.gartner.com/it/page.jsp?id=2153215

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ers are highly customized by the very users themselves. Customization itself has become a primary activity [11, 16], e.g. to make the device more efficient or manage complexity. Yet it is unknown if the design goal of task-relatedness also emerges when users arrange their mobile menus themselves. This is what this paper focuses on.

This paper contributes to the understanding of people's practices when customizing mobile app launchers. We investigate the concepts people use when arranging icons and how these concepts impact the visual layout. Additionally, we explored the phenomenon of meta-applications that people build when clustering app icons for task-related functionality, and discuss implications for the design of adaptive smartphone menus.

RELATED WORK

Pioneering work on users' practices for organizing icons and digital information in general was done in the desktop domain. Barreau and Nardi [2] summarized their studies of file organization on personal computers. They found that a visual search for files based on location is preferred over text-based search, that people put icons at special places as a reminder, and that information can be categorized by ephemeral, frequently-used, and archived. Ravasio et al. [20] investigated habits and problems during document classification and retrieval. Among others, they show that people cluster documents by their types, and that people use different desktop areas for different purposes. Shipman et al. [23] investigated the implicit structure that humans implement in layouts when manipulating icons or other visual objects. They propose to parse and exploit this structure for assistive facilities. In this paper we go beyond desktops and set out to explore people's practices on smartphones.

The more ubiquitous and popular smartphones and mobile apps became, the more important it became to understand the principles of mobile app usage, in particular against the backdrop of mobile users' contexts and changing tasks [1]. For instance, Verkasalo [25] shows that people use certain types of mobile services in certain contexts, e.g., they mostly use browsers and multimedia services when they are on the move but play more games at home. Böhmer et al. [5] found that app usage changes during the course of the day as well as depending on location. Similarly, Do and Gatica-Perez [8] analyze patterns of mobile app usage based on a sample of more than 230,000 hours of app usage provided by 111 people. Based on this data they verify a model for recognizing patterns in daily application usage, and for describing user behavior based on the found patterns. So far, research on the recent generation of mobile apps addresses only how people use apps by means of installing or executing them. So far, there is little published work on how people customize their menus and organize their apps on their devices.

Bridle and McCreath [6] have investigated shortcuts for mobile phone UIs that can be adaptively injected into users' main menus. They evaluated different approaches to provide users with shortcuts to common tasks on their mobile devices. Vetek et al. [26] presented *SmartActions*: a context-aware menu that automatically creates context-aware shortcuts to phone functionality based on unsupervised learning. However, none of these works investigates where to spatially place adaptive shortcuts within a mobile menu. This, instead, has been a topic of work on non-mobile menus. For instance, Cockburn et al. [7] present a theoretical model to predict user performance for different desktop menu designs. Based on the Hick-Hyman Law and on Fitts' Law, the model allows for evaluation of different menu layouts before actual implementation. However, we argue with Findlater et al. [9] that findings on classical desktop menus are not necessarily valid for mobile devices. Moreover, mobile menus have the additional requirement to fit to various tasks and changing contexts [1].

St. Amant et al. [24] investigate the optimization of hierarchical text-based menus for cell phones that can be traversed by keyboard input. Based on their findings, they propose options for optimizing menu structures that result in reducing traversal time, e.g. by putting commonly used items higher in the hierarchy. Their approach for menu redesign results in time savings of 30% in simulation studies. Also, Matsui and Yamanda [17] presented an algorithm for optimizing the menu structure for hierarchical menus on mobile devices. In their experiment they minimize menu item selection time by changing menu structures. Ziefle and Bay [27] investigated people's abilities to build mental models of their hierarchical smartphone menus. They found that younger people have a better mental model of their smartphones' menus. Further, they also found that the awareness of the menu's structure increases navigation performance. Kim and Lee [15] investigate the impact of cultural differences on mobile menu interfaces. They found that Koreans preferred a thematically grouped menu and Dutch participants preferred a functionally grouped menu. To the best of our knowledge, only the following paper examines how people spatially distribute their mobile apps to fit onto the screen's limited real estate: Böhmer and Bauer investigated the impact of context on users' icon arrangements [4]. They studied the way people arrange their icons in four different contexts and found that icons of apps that are more relevant to a certain context appear in more prominent positions within users' icon arrangements. However, in contrast to the controlled user study presented in [4], we are aiming for a more natural sample in our work, and we move beyond most of the existing literature by focusing on user-defined organization schemes.

STUDY METHOD AND SETUP

Our work was inspired by a screenshot-based diary study on mobile task interruption [14]. We have adopted the method of a screenshot-based study for two reasons: Firstly, in contrast to Böhmer and Bauer [4], who asked subjects to arrange icons ad-hoc within a launcher menu mock-up, we did not want to bias our sample by the arrangement task itself. Further, since the customization of functional phone settings happens over the long term [11], the chosen design allows us to collect data that have evolved naturally. Secondly, we decided against using a logging app as proposed for mobile in-the-wild studies [12] since by introducing a dedicated app with its own icon, we would have biased what we wanted to observe. As a result, we have chosen to investigate iPhone and Android devices, since at time of the studies these were the only

widespread representatives of the current generation of smartphones (allowing users to install apps and arrange icons) with capability to easily take screenshots[3]. Thereby we were able to collect data in the wild without imposing too much effort on our subjects.

Our study had two steps: First, we asked volunteers to make screenshots of their menus for the purpose of analyzing their icon arrangements, and to send them to us by email. Secondly, we sent a short questionnaire to all participants. In four groups of questions, we asked for their device customization habits, general phone usage, personal info, and general comments. We set up a website with instructions, and recruited subjects by email invitation, Facebook and Twitter. Data collection was done during June and July 2011 for iPhone, and during July and August 2012 for Android (when screenshots became possible on Android 4.0).

We asked people to send us screenshots of their customized launchers. As such, our samples might be biased in that we did not receive data from people who do not customize their menus at all. However, our goal was to investigate how people customize their menus, not whether they do so at all. The latter can be concluded from related work (cf. [3, 11, 16]).

SCREENSHOT STUDY

Data Characteristics

In total we received data from 132 people: 1,486 screenshots from 106 iPhone users[4], and 144 screenshots and from 26 Android users[5]. 22 participants were female and 108 were male (2 unknown). Their mean age was 28.32 years (SD 8.48). We reached participants from various countries: 60.5% from Germany, 11.4% from the United States, 4.5% from the United Kingdom, and the rest from 20 other countries.

We asked our participants to categorize their smartphone experience on a 4-point scale between *novice users* (level 1) and *expert users* (level 4). The mean level of experience of our participants is 3.46 (SD 0.71). Therefore, we clustered our participants into 58 less-experienced (those with level 1, 2 and 3) and 74 more-experienced users (those with level 4).

Practices of Installing, Arranging, and Removing

We asked participants on a 5-point scale (0 times, 1-10 times, 11-20 times, 21-30 times, >30 times) how often they have installed apps, rearranged icons, or uninstalled apps in the last month. We designed the scales based on anecdotal reports and to capture a wide range of frequencies for installing, arranging and removing apps. The median is 1-10 times for all, i.e. in the last month our participants have on average installed 1-10 apps, rearranged their icons 1-10 times, and uninstalled 1-10 apps.

The more often people install apps, the more often they also uninstall apps (*Spearman's rho 0.79, $p<0.001$*). This suggests that people either try new apps — i.e. install them and remove them if they are not worth keeping it — or that they remove older apps that they do not need any more when they install new ones. By removing apps when installing new ones, they either replace the functionality of the removed app with the new app, or they simply create free space for the new app. Further, we found that the more often people install apps, the more often they also arrange the icons (*Spearman's rho 0.68, $p<0.001$*). This suggests that people sort their icons when they have installed a new app, so the act of arranging icons is often triggered by a new app being installed.

Common Concepts for Arranging Icons

Beyond these basic statistics on our menu structures and arrangement practices, we looked into our participants' concepts for arranging icons.

Concepts Discovered

We asked our participants to describe the concepts they use to arrange their icons, if any. We chose a free text field over a predefined set of answers, since we wanted to explore existing concepts instead of providing pre-defined categories. Based on the participants' descriptions, we deductively extracted five concepts for arranging icons following a grounded theory approach.

- *Usage-based icon arrangement*: People who apply the concept of usage-based arrangement order their icons by a specific criterion that quantifies an inherent attribute of a single app. In most cases, we found the frequency of using an app to determine this value. Many of our participants move frequently used applications to the first page of their devices. Some also said that they would move least used apps to the last page of their menu — it is worth mentioning that from sorting of the first pages a sorting of the last pages does not follow implicitly. Additionally, some people used terms like importance or relevance to name the criteria that they used to order their icons. The latter somehow relate to frequency, but are not necessarily associated with each other. We put these two concepts together since on the one hand they are indistinguishable from the wording that people use to describe their concepts, and on the other hand they both relate to an attribute that is inherent in the application of an icon.
- *Relatedness-based icon arrangement:* Participants who follow this concept cluster apps by their functionality, i.e. apps that are related to each other are put into one folder or on one page, e.g. the two social network apps *Facebook* and *Twitter*. The similarity of two apps is due to people's subjective assessment. For instance, Twitter might also be clustered together with mail clients, when clustering communication apps. In contrast to the usage-based concept, this concept takes two or more icons into account when it comes to arranging the icons.
- *Usability-based icon arrangement:* A third concept that we found among our participants is the idea of organizing apps such that the usability of their device is optimized. For instance, one argument was to be able to easily reach icons with their thumb (since performance of thumb-interaction depends on icon position [19]), or to have space to swipe through the screens without accidentally clicking on icons.

[3]Not possible on most Windows Phones at the time of writing.

[4]iPhone 4 and earlier versions.

[5]Since taking screenshots on Android is only built-in since the latest version of Android OS (4.0) we had to rely on a smaller user base.

Of course the previous two concepts also contribute to usability, but people in this category have explicitly conceptualized and named usability aspects for arranging icons.

- *Aesthetic-based icon arrangement:* Participants who follow this concept have a tendency to arrange their icons in a way that is aesthetically pleasing to them. For instance, one user without icons on the first page wants to be able to see the background image showing his girlfriend on the first page; other participants cluster icons by their color, e.g. a checkered pattern of brown and blue icons.
- *External concepts for icon arrangement:* We identified a fifth group of people who use external concepts to arrange their icons. These participants use sorting patterns that have evolved externally from their smartphones and apply them to their icon arrangement. For instance, people using this concept keep the sortation that was pre-configured on the device. Others have stated that they keep their apps in the order of installation (default sortation). One user said he would arrange his icons alphabetically.
  Some people also explicitly stated that they have no concept for arranging their icons. Yet, since every icon arrangement has an inherent order, it is unclear how this order emerged. It is most likely that people who do not have any explicit concept also follow an external concept, e.g. just leave the arrangement as it was preinstalled or add the icons of new installed apps to the first free spot in the menu.

Hybrid Concepts

It is worth mentioning that these five concepts are not mutually exclusive, i.e. a user may apply two or more concepts in parallel. For further analysis, all participants have been categorized based on the five concepts we found. To reduce the subjectiveness of the categorization, the labeling has been done by three different analysts whose results have been merged by the principle of majority rule. Therefore we take their merged classification as ground truth. We have been able to partially cross-validate peoples' textual description with the screenshots: For people who said that they group by similarity, we found folders of apps, and those who claimed to exploit icons' colors have also been proven to be right. We had to trust participants' feedback on the usage-based concept, since we did not collect any statistics on app usage.

On its diagonal, Table 1 shows how often the emerged concepts appear within our sample. Only 10 participants did not give any answer as to how they organize their menus. Two of the ten participants using external concepts explicitly stated that they do not use any concept. As an interesting fact, these two participants graded their own iPhone experience as less-experienced (level-1 and level-2).

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
usage-based (1)	*79*	35	8	3	5
relatedness-based (2)	35	*76*	7	4	4
usability-based (3)	8	7	*11*	2	0
aesthetic-based (4)	3	4	2	*6*	0
external concepts (5)	5	4	0	0	*12*

Table 1. Co-occurrences of different concepts for arranging app icons. The diagonal shows how often every single concept appears in our data.

The most commonly used concepts for icon arrangement are relatedness-based (76 participants) and usage-based (79 participants). Table 1 shows the pairwise number of concepts' co-occurrences; the values on the diagonal show the number of single appearances. The most often applied tuple of concepts is the combination of the usage-based concept with the relatedness-based concept, which is used by 35 participants. The usability-based, aesthetic-based and external concepts appear less frequently together with the two other major concepts. Nonetheless, we tested for significant correlations but did not find any systematic couplings between concepts.

These concepts emerged both from iPhone and Android users, and all concepts appeared on both platforms. We did not find any concept appearing on only one of the platforms. Understanding which concepts a user applies will allow us to provide him with targeted support when he arranges icons.

Specific Reasons for Arranging Icons

In addition to the aforementioned common concepts for arranging icons, we also found more specific and subtle reasons for customizing launchers.

Besides the first page, which is mostly used for apps that are used frequently, some participants also mentioned that they use the last pages of their menus for apps they do not use often, "silly apps", or apps "that are never used but might come in handy some day". One user refers to his last page as the "land of misfit apps", and explains that he puts apps there which do not fit into his sorting schema, which is usage- and relatedness-based. Interestingly, only one user reported that he consequently removes apps that he did not use for a month. Another user who follows the usage-based concept reports that he intentionally also puts apps on the first page if he wants to use them more often, e.g. a note taking app.

Further, for some people having as few pages as possible also seems to be a goal of arranging icons. One participant reported that he does so to have less pages to browse.

We also got comments from our participants suggesting that context of use plays a role when people arrange their apps. One user reported that he has a folder for apps to give them a try, when he has "a few minutes free". Further, the general purpose of the device also is a moderator for the arrangement. One participant reported that she tries "to put games in the back and work apps in front, because it's a work iPhone".

Interestingly, one participant told us that he starts to arrange apps into folders when he loses track of which apps are installed. Only one participant reports that he makes use of the search functionality provided by the iPhone to search for apps.[6] It is known that people prefer visual search over search by names, since the latter has to be remembered [2].

In addition to the usability-related aspects we already have mentioned, one user explicitly explained that he tries to keep icons of certain apps "at the same position". Another user purposely keeps icons that look similar at different positions, to be able to distinguish them more easily at a quick glance.

[6] All iPhone participants had Spotlight available for textual search.

iPhone-specific Results

Constraints of iPhone Devices

The iPhone's launcher has some constraints that limit the way people are able to arrange their apps' icons. Users are able to distribute icons over pages and cluster them into folders, as Figure 1 shows. They can swipe through the pages, and folders are represented by special icons, which can be opened by clicking them. Theoretically, people can have as many apps as they want and put them onto as many pages as they like. On one page they can have up to 20 icons, which can be arranged within a grid with four columns by five rows. The fifth row has a special function: its icons appear on every page as a quick start bar. In the first four rows above, the icons are arranged in a text-like flow from upper left to bottom right, i.e., users can only fill up rows icon by icon, with no gaps. The hierarchy of the menu is limited to two levels: On the first level, people can have icons for apps and icons for folders, and on the second level people can put icons for up to 12 apps into folders.

iPhone Data Characteristics

Among the iPhone participants, there were some who customized their devices by *Jailbreaking*[7]. Therefore, and since these users most likely also had unusual high technical ability, we removed these four records from our data. We also removed one participant who submitted screenshots of his iPod Touch, since it is not a communication device in the first place and therefore not comparable to smartphone customization. Interestingly, this device had many more screens (122) than the other participants' iPhones.

As such, our cleaned iPhone data set contains 101 participants, 1,166 screenshots (379 pages, 787 folders), and 3,415 unique apps shown as 9,649 icons. An average subject has a mean of 95.53 apps installed (min 22, max 278, SD 53.62), distributed her icons over 3.75 pages (min 1, max 11, SD 1.88), and created 7.79 folders for additional organization (min 0, max 37, SD 7.31). Figure 2 shows the distribution of our participants' number of pages. Most people have two launcher pages; two participants have only one page. The top apps that are installed on every device are the pre-installed iPhone apps, e.g. *Phone*, *Contacts*, *Notes*, *Compass*, *Mail*, or *Calendar* (they cannot be deleted). On average, every app was installed by 2.83 subjects (min 1, max 101, SD 8.797).

Impact of Concept on Icon Arrangement

Based on our categorization, we investigated whether the concepts have any impact on the user-defined menu structures. In this section, we analyze the data inferred from the screenshots to quantitatively ground the concepts that emerged.

We found that the number of apps people have on their first menu page significantly differs between participants who apply the usage-based concept or not (*t-test, t=2.475, p<0.05*). Figure 3 shows a histogram of the number of apps on the first page for both categories of users. The graph shows that people who arrange their apps by usage tend to have more apps on the first page.

[7]http://en.wikipedia.org/wiki/iOS_Jailbreaking

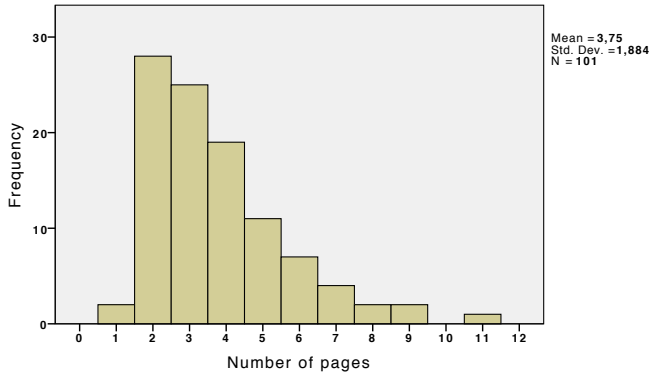

Figure 2. Frequency of number of pages in participants' launchers.

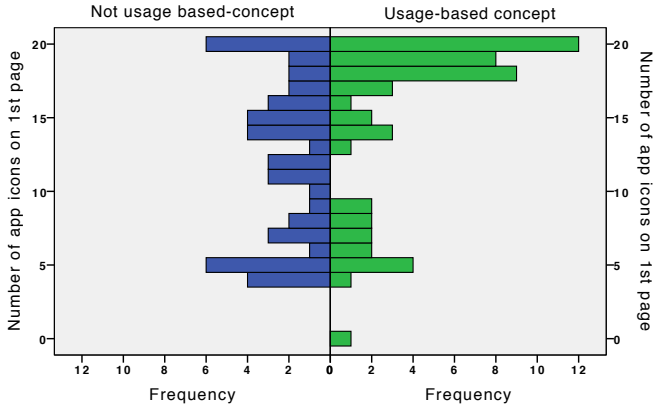

Figure 3. Histogram of number of app icons on first page grouped by usage-based concept. Right side (green) shows distribution of participants using the usage-based concept, left side (blue) shows distribution of participants not using the usage-based concept. Note positive x-axis on both sides.

The number of folder-icons on the first page significantly differs between participants who apply the relatedness-based concept and those who do not (*t-test, t=2.198, p<0.05*). Figure 4 shows a histogram of the number of folder-icons on the first page segmented by usage of relatedness-based concept. It appears that people who apply the relatedness-based concept are more likely to have folders on the first page of their menus. This suggests that such participants also use the concept of similarity to cluster their most important apps.

Further, the distribution of the number of rearrangements significantly differs between subjects who do apply the relatedness-based concept for arranging their icons and those who do not (χ^2*=6.634, p<0.05*). Figure 5 shows that people who keep their apps clustered by similarity do rearrange their icons more often. This suggests that these participants actively make use of the customization function to keep their apps in an arrangement that fits their own preferences.

Finally, we found a significant difference (*t-test, t=2.766, p<0.01*) in the average number of apps people put into a folder between participants who apply external concepts (mean 5.2) and those who do not (mean 6.8). It is likely that the external concepts people apply (e.g. the alphabet or order of installation) provide an order in only one dimension. Thus, people who apply an external concept are less likely to sort apps into folders.

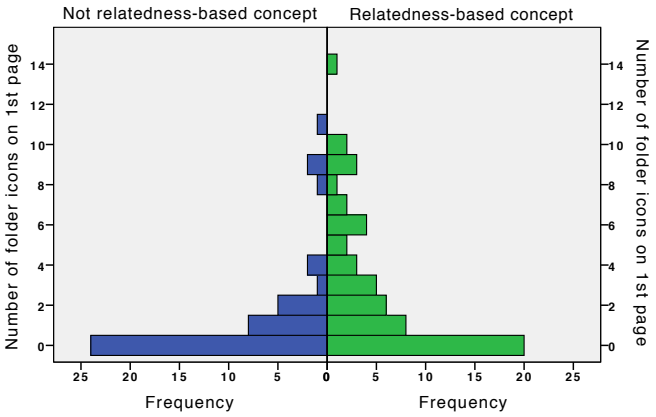

Figure 4. Histogram of number of folder icons on first page grouped by relatedness-based concept. Right side (green) shows distribution of participants using the relatedness-based concept, left side (blue) shows distribution of participants not using the relatedness-based concept. Note that x-axis is positive on both sides.

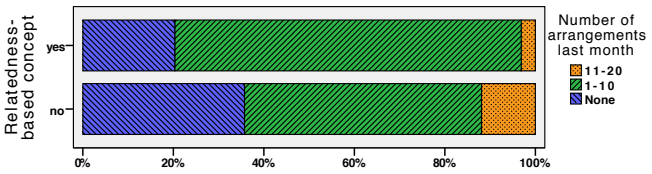

Figure 5. Effect of relatedness-based concept on arrangement frequency.

Grouping of Apps into Folders

Further, we looked into how people cluster apps into folders. Understanding how people cluster their apps together will allow us to exploit this user-defined spatial relation of app icons. Participants applying the relatedness-based concept reported that they use folders to group apps with related functionality. However, participants who did not explicitly state that they used this concept have also created folders and grouped apps. Therefore we did not distinguish between concepts for investigating folder arrangements.

A maximal co-occurrence can be found among those apps that are pre-installed on the iPhone. This is not surprising since these apps are installed on every device. For instance, the *Voice Memos* app appeared 74 times together in a folder with the *Compass* app, and 74 times together with the *Calculator* app. Next, *Compass* and *Calculator* appear together 64 times, *Voice Memos* and *Stocks* 60 times. Some of our participants have also reported explicitly that they cluster the original iPhone apps together.

Further, we looked into apps that people have installed from the *AppStore*. For instance, *Instagram*, which is an application for social photo sharing, was installed by 29 participants. Most often it appears together with *PS Express* (10 times), an app for photo editing, and *Photosynth* (10 times), which is an app for browsing large photo collections and creating panorama images, and the default *Photos* app for browsing pictures (8 times). Basically, these three apps provide follow-up actions after taking pictures. Additionally, *Instagram* also co-occurs with other apps for taking pictures, i.e. apps that basically provide the same functionality as *Instagram*. These apps are the default *Camera* app (8 times), which provides basic functionality for taking pictures, and *Hipstamatic* (8 times), which is a camera app that provides additional effects.

Next, we looked into what kind of apps people group with *Facebook*, an app for taking the social network mobile that was installed by 82 participants. It appears that *Facebook* is most often clustered with *Twitter* (28 times), which is another app in the category of *Social Networks*. Additionally, other social network apps like *FourSquare* (18 times), *LinkedIn* (14 times), *XING* (10 times), appear frequently together with *Facebook*. The second most frequent app appearing together with *Facebook* after *Twitter* is *Skype* (24 times), which is also listed under the *Social Networks* category, but the main purpose of this app is communication.

For the *Games* category we investigated which other apps people cluster together with *Angry Birds*. Different versions of *Angry Birds* have been installed by 34 of our participants. On their smartphones, it appears together with other apps of the *Games* category like *Cut the Rope* (18 times), *Fruit Ninja* (16 times), *Tiny Wings* (12 times) and *Doodle Jump* (12 times). Additionally, the iPhone's *Game Center*, which is a social gaming platform, appears quite frequently together with *Angry Birds* (16 times).

We also looked into apps for shopping. It appears that the *eBay* app, which has the category *Lifestyle*, co-occurs most often with a German craigslist-like app (16 times). Secondly, it also appears 12 times together with *PayPal*, which is an app for mobile money transfers and is in the category *Finance*, and also 12 times together with *Amazon*, which is an additional marketplace which is listed under *Lifestyle*.

These examples provide evidence that people cluster related apps into folders. Based on our quantitative screen analysis we can identify two additional reasons for putting apps together based on their relatedness: On the one hand, people put apps with similar functionality into folders. When they navigate into a folder, e.g. with games, in the second step they can decide which game to play. For instance, one of our participants has a folder on his first page containing two apps: the default short messaging app and *WhatsApp*, which is an alternative messenger that transmits text via data networks. On the other hand, people put together apps that belong to a certain workflow, e.g. photo editing together with camera apps, and payment apps together with shopping apps. Menus arranged according to these two approaches — functionally and thematically clustering — have also been found to be differently favored by cultures by Kim and Lee [15]. We have found that these two approaches also emerge when users organize menus themselves, yet we have not been able to show any significant cultural differences.

Figure 6 shows the number of less-experienced and more-experienced users according to whether they rearranged their icons within the last month or not. It appears that more-experienced users rearrange their icons more often than less-experienced users. We further found that the more-experienced users make more use of folders in terms of filling them with icons. The mean number of apps a more-

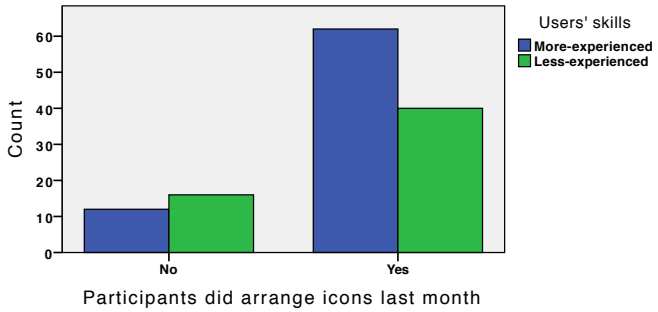

Figure 6. Rearrangements within the last month compared between less-experienced and more-experiences.

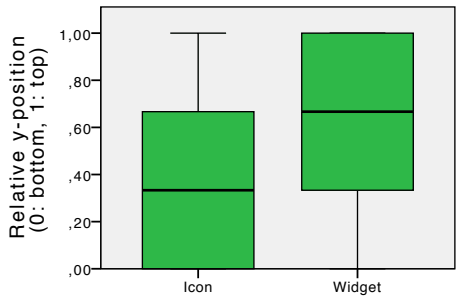

Figure 7. Relative y-position of widgets and icons on peoples' screens.

experienced iPhone user puts into one folder significantly differs from the number of apps a less-experienced user puts into a folder on average (*t-test, t=3.31, p<0.001*). More-experienced users fill their folders with more apps: on average less-experienced participants put 6.0 apps into one folder, and more-experienced participants put 7.1 apps into one folder. Also, from stationary computers we know that more skilled people apply more elaborate arrangement concepts more consciously [20].

Android-specific Results

Constraints of Android Devices

Android differs from iPhone and gives users more freedom for customizing launchers. People can place not only icons but also widgets on their screens. Widgets provide small self-contained UIs for self-updating data, e.g. on weather, news, stock markets, or social network streams. Further, Android has a dedicated app menu — called the app drawer — that contains the icons of all apps installed, and from there people can drag-and-drop them to their screens. People can also place more than one instance of an app icon on their screens. Most interestingly, on Android people can freely place icons everywhere in the menu grid, while on the iPhone they can only start in the upper left corner and fill screens up to the bottom right. Android also provides a quick-start bar for icons of apps and folders that appears at the bottom of every page.

Android Data Characteristics

Our Android data set is based on 26 participants, 144 screenshots (of 115 pages and 29 folders), and 493 icons. On average our Android users had 4.32 pages (note: the number is preconfigured on Android and pages may be left empty), and 18.16 app icons on their pages. They used an average of 5.16 widgets, occupying 26.88 icon positions on average per user, i.e. our Android participants used more screen space for widgets than for app icons. Due to sparsity of our Android dataset we did not investigate people's grouping of apps into folders or analysis of single apps.

Investigating free Icon Positioning

For Android we investigated where on the screen people place their widgets and icons, and analyzed which screen positions of the grid are filled with either icons or widgets. The median of the relative y-position of icons is 0.33, and the median of the relative y-position of widgets is 0.66 (with 1 being top and 0 being bottom edge of the grid). A Mann-Whitney's U test revealed that there is a significant difference in the y-position between icons and widgets (*U=496, Z=-9.089, p<0.001*), with the former being placed more in the upper part of the screen, and the latter in the lower part of the screen, as Figure 7 shows. Since most widgets are not built for app launching but rather for mere data presentation or settings (e.g. do not have buttons to click on), one explanation is that at the lower part of the screen people can reach their app icons more easily to start apps when using their thumbs [19]. 6 participants have left the clock and weather widgets at the upper screen positions, where they are usually predefined by device manufacturers.

We also analyzed the horizontal placement: icons have been placed equally on both sides (median 0.5; with 0 being left side), and widgets have a tendency to be placed more on the left (median 0.33); though there is no significant difference.

DISCUSSION AND IMPLICATIONS

Support for Less-experienced Users

We found that less-experienced users install apps as often as more-experienced users, but do not arrange them equally often. Additionally, it appears that they have not yet developed a concept to arrange their icons. They might feel lost and lose track of their apps on their devices more easily. Therefore, we suggest supporting less-experienced users with functionality for better app organization. This support can be stopped, as soon as the users show an increase in app removal and arrangement on their own, or after some time of device usage. Convenient patterns of app arrangement can be adopted from more-experienced users, e.g. clustering by app functionality and type (for instance following the categories of apps on the market), or by placing frequently used apps at the front.

Although Ziefle and Bay [27] found significant differences between old and young people concerning the mental model that they build of their smartphone menus, we did not find any significant effect of age on any of the variables we measured. Further, we did not find any significant differences concerning genders or countries.

Supporting Icon Arrangement

Five participants reported that arranging icons can be annoying and time consuming. One explained that it would be too time consuming to move an icon from the last page to the first page, and therefore reported leaving icons at random places occasionally. As a solution, one participant explained that she

arranges her icons on her stationary computer and then synchronizes her mobile.[8] Another participant reported that on his iPad he would put more effort into arranging icons. This suggest that it is easier to arrange icons on bigger screens. Since we found that the majority of people do arrange icons, we can assume that people do benefit from their arrangements. Subsequently, this suggests that icon arrangement on smartphones can be improved by supporting the user.

We found that frequency of rearrangements relates to frequency of installations, i.e. new apps are sorted into the existing schema. Therefore one way to help people to keep their applications arranged is to provide assistance when installing new apps. The icon of the new app could be placed next to icons of those apps next to which other people have placed it, instead of just adding it to the first free spot in the menu. According to our data, somebody who installs *Hipstamatic* could be advised to place the icon into the folder where the icons of *Instagram* and the *Camera* already reside. Additionally, a device might advise its user to put icons of frequently used apps on the front page, since this is a common concept.

User-built meta-applications

We found that people cluster complementary apps for workflows, e.g. photo taking, photo editing, and photo sharing (see Figure 8). Compared to stationary computers, where software usually provides richer and more comprehensive functionality, mobile apps have a more specialized and self-contained functionality. As we found, people seem to take single apps as building-blocks and arrange them into meta-apps for certain tasks. Instead of having different menu options within one app (e.g. for photos), people cluster functionality of apps as building blocks, and encapsulate them behind a folder icon or in dedicated screen areas, as Figure 8 shows.

This is interesting for app designers: Knowledge about which other apps have been placed in the neighborhood of an application is valuable for the designer of that particular application, since this will provide him with insights about what functionality might be worth integrating into the application itself (e.g. payment options into shopping apps, picture sharing options into camera apps). This gives rise to a better understanding of user needs. Further, this is also interesting for mobile operating systems: Once the system determines that a user is clustering applications together, it might provide support for a UI that goes beyond folder icons. Instead of arranging icons into folders, the system might provide a new synthesized application that incorporates the single apps as building blocks and acts as an app on its own.

The Case for Context-aware Paging

The iPhone design as well as pioneering work on context-aware mobile launcher menus suggest that app icons should be ordered from top-left to bottom-right in a text-like flow related to contextual relevance of apps. This is the conclusion of Böhmer and Bauer [4], and Fukazawa et al. [10] as well as Shin et al. [22] use this design approach to study adaptive launcher menus. According to our results this assumption needs to be revised. The results of our Android screenshot study shows that people place app icons on the lower instead of the upper part of their mobile screens for launching apps, and put other content above.

As such, for purely adaptive icon menus we conclude that the mapping of relevance of apps to screen positions should be the opposite of what is used so far: app icons should be shown from most important at bottom to least important at top, to make the application that is most likely to be launched most easily accessible. For combining adaptive and static menu items within split menus [21], we propose to adapt our Android participants' pattern of putting static icon menus to the lower part and the adaptive content to the upper part of screens. This will combine fast access to static icons leveraging motor memory, plus space to present adaptive content.

However, we do not suggest auto-sorting icons in adaptive launchers as proposed by others [4, 22] since this would break the mental models users build of their menus [27]. We instead suggest implementing adaptivity on the higher granularity level of pages and folders. We found evidence that people dedicate folders to specific contexts, and this provides evidence that people build their own task-related menus. Based on this, and because usage of mobile apps (e.g. weather apps, social apps and games) is not equally distributed over the the course of the day [5, 22] and in addition such apps can be found on different pages and within different folders (see Figures 1 and 8), launchers should support users by forwarding them directly to the place that contains the app with the highest probability of being launched. In contrast to automatically rearranging icons — where people have the feeling of losing control [22] — this would save time taken to search for the app and navigate to it, and yet keep the user's icon layout and mental model in sync. This implies that for mobile context-aware smartphone menus — which are motivated by users' perpetually changing contexts [1, 5, 22] — one should leave the myopic level of single apps for arranging icons and rather provide adaptive support on a higher level; e.g. jump to a folder/page (in the case of iPhone/Android-like launchers), scroll to the right position in an app list (in the case of WindowsPhone-like launchers), or open the right meta-applications as introduced earlier.

Exploiting Icon Placement and Spatial Proximity

People do not necessarily remove apps to solve the problem of limited space. We encountered the phenomenon of people having a special place to move unused app icons, referred to as "the land of misfit apps" by one participant. Either they place them on a special page in their launchers, or bury them in special folders. In particular this is the case for apps that cannot be uninstalled from a device, but also applications that are only rarely used or do not fit to a user's general device usage. Since the deinstallation of apps is sometimes missing, this "burying" of apps can be used as an implicit signal about app quality, e.g. to inform app recommender systems.

Since apps' categories are defined by the developers, who might have various reasons for putting an app into a specific category (e.g. into *Social* for exploiting it as a marketing

[8] Arranging icons and synchronizing them to the iPhone is supported by *iTunes* (desktop software for managing *iPhone* content).

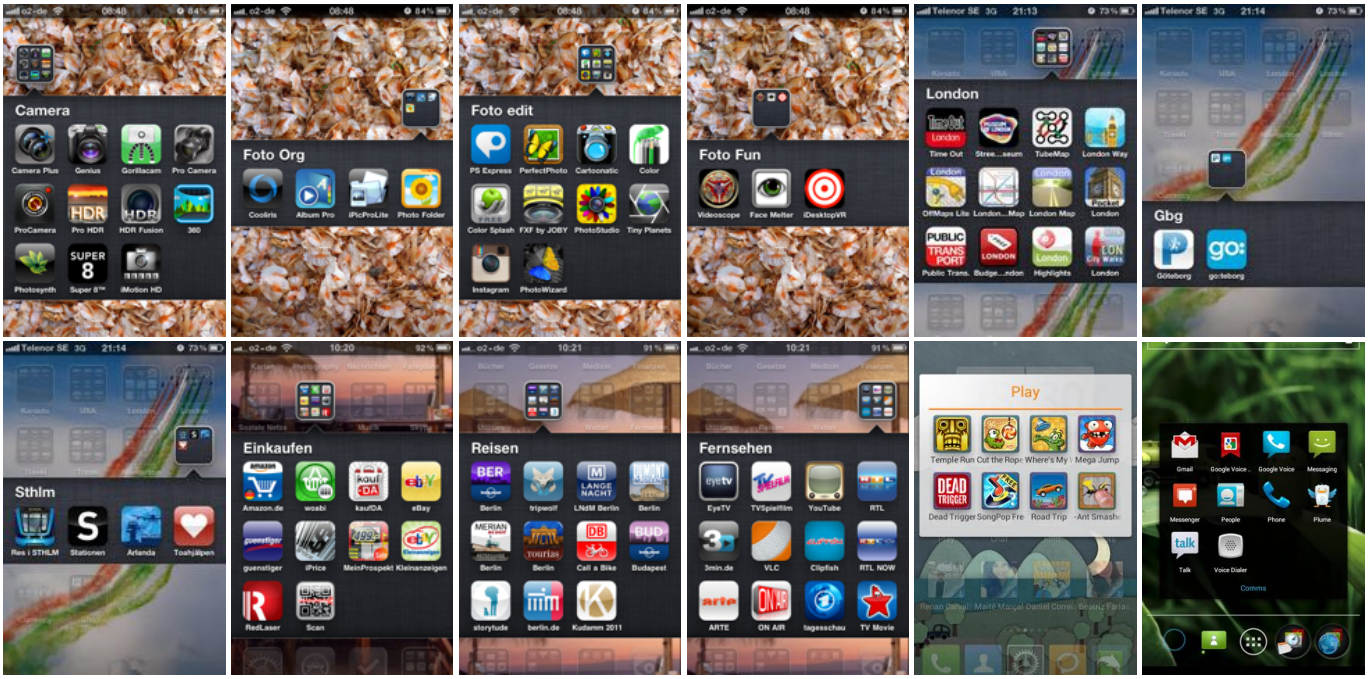

Figure 8. App clusters of different users: photo-related (1-4), city-related (5-7), activity-related (8-10), games (11), communication (12).

label), the categorization schema of app markets can be enriched from the user's perspective. Two apps belonging to the same category are not necessarily related. For the end-user, it would be better to give a task-related overview.

Further, we have found participants who cluster their apps in a way that is even more specific than the market categories. For instance, Figure 8 shows four folders of a user who has assorted apps related to photography, but the user has clustered them into more specific partitions: general camera apps, apps for organizing photos, apps for editing photos, and apps for making funny photos. Similar fine-grained sorting schemata can also be found among other users and for other topics, e.g. racing games vs. brain-twister apps, or traveling by car vs. traveling by public transport.

We have seen previously that clustering of apps into folders results from peoples' subjective assessment of relatedness, and people put effort into the arrangement of their icons and create a valuable — yet unused — source of information. In the line of thinking of Shipman et al. [23] we propose to exploit the spatial layout of app icons within people's launchers to infer relatedness between apps. This is complementary to exploiting temporal chains of app launches [5].

Similarities and Differences to Desktop Computers

While for desktops Barreau and Nardi [2] found three different types information to be orgainzed — ephemeral, frequently-used, and archived — we could not find an area within smartphone menus where people place ephemeral information, i.e. fast changing icons. This is surprising since one would expect people to have ephemeral states since their mobile environments are perpetually changing. Though we did not cover any temporal dimension in our study, we found that users do not arrange icons as frequently as one might assume (median of 1-10 times in last month). Instead, on smartphones ephemeral information (e.g. mails, todos, appointments) are rather contained within apps and cannot be embedded into the launcher itself. However, we also found that frequently-used icons have a special role, and that archived icons exist in form of loosely organized launcher subparts.

We found a strong relation to context of use for icon arrangements. While on desktops users adapt their organization to their current work [2], we argue that this phenomenon is even more specific for mobile devices. For smartphones one can find a stronger and more diverse context-related arrangement of applications; e.g. we assume that on a desktop computer one would only rarely find menus customized for specific locations or shopping.

Further, and most interestingly, we found ergonomic aspects of smartphone interaction to have major impact on icon arrangement. This motivation was explicitly mentioned by participants of our study, and this is also implicitly suggested by the results of the Android study, where people place icons at the bottom of screens.

One launcher fits all

Overall, subsuming all aspects, it appears that people divide their menu into three common conceptual spaces that are distributed on the menu pages: (1) most often used and important apps, (2) apps that relate to each other, (3) and least used and unimportant apps. A common spatial distribution is: most frequently used applications on the first page, followed by pages with folders for apps that are related, and on the last screen apps that either are only used rarely or that do not fit into any cluster of related apps. Further, one-handed interaction should be taken into consideration when designing launcher menus.

The concepts we found for mobile launchers essentially describe how people arrange apps. These patterns are applicable on smartphones where people can move the apps' icons, and which cope with the lack of space by allowing users to have apps on different virtual spaces (e.g. pages or folders, or scrolling a long list of tiles on the Windows Phone). We propose this conceptual distribution to smartphone designers to build launchers that need to work for all users. Partly these practices relate to what people do on stationary computers.

CONCLUSION

We investigated which concepts naturally emerge when people arrange their icons on their smartphones. The majority of smartphone users arrange app icons (i) so they can reach the most-used apps quickly, (ii) to cluster similar apps together so they can easily choose between alternatives and follow-up apps for a certain task, (iii) so that their launcher looks nice, or (iv) so they have a good usability. These concepts emerged from a qualitative study of more than 130 smartphone users; quantitative evidence was found in the analysis of more than 1,400 screenshots of our participants' launcher menus. Further, we found that the concepts people apply impact the layout, e.g. arranging app icons based on app-similarity results in more folders on the first page and rearranging icons more often. Finally, we discussed how the inherent value of icon arrangements can be exploited (e.g. to improve app categorization), how app launchers can be improved (e.g. be recognizing users' self-built meta applications), how context-aware launchers could benefit from pages/folders instead of icons as a higher level of granularity, and compared sorting icons on smartphones to sorting information on desktops.

We are first to provide evidence for patterns of smartphone launcher customization that is drawn from a large data set going beyond anecdotal findings. This data is available for the CHI community[9] to foster research in line with the work of Kim and Lee [15], Ziefle and Bay [27], and Shipman et al. [23] to deepen and extend their and our findings.

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[9]Data available on http://goo.gl/cz1Vg