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How Are Your Zombie Accounts? Understanding Users' Practices and Expectations on Mobile App Account Deletion

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Abstract

Account deletion is an important way for users to exercise their right to delete. However, little work has been done to evaluate the usability of account deletion in mobile apps. In this paper, we conducted a 647-participants online survey covering two countries along with an additional 20-participants on-site interview to explore users' awareness, practices, and expectations for mobile app account deletion. The studies were based on the account deletion model we proposed, which was summarized from an empirical measurement covering 60 mobile apps. The results reveal that although account deletion is highly demanded, users commonly keep zombie app accounts in practice due to the lack of awareness. Moreover, users' understandings and expectations of account deletion are different from the current design of apps in many aspects. Our findings indicate that current ruleless implementations made consumers feel inconvenienced during the deletion process, especially the hidden entry and complex operation steps, which even blocked a non-negligible number of users exercising account deletion. Finally, we provide some design recommendations for making mobile app account deletion more usable for consumers.

1 Introduction

Mobile apps overtook PC Internet usage many years ago [16]. Statistics up to 2021, there are more than three million apps on Google Play Store and two million apps on Apple Store developed by different vendors [18]. The smartphone plays an important role in daily life and people have gathered a long list of app accounts over the years. In order to better serve the users, app vendors collect and store a large amount of users' personal information, which raises severe security and privacy concerns [4, 26]. Therefore, many regions across the world have passed data protection laws, such as the General Data Protection Regulation (GDPR) in the EU [6], California Consumer Privacy Act (CCPA) in California, the U.S. [2] and the Personal Information Protection Law (PIPL) in China [21], which explicitly grant people the rights to manage their personal information.

The right to have personal data erased is one of the important rights for privacy protection, for example, "the right to be forgotten" in GDPR (Article 17) [6], "consumers' right to delete personal information" in CCPA (1798.105) [2], and "the right to request deletion" in PIPL (Article 47) [21].[1] Thus, vendors have designed mechanisms for customers to exercise their deletion right when necessary. Users can optionally delete their specific data, such as activity data on Google services [12] and posts on social platforms like Facebook. Prior work studied users' understandings and practices of this kind of initiative data deletion, including online data [45, 46, 52], cloud data [38, 47] and data in old devices [32]. However, little work has been done to study users' understandings of account deletion, which is also an important mechanism designed by vendors for excising RTD when users stop using apps.

Motivation. Omitted account deletion leads to the proliferation of zombie accounts, which may cause serious security and privacy consequences [11]. A number of essentially defunct platforms, such as Myspace [17] and Google+ [23], suffered from data breaches that affected tens of millions of users who may not have used the platforms in years [10]. Those accounts that are no longer in use will make users' online records and personal information preserved for a long time, increasing the risk of the disclosure of personal information [13, 25]

A few prior works [34, 35] discussed the design and user perspectives of data deletion on the Web. However, the user interface and needed operations in mobile apps have key differences from the Web, which lead to new challenges for users to fully understand and fulfill the account deletion procedure and thus new privacy implications. For example, uninstalling apps may confuse users with account deletion, and cross-app operations may annoy users (Section 6.3). Further, in the real world, the account deletion process is

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[1]These rights in different regions have a little difference but hold similar meanings. This study calls them the right to deletion (RTD) without differences.

designed heterogeneously by different app vendors in the absence of standard practices. For example, the *Instagram* app does not have a button for account deletion. Users need to access the *"Delete Your Account page"* from a browser [8]. For *Affirm* app, users have to write an email to the app vendor to delete their accounts. Recently, Apple released a new policy that requires all vendors to provide a pathway for account deletion within the app by January 31, 2022 [1].

Our study. In this paper, we take a first step toward understanding the users' perspectives and practices on the mobile app account deletion. We conducted a 647-participants online survey covering two countries (279 in the United States and 368 in China) along with an additional 20-participants on-site interview to explore users' awareness, practices, and expectations for account deletion. The designed questionnaires were motivated by and based on our empirical measurement of 60 popular apps' account deletion process (Section 4), which first proposes a full view model of mobile app account deletion. Our findings answer the following research questions:

RQ1: [Necessity and Awareness] *Is account deletion necessary in people's daily life and are users aware of protecting data through account deletion?*

In our online survey, most participants were willing to take actions to protect their personal data (89%) and didn't want the data to be continuously used by app vendors when the apps were no longer used (95%). However, a considerable portion of participants (75%) likely kept accounts that should have been deleted, which reveals that account deletion is necessary for users, but users' practices are contradictory to their desire for data protection. Our results highlight that the public's awareness of account deletion needs to be seriously improved.

RQ2: [Practice and Understanding] *How many users exercised mobile account deletion in practice and how do they understand it?*

The online survey shows that more than half of the participants (55%) had successful account deletion experience although zombie accounts exist widely, while about one-third of the participants never tried to delete an account mostly due to unawareness of the account deletion. Also notably, the unfriendly design of the account deletion operation significantly hindered or blocked a considerable number of participants for account deletion. Furthermore, we find participants who had the experience of account deletion tend to read relevant instructions, while most people, in general, did not understand or believe the real effect of account deletion.

RQ3: [Feeling and Expectation] *Do account deletion designs in modern mobile apps meet users' expectations?*

We investigated this question by online surveys and an additional offline interview that can better inform users' fresh-memory feelings. The majority of the participants felt inconvenience during deletion processes, especially the entry points that are difficult to find and complex operation steps. The idea mentioned most was simplifying account deletion, *"I just want it to be easy to find and handle."* 70% of our participants thought that the existing account deletion design can not meet their expectations. The potential reasons for the gap between users and apps are the lack of a standard for account deletion, as discovered in our study.

Contributions. Contributions of the paper are as follows:

• *New issue revealed.* This study takes the first step toward understanding the mobile account deletion from the user perspectives. Our user study reveals a new issue that the right to deletion is highly demanded but account deletion, an important way to exercise the right, is usually neglected by users. Thus, new efforts should be done to help users exercise their right to deletion.

• *New design gap identified*. We did an empirical measurement study on sixty typical apps and concluded an account deletion model, based on which we conducted an online user survey and an offline interview about users' feelings and expectations about app account deletion. Results show that the app account deletion design today is too complicated and cannot meet most users' expectations.

• *New suggestions*. Based on the survey results and users' open responses, we proposed several suggestions for designers and vendors to improve users' consciousness of the right to deletion and help them better exercise the account deletion in a more usable way, which contributes to better protecting the data security and privacy of users.

2 Background

2.1 The Right to Deletion

Many countries and districts have enacted laws to protect the data of individuals, constraining the companies and businesses that collect and process data. The right to deletion (RTD) is widely acknowledged around the world. Under certain conditions, the information subjects have the right to ask the information controller to delete their personal information, and the information controller has the obligation to delete it. In May 2018, GDPR of the European Union stipulated "the right to be forgotten (RTBF)", which contains the meaning of RTD [6]. Compared with RTBF, RTD is more wildly stipulated in data protection laws of other regions around the world. For example, California Consumer Privacy Act (CCPA [2]) and Personal Information Protection Law (PIPL [21]), were approved in August 2020 and November 2021 in California, the U.S. and China, respectively. The laws both grant users the right to make a verified request to vendors to delete their personal data. Although the content of RTD in different regions may be slightly different, this work mainly focuses on the common, core concepts and uses the term RTD. That is, RTD generally mandates that if a user requests the vendor to delete his or her personal data, the vendor is legally required to delete the requestor's personal information in most situations.

2.2 Account Deletion

Conforming to data protection laws, app vendors provide mechanisms for users to manage their data. Implementations of RTD vary from the ability of consumers to delete certain information related to their profiles to account deletion request forms [35]. When a user decides no longer to use an app or never again wants access to the profile, friends, photos, etc., he or she can make use of the account deletion function to request the app vendor to delete most data belonging to the account, which usually includes personally identifiable information and account information like the nickname and browsing history. Once the request is received, the app vendor deletes or anonymizes the data of that account.

Account deletion is supported by nearly all common apps and is usually specified in the privacy policy or the help center. However, due to the absence of a standard and diverse applications, different vendors may have different designs and implementations of the account deletion [9]. For example, the effect of account deletion is illustrated differently by vendors. According to the policy of *Spotify* [24], *"we'll delete or anonymize your personal data so it no longer identifies you unless we're required to keep something or we still need to use it for a legally justifiable reason."* By contrast, *Facebook* [5] explains what will be deleted or kept more clearly: *"we delete things you have posted, such as your photos and status updates, and you won't be able to recover that information later. Information that others have shared about you isn't part of your account and won't be deleted."* The implementation of the account deletion process also varies. A *WhatsApp* user can find the account deletion entry by tapping *"More options* > *Settings* > *Account* > *Delete my account"* in the mobile app and complete deletion, as shown in Figure 1, while an *Instagram* user has to visit the account page in the browser for account deletion. Motivated by such an observation of ours, we performed an empirical measurement study on sixty popular apps to better understand and generalize account deletion practices developed by different vendors today (Section 4).

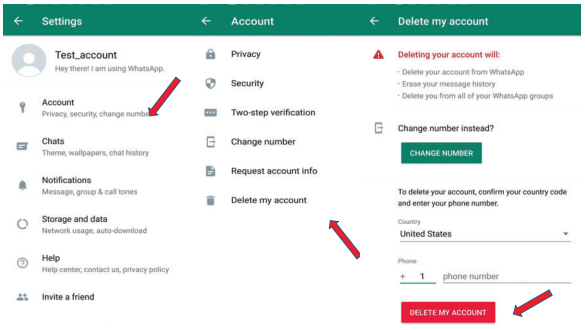


Figure 1: How to delete the WhatsApp account

3 Related Work

Privacy choices. It is generally considered that users may make privacy choices or configure privacy settings on websites and in mobile apps, with discretion over the collection, use, sharing, and retention of their data. Data deletion is usually considered part of privacy choices. In the context of the Web, Sathyendra et al. [51] and Kumar et al. [31] proposed machine learning and NLP based methods to extract privacy choices from privacy policies to help users discover the settings of websites. Except for privacy policy analysis, Habib et al. [35] conducted an empirical study on 150 websites in 2019 to assess the usability and interaction paths of the privacy choice design, which identified several issues that may make it difficult for users to find or exercise their choices. In the context of mobile apps, there are some works that focus on privacy setting recommendation [39–41]. Only Chen et al. [33] focus on in-app privacy settings from the users perspectives. They developed an automatic analysis tool to identify the privacy setting UI and found that one-third of the privacy settings in apps are hidden.

Compared to many prior works on general privacy choices, a few [35, 38, 45–47, 52] systematically studied data deletion and focused on the Web particularly. By contrast, our work pays attention to the account deletion of modern mobile apps. In particular, our study first comprehensively evaluated the account deletion design of mobile apps (Section 4), and reveals that the UI designs and required user operations in mobile apps for account deletion are different (Section 6.3), leading to new challenges for users to fully understand and fulfill account deletion procedure and thus new privacy implications or even legal non-compliance issues. Notably, our systematic study is based on a new, generalized model of account deletion in mobile apps, which is fundamental to further guide us to better survey users' awareness, practices, and expectations in the mobile context.

Users' perception of data deletion. To the best of our knowledge, few prior works focused on this area, possibly due to RTBF being just legally acknowledged recently, e.g., by GDPR in 2018. Before that, Herrmann et al. [36] quantified the effectiveness of the right of access to personal data in Germany. They found that for both apps and websites, only 52% to 57% of account deletion requests were answered satisfactorily by vendors. Mangini et al. [42] first investigated users' perspectives on GDPR's right to be forgotten. They showed that GDPR, including the right to be forgotten article, was costly and difficult to implement. Murillo et al. [46] explored users' understandings of online data deletion and identified two major views on online deletion: UI-Based and Backend-Aware. Habib et al. [34] evaluated the usability of websites' privacy choices by a user study revealing the design was difficult for consumers to exercise in practice. Some work focuses on users' perceptions of a certain deletion function. For example, [45, 52] focused on the posts on social media

and messages on communication applications respectively, and [38, 47] focused on the data stored on the cloud. Besides online services, Hassan Khan et al. [32] investigated users' practices on the data deletion of old devices for disposal.

By contrast, we focus on the account deletion function developed by mobile apps, which is an important way to exercise RTD but much less studied than on the Web. We provide the first systematic study and approach, up to our knowledge, to identify the gap between modern mobile app account deletion designs and users' practices and expectations, which complements prior studies. Based on the new understanding, we further provide new insights and recommendations in the mobile context for addressing usability issues to effectively exercise account deletion and fulfill the RTD.

4 Pre-Study

Since there are no clear regulations on account deletion, the practices of vendors vary. To answer RQ2 and RQ3, as a first step in exploring users' attitudes towards account deletion, we need to have a full view of vendors' account deletion practices. In this section, we conducted an empirical measurement of app account deletion practices as the pre-study and summarized a general account deletion process model.

4.1 Methodology

To summarize the account deletion practice of common apps, we first picked sixty apps in China and the U.S. (with the full list released online [7].) Second, we manually explored and recorded the whole deletion process of those apps with a new smartphone, email address, and phone number. Finally, we summarized the whole process based on our observations and the tutorial websites [3, 9, 15] which provide the information on "How to Delete online accounts".

App sampling. To generally ground our investigation of account deletion, we selected sixty apps with different popularity levels based on the leaderboards of app stores in China and the U.S.

For China, as there is not a dominant app store, we selected popular apps from four highly popular app stores provided by major smartphone manufacturers, i.e., Xiaomi [30], Huawei [14], Oppo [19] and Vivo [28]. To deal with different app popularity rankings in four app stores, we leverage a simple weighting method to assign a standard popularity score to top apps in these app stores. Specifically, for the top 200 apps in each store, we assigned a progressively decreasing score (20 to 1) to them based on the ranks (e.g., top 10: 20, top 11-20: 19, rank 191-200: 1). The final popularity score of an app is the additions of all scores in the four app stores. For example, if an app appeared at the top 10 in three stores and top 11-20 in another store, it got a score of 79. After finishing scoring the 200 apps in each store and removing duplicates, we got 372 apps in total. We divided these apps into three groups based on the popularity score ranking almost evenly and randomly sampled 10 apps from each group.

For the U.S., we chose Google Play's "top 200 free apps" [27] list as the popularity indicator. Based on the app popularity ranking in the Chinese app stores, a portion of apps tied for their ranking. For better consistency between the distribution of apps in the U.S. and Chinese app stores, we divided apps into three categories of popularity (with the middle rank having slightly more apps): top (ranks 1 - 65), middle (ranks 66 - 135), and low (ranks 136-200) and randomly selected 10 from each group as samples.

Altogether, we sampled 60 apps from the Chinese app stores and the U.S. All the ranking lists were obtained in October 2021 and our results may be limited to the specific time window of the research and the market's ranking lists.

Exploring process. With a new phone, email address, and phone number, we carefully explored the full account deletion process of these sampled apps. For each app, we registered a new account and used it for at least half an hour like normal users, such as filling in the profile information, posting articles, and browsing news. Then, we started deleting the account and paid special attention to the whole operation process (both in-app and out-app) and all related text explanations about the account deletion during the experiment. Specially, we recorded, not limited to, the operation steps, conditions of account deletion and any popup notifications or instructions. In this process, we tried to summarize an account deletion model. It was first proposed by the expert based on the observations on account deletion practice of a subset of apps. Then different researchers checked the model on other apps and feedback inconsistency to the expert to continue adjusting the model until it could match all the test apps.

4.2 Results and the Account Deletion Model

Through our experiment, we observed that different apps had different settings for account deletion. There was no fixed rule for the deletion locations or steps. The instructions for account deletion may appear in the deletion process, in the privacy policy, or in Q&A. The content mentioned in these instructions also varied from the conditions of account deletion to the effects of deletion. In general, the mobile app account deletion consists of four components: *operation, condition, effect, and time frame*, as shown in Figure 2.

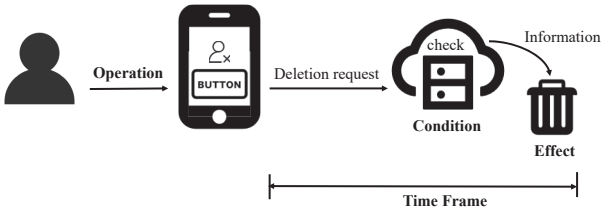


Figure 2: General account deletion process

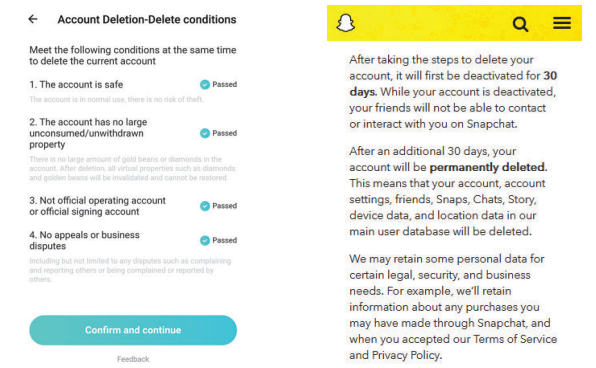
Operation. The operation refers to the actions that a user needs to perform for completing the account deletion. It includes two parts: discovering the account deletion entry (Entry) and finishing the account deletion request (Steps).

Finding the entry is the first step for users to apply for account deletion. Users can apply for the account deletion on their mobile phones, via the self-service portal on websites, or by sending an email to the customer service. According to our experiment, eight apps did not support self-service deletion and three apps required users to complete the deletion on the websites, which account for 18% (11/60) in total. Excluding apps that do not support self-service deletion, 65% (34/52) of the apps offer the account deletion choice under an "*Account Setting*" or "*Settings*" page inside the apps, which was relatively easy to find. 19% (10/52) of the entries were located in the FAQ or help center. Users need to follow the guide step by step to get the account deletion option. After finding the entry of account deletion, users need to go through several steps to finish the request, which depends on specific implementations of different apps. We have summarized the following three common operation steps: notification (65%, 34/52), authentication (42%, 22/52), and reason gathering (31%, 16/52). The results show that there is no clear standard for how to delete the account. On average, users need to click 6.14 times to complete the process, including 4.01 clicks to find the account deletion option.

Condition. Account deletion conditions are a common component set by vendors to verify whether the requested account can be deleted. Most of the conditions are written in the privacy policy or help center along with deletion instructions. These are designed for security reasons or business requirements according to the apps. For example, Figure 3(a) shows the conditions of *Bigo Live*. We also found that some apps (8%, 4/52) require users to do some preprocessing before deleting their accounts. For example, *Pandora* [20] stated *"Subscribers who would like to completely delete their Pandora accounts will first need to cancel their subscription, ..."*

Effect. Once requests from users are accepted, vendors will start the account deletion process. The effect of account deletion mainly refers to the types of data to process and the processing methods (e.g., deletion or anonymization). We classified the data to be deleted or anonymized into ten categories, based on privacy policies and in-app statements (Q19 in Section 6.2.1). 65% (34/52) of the apps indicated the types of data that would be deleted based on their instructions. Among them, account information was mentioned most (79%, 27/34). 32% (11/34) apps indicated that the personal information like email address and phone number would be deleted after deleting the account. In addition to deletion, anonymization is another common processing method that is acceptable by law. In the tested apps, 58% (30/52) mentioned that anonymization technology would be used to process users' related information after deleting their accounts.

Time frame. The time frame varies by apps to respond to the user's deletion request and fulfill the process. This is likely due to the lack of clear specifications and requirements in the laws; for example, GDPR stated that "Businesses must respond to your request within 45 calendar days," but failed to specify the expected time frame for the vendor to complete the deletion. 42% (22/52) of the tested apps informed users of the time frame. During this period, the account would be inactive and a few apps allowed users to withdraw the deletion requests. The length of this period ranges from right away to one year at most (14.75 days on average). Figure 3(b) shows the notification of the time frame in *Snapchat*.



(a) The conditions of *Bigo Live* (b) The time frame of *Snapchat*

Figure 3: App account deletion settings we encountered in pre-study. (a) is the deletion conditions of *Bigo Live*, and (b) shows the notification of the time frame of *Snapchat*.

5 Method

Our study addressed the three research questions as follows. First, to understand the necessity of account deletion and users' awareness of utilizing account deletion to protect personal data (**RQ1**), we investigated how users dealt with the app accounts that they no longer used. To identify current users' practices and understandings of account deletion (**RQ2**), we asked participants about their own experience of account deletion, the potential reasons behind these behaviors, and what their cognition of account deletion was. To assess users' feelings and expectations of account deletion (**RQ3**), we asked participants how they felt during the account deletion process and what their expectations were in the online survey. It may have been a long time since the participants last deleted an account, and their memories of the account deletion process may be blurred. So we supplemented an independent offline semi-structured interview to better collect users' feelings and expectations. The designs of our online survey and the on-site interview are guided by our model proposed in the pre-study (Section 4). Note that our study was approved by our IRB and we did not collect or store any personally identifiable information (PII) of the subjects.

5.1 Survey Instrument

This section will explain the study procedure of our online survey and the offline semi-structured interview. This survey was conducted in both the U.S. (in English) and China (in Chinese). Due to the differences of the laws and popular apps between the two countries, we made slight modifications to several expressions (e.g., replacing some words or adding one or two questions) to make them in line with the local practices. The contents of the questionnaire stay consistent in different languages. The full questionnaire is shown in the Appendix.

5.1.1 Online Survey

The survey started with some questions about demographics and a question asking whether the participant is familiar with using smartphones. Those who have never used a smartphone were excluded from the study. The survey begins with demographic questions in an attempt to reveal whether certain participants never used smartphones and their demographics. Analysis of the demographics will be reported in Section 5.2. The survey consists of the following three main parts.

Part 1: Necessity and awareness. The questions of this part are structured around two problems: (1) whether participants were willing to protect their personal data, and (2) whether there were scenarios where participants should have deleted mobile app accounts. We first asked all the participants whether they knew the rights in the law of protecting personal data and whether they were willing to protect the data. Then we provided a scenario to the participants in which the account should be deleted and asked them what they would do. Next, we inquired the participants whether they had app accounts that were no longer used and what the status of these accounts was with a series of questions. Following this, we asked participants if they knew the impact of forgetting to delete an account or had a negative experience with a brief free-text justification. At last, we designed a question to get their concerns about the storage and use of data in zombie accounts.

Part 2: Practice and understanding. We first inquired participants about the experience of deleting accounts. Then we asked participants who deleted accounts the types of apps and corresponding reasons, who tried account deletion but failed the reasons for the failure, and who never tried the reasons for not doing so. For participants' convenience, we presented some possible reasons for them to choose from along with an optional open-ended response. Next, we asked participants how much attention they paid to policies (or instructions) about account deletion. At last, we collected their understandings of account deletion. For participants in the U.S., we additionally obtained their understandings of account deactivation, which could be easily confused with account deletion.

Part 3: Feeling and expectation. Before moving on to collecting users' expectations, we asked participants who had account deletion experience whether there was any inconvenience during the deletion operation. Note that this question (Q21) was put in Part 2 to improve the fluency of response. The multi-select choices include "no inconvenience", "too strict condition", "undiscoverable entry", "complicated procedure", "long deletion time", and "other" with a brief free-text justification. Also based on the model we summarized in the pre-study, we set questions to get participants' expectations on the four components (*operation, condition, effect, and time frame*, see Section 4).

5.1.2 Offline Interview

We conducted an offline interview to collect users' fresh-memory feelings and expectations about the account deletion (RQ3). We began the interview by obtaining consent and explaining the purpose of the study. We used a semi-structured interview protocol to probe participants for more information (with the guideline released online [7]). The offline interview was conducted from November 2021 to March 2022 in reserved classrooms on our university campuses. We interviewed participants offline to ensure the consistency of the experiment equipment and to avoid misoperations on their own phones and accounts. We also strictly followed the CDC guidelines related to COVID-19 at the time including "social distancing" and "consistent and correct mask use." The interview includes the following two parts:

Part 1: Experiment. In this part, each subject was provided with an up-to-date Android smartphone with our SIM card and asked to completely delete accounts of three apps. The apps we selected in this part were a subset of the sixty sampled apps in the pre-study. Specifically, we used the *composite scores* method [44] to divide the sixty apps into three groups according to the operation complexity of account deletion. The items impacting an app's composite score are *Operation Entry* and *Operation Steps*, which could directly affect users' experience and thus feelings about account deletion of the app. We used a unit weighted model and each item was equally weighted. The final score for each app is calculated as: $X = mean(Operation\ Entry, Operation\ Step)$. The scoring criteria are shown in Table 1. Based on the scores, we divided the apps with 3-points, 2-points, and others (1-point or 0-point) into three groups (a higher point indicates that the app offers relatively simpler or less complicated operations for account deletion). We then selected three apps from each group to obtain Group A, B, and C for this experiment. For the interview of each participant, from these nine apps, we randomly chose one app from each group. Before the experiment started, we registered and logged into the experiment accounts for these apps, provided participants with related credentials, and told them to treat the accounts as their own. In addition, during the experiment, participants could pause the experiment at any time once they felt uncomfortable, such as not being willing to make a phone call or sending an email

Table 1: Composite scores table for account deletion.

Dimension	Items	Scores
Operation: Entry	Common path*	2
	Hidden path	1
	No entry in the app	0
Operation: Steps	1-4 steps	1
	More than 4 steps	0

* We define the entry as a common path as long as "Account deletion" is located under the settings related to the account.

to the customer service. We recorded the subject's whole operations by recording software on the phone for further analysis, such as the clicking traces to find the account deletion entry.

Part 2: Interview. After the participant finished the experiment part, we started the semi-structured interview to obtain realistic feelings and expectations based on the fresh experience. Participants were first asked about their attitudes towards the setting of the account deletion entry. Next, we probed their experience of the account deletion process, asking questions such as "Do you think the account deletion process is complicated?", "Do you think any steps are redundant?", "How do you think the conditions of account deletion?" Last, we inquired the participants about suggestions and anything else that they would like to share with us about account deletion.

5.2 Recruitment and Demographics

Online survey. We recruited 688 participants via online research platforms, 288 by Prolific [2] in the U.S. and 400 by Wenjuanxing [3] in China respectively. We rejected the responses that were completed in less than 2 minutes to ensure the quality and got 647 (94%) qualitative responses. On average, it took 9.97 minutes to finish the survey. Based on the local income, participants who completed the survey in China received 4 CNY and participants in the U.S. received 2 USD. The survey lasted from November 2021 to January 2022.

We sought balanced recruitment considering gender, age range, and educational background. Purposive sampling was performed using Prolific and Wenjuanxing built-in study inclusion criteria which allowed researchers to specify availability based on prescreened demographics. We additionally collected proficiency of smartphones and all participants claimed an experience with the smartphone. The participants' demographics are presented in Table 2.

Offline interview. Our offline interview recruited a total of 20 participants. We published our recruitment advertisement on the school bulletin board and anyone interested can contact us with their demographic information, including gender, age range, education background, and smartphone proficiency.

[2]Prolific: https://www.prolific.co

[3]Wenjuanxing: https://www.wjx.cn

Table 2: Demographics of the questionnaire participants.

		The U.S. (n=279)		CHN (n=368)	
		n	**%**	**n**	**%**
Gender	M	137	49.1	180	48.9
	F	138	49.5	188	51.1
	No-binary	3	1.1	0	0
	No answer	1	0.4	0	0
Age	18-25	78	28.0	110	29.9
	26-35	90	32.3	95	25.8
	36-45	69	24.7	86	23.4
	46-55	23	8.2	61	16.6
	56+	18	6.5	16	4.4
	No answer	1	0.4	0	0
Education	Below bachelor	126	45.2	148	40.2
	Bachelor	138	49.5	146	39.7
	Master or above	55	19.7	74	20.1
	Choose no	6	2.2	0	0
Proficiency	Developer	46	16.5	72	19.6
	Familiar	233	83.5	265	72.0
	Basic	0	0	31	8.4

The average time of the interview is 19.9 minutes. Each participant was paid 6 USD (15 CNY) as a reward.

The demographic information for participants of the semi-structured interviews is released online [7]. More than half of the subjects are students aged 18-25 pursuing a bachelor's degree. All participants can skillfully use smartphones, among which 3/20 have certain programming skills.

5.3 Analysis

Qualitative analysis. We used inductive coding [50] to analyze participants' expressions on the interviews and open-ended questions (Q14, Q36) in the questionnaire. It is a common method for analyzing qualitative data and can help us to get a more complete, unbiased look at the themes. Two researchers were involved in the coding. First, a primary coder created an initial codebook based on the responses in the interview and questionnaire. Next, a secondary coder encoded 20% of the sub-sample for each topic. The result of the secondary coder continued iterating with the primary coder, until Cohen's κ, which represented the inter-coder agreement, was greater than 0.7. We solved coding conflicts through sufficient group discussion among coders, following the practices of other works [34, 43, 45]. The codebook is released online [7].

Statistical analysis. We used the Chi-squared test to quantitatively compare associations between different variables when all expected frequencies were at least 5, and Fisher's Exact Test (FET) otherwise (all $\alpha = 0.05$).

Specifically, we used the Chi-squared test to find out the correlation between whether the user knew about RTD (Q6) and how the account was handled (Q7), and to analyze relations between the number of apps on the phone that would no

longer be used (Q9) and the total number of apps in mobile phones (Q8). The association between deleting an account (Q16) and reading the introduction (Q23) was also analyzed by the Chi-square test. We performed Fisher's Exact Test to analyze the answer of Q14 about zombie accounts and their actions in practice (Q7). For the questions involved in the analysis, to accurately measure the correlation, we binned "Others" and "No responses" choices.

5.4 Limitations

Our study is limited in its recruitment. We attempted to compensate by performing purposive sampling on the online platforms to balance demographic factors like age and gender, but we cannot claim the full generalizability of the results. Despite this limitation, prior work [48] suggested that online studies about privacy and security behavior can approximate the behaviors of populations. Similarly, most in-person interviews were limited on the campus. Due to the outbreak of COVID-19, the number and demographics of interviewees are limited.

Moreover, the user study design is in part based on the results of the pre-study, which only focuses on the Android market. But to the best of our knowledge, this is the first systematic measurement of the mobile app account deletion practice. At last, social desirability may lead to participants over claiming their awareness and understandings of account deletion as they may believe that this is the expectation of the researchers but not their actual thoughts or behaviors.

6 Result

This section is structured along with our three key research questions. We first present our findings concerning the necessity of account deletion and users' awareness of it for data protection (RQ1, Section 6.1). Second, we show users' practices and understandings of account deletion (RQ2, Section 6.2). Third, we assess users' feelings about the current account deletion processes and indicate their expectations (RQ3, Section 6.3). Our research includes participants from the U.S. and China, and their choices are homogeneous on most questions in our results. Thus, in the following sections, unless specially clarified, our result analysis and discussions are based on the entire set of online surveys (647 participants) and offline interviews (20 participants) without discriminating the countries.

6.1 RQ1: Necessity and Awareness

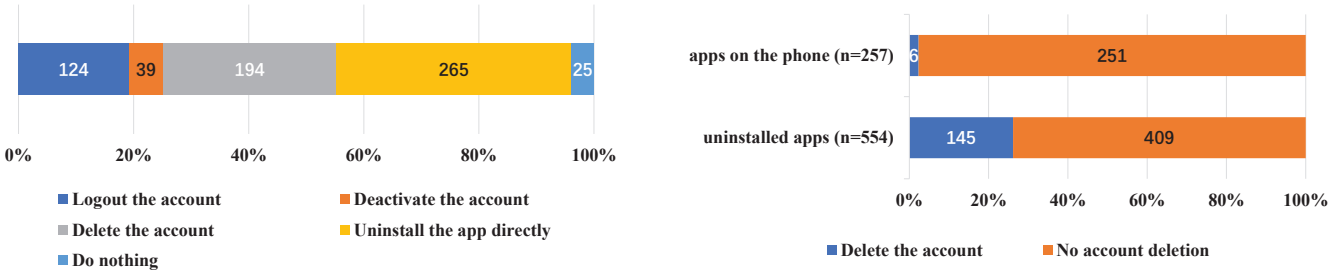
We find that most users keep zombie accounts, though they know the RTD by law and want to protect personal data.

6.1.1 Awareness

We first collected participants' attitudes towards privacy protection (Q5) and data protection laws (Q6). 89% of our participants were concerned about their personal information and they would like to positively take action in daily life. For the rights of personal data, the options of Q6 were designed differently according to the rights given to data subjects under different laws, but both China and the U.S. presidents have the RTD. Most participants (78%) indicated they were aware of the RTD. The proportion was slightly different in the U.S. (68%, 191/279) and China (80%, 315/368), which is probably because CCPA is not a nationwide law in the U.S.

After that, we tried to get a first impression of participants' consciousness to delete zombie accounts by providing a scenario where the user registered an app account that would never be used in the future (Q7). Only 30% of our participants chose that they would delete the account. Others chose to remove the app directly or logout the account. Figure 4(a) shows the full results of this question. The results mean considerable users know they have RTD but do not clearly know in which situations should they delete an account. A Chi-squared test found participants who knew RTD tend to deal with their accounts more securely ($\chi^2(1) = 7.6877$, $p = 0.006$). Note that, in this imaginary situation of Q7, the proportion of participants who deleted the account timely could be overestimated than in practice because participants may believe this is the expectation of the researchers.

To further learn users' awareness of account deletion in their daily practices, we then asked them what were the statuses of the app accounts that were no longer used with a few questions (Q8-Q10 for apps on the phone, and Q11-Q13 for uninstalled apps). Figure 4(b) shows the results of the two situations. 40% of the participants acknowledged that they kept a few apps on the phone that would no longer be used (58% (162/279) in the U.S. and 26% (95/368) in China, Q9). According to the analysis of the Chi-squared test, we proved that this value was directly proportional to the number of apps on mobile phones ($\chi^2(4) = 31.6287$, $p < 0.001$). The questionnaire results (Q8) showed that American participants had more apps on their mobile phones on average (avg_app_nums = 38.5) than Chinese participants (avg_app_nums = 28.5), so it is reasonable that there were more unused apps among the U.S. participants. Unfortunately, almost all participants (98%, 251/257, Q10) said the accounts of these zombie apps were not deleted. The following three questions inquired about the account status of those uninstalled apps. In general, the majority of users (65%, Q11) had more accounts than apps. For participants (86%, Q12) who chose "The app is used once or twice and may no longer be used again, so I uninstalled it", less than one-third of them (26%, 145/554, Q13) deleted the accounts when asked "What do you do before uninstalling apps that you will not use again?". Over half of the participants (57%, 314/554, Q13) expressed they would do nothing



(a) What would you do with those accidentally downloaded apps? (Q7)

(b) Did you delete the accounts for unused apps? (Q10, Q13)

Figure 4: Based on hypothetical scenarios and users' experience, three quarters of participants didn't delete their unused accounts.

but uninstall apps directly. In conclusion, a vast number of participants (75%, which is consistent with the proportion in Q7) held zombie accounts. This means the awareness of account deletion, an important way of exercising RTD, needs to be improved.

6.1.2 Necessity

As mentioned before, most users have zombie accounts. Next, we further explored whether users are willing to protect the data in zombie accounts. First, we asked participants whether they know any risks and whether they have experienced any trouble caused by their zombie accounts (Q14). More than half participants (60%) expressed their concerns. Fisher's exact test found participants who expressed concern appeared more likely to delete their accounts in practice (FET, $p < 0.05$). Surprisingly, 10% of participants indicated that they had experienced or heard of the impact of not deleting accounts timely, and some of them (56%, 35/63) wrote down their experiences of trouble. Qualitative coding of these free-text responses summarized three kinds of troubles met by participants: (1) persistent promotional pushes, including emails, messages, calls, etc. (60%, 21/35), (2) information disclosure, e.g., harassing messages from other companies (34%, 12/35), and (3) financial loss, e.g., charging for subscription automatically (6%, 2/35).

Next, we took a real data usage and collection claim from the privacy policy of a specific app to ask whether participants want the app vendor to continue storing and using these personal data if the app has not been used for a long time or even will never be used again (Q15). 95% of the participants hold a negative attitude, which indicates that most people are strongly desired to delete personal data in zombie accounts.

In addition to Q14 which informed participants of the impact of zombie accounts on themselves, we took a representative case to ask whether users had the experience that although it was the first time to use an app they accidentally used another person's account (Q24). Surprisingly, 22% of participants answered yes or indicated similar cases. This real situation is hard to be noticed by the zombie account owner but puts the owner's information at great risk. Note that to avoid bias against users' awareness, we put this question in part two after we got the results of part one. In conclusion, zombie accounts have non-negligible impacts on users and account deletion is necessary, desired by most people.

6.2 RQ2: Practice and Understanding

We find that more than half of the participants had successful account deletion experiences although zombie accounts exist widely, while about one-third of users never tried to delete an account mostly due to the unawareness of the account deletion. Also notably, the unfriendly design of the account deletion operation blocks a non-ignorable number of users from deleting accounts. Furthermore, we find participants who had the experience of account deletion tend to read relevant instructions, but most people, in general, do not understand or trust the real effect of account deletion.

6.2.1 Practice

Participants were first asked if they had ever deleted a mobile app account (Q16), and then inquired about related reasons based on different answers (Q17-Q19).

Compared to the results in RQ1 that 75% of the participants kept zombie accounts, 55% (Q16) of the participants expressed that they had successfully deleted an account before, which means a number of users know the account deletion but usually forget to deal with the zombie accounts. The results of Q16 also show differences between the American and Chinese participants: users in the U.S. could have better account deletion habits as 66% (184/279) of American participants claimed they had account deletion experience while the portion in China is 46% (171/368). The types of apps deleted by participants were scattered, as shown in Figure 5 (social media takes the most (40%, 142/355, Q19)). The reasons for their deletion varied from only stopping the account to terminating using the app, including deleting the history in old accounts, getting tired of the app, security concerns, etc. By contrast, 30% (Q16) of the participants indicated they never tried to

delete an account. "Never consider deleting the accounts" is the most common reason (82%, 157/192, Q18), while "all the accounts are in active use" only takes 8% (16/192, Q18). This also proves that the lack of awareness contributes a lot to the born of zombie accounts, which is aligned with the results in RQ1.

Some participants (15%, Q16) claimed they tried to delete accounts but failed for some reasons. We asked them about the failure reasons (Q17) by providing some choices, which are designed based on the account deletion model in our pre-study (Section 4), along with a free-text justification. According to the results, the unfriendly operation is the most important reason preventing participants from account deletion. Specifically, 62% (62/100) of the participants said they could not find the entry, *"the service didn't have the option for deleting the account, at least not easily discoverable."*(P133). 58% (58/100) of the participants expressed that *"too many steps"* prevented them from successfully completing the account deletion process. In addition, we noticed that users do not change their minds easily once they decide to apply for account deletion. Only 4% (4/100) of the participants failed the deletion because of regret.

6.2.2 Understanding

After collecting users' practices of account deletion, we sought users' understandings of account deletion. We firstly asked participants how much attention they paid to the privacy policy about account deletion (Q22, Q23), which may illustrate account deletion in detail. The results show large quantities of participants never read (37%) or only took a glance at (56%) the policy. Correlation analysis on Q23 and Q16 reveals that most people who deleted accounts tend to read the introduction of account deletion in the privacy policy ($\chi^2(2) = 47.7039$, $p < 0.001$). This means people who delete their accounts are willing to learn what the exact impacts of this operation are.

Next, participants were asked to pick out the options they consider to be in line with the concept of account deletion (Q25). The options include basic statements extracted from the privacy policy and some misleading descriptions we crafted on purpose. Figure 6 presents users' understandings of account deletion. The cognition of most participants was quite different from the claim of app vendors. Some basic common effects of account deletion were not understood or trusted by users, for example, more than half of the participants thought that their personal data would not be deleted after account deletion (57%, 1 - 280/647), and the deletion is reversible (61%, 1 - 251/647). This means users may not correctly or completely understand account deletion (considering most people do not read the privacy policy carefully or cannot fully understand the obscure expressions [49]) or be privacy resigned and not believe the action will take effect.

Additionally, during the pre-study, we noted that account deactivation is popular in the U.S. and could confuse users. For example, according to Instagram's privacy policy [8], "If you don't want to delete your account but want to temporarily stop using the Products, you can deactivate your account instead." Therefore, we added Q26 for the U.S. participants in order to study their understandings of this confusing function. We collated the practices of different vendors on account deactivation and let the participants (n=279) select statements that are consistent with their understanding. Unexpectedly, 45% (125/279) of the participants mistakenly believed deactivation was a way to delete data.

6.3 RQ3: Feeling and Expectation

As mentioned in Section 5.1, RQ3 was addressed by both the online survey and in-person interviews. In the online questionnaire, only those participants who succeeded in deleting accounts (n=355) were asked about their feelings about the process of account deletion (Q21). The results gave us the first impression of users' sentiments about the current account deletion designs: only less than one-third (30%, 105/355, Q21) considered no inconvenience was found during the deletion. To further obtain fresh-memory operation feelings and expectations of the participants, we did an in-person interview study (Section 5.1.2). For expectations of account deletion, the results are mainly acquired by Part 3 of the online survey (Q27-Q36). In order to get more opinions from users, an optional free-text question (Q36) was designed at the end of the questionnaire that asked for suggestions. In this subsection, we report our findings structured with the account deletion model proposed in Section 4.

6.3.1 Operation - Entry

The results of Q21 show that finding the account deletion entry (62%, 155/250) is the most frequently reported issue. For the interview results, we analyzed the recorded videos of participants' operations and their open responses during the interview. We found that the design of the account deletion entry was hard to find. Participants needed to click 13.04 times to find the entry for account deletion per app on average. That's a third as many clicks as the average path measured in the pre-study, which means participants experienced lots of failures before discovering the account deletion button. In a very extreme case, interviewee No.7 clicked 72 times to get the account deletion entry of *Weibo*. During seeking the entry, about a half of the participants (50% 10/20) in the experiment turned to a search engine for help, three participants (15%) asked customer service for help, and one person tried to read the privacy policy. When asked how they felt about the design of account deletion entry after the experiment, almost all participants felt disgruntled with the current settings. "*This app seems to intentionally not want me to find the account deletion portal.*", stated by interviewee No.8.

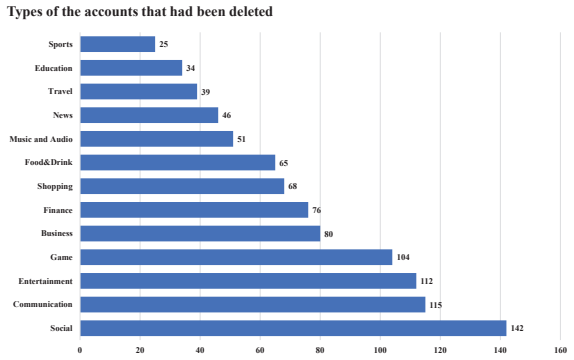


Figure 5: For participants who deleted the account successfully (n=355), we asked the types of deleted accounts. It is proportional to the popularity of apps. (Q19)

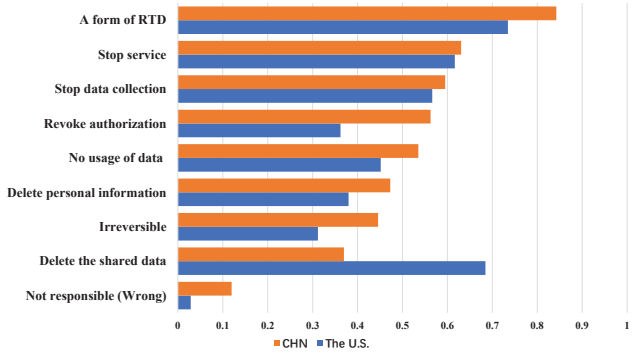


Figure 6: Participants in China (n=368) and the U.S. (n=279) basically had similar understanding of the account deletion. (Q25)

Experience matters. Based on the videos, we also find that experience of account deletion may impact users' exploration path. As the experiment went on, it was obvious that the participants would refer to the operation of the previously completed account deletion process when they deleted the second or the third account. This finding is also proved by users' open responses during the interview. *"I wasn't sure if there's a delete portal, but based on my previous attempts it was probably here, so I clicked on it."*, interviewee No.9 said.

Expectations. The results of Q36 show users' expectations on the entry for account deletion. Through our qualitative analysis, 23% (76/327) of the participants pointed out that the entry should be easier to discover. P385 and P391 stated, *"Please put it in an easy to find location."*, *"I think most apps should make it easy to delete, often it is hard to find the option."*. In the interview, we asked the participants for some advice about the account deletion entry design. The results were consistent with those in the questionnaire, 16/20 of the participants believed the entry should be located more apparently and easier for users to find. Besides being easy to find, 13/20 of them explicitly expressed that the account deletion entry should be in the app and support self-service. 7/20 of the participants expressed that if the account deletion requests needed to be made over the phone or by email, they would likely give up the deletion. We added an additional question (Q34) to ask the U.S. participants about their attitudes towards the way to account deletion in the questionnaire, as we observed that a few popular apps in the U.S. required users to operate outside the apps (e.g., accessing a website or sending an email). Similarly, according to the results, 91% (253/279) of the participants preferred to be able to delete accounts within the app, without having to open an extra browser and log in the website.

6.3.2 Operation - Steps

In our online survey (Q21), the complicated account deletion process was chosen as the second inconvenient factor (51%, 128/250). In general, participants believed these steps were reasonable, but should be more concise. *"The process should be as easy as opening an account."* (P551) and *"Companies should make it very easy for customers to accomplish."*(P585). According to our observation in pre-study, steps of account deletion generally include the following contents: notification, reason gathering, and authentication. Therefore, our semi-interview is organized surrounding these three steps.

Notification. After participants finished the experiments, we asked them if they would read the notice or instructions when deleting the app accounts. 14/20 participants claimed they did not carefully read the deletion notice or did not read at all before clicking "I agree", even though there was a mandatory reading time. Meanwhile, according to the results of our pre-study, not every app notifies users of the risks and effects of deletion. Interviewee No.6 indicated he would read the notice depending on whether the accounts contain much sensitive personal data. For those who read the notice, their main concern was what information would be deleted after the account was deleted. As No.12 responded, *"I mainly care about the effect of the deletion, like what gets deleted."*.

Reason gathering. For the step of collecting deletion reasons, we asked 17 participants who encountered the reason inquiry. 11/17 participants indicated it was acceptable, among which 4 participants explicitly expressed they would give feedback seriously. *"User feedback is necessary, I hope that manufacturers can absorb my advice to improve products. This is better for users"*, one interviewee (No.9) said. On the other hand, 35.3% (6/17) participants felt this step is unnecessary as they thought users get no benefit but being delayed. Interviewee No.10 stated, *"I don't think choosing reason is meaningful, I just picked randomly. Anyway, I don't want to*

use it anymore.".

Authentication. We then asked 18 participants who encountered authentication during the deletion process the necessity of the authentication step. Overall, 77.8% (14/18) of them hold positive opinions. They believed additional authentication would better guarantee security (4/14). However, 5/14 (35.7%) of them indicated the authentication method should not be more complex than receiving an SMS/email verification code. They didn't want to take extra actions to delete an account, such as sending a text message, which would be charged by the telecommunications companies. While the other 22.2% (4/18) participants held a negative attitude. As interviewee No.3 said, *"When I was in the account deletion process, I must be already logged in. So why need I confirm my identity again? If I lose my phone and someone takes it away, he can still receive the SMS verification code, which seems to be a meaningless step."*

6.3.3 Condition

A few participants (14%, 36/250, Q21) in the online questionnaire chose "The deletion preconditions are too strict". We asked 14 interviewees who encountered the conditions to check whether they thought the preconditions of apps are reasonable. Only one participant indicated that there should be nothing blocking account deletion, while the others accepted current settings in general. Some specific preconditions are not reasonable according to some participants' feedback, such as the premium member cannot delete the account (e.g., *Migu Video*), the balance in the account must be empty. E.g., In *MoMo*, to withdraw cash, users need to bind their bank cards and authenticate with their real names which are meaningless for the users who want to leave the app. Some apps require users to manually complete some operations, such as *Pandora*. For these conditions requiring user's operation, interviewee No.4 suggested that apps could provide a button directly linked to the preprocess page for users to operate when they delete the account. For the conditions set for security reasons or business requirements, such as no account changing within 30 days and no order in process within 30 days, participants generally indicated that the shorter time limit is the better. Interviewee No.12 stated that "*After thirty days, I would forget that there is an account waiting to be deleted. Seven days or less would be better.*"

6.3.4 Time Frame

In the online survey (Q21), 42% of the participants complained the deletion cannot be completed immediately. To further justify what the best design of time frame is, we asked participants how long they expected the app vendor to completely delete all their personal information (Q29) and whether they wanted to have the ability to withdraw the deletion after applying for account deletion (Q30). Results show that people's expectations are notably shorter than the current app designs. 44% of the participants expected the personal data to be deleted immediately. Almost all (90%, 584/647) participants wished the data to be deleted within seven days. However, according to our measurement in Section 4, the average deletion period of current apps is 14.75 days (shortest: immediately, longest: one year).

Additionally, we observed that several apps provided notifications when the account deletion was completed and some apps allowed users to withdraw their deletion request or continue to use the account before it was finished. We further asked how participants thought about these three functions (Q30, Q31, Q32) (Q30 and Q31 were only presented to those who hoped not to delete the account immediately (n=363)). Results show that most people (88%) expected to be notified when their account deletion request was finished. Nearly half of the participants (48%, 174/363) wanted to keep the right to withdraw deletion in case of regret, and 63% (227/363) of the participants expected the account to be inactivated and should not be used as normal in the time frame period.

6.3.5 Effect

We asked what data interviewees would like to be deleted after account deletion in the in-person interviews. Some interviewees (No.1, No.10) said that "*Accounts should be deleted in full*", "*It shouldn't be a hustle and all apps should be able to delete all the information about users.*". In their expectation, once the deletion is requested, all information connected to that account should be permanently deleted as well.

In the results of the questionnaire (Q27), identity information (e.g., phone number, email, ID number) is the one most participants expected to be deleted, accounting for 87%. Followed by the account information (86%) including the nickname, profile photo, personality settings, etc. However, only 32% of the tested apps clearly claimed in their policy to delete all users' personal information, which doesn't match users' expectations.

For the data processing methods, we asked participants what their expectations are (Q33). In the pre-study we noticed that half of the tested apps did not clearly state what data was deleted or anonymized because both ways are in line with legal requirements. However, only 12% of participants were fine with the handling, believing that anonymization had the same effect as deletion. 60% of our participants only accepted physical deletion. In their opinion, other methods are not secure and could be recovered possibly.

In the optional open-ended question Q36, 24% (80/327) participants showed their concern about the real impact of account deletion. It is important to make sure the data is completely deleted after deleting the account. However, as normal users, they can hardly confirm this. *"Please actually delete the info unlike Facebook"*, *"It should remove all information of the user without any limitation."*, P413 and P460 said.

6.3.6 Others

There are also other interesting findings from our interviews and optional open-response suggestions.

Willingness affects behaviors. Facing the complex account deletion operation in the interview, more than half of the participants indicated that if they had a strong willingness, no matter how hidden the entrance was, they would find it by all means. *"As long as I firmly want to delete the account, these problems will not hinder me from completing it and even make me more want to delete it."*, one interviewee said (No.7). While if the willingness is not strong enough, they may give up the deletion.

The types of apps also influence users' willingness. 30% (6/20) interviewees indicated that if the app involved financial or contained a lot of information, no matter how difficult the operations were, they would delete the account. *"If the app has little information or does not involve money while deleting the account is so troublesome, I would give up."*, one interviewee said (No.12).

Automatic account recycling is helpful. We observed some vendors will automatically delete accounts if users do not log in for a long time (e.g., *Yahoo*). So, in the online survey, we asked what participants thought about this account deletion relevant service (Q35) on a 5-point Likert scale. The average score is 3.27, which means most participants hold a positive attitude towards account recycling. Some supporters said "*I wish all services had offered this. If I haven't used it in a year, I'm unlikely to do so with the old account.*" (P390), while others thought *"It should be my choice only."* (P622). It was hoped that the vendors could make a request to users before deleting the unused account, and delete it only after getting their confirmation. As P459 stated, *"It is a good idea, but if I want to keep it, there should be an option to keep it forever without worrying about the deletion."*

7 Discussion and Recommendation

Our findings indicate that RTD and account deletion are highly demanded by users, but most users likely forget to deal with their zombie accounts. The security and privacy implications of zombie accounts are also strengthened, e.g., 22% of participants stated they unwittingly took over accounts of other people (Q24), indicating the realistic privacy and security risks caused by zombie accounts. Meanwhile, the account deletion implementations of the apps today do not meet users' expectations and may even block users from exercising RTD. Our study did show that the account deletion processes of certain vendors are more complicated or with more conditions imposed than other vendors. Obviously, vendors have motivations to keep users, which probably leads to a design of complex operations, strict conditions, and long time frames. We try to systematically measure current apps' practices and provide several recommendations based on users' expectations to effectively improve the usability and privacy benefits of mobile app account deletion. Our recommendations below not only serve as concrete guidelines for the app or system designers but also have the potential to help policymakers understand current account deletion practices and gaps in legislation for better regulating data practices and protecting user data.

Improve users' consciousness. Zombie accounts seem widespread and indeed jeopardize users' privacy and security [11], which is also reflected by our survey. Our study indicates a sad reality that account deletion is not commonly used, although users are not willing to let personal data in zombie accounts continue to be used by vendors. As discussed in RQ1 (Section 6.1), 78% of the participants knew they have RTD, but 75% of users kept zombie accounts. Meanwhile, more than half of the participants expressed their concerns about the impact of not deleting accounts timely. However, in this case, 30% (Q16) of our participants even never tried to delete an account. Therefore, the policymakers and media should strengthen publicity that account deletion is an important way to exercise RTD and to protect personal data.

Besides publicity, app and system designers could add pop-up notifications to remind users of exercising RTD. For example, similar to the runtime permission request design in Android that actively indicates what data will be collected [22], mobile apps can design a kindly reminder mechanism for account deletion. One participant P293 in our survey said, *"If there was a prompt when I uninstall the app, I would remember to delete the account."*

Automatic account deletion is likely another useful method to address the trouble caused by zombie accounts. About half of the participants (46%, avg=3.27) held a relatively positive attitude towards automatic account deletion (Q35), as one participant (P391) mentioned, "*I have many created many accounts over the past 20+ years that I've forgotten about. I wish all services had offered this. If I haven't used it in a year, I'm unlikely to do so with the old account.*" Most participants who expressed the negative answers wished vendors to remind them to delete their accounts, but not delete them without users' explicit permissions.

Simplify the account deletion operations. A simpler design of account deletion operations would likely encourage users to better exercise RTD. In our study, 55% (Q21) of participants who had account deletion experiences expressed that the entry was too hard to find, which is likely due to too many required clicks as shown in our pre-study results. The negative effect of the required number of clicks on users was also proved by the work of Chen et al. [33]. Unified settings in a standard location reachable within three clicks would be helpful, for example, "*Settings* > *Account Security* > *Account Deletion*", as indicated by our observations and participants' feedback from our interviews. Similarly, the operation steps of making the deletion request also troubled the participants. 15% of participants who tried to delete an ac-

count were blocked by the complicated design of the account deletion operation (Q16). Many participants left suggestions in the open-response question like *"The easier, the better"* (P310). On the other hand, because the account deletion is a security-sensitive function, the operation design should balance both usability and security. Habib et al. [34] proposed several suggestions for completing the privacy choice tasks easier on websites, including providing unified settings in a standard location and offering multiple paths for users to conveniently reach the location. Our study indicates that such suggestions obtained on the Web can be further generalized to mobile contexts.

Improve the transparency. Unlike active opt-out privacy choices that have a specific impact, account deletion usually does not have a clear effect. As shown in our results (Section 6.2.2), more than half of the users do not correctly understand the effect of account deletion. A possible reason could be the ambiguous and non-uniform instructions of different apps as found in our pre-study. For example, the privacy policy of *Wechat* [29] describes *"delete or anonymize your personal information within a reasonable period"*, the specific data to be deleted, the data to be anonymized and the period are all not clearly clarified. Also, our survey and other studies [37] showed that users rarely read and understand the entire privacy policy. Thus, vendors not only should use a standard and detailed expression of account deletion but also need a user-friendly interface to display the policy. Our account deletion model in Section 4 can be used as norms for building a standard expression. In the pre-study, we found some apps provided an individual document besides the privacy policy for explaining the account deletion and sent users an email to notify them of what had been done. These means can be used to help consumers better understand account deletion and that is what users expect. P381, P569 said *"I want an email stating the details."* and *"I wish it was clearer what it meant and easier to do."*

Comprehensive and user-definable settings. Our survey shows that different participants may have different expectations for account deletion, e.g., whether the deletion should take effect immediately, whether the account should continue to be used after applying for the account deletion, and whether the account deletion application could be withdrawn, etc. Therefore, we believe that instead of taking their own various implementations and making the process complex to keep consumers, app vendors should better provide users the flexibility of choice, which would satisfy more users' expectations. Moreover, we find users expect more comprehensive functions. 88% of the participants would like to receive notifications when the deletion is done (Q32). Some participants want to locally back up the account data before deletion. Some expect that the vendors cannot use the data after deletion but users can restore the account whenever they want. This regretful feature of account deletion is never seen in current apps' implementations as far as we know. Designers could leverage state-of-the-art cryptography techniques to realize this in the future.

Bolster users' confidence. Similar to the concern of privacy choices revealed by previous work [46], participants in our study were also skeptical about whether the account data would actually be deleted by app vendors. This concern is reasonable because the deletion can hardly be verified from the client side based on current commercial technical architecture. Specifically, in our study, 11 participants complained in free-text questions that they still received the relevant promotion text messages or harassing phone calls after they had deleted their accounts, which annoyed them. The fact that vendors do not completely delete users' data is also demonstrated by our experiment in pre-study. With a new smartphone and a new mobile number, researchers continue receiving messages and phone calls even though all app accounts have been deleted. In addition to strict supervision from the government, state-of-the-art techniques like secure enclaves, remote attestation, and privacy-preserving computation would contribute to a more trusted data management and improvement of users' confidence, especially by providing a mechanism for users to ensure the data is deleted.

8 Conclusion

We conducted a 647-participants online survey covering two countries along with an additional 20-participants on-site usability evaluation to explore users' practices, understandings, and expectations of mobile app account deletion. The studies were based on the account deletion model we proposed, which was summarized from an empirical measurement covering 60 mobile apps. Our findings revealed that the right to deletion is highly demanded but account deletion, an important way to exercise the right, is usually neglected by users. Combining the measurement data and current users' feelings and expectations, the results highlight the need to raise users' consciousness and simplify the mobile account deletion operation. Moreover, improving transparency and providing comprehensive and user-definable settings will help narrow the current gap between users' expectations and apps' implementation. In conclusion, our new findings and understanding will lead to a better design of today's mobile app account deletion and contribute to better protection on consumers' personal data.

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Appendix

Questions in the online survey

Part 0: Basic information of respondents

1. How old are you?
(a) 18-25 years old; (b) 26-35 years old; (c) 36-45 years old; (d) 46-55 years old; (e) 56+ years old (f) No response

2. What is your gender?
(a) Female; (b) Male; (c) Not listed above; (d) No response

3. What is your educational background?
(a) Below Bachelor degree (b) Bachelor degree (c) Master degree or above (d) No response

4. Which of the following best describes your level of proficiency with smartphones?
(a) Basic (I use pre-installed apps only); (b) Familiar (I can perform normal tasks such as installing new applications); (c) Developer/Professional; (d) Not familiar (I do not have a smartphone).

Part 1: Understanding of the account deletion

5. Do you care about your personal information?
(a) I am very concerned about my personal information and try my best to avoid the leakage of personal information in my daily life. (b) I care about my personal information and try to protect personal information in my daily life. (c) I am a little concerned about the protection of personal information, but have never acted. (d)I do not care about the protection of my personal information at all.

6. Which of the following are "Consumer Rights and Information" under CCPA? (multi-select)
(a) Price discrimination based upon the exercise of the opt-out right (b) Consumers' right to prohibit the sale of their information (c)

Consumers' right to receive information about onward disclosures (d) Information required to be provided as part of an access request (e) Consumers' right to deletion (f) Consumers' right to receive information on privacy practices and access information

7. Suppose you were invited to participate in the lottery. The organizer asked you to download a specific app and you registered an account for it. After that activity, the app may have no other value for you and you will never use it again. Then, what will you do with this app?
(a) Do nothing and just keep it in the phone. (b) Uninstall the app directly. (c) Logout the account and uninstall the app. (d) Logout the account and keep the app. (e) Delete the account and then uninstall the app. (f) Delete the account and keep the app. (g) Deactivate the account and then uninstall the app. (h) Deactivate the account and keep the app. (i) Others ([free text])

8. How many apps do you currently have in your mobile phone (excluding those pre-installed by the manufacturer)?
(a) less than 10 (b) 11-30 (c) 31-50 (d) 51-100 (e) 100+

9. Do you keep any apps that you will not use in the future on your phone?
(a) Yes, I have a few apps on my phone that are no longer used. (b) No, all apps on my phone will be used.

10. (If Q9. (a) is selected, answer this question) What is the current account status of the app(s) that is(are) no longer used?
(a) Stay logged in (b) Logout status (c) The account has already been deleted (d) The account has been deactivated

11. Please roughly estimate the number of app accounts you have registered and compare it to the number of apps now on your phone.
(a) The number of accounts is less than the number of apps (b) The same (c) The number of accounts is slightly more than the number of apps (within 10 more) (d) The number of accounts is more than the number of apps (10-20 more) (e) The number of accounts is far more than the number of apps (more than 20).

12. Which of the following are your reasons for uninstalling an app? (multi-select)
(a) The app is used once or twice and may no longer be used again, so I uninstalled it. (b) Although the app is not often used, it could be used again. So, I uninstall it temporarily.

13. (If Q12. (a) is selected, answer this question) What do you do before uninstalling apps that you will not use again?
(a) Do nothing, uninstall directly. (b) Logout the account and then uninstall the app. (c) Delete the account and then uninstall the app.

14. Do you know what will happen if you do not delete your account in time for the app that you will no longer use doubtlessly?
(a) I have no idea. There is no risk in not deleting idle accounts. (b) There may be some risks, but I have not encountered them. (c) I experienced some trouble.([free text]) (d) I've heard of cases about that. ([free text])

15. For apps that have not been used for a long time or even never be used again, do you want the app vendor to continue storing and using your personal information they have collected? (For example, an app may collect your phone number, email address, and other activities for their services.)
(a) No, I don't want my personal information to be used when I stop using the app. (b) Yes, the manufacturer can use my personal information at any time even if I no longer use the app. (c) It doesn't matter. I don't care about my personal information.

Part 2: Practice of the account deletion today

16. Have you ever tried/thought of deleting an app account? Did you complete the deletion process?
(a) I have tried and successfully deleted my account. (b) I tried, but I couldn't delete my account for some reasons. (c) I have never tried to delete my account before.

17. (If Q16. (b) is selected, answer this question) Why did you fail to complete the account deletion? (multi-select)
(a) I don't know how to delete my account or cannot find the entry. (b) There are too many steps to delete the account, so I give up. (c) I don't understand the deletion instructions. (d) The account does not meet the deletion criteria. (e) I suddenly regret during the account deletion process (f) Other reasons ([free text])

18. (If Q16. (c) is selected, answer this question) Why haven't you tried deleting your accounts? (multi-select)
(a) I never consider deleting the accounts (For the apps I no longer use, I uninstall them directly.) (b) I have once considered deleting the accounts, but I think it is unnecessary (it doesn't matter to me whether I delete my account or not.) (c) There has never been a scenario where I need to delete the accounts (apps that have been downloaded and the accounts are all still in active use) (d) Other reasons ([free text])

19. (If Q16. (a) is selected, answer the following three questions: Q19-Q21) What kind of apps did you try to delete? And what is the deletion scenario? (Scenario A: the app(s) is no longer used. Scenario B: I abandon this account but may register another new account later.) (multi-select)
(a)Business Apps ([free text]) (b)Communication Apps ([free text]) (c)Education Apps ([free text]) (d)Entertainment Apps ([free text]) (e)Finance Apps ([free text]) (f)News Apps ([free text]) (g)Social Apps ([free text]) (h)Shopping Apps ([free text]) (i)Music and Audio Apps ([free text]) (g)Travel Apps ([free text]) (k)Sports Apps ([free text]) (l)Game Apps ([free text]) (m)Food&Drink Apps ([free text])

20. What's your reason for account deletion? Please write down the reason in the blank according to the type of app (Option depends on the choice of Q19 along with the free text).
Following are some possible reasons you can refer to: A. Delete the using history and memories contained in the account. B. The Account is hacked. C. The app has an awful design. D. I don't want to continue exposing my privacy.

21. Is there any inconvenience in the process of account deletion? (multi-select)
(a) No, there is nothing inconvenient about it. (b) The deletion description is too complicated to understand. (c)The deletion entry is hard to find. (d)The deletion procedure is too complicated. (e)The deletion preconditions are too strict. (f)The deletion cannot be completed immediately (g)Other ([free text])

22. Have you read the privacy policy?
(a) Never read (b) Take a glance (1-3 minutes) (c) Read some parts carefully (about 10 minutes) (d) Read thoroughly and very carefully (more than 30 minutes)

23. (If Q22. (a) is not selected, answer this question) Have you read the instructions related to the account deletion in the privacy policy?
(a) I tried to read it but the privacy policy does not contain such

part. (b) I've never read it before. (c) I read this part when I want to find something about account deletion. (d) I read it thoroughly and carefully.

24. Have you ever encountered the following situation in your life: when you download and register an app for the first time, you find that your mobile phone number has been registered.
(a) No, I never meet. (b) Yes, I have experienced the situation. ([free text]) (c) I've heard of such a problem from people around. ([free text])

25. Which of the following statements is consistent with your understanding of the account deletion choice? (multi-select)
(a) Account deletion is a way for users to exercise the right to be forgotten/deleted. (b) The app's authorization of gathering user information will be automatically revoked. (c) The app will stop providing products or services to the user of this account. (d) The app will stop collecting the personal information of the user corresponding to this account. (e)The app will delete or anonymize the personal information provided by the user. (f) The app will notify the data sharing party to delete relevant information of this account. (g) Account deletion is irreversible. Deleted information cannot be restored. (h) You will no longer receive any marketing information related to this app. (i) Users are not responsible for their actions before account deletion. (j) Others ([free text])

26. (For the U.S. only) Which of the following statements is consistent with your understanding of the account deactivation? (multi-select)
(a) Account deactivation is a way for users to exercise the right to be forgotten/deleted. (b) Account deactivation is a pre-procedure for deleting an account. (c) Account deactivation can be applied for separately and is not conflicted with account deletion. (d) Account deactivation is the same as account deletion, deactivation is another name for deletion. (e) I have no idea about that.

Part 3: Users' expectations for account deletion

27. Which of the following information do you expect to be deleted by the vendor after account deletion? (multi-select)
(a) Published articles and comments, etc. [Published information] (b) Nickname, profile photo, personality settings, friends list, etc. [Account information] (c) Phone number, ID number, email address, etc. [Authentication information] (d) Name, address, occupation, photos, etc. [Personal information] (e) MAC address, device ID, and IP address, etc. [Device information] (f) Browsing and searching history, etc. [History information] (g) Membership, reward points, virtual currency, etc. [Membership benefits] (h) Payment records, transfer records, order history, credit records, etc. [Financial information] (i) Information obtained from third parties [Information from third parties] (j) Information shared with the third parties [Information shared with third parties]

28. After you have deleted your previous account, do you expect to keep the ability to register a new account using the original login credentials? For example, you can register a new account using the same mobile number again after account deletion.
(a) Yes, I hope that I can immediately register a new account. (b) Yes, I hope that the new account can have the same username as the old one, but there is no previous information in that account. (c) Yes, I hope that the new account is still the old one and all the information about the account is kept. (d) No, I hope the original login credential can no longer register any new accounts. (e) No, I hope that I can register a new account but after deleting the previous account for a period of time.

29. How long do you expect the app vendor to completely delete all your personal information (except those required to be retained by law) after you apply for the account deletion?
(a) Immediately (b) Within a day (c) Within 3 days (d) Within 5 days (e) Within 7 days (f) Within 15 days (g) Within 30 days (h) Within 60 days (i) Others ([free text])

30. (If Q29. (a) is not selected, answer the following two questions: Q30, Q31) Do you want to take the initiative to withdraw the deletion after you apply for an account deletion?
(a) I hope that it can be withdrawn to prevent regret (b) I don't want to be able to withdraw the deletion. Please delete the account as soon as possible. (c) It doesn't matter. I don't care about that.

31. After applying for account deletion, the information may not be deleted immediately as you expect. During this time, do you want to use the account as usual?
(a) I hope that the account cannot be used after I delete the account. (b) I hope to continue using the account normally before the manufacturer fully deletes my account information. (c) It doesn't matter. I don't care about that.

32. After the account is completely deleted, do you think it is necessary to inform you of the account status by SMS or email?
(a) Yes, it can let me know that my account has been deleted. (b) No, I don't care whether I finish deleting my account or not. (c) Others ([free text])

33. How do you expect the app vendor to handle your personal information after account deletion? Delete or anonymize?
(a) Only physical deletion can be accepted. Other methods are not secure and can be recovered possibly. (b)Anonymization is different from physical deletion, but it is enough to ensure the anonymity of personal information (c) It doesn't matter. They work the same way, either is fine.

34. (For the U.S. only) Which of the following deletion methods do you prefer? (sort the items)
(a) Click account deletion options directly in the app and complete the deletion process within the app. (b) Click the account deletion link in the app and jump to the website through the browser in the mobile phone. (c) Users need to access the website to complete the whole account deletion process. (d) Users need to contact the customer service and propose their account deletion request.

35.If you do not login an account for a long time (e.g., more than one year), the vendor may delete your account automatically to save server resources without your voluntary permission (They may send a notification email before deleting the account). How do you like this "the automatic account recycles"? (5 for the most satisfaction)

36. Do you have any suggestions about the "account deletion"? ([free text])

37. How seriously did you complete the questionnaire? (5 for the most serious)