Children's Exposure to Mobile In-App Advertising: An Analysis of Content Appropriateness

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***Abstract*—There is a rising concern among parents that mobile advertisements may contain violent and sexual content even when the app itself is safe for children. Because mobile advertisements are not controlled by the content rating of apps, unexpected objectionable contents may occur and be harmful to children's mental health. This study is the first to explore the content appropriateness of the in-app advertisements on mobile devices from children's online safety perspective. We find in-app advertisements are common in the free apps designed for children on smart platforms. Experimental results show that a large percent of the in-app advertisements carry inappropriate contents for children. Unfortunately, neither mobile platforms nor advertising networks provide maturity policies to restrict the content appropriateness of the in-app advertisements. This research suggests that these challenges cannot easily be tackled by one entity. Instead, advertisement providers, advertising networks, app developers, and mobile platforms should collaborate in developing policies and mechanisms to monitor the content appropriateness of the in-app advertisements.**

Keywords-children safety; Android apps; iOS apps; applications (apps); maturity rating; mobile advertisement (ad); in-app advertisement (ad); advertising network

I. INTRODUCTION

With the rapid adoption of smartphones, tablets, and mobile apps, more and more people use these personal digital devices for communication, entertainment, and professional activities. Among smartphone and tablet operating systems, Google's Android and Apple's iOS dominate the U.S. smartphone market by 52.5 and 34.3 percent, respectively [1]. The sweeping popularity of smartphones and tablets also affects the user population of children and adolescents. It has been reported that 25% of toddlers used their parents' smartphones in 2011 [2], and 23% of children and teens between the ages of 12 and 17 owned their own smartphones in 2012 [3]. Meanwhile, more and more apps that are specifically designed for children appear on smart devices. As a result, parents start worrying about the content appropriateness of mobile apps for their children.

In order to help parents choose age-appropriate mobile apps for their children, both Android and iOS apps have maturity ratings that are similar to the movie and video game industries. Such maturity ratings examine the existence and intensity of mature themes such as violence, offensive language, sexual content, and reference of drugs within each app. Android maturity rating policy contains four maturity-rating levels: "Everyone", "Low Maturity", "Medium Maturity", and "High Maturity", while iOS's policy provides four different maturity-rating levels based on the suitable age of audience: "4+", "9+", "12+", and "17+". Higher maturity levels represent apps containing more objectionable contents.

These maturity rating policies on Android and iOS platforms may prevent children from being exposed to the inappropriate contents. However, neither mobile platforms nor advertising networks apply these maturity policies to restrict the contents of in-app advertisements. As a result, children may still be able to view high maturity contents from in-app advertisements within those apps rated with low maturity. For example, as a *4+* app on iOS platform, *Angry Birds* should "*contain no objectionable materials*". However, it allows a full-screen advertisement (Fig.1) with bloody scenes from a high maturity app appearing inside the app (the source of this bloody scene comes from the *9+* app *Blood Brothers* containing "*Infrequent/Mild Cartoon or Fantasy Violence*"). Further, *Angry Birds* also allows sexual banner advertisements shown on the up-right corner of the screen (Fig.3). As pointed out by the Washington Post, "*there have been complaints that violent and sexual ads pop up in some apps aimed at children*" [4]. However, according to our best knowledge, no systematic research has been conducted to analyze the content appropriateness of in-app advertisements for children's protection. This work is designed to bridge the gap in the literature. We aim to contribute the following:

- This is the first study to measure the content appropriateness of the in-app advertisements from the perspective of protecting children's online safety. Previous work rarely considers children as a special group of mobile users.
- We aim to examine how the advertising networks regulate and monitor the content appropriateness on their advertisements. Our preliminary findings suggest that none of the advertising networks integrates the parental control settings from mobile devices to deliver the age-appropriate in-app advertisements to end-users.
- We propose methods to calculate ads' maturity levels, and uncover the age appropriateness for different types of in-app advertisements.

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Figure 1. Sample full-screen ad in "Angry Birds".

Figure 2. Sample pop-up ad in "Burrito Maker".

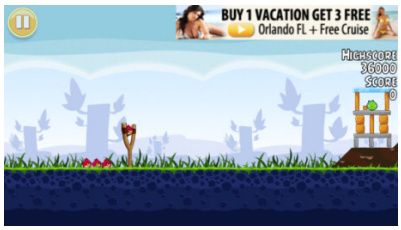

Figure 3. Sample banner ad in "Angry Birds".

This paper is structured as follows: we first review the relevant works, followed by proposing our research questions and describing the research methodology. Then we present our experimental design and findings. We summarize our findings in the discussion section and then conclude this work. (In this paper, "advertisement" and "ad" may be used interchangeably).

II. Related Work

Researchers have examined the security and privacy risks caused by the in-app advertisements on mobile platforms [5, 6]. This stream of research concludes that, to support the in-app advertisements, apps usually require more permissions than they actually need [7, 8]. In addition, to better target customers, the in-app advertisements also aggressively collect users' information from their mobile devices [5, 9]. To address privacy and security concerns, researchers have proposed different mechanisms to control and separate advertisements from the host apps [10, 11]. However, few research has considered children as a special group of mobile users or studied the in-app advertisements from the content appropriateness perspective for protecting children's safety. A most relevant study [12] has examined how inaccurate app maturity ratings on mobile platforms bring problematic contents to children, and developed a new algorithm to automatically measure the actual maturity levels of each app based on its textual descriptions and reviews. However, the content appropriateness of the in-app advertisements was not examined in [12].

III. Research Question

As discussed earlier, we aim to examine the content appropriateness of the in-app advertisements on mobile platforms for children's protection. Our first research question is to ascertain:

1. *Is the placement of in-app advertisements a common practice in free apps designed for kids?*

In addition, we seek to find out whether the advertising networks regulate and monitor objectionable contents for the in-app advertisements. Therefore, the second research question is raised as:

2. *What types of objectionable contents within the in-app advertisements are regulated and monitored by the advertising networks?*

There are different types of in-app advertisements available on mobile platforms, such as full-screen ads (Fig. 1), banner ads (Fig. 3), pop-up ads (Fig. 2), and etc. The visual effects vary among different types of in-app advertisements. For example, full-screen ads are visually more significant than banner and pop-up ads. In addition, the in-app advertisements may also have different targets. For example, there are advertisements promoting other mobile apps that are linked to external websites. Given the different visual effects for different types of in-app advertisement, our last research question is to examine:

3. *How does age appropriateness vary among different types of in-app advertisements?*

IV. Methodology

In order to answer our research questions, we first collected the in-app advertisements from both Android and iOS platforms. In the context of this research, we focused on those apps which were specifically developed for children (further denoted as "kid-specific apps"), and conducted content analysis on their in-app advertisements.

A. Kid-specific Applications

To select kid-specific apps, we searched "app for kids" and "app for children" on both Android and iOS app stores. In order to compare the content appropriateness of the in-app advertisements on these two platforms, we focused on the intersection of the result sets and downloaded the free apps that were available on both platforms.

To confirm the intended audience of the kid-specific apps, we adopted FTC's approach to search keywords on the app descriptions [13], such as "infant", "toddler", "child", "kid", "preschool", "elementary school", "parent", "teacher", and "family". Once acquiring the general age groups of apps' intended audiences, we follow the FTC's approach [13] to search keywords such as "age", "year old", and "grade" to specify the age ranges (e.g. 3~8 years old) of the apps' intended audiences. With the general age groups and specific age ranges of apps' intended audiences, we could select the apps specifically developed for kids.

B. Advertising Networks Used by Applications

After downloading the kid-specific applications, we identified the advertising-supported apps by applying static analysis to locate the libraries of the advertising networks from these apps.

Android apps were packaged as *.apk* files. After decompiling, each app folder contained all the resources used in the app, as well as the disassembled codes (with all function names and the parameters). By searching through the disassembled codes, especially the *AndroidManifest.xml*

file, we found the libraries of the advertising networks used in the apps.

Similarly, iOS apps were packaged as *.ipa* files. Those files could be automatically decompiled once installed on iOS devices. We then utilized device manger to download the decompiled folders from the devices, and searched for the libraries of the advertising networks in those folders.

C. In-app Advertisements on Mobile Platforms

Once advertising-supported apps were selected, we could collect the advertisements from those apps. On Android platform, we utilized dynamic analysis to collect the in-app advertisements. Android is an open source platform, and it provides various debugging tools to test the functionalities of the apps. The app packages downloaded from Google Play app store were installed by *Android Debug Bridge (ADB)* [14]. To ensure collecting most of the advertisements shown in apps, we manually opened every app and clicked on the in-app advertisements to trigger the redirect events. Android logging tool *logcat* [15] automatically recorded the URLs of the advertisements. On iOS platform, we manually recorded the types and the URLs of the in-app advertisements.

D. Content Analysis of In-app Advertisements

After collecting the in-app advertisements, we proceed to analyze their content appropriateness. Firstly, the in-app advertisements were categorized based on their targets (i.e., the contents promoted by the advertisements). There were three types of ad targets: 1) iOS apps; 2) Android apps; 3) external websites. The maturity levels of the advertisements were equivalent to the maturity levels of their targets. For instance, if an advertisement promoting a 9+ iOS app appeared in a 4+ app, the maturity level of the advertisement was determined as 9+, for reflecting the maturity level of its target. It was observed that the maturity levels of 98% ads' images reflected the maturity levels of their targets, while the maturity levels of the rest 2% ads' images even exceeded the maturity levels of their targets to attract attention. Therefore, the maturity levels of ads' targets were used to present ads' maturity levels in this study. We proposed the following formula to calculate ads' maturity levels:

$$L_{ad} = \begin{cases} L_{iOS} & if\ ad \rightarrow iOS\ app \\ L_{Android} & if\ ad \rightarrow Android\ app \\ L_{ALM} & if\ ad \rightarrow web\ page \end{cases} \quad (1)$$

For advertisements promoting Android and iOS apps, their maturity levels equivalent to the maturity levels of the target apps (Google and Apple provides a maturity rating for each app on its description page). In addition, for advertisements promoting external websites, we adopted the ALM (stands for "Automatic Label of Maturity Ratings for Mobile Apps") algorithm [12] to calculate their maturity levels. The ALM algorithm was originally developed to infer mobile apps' maturity levels based on their descriptions, which provided detection accuracy over 96%. We adopted ALM to analyze the contents of external website pages and measure their maturity levels.

V. Experiment

In this section, we described our experimental dataset, design and results.

A. Data Collection

By searching "app for kids" in both Google Play Store and Apple iTune Store, 405 free apps were found available on both Android and iOS platforms. *APK Downloader* [16] was used to download apps on Android platform, while apps on iOS platform were downloaded manually.

In total, 3921 advertisements were collected from the apps. Most advertisements frequently appeared in those apps during April and May 2013. There were 1521 in-app advertisements collected from the Android platform, and 2447 in-app advertisements collected from the iOS platform.

B. Experiment 1: Kid-specific Applications

We crawled the app descriptions from both iTune app store and Google Play app store, and found that apps' Android version and iOS version had the same descriptions. Furthermore, we searched through app descriptions based on three sets of keywords: 1) children: "infant", "child", "kid", "preschool", and "elementary school"; 2) adults: "parent", "teacher", and "adult"; 3) family: "family". These three sets of keywords represented the general age groups of the apps' intended audiences. The distribution of the apps based on the general age groups of intended audience was presented in Table I.

Some descriptions contained combination of keywords, and keywords representing adults were always mentioned with the keywords representing children. According to Table I, 73.6 percent of the apps were specifically developed for children, and 7.9 percent of the apps—32 apps—were even designed for infants and toddlers.

TABLE I. INTENDED AUDIENCE—GENERAL AGE GROUPS (N=405).

General age group	% of apps	Combined % of apps
Infant/toddler	7.9%	73.6%
Child	23.5%	
Kid	34.3%	
Preschool	7.4%	
Elementary school	0.5%	
Parent	10.6%	18.5%
Teacher	2.2%	
Adult	5.7%	
Family	12.8%	12.8%

TABLE II. INTENDED AUDIENCE—SPECIFIC AGE RANGES.

		Maximum recommended age						% of apps with this min. age
		0-2	**3-4**	**5-6**	**7-8**	**9-12**	**13+**	
Minimum recommended age	**0-2**	11	3	15	2	5	36	18%
	3-4	-	46	2	6	1	3	14%
	5-6	-	-	11	2	-	4	4%
	7-8	-	-	-	3	1	-	1%
	9-12	-	-	-	-	5	2	2%
	13+	-	-	-	-	-	1	0%
% of apps with this max. age		3%	12%	7%	3%	3%	11%	**n=405**

Furthermore, we searched through the app descriptions based on the age keywords such as "age", "year old", and "grade", to find out the suggested age ranges of the apps. After converting the grade levels to ages, we categorized the results and listed them in Table II. Similarly, 60 out of 405 (14.8%) apps were designed only for toddler and infants (i.e., under 4 years old) to use, and approximately 18 percent of the apps indicated they were expecting newborns to use.

Interestingly, according to Apple's maturity policy, iOS apps are only for 4 years and older. However, according to our results and FTC's report [13], Apple had approved many apps which were developed specifically for toddlers and infants, and placed them on iTune app store for users to download. Moreover, according to a 2011 report [2], there were already 25% of toddlers using their parents' smartphones. Therefore, we suggest that Apple adjust its maturity rating policy to better monitor the contents of the apps and the in-app advertisements for protecting toddlers and infants.

C. *Experiment 2: Advertising Networks*

1) *Usage of Advertising Networks in Applications*

To further select the advertisement-supported apps, we searched the libraries of the advertising networks inside the 405 apps.

For Android apps, *android-apktool* [17] was used to decompile the *.apk* packages (Android app packages). For iOS apps, *iTools* [18] was used to download the related decompiled folders of the installed *.ipa* packages (iOS app packages). Once the apps' decompiled files were ready, static analysis was applied to search the embedded libraries of the advertising networks. The distributions of the advertising networks used by Android apps and iOS apps were shown in Fig.4 and Fig. 5, respectively. We only listed the advertising networks used by at least 5 percent of the apps (i.e., used by at least 20 apps). *Google ads* advertising networks included Google's *AdSense* and *AdWords* advertising networks.

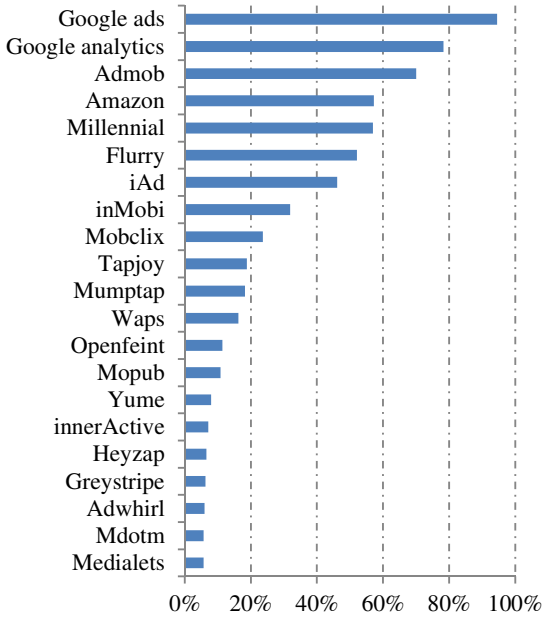

Figure 4. Distribution of advertising networks in Android apps.

According to Fig. 4, 351 out of 405 Android apps (i.e., 86.7%) embedded advertising networks. Surprisingly, on average, each app embedded 6.97 advertising networks. One reason why Android apps embedded many advertising networks was that app developers allowed mediation options when they registered apps on the advertising networks. The mediation options were provided by most of the advertising networks; the advertising networks centrally controlled the integration of the advertisements from other advertising networks into their own ad pools. Once mediation had been enabled, other alliance advertising networks could also display their advertisements inside the apps. For example, Google *Admob* advertising network allowed mediation with 16 other advertising networks: *Adfonic*, *Drawbridge*, *Flurry*, *Hunt Mobile Ads, InMobi, Jumptap, LG U+AD, MdotM, Medialets*, *Millennial Media*, *MobFox*, *Mojiva*, *Nend*, *TapIt*, *i-mobile*, and *iAd.*

As shown in Fig.4, the distribution of the advertising networks used by the kid-specific Android apps were similar to the distribution of the advertising networks used by the general Android apps [5]. We noticed that the top three advertising networks used by Android apps were all from Google. Therefore, Android developers had strongly skewed towards Google advertising networks.

According to Fig.5, the distribution of the advertising networks used by iOS apps was slightly different from the distribution of the advertising networks used by Android apps. Firstly, only 290 out of 405 iOS apps (i.e., 71.6%) embedded advertising networks, and the average number of advertising networks embedded in apps was 4.13, lower than that on Android platform. Hence, developers might choose to mediate with less alliance advertising networks on

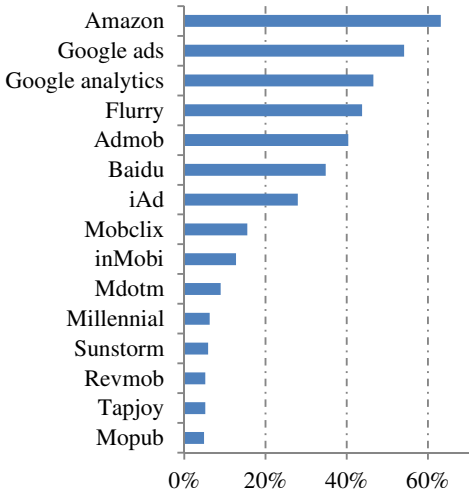

Figure 5. Distribution of advertising networks in iOS apps.

iOS platform. Secondly, the selection of the advertising networks on iOS platform was more diverse. There was no dominating advertising network on iOS platform.

Since the advertising networks were widely used on both platforms, and most of the kid-specific apps embedded many different advertising networks, the contents of advertisements could be frequently viewed by children. Therefore, if the in-app advertisements contain objectionable contents, it is highly possible that children will be exposed to those inappropriate contents.

2) Advertising Networks' Policies Regarding Content Appropriateness

We further examined the policies of the advertising networks to check whether they considered and monitored the content appropriateness of the in-app ads. We analyzed the *terms of use* of the top 50 advertising networks. A total of 11 advertising networks were missing either because the *terms of use* information was not available online, or was written in foreign languages. We ended up with 39 ad networks in our analysis. We considered four types of objectionable contents: 1) violence and horror themes; 2) sexual and nudity contents; 3) offensive and hateful language; 4) references to gambling, alcohol, tobacco, and drugs. These types of contents were considered harmful for children on both Android and iOS platforms. Due to the space limit, we only presented the results of policy analysis of top 20 advertising networks in Table III.

According to Table III, 40 percent of the advertising networks did not regulate any types of inappropriate contents in their advertisements. They either did not provide specific remarks regarding the content appropriateness (e.g., *iAd*), or shifted the responsibility to ad designers and end-users. For instance, *Mobfox* provided the following statement in the *terms of use*:

> *MobFox may have no control over any mobile websites or resources which are provided by companies or persons other than MobFox.*

TABLE III. FORBIDDEN CONTENTS AT TOP 20 ADVERTISING NETWORKS.

Ad network	Violence, horror	Sexual, nudity	Offensive language	Gambling, alcohol, tobacco, drugs
Admob	X	X	X	X
Google ads		X		X
Flurry	X	X	X	X
Google analytics		X	X	X
Millennial media				
Mobclix				
Adwhirl	X	X	X	X
iAd				
YuMe				
Mobfox				
Komli mobile	X	X	X	X
inMobi	X	X	X	X
Wooboo	X	X	X	X
AdMarvel				
Smaato	X	X	X	X
Airpush	X	X	X	X
MdotM				
Vdopia	X	X	X	
Wiyun		X		X
Adhubs				

Mobclix stated:

> *Our websites target an audience that is over the age of 18 and some content may not be appropriate for all ages. We recommend that minors over the age of 13 ask their parents and/or legal guardians for permission before sending any information about themselves to anyone over the Internet.*

Similarly, *YuMe* stated:

> *The YuMe Services are not for persons under the age of 13. If you are under 13 years of age, please visit another site – there are lots of other great web sites for you.*

Moreover, the advertising network *Jumptap* even allowed adult contents (i.e., sexual and nudity contents) to appear on their advertisements.

Among the rest advertising networks (60%), all of them forbade pornography and adult contents to appear on their ads. For other types of inappropriate contents such as violence, offensive language, and gambling, only some advertising networks forbade them to appear on the advertisements.

Although some advertising networks monitored ad contents and provided setting options on their dashboards for app developers to manage the categories of the expecting advertisements, they failed to provide fine-grained maturity levels for developers to filter out inappropriate contents. For example, *Admob* advertising network stated that they reviewed ads' contents and classified ads into two categories: "all ages" and "adult". App developers could filter out ads in the "adult" category. However, since *Admob* did not classify the ads to more detailed categories,

such as "4+" and "9+", infants and toddlers still could be exposed to inappropriate contents. Other advertising networks only provided vague statements regarding how they monitor ad contents. For example, *Adform* stated that they "*monitor unsafe content*".

Since many advertising networks did not consider the content appropriateness of their advertisements, and provided no fine-grained opt-out options for app developers to filter out inappropriate ads, those inappropriate contents in advertisements were delivered to mobile devices and eventually reached children.

D. Experiment 3: Age Appropriateness of In-app Advertisements

In this experiment, we aim to analyze the content appropriateness of the in-app advertisements. We notice that the advertising networks provided targeting options to deliver advertisements to different groups of users. In order to collect an un-biased sample of the in-app advertisements, we first analyzed the targeting options provided by the advertising networks.

1) Advertising Networks' Targeting Options

The advertisement targeting options from the top 39 advertising networks were analyzed and the results were summarized in Fig. 6.

According to Fig.6, the advertising networks delivered their advertisements by users' demographic information, app category, and device information/usage. Users' demographic information included gender, age, income level, education level, language, and relationship status (e.g., single, married). The advertising networks could deliver advertisements by users' demographic information if it was available on users' mobile devices. Some of them also allowed to deliver ads to audiences by certain age ranges, such as 18~24, 25~34, 35~44, 45~54, 55~64, and 65+. Currently there were no rules designed to deliver ads to audience less than 18 years old. In addition, the advertising networks could also deliver ads to certain categories of apps or a specific app. Furthermore, they could deliver ads by device information: days (e.g., weekend 10:00am~ 10:00pm), location, Internet connection (e.g., wifi or 3G), carrier (e.g., AT&T, Verizon), device (e.g., iPhone 4GS), and user events/timing. User events/timing included the activities users conducted on devices, such as the keywords users searched on devices, the time users spent on apps, users' purchasing and transaction history, and etc.

According to Fig.6, the advertising networks mostly delivered their advertisements by location, device, demographic information, and etc. To eliminate the influence of those factors and collect un-biased sample of advertisements, the apps were installed on 4 different devices. The Android apps were installed on a Nexus S device (system version is 2.3.6), while iOS apps were installed on an iPhone 5 device, an iPhone 4 device, and an iPod touch 3 device. Two different accounts were used to install the apps, one was a male account with age range 65+, the other was a female account with age range 18~24. We did not type in any other information into the accounts, and the devices were all reformatted before use.

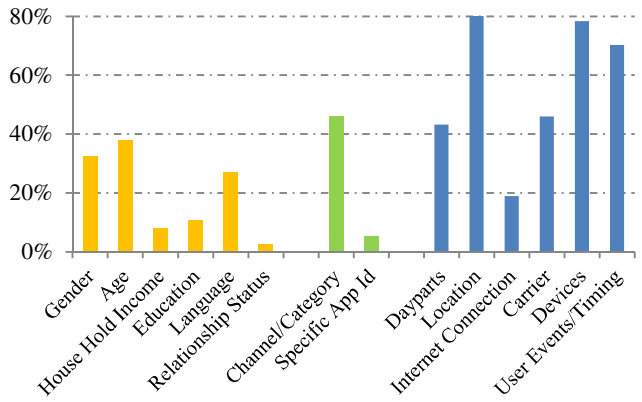

Figure 6. Targeting options provided by top 39 advertising networks.

TABLE IV. APPS' FEATURES ON ANDROID AND IOS PLATFORMS.

	Android	**iOS**
Total	405	
With no ads	36	114
Not compatible with device	17	0
Cannot use	1	1
With ads	351	290
With (→app) ads	159	217
With (→website page) ads	157	66
With banner ads	172	203
With full-screen ads	89	105
With pop-up ads	23	18

2) Content Analysis of In-app Advertisements

According to Table IV, three types of apps were excluded from the dataset: 1) apps without advertisements; 2) apps not compatible with our devices; 3) apps could not be used in the location conducting the experiment. In total, there were 351 Android apps and 290 iOS apps in the dataset. "(→app) ads" denoted the ads promoting Android apps, and "(→website page) ads" represented the ads promoting external websites. In addition, only three types of in-app advertisements were observed on both Android and iOS platforms: *banner ads*, *full-screen ads*, and *pop-up ads*. Table IV showed the numbers of apps with each type of in-app advertisements. The advertisements pre-integrated with the apps were not considered, for those were not dynamically pushed by the advertising networks, and app developers should have integrated the maturity levels of those advertisements into apps' maturity levels.

In total, 1521 in-app advertisements were collected on Android platforms, and 2447 in-app advertisements were collected on iOS platforms. The maturity levels of the advertisements were calculated and compared with the host apps' maturity levels. The features of the in-app advertisements on Android and iOS platform were presented in Table V.

TABLE V. FEATURES OF THE IN-APP ADS ON ANDROID/IOS PLATFORMS.

Ad types	Total	Ad maturity > app maturity
Total	1521 / 2447	35.9% / 38.9%
(→App) ad	645 / 2251	**45.7% / 40.8%**
(→Website page) ad	876 / 196	28.6% / 17.3%
Banner ads	- / 818	- / 33.6%
Full-screen ads	- / 1609	**- / 42.1%**
Pop-up ads	- / 20	- / 0%

According to Table V, on Android platform, there were 645 in-app advertisements promoting Android apps, and 876 in-app advertisements promoting external websites. We adopted the formula (1) (in Section IV. *D*) to calculate ads' maturity levels. Furthermore, *t-test* was performed to measure the distinction between ads' maturity levels and their host apps' maturity levels. *t-value* was used to measure the distinction, and *p-value* was used to measure the significance of the results. 45.7 percent of the ads promoting Android apps exceeded their host apps' maturity levels ($t=13.97$, $p<0.001$, within 98 apps), while 28.6 percent of the ads promoting external websites exceeded the host apps' maturity levels ($t=8.73$, $p<0.001$, within 65 apps). The ads promoting Android apps also had higher chance to exceed the host apps' maturity levels than the ads promoting external websites ($t=5.20$, $p<0.001$, within 89 apps).

Since *logcat* was used on Android to record the in-app advertisements' urls, it failed to record whether the advertisements were banner ads, full-screen ads, or pop-up ads. Therefore, their maturity levels were not examined on Android platform.

Similarly, according to Table V, 40.8 percent of the ads promoting iOS apps exceeded their host apps' maturity levels ($t=17.42$, $p<0.001$, within 151 apps), while 17.3 percent of the ads promoting external websites exceeded the host apps' maturity levels ($t=4.51$, $p<0.001$, within 21 apps). The ads promoting iOS apps also had higher chance to exceed the host apps' maturity levels than those promoting external websites ($t=7.56$, $p<0.001$, within 8 apps).

There were 818 banner ads, 1609 full-screen ads, and only 20 pop-up ads collected on iOS platform. The banner ads normally appeared for most of the time while apps were open on the foreground, and usually stayed for 20~30 seconds before refresh (developers could change the settings on display time, interval and refreshing rate). The full-screen ads normally appeared when users triggered certain events inside the apps. The events could be "played the app for over 1 minute", "finished a level", "restarted a level", and etc. The pop-up ads normally appeared when apps started, and never displayed again unless the apps are re-opened. Both full-screen ads and pop-up ads required immediate responses.

In total, 33.6 percent of the banner ads exceeded their host apps' maturity levels ($t=14.53$, $p<0.001$, within 130 apps), while 42.1 percent of the full-screen ads exceeded their host apps' maturity levels ($t=13.46$, $p<0.001$, within 77 apps). The full-screen ads also were more likely to exceed the host apps' maturity levels than the banner ads ($t=2.87$, $p=0.003$, within 57 apps). For the pop-up ads, none of them exceeded the host apps' maturity levels. Since the full-screen ads also had more significant visual impression than any other types of ads, the high maturity full-screen ads might be the most harmful to children's mental health. In contrast, the pop-up ads only contained texts. According to Table V, their maturity levels were consistent with the host apps' maturity levels. Therefore, it seems that the pop-up ads were the least harmful to children.

From the results on both platforms, a large proportion of the in-app advertisements had higher maturity levels than the host apps. It was highly possible that children would be exposed to inappropriate contents while playing with those apps. The results also showed that the advertisements promoting other apps and the full-screen advertisements tended to be shown on lower maturity apps.

3) Types of Inappropriate Contents in Mobile Advertisements

Further, we examined the in-app advertisements that contained higher maturity levels of objectionable contents than that of their host apps. Apple provided detailed reasons for each app's maturity rating on iTune app store if it was higher than 4+. For example:

Rated 9+ for the following:

- *Frequent/Intense Cartoon or Fantasy Violence*

Therefore, for the advertisements promoting iOS apps with maturity levels higher than the host apps, the reasons of their maturity levels were collected and the results were presented in Fig. 7.

According to Fig. 7, three types of objectionable contents mostly appeared in the high maturity in-app ads: 1) cartoon, fantasy violence; 2) simulated gambling; 3) mature/suggestive themes. We believed the results could bring more insights to parents about what types of objectionable contents to expect in the advertisements exceeded the maturity levels of the host apps.

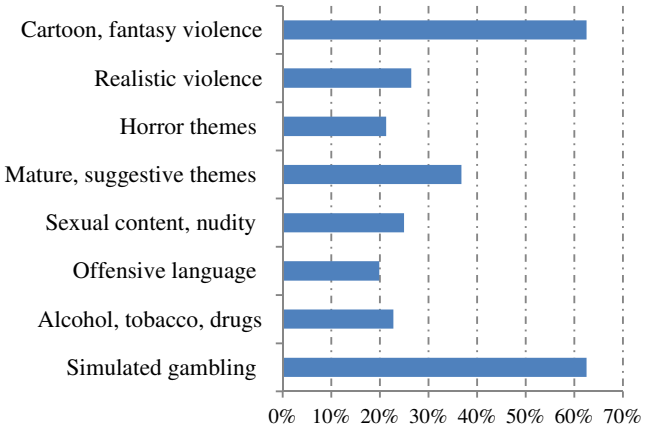

Figure 7. Types of objectionable contents in high maturity in-app advertisements on iOS platform. (n=136)

VI. CONCLUSION

Both Android and iOS allow app developers to link their free apps with advertising networks to increase revenue. Behavioral research on users' privacy practices suggests that mobile users would rather engage free apps with in-app ads than pay for no-ad apps [19]. As a result, mobile in-app advertising now becomes a common practice. However, few research has systematically uncovered the extent and severity of the inappropriate contents on the in-app advertisements. To bridge this gap, our study explores the content appropriateness of the in-app advertisements on both Android and iOS platforms.

Our research has several contributions. First, the advertisement content regulations and the monitoring methods provided by the major advertising networks were practically examined. Only a small percentage of the advertising networks considered the content appropriateness of their advertisements, and provided opt-out options for app developers to filter out inappropriate advertisements. Secondly, experimental results showed that regardless of the advertisement types and the advertising targets, a large percentage of the in-app advertisements exceeded their host apps' maturity levels, especially the full-screen ads and the ads promoting other mobile apps. Therefore, both Android and iOS should develop corresponding maturity rating policies to restrict the content appropriateness of the in-app advertisements. Lastly, we point out that while viewing the contents of advertisements, users may also be affected by the objectionable user-generated contents on social media. We believe that our findings provide insights for parents, advertising networks, platform providers (e.g., Google or Apple) as well as for regulatory bodies and application developers to better collaborate in protecting children's online safety.

The limitation of this research is that we only analyzed apps compatible with iOS and Android platforms, and focused on the top 39 advertising networks. In the future, we will expand the size of the dataset to include more advertisement networks. Besides, we will look into the influence of culture differences on content appropriateness.

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