(M)ad to see me? Intelligent Advertisement Placement: Balancing User Annoyance and Advertising Effectiveness

NGOC THI NGUYEN, Information Systems Technology and Design, Singapore University of Technology and Design, Singapore
AGUSTIN ZUNIGA, Department of Computer Science, University of Helsinki, Finland
HYOWON LEE, Insight Centre for Data Analytics, Dublin City University, Ireland
PAN HUI, Department of Computer Science and Engineering, Hong Kong University of Science and Technology, Hong Kong and Department of Computer Science, University of Helsinki, Finland
HUBER FLORES, Institute of Computer Science, University of Tartu, Estonia
PETTERI NURMI, Department of Computer Science, University of Helsinki, Finland

Advertising is an unavoidable albeit a frustrating part of mobile interactions. Due to limited form factor, mobile advertisements often resort to intrusive strategies where they temporarily block the user's view in an attempt to increase effectiveness by forcing the user's attention. While such strategies contribute to advertising awareness and effectiveness, they do so at the cost of degrading the user's overall experience and can lead to frustration and annoyance. In this paper, we contribute by developing *Perceptive Ads* as an intelligent advertisement placement strategy that minimizes disruptions caused by ads while preserving their effectiveness. Our work is the first to simultaneously consider the needs of users, app developers, and advertisers. Ensuring the needs of all stakeholders are taken into account is essential for the adoption of advertising strategies as users (and indirectly developers) would reject strategies that are disruptive but effective, while advertisers would reject strategies that are non-disruptive but inefficient. We demonstrate the effectiveness of our technique through a user study with $N = 16$ participants and two representative examples of mobile apps that commonly integrate advertisements: a game and a news app. Results from the study demonstrate that our approach improves perception towards advertisements by 43.75% without affecting application interactivity while at the same time increasing advertisement effectiveness by 37.5% compared to a state-of-the-art baseline.

CCS Concepts: • **Human-centered computing** → *Ubiquitous and mobile computing design and evaluation methods*.

Additional Key Words and Phrases: Mobile Advertisement, Affective Computing, Mobile Cloud

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Authors' addresses: Ngoc Thi Nguyen, thingoc_nguyen@mymail.sutd.edu.sg, Information Systems Technology and Design, Singapore University of Technology and Design, Singapore, Singapore; Agustin Zuniga, agustin.zuniga@helsinki.fi, Department of Computer Science, University of Helsinki, Helsinki, Finland; Hyowon Lee, hyowon.lee@dcu.ie, Insight Centre for Data Analytics, Dublin City University, Dublin, Ireland; Pan Hui, panhui@cse.ust.hk, Department of Computer Science and Engineering, Hong Kong University of Science and Technology, Hong Kong, Hong Kong, Department of Computer Science, University of Helsinki, Helsinki, Finland; Huber Flores, huber.flores@ut.ee, Institute of Computer Science, University of Tartu, Tartu, Estonia; Petteri Nurmi, petteri.nurmi@cs.helsinki.fi, Department of Computer Science, University of Helsinki, Helsinki, Finland.

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1 INTRODUCTION

Advertising has become an unavoidable part of the mobile ecosystem. For marketers, the prevalence of mobile interactions makes mobile advertising an optimal medium for reaching users, whereas for mobile app developers revenue from third-party advertisements serves as a way to fund and sustain development with most free apps integrating some form of ads [21, 41]. The significance of mobile advertising is further highlighted by the fact that the value of mobile advertising has already surpassed its desktop counterpart [9, 37]. Indeed, global spending in mobile advertising was estimated to exceed $150 billion in 2018, and forecasts suggest spending to reach $250 billion by 2022[1]. While ads are critical for mobile app developers [20], users tend to perceive them as an unfortunate and unavoidable reality that degrades overall user experience rather than enhances it [61]. Negative user experience from ads can also strongly influence the user's perception and attitude towards the advertised product/brand [60]. Besides negative user experience, ads can become a privacy risk due to active user profiling [19]. The inclusion of ads in mobile apps is also perceived visually intrusive by users whose attitude is mostly negative towards ads [22, 60]. Extensive use of ads has been shown to lead to high energy drain [49, 66] which in turn can lead into users abandoning the app [56, 69]. Indeed, excessive or otherwise disruptive advertisements have been shown to be one of the top three reasons for uninstalling an app with over 20% of users removing apps that show such ads[2].

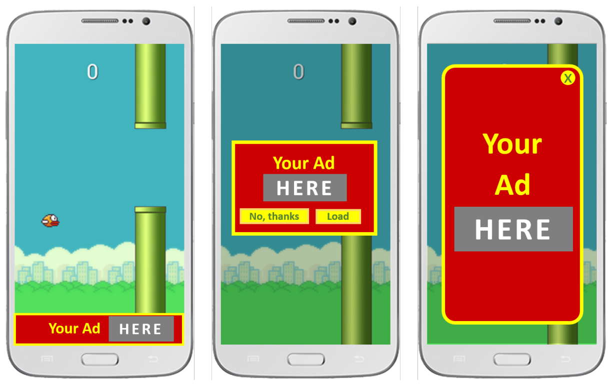


Fig. 1. Common places to locate ads in smartphone apps.

The success – or failure – of mobile advertisement strategies ultimately depends on how marketers and users perceive them. For marketers, advertising strategies need to be *effective*, i.e., improve sales or awareness of the advertised products, whereas for users the advertisements need to be the least *disruptive* as possible. Unfortunately, current mobile advertisement strategies fail to simultaneously meet the needs of both stakeholders as the strategies either are highly disruptive or minimize disruption at the cost of decreased advertising effectiveness. Achieving a trade-off between the needs of both stakeholders is essential for the adoption of advertising strategies as any strategy improving user experience but decreasing effectiveness will not be adopted by advertisers. Conversely, strategies that solely optimize effectiveness will be rejected by app users. To illustrate how current strategies fail to achieve this trade-off, consider the placement strategies shown in Fig. 1. The strategy shown on the left minimizes negative effects of ads, but suffers from low effectiveness due to banner blindness whereby users become accustomed to the position of advertisements and are able to avoid paying attention to them [47, 52]. The strategies shown in the middle and right, on the other hand, suffer from being highly disruptive, and consequently degrade overall user experience and can lead to users stopping to use an app [31, 54].

[1] https://www.statista.com/statistics/303817/mobile-internet-advertising-revenue-worldwide/
[2] https://clevertap.com/blog/uninstall-apps/

In this paper, we contribute by developing *Perceptive Ads* as a novel and innovative mobile advertisement strategy that minimize user annoyance and frustration while maintaining sufficiently high effectiveness to help developers sustain their development and ensure advertisers deploy the strategies. Our work is motivated by supporting users and app developers who have little or no control over the ad ecosystems. Indeed, disruptive placement strategies would result in users becoming frustrated and annoyed, which could lead them to uninstall the app [26], triggering developers to lose revenue. Perceptive Ads relies on an *adaptive placement strategy* that optimizes the placement and presentation of advertisements according to characteristics of the user's interactions. The placement of interface elements, including advertisements, is critical for overall user experience, particularly within mobile apps where limited screen estate constrains user's interaction opportunities [13, 55]. While efficient design of interface elements has been widely researched in the context of app design [16, 46], surprisingly little effort has been put on optimizing the placement of advertisements within the user interface. Perceptive Ads draws inspiration from research focusing on optimizing the placement of interface elements, while taking into consideration factors that affect user attention and that can improve effectiveness of advertisements. Unlike existing methods, Perceptive Ads determines a visually salient presentation of the advertisement (to maximize effectiveness) within a region of the interface where the advertisement is visible, but not disruptive to the user experience. The presentation is chosen according to the interaction and attention demands of the application. Specifically, for applications requiring high degree of attention and interactivity, Perceptive Ads segments the advertisement into parts, and renders the different parts as overlays, similarly to how movies and games use product placement as a salient but non-disruptive advertising strategy. For applications requiring lower degree of attention and interactivity, the entire ad is shown in a location where it is visually prominent but non-disruptive to the interaction.

We evaluate the effectiveness and level of disruption caused by Perceptive Ads through a controlled user study with $N = 16$ participants. In our study, we consider two representative mobile apps that represent different ends of user interactivity and disruption impact spectrum: a news reader with low user interactivity and disruption impact; and a mobile game with high user interactivity and disruption impact. As part of the study we compare Perceptive Ads against a conventional advertisement placement strategy, demonstrating that our approach improves perception towards advertisements by 43.75% without affecting application interactivity and while at the same time increasing advertising effectiveness by 37.5% compared to the baseline. To obtain further insights into Perceptive Ads, we also conduct a post-study probe with $N = 8$ participants that focuses on comparing the effects on user perception and ad effectiveness when ads are served as a whole or as segments. Results of our post-study probe suggests that adapting interactions depending on the level of user interactivity results in improved user acceptance and increased engagement with ads. Our results also show these results to be robust across both low and high interactivity applications.

Summary of Contributions:

- **Novel insights on advertisement placement strategies.** We demonstrate that *level of user interactivity* and *level of disruption impact* are significant factors to be considered when developing in-app ad placement strategies that maximise the balance between ad effectiveness and user perception.
- **New advertisement placement strategy.** We develop Perceptive Ads as a novel advertisement placement strategy that strategically places ads based on the app's level of user interactivity as well as the impact level that disruption imposes on the task quality (Section 3.2).
- **Improved performance.** We develop rigorous experiments using two apps that are representatives of both low and high levels in user interactivity and disruption impact. Our ad placement strategy improves both the perception that users have towards ads and the effectiveness of ads by 43.75% and 37.5% respectively while at the same time ensure the level of user interactivity does not suffer (Section 5).

2 BACKGROUND AND RELATED WORK

Ad Placement. Advertisement placement deals with scheduling ads and finding appropriate place to show them [2]. Given a fixed size of geometric space, a specific duration of time and a collection of ads, ads must be displayed corresponding to a scheduled number of time slots within the pre-defined space. Ad placement problem has been strongly guided by increasing brand's impression and maximizing revenue for ad space providers by determining optimized schedules to display all ads on Internet websites or selecting a subset of ads that would produce the highest revenues for the providers [2, 15], or by designing ad delivery systems that would maximize the number of users seeing the ad [30]. In motion pictures, with users continuously watching the video broadcasted from live TV broadcasting programs or streamed from multimedia streaming sources, the ad placement problem aims to determine the timing to insert the ad within a video scene [33] or between video scenes, the number of commercial breaks and the lengths of these breaks that would boost the brand's impression at the highest level [67].

On mobile platform, the ad placement problem inevitably requires accounting for the small screen estate of mobile devices. Ads are shown one-by-one in a mobile app instead of side-by-side as they would be on larger screen devices such as desktop or laptops. The impact of an ad is commonly measured by examining whether users tap or not on the ad (which can be enforced) as this is the most immediate measure and can be calculated without long-term observation. As a result, most mobile advertising companies are not concerned about creating effective ads that create interest in the users, but rather about having an infrastructure with the greatest number of possible users to propagate ads indiscriminately[3]. When injected into the app content, ads cause sudden interruption to the flow of content, e.g., by extending the length content needs to be scrolled, affecting negatively the user's experience. The objectives of the ad placement problem become either to minimize disruption to the user or to maximize user's awareness of the ad. In common ad placement strategies, the ads are co-located with the app content (left in Fig. 1) or assigned between app content (middle and right in Fig. 1). Nevertheless, the presence of ads on the small screen impedes user interaction and the interest of users in receiving ads on mobile devices is very low [60]. In addition, as the presence of ads is not required by the main functionality of the app, the interference that ads cause on the app's UI triggers user's complaints and negative perception towards the app [20]. When ads are irrelevant to the user, they become the source of negative user perception and attitudes towards ad placement [60], from ignoring the area where ads are displayed (e.g., banner blindness [47, 52]) to uninstalling the app [26].

User Reaction. The response of users on within-app ads conflicts with interests of advertisers. To make ads more interesting than annoying to the user, the use of incentives has been widely explored to enhance the attitude of the user towards receiving ads [8]. Gamifying the ads has been employed to make the appearance of ad enjoyable and effective [3]. Integrating an ad inside a game app (in-game advertising) [58] is a particular case of ad placement and has been studied in terms of influencing the players' brand impression [65]. In addition, requesting users' permissions for showing ads was considered in improving users' attitude [1]. Ad personalization has been adopted to display ads that are closely relevant to user's preferences and needs based on the user's context [51], e.g., advertising relevant promotions based on the customer's shopping list at a supermarket [45]. More sophisticated approaches have proposed to infer the emotional state of the user, e.g., mood, in order to determine the right time to show an ad and to get feedback about it [18, 25, 48]. Analyzing user personal traits to personalize ads to users also have been studied [12]. In terms of mechanisms, in-app engines embed ads inside 3D games, and data profilers can be used to analyze user's interests[4][5].

A sizable work in this area attempts at automatically and optimally inserting an ad in a document real-time, e.g., by proposing a mechanism for ranking and allocation rules and payments for ads [11]. Framing the ad insertion issue as efficiency-quality trade-off, an algorithm to determine the size, location, density of ad was proposed thus

[3] http://www.airpush.com/
[4] http://www.rapidfire.com/
[5] http://www.inmobi.com/

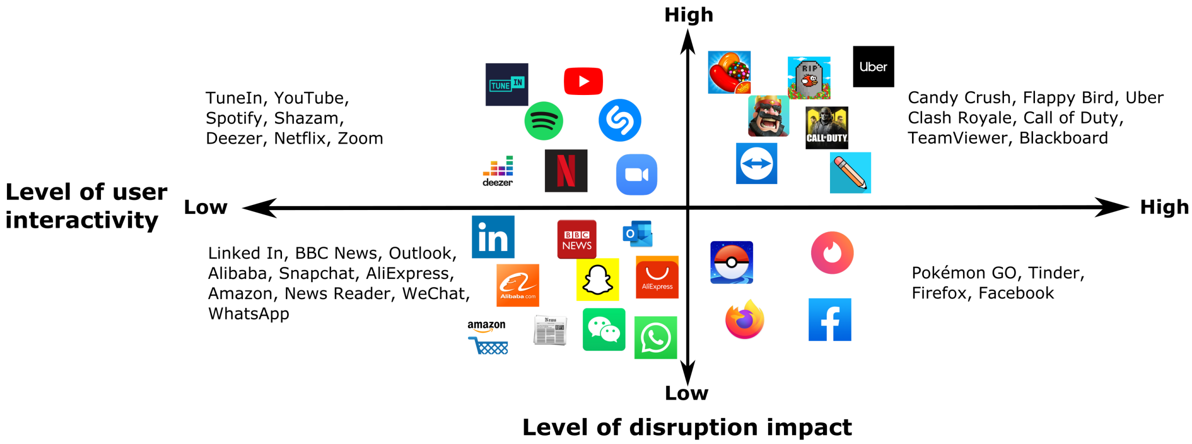


Fig. 2. App categorization based on its required level of user interactivity and disruption impact.

a best insertion to a document is to be ensured [10]. Allowing the user more control over the ads was deemed beneficial in terms of user experience and enjoyment [38]. Also users' perception on the ad placement algorithms in terms of transparency, i.e., explaining the reason for a particular ad to be shown, has been studied [13].

IntelliAd focuses on reducing annoyance towards ads by automatically measuring ad consumption (measured costs) and providing developers feedback for optimizing their ad-embedding schemes [17]. Muhkherjee et al. [39] proposed to minimise the decision time of real-time ad placement algorithms. Another approach is to detect fraudulent advertisement inserted in the app or website without appropriate protocol or permission. Automatically navigating within apps and optimally scanning through a large number of elements in a short time, DECAF system detects ad placement frauds [34].

While the algorithmic issues on optimizing the choices of ad types, time sharing and space sharing, and different paradigms of ad placement have been the active subject of research, the actual design of the ad itself and its placement in relation to the app is currently understudied. Our work addresses this omission, offering a solution that determines the *right spot* to display the ad without taking much of extra screen space and the *right presentation* of ad such that user's annoyance is mitigated while the effectiveness of the ad is retained.

3 PERCEPTIVE ADS

The placement of advertisements has traditionally been based on the desire to increase awareness and impressions of a brand, and to maximize revenue for ad space providers [2, 15] using one-size-fit-all ad placement approaches for all apps. In mobile advertisement, *in-app* ad placement mechanisms consider factors relevant to the app content and developers' registered interests without considering how the user interacts with the application. Consequently, ads compete with what users expect when using an app (e.g., reading, playing game, searching for information), making users not only ignore ads - thus low recognition of the advertised products/brands, but also feel annoyed towards ads [20]. Even with ad personalized to individuals [35], app recommendation [64], user segmentation [36] and targeted advertising [68], using the same ad placement mechanism for any app thus assuming all users use the app in the same way would impress certain individuals/groups at the risk of degrading user experiences of others.

We argue that in-app ad placement should include the *level of user interactivity* and the *level of disruption impact* as design factors for determining optimal ad placement on mobile platform. Depending on the app design goal, the main functionality of an app requires specific interaction style (e.g., discrete cf. continuous, non real-time cf.

real-time) and may be susceptible to disruption (e.g., disruption during a game could result in the player losing the game). Notably, for the same app, different users interact at different levels of interactivity depending on the user's context, preferences and needs. For example, some users could passively consume content from Facebook app while others actively contribute to Facebook content. To account for such variations, advertisement placement strategies need to be able to switch their mode depending on the user's interaction patterns.

We refer the *level of user interactivity* as the degree of intensity in interaction between an app user and the app, through which user engagement is motivated and takes place. Apps characterized by low level of user interactivity are those that accept discrete or non real-time user input responses whereas apps with high level of user interactivity require continuous or real-time input from the user. The *level of disruption impact* refers to the negative cost that disruption causes to the outcome of user interactivity. With low level of disruption impact, the main functionality of the app can be resumed at any point without interfering the final outcome. In contrast, apps characterized by high disruption impact are ones where the main functionality is susceptible to disruption. These apps likely have start and end points during which interaction is continuous, thus any interruptions could prevent the task being done or at least seriously hamper it.

Fig. 2 provides examples of app classification under levels of user interactivity and levels of disruption impact. Apps that feature both low level in user interactivity and disruption impact (bottom left quadrant) likely require basic, simple user interaction and their main functionality can be resumed at any point without interfering the final outcome. As an example of this type of app, a news reading app enables users to browse the app content at their own pace. Disruptions do not change the contents and thus do not change the state of interaction – even if they can negatively impact user experience and cause frustration. Video apps are candidates for apps with low level of user interactivity but high level of disruption impact (top left quadrant). Although the apps do not require frequent user input, the app content changes and demands continuous user attention. Pokemon Go is an example of an app demanding high level of user interactivity but having low level of disruption impact (bottom right quadrant). Finally, examples of apps characterized by high level in both user interactivity and disruption impact (top right quadrant) include certain types of games (e.g., visually intensive arcade games) and augmented reality apps. As this type of app requires continuous and real time user responses, any disruption encountered while the user plays this type of games would affect user attention, thus leading to unwanted ending of the game play.

To account for differences in interactivity and disruptions, we have designed Perceptive Ads as an advertisement placement strategy. Perceptive Ads focuses on the two most extreme application groups as users of applications in these two groups are most likely vulnerable to one-size-fit-all ad placement mechanisms. Specifically, Perceptive Ads targets users in the groups with low level in both level of user interactivity and the level of disruption impact, and with high level in both of the level of user interactivity and the level of disruption impact. Consider a full-screen ad being displayed when the user navigates between news stories in a news reading app (an example of low user interactivity and low disruption impact) using conventional ad placement techniques. The interval between ad appearances is determined by the time the user takes to finish reading a news story before moving to the next one. How frequent the user sees the ad depends on the time the user spends on reading the news article. As fast reading users will see more ads than slow reading users do during a period of time, the former group experiences more frustration and annoyance than the latter group does. Capturing the user perceptions and uses from these two extreme groups as a starting point will help initial understanding of pertinent aspects of the Perceptive Ads (in comparison to conventional ones). In addition, advertisement placement for the other two groups can be in many cases optimized by switching between the two different extremes depending on nature of content and interaction. With Perceptive Ads, ads are placed in the app based on the level of user interactivity that the app requires and the level of impact that disruption could cause. Perceptive Ads places salient visual presentation (e.g., ad icon, ad segment) of the ad within a prominent region that least disrupts user interaction. In addition, Perceptive Ads adds potential interaction with the ad based on how intensive the user uses the app. An overview of Perceptive Ads' strategies is shown in Fig. 3.

Fig. 3. Perceptive Ads overview: a) ad placement for low level of user interactivity and low level of disruption impact, b) ad placement for high level of user interactivity and high level of disruption impact.

3.1 Design Goals

Unlike desktop-based advertising where advertisements are often shown at strategic locations (e.g., left/right side of the main content of a web page), typical mobile screens such as smartphones' ones are small enough to fit in the user's view without turning head or changing the gaze much. Coupling with visual salience of ad design, strategic locations for ad placement could be anywhere which are not blocked by the user's finger(s). Aiming to minimizing disruptions to users – thus mitigating user annoyance towards ads, Perceptive Ads places ads based on the level of user interactivity with the app as well as the impact level that disruption imposes on the task quality.

Adaptive Placement. Adaptively placing ads at a position within an occlusion-free zone is the key characteristic of Perceptive Ads as it reduces the chance of the user accidentally clicking on the displayed ad. We define *occlusion-free zone* as the area on the screen that is always visible in the user's view, i.e., not prone to occlusion due to the user's finger(s). Occlusion-free zones vary depending on device form factor and how the device is held by the user, i.e., holding the device vertically (portrait orientation) or horizontally (landscape orientation) using one hand (unimanual) or two hand (bimanual). As users can freely and frequently change the way they hold the phone [24, 29], characteristics of interactions with app content can change dynamically [4]. This makes it crucial to dynamically detect the respective changes in occlusion-free zone(s) and adaptively place ads within them.

In unimanual finger-interaction wherein a smartphone is held by one hand and user inputs are provided by the thumb of the same hand holding the smartphone, occlusion-free zone is the outside area of the common functional area of the user's thumb (Fig. 4a, 4d) – the opposite upper corner of the smartphone screen [7] or the opposite side of the phone respectively). In bimanual interaction scenario, the smartphone is held by both hands and user inputs are provided by both thumbs, occlusion-free zone could be inferred as the area covering both upper part of the smartphone screen (Fig. 4c, 4f). Similarly, when user inputs are provided by a (usually index) finger of the dominant hand [6] while the phone is held by the non-dominant hand (i.e., "cradle" [24]), occlusion-free zone is the area that is not occluded by the finger movement trajectory (Fig. 4b, 4e).

In this paper, we primarily focus on ad placement when the device is in portrait orientation as it has been shown to be the common way that users hold their phone (49% of users hold their phone vertically by one hand, and for those holding their phones by two hands, 90% of them hold the phone vertically [24]). However, our approach supports also other placements as long as the respective occlusion free zones can be estimated reliably.

Adaptive Presentation. This requirement takes into account both current app's content and its presentation to ensure the presentation of an ad would be easily distinguished from the content of the app wherein the ad is hosted. As accidental clicks which often happen on in-app advertisement [59], this will help reducing user's tapping on the

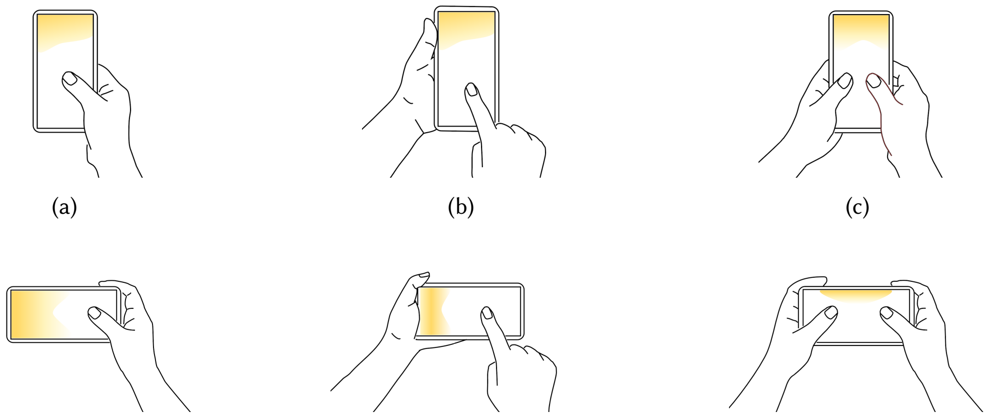


Fig. 4. Shaded area depicts occlusion-free zone in (a) thumb-based input in unimanual interaction, (b) index-based input in bimanual interaction and (c) thumb-based input in bimanual interaction when phone being held vertically; (d) thumb-based input in unimanual interaction, (e) index-based input in bimanual interaction and (f) thumb-based input in bimanual interaction when phone being held horizontally.

ad by mistake. For examples, for apps that predominantly feature text content, ad could be presented as an image icon whereas apps with image-dominant content, ad could be presented as text when possible. An ad can be served as the whole message or decomposed into smaller segments depending on the refresh rate of the app content or the level of user interactivity that the app requires.

Adaptive Interaction. Ad's behavior should not compete with the functionalities and interactions of the app on which the ad is served, i.e., the ad should not interfere with current app content. For apps requiring low frequency of temporal responses from users, interactions with ads could be encouraged whereas app requiring users' high or fast temporal responses, interactions with ads should be minimized. In some situations, the same app could be considered having different levels of interactivity depending on the user's approach or attitude in using the app (e.g., providing user input on one device while focusing attention on another device running the same app [42], multi-tasking among multiple apps, or talking to somebody while using the app) or on different stages of the app (e.g., teaser page that does not interest the user cf. an intensive game sequence), making this aspect more complicated when trying to design accordingly.

3.2 Design Rationale

Perceptive Ads is designed to place an ad inside the occlusion-free zone. For example, in the case of portrait orientation with left hand holding the phone, the advertisement is placed at the upper middle or upper right corner of the app content (given majority apps have menus or important UI elements placed at upper left corner, we exclude this area from initial ad placement) and below the content header area (*Adaptive Placement*). Ad presentation is decided based on the app content as described in the *Adaptive Presentation*. The degree to which users could interact with an ad is based on the detected level of user interactivity that the user has with the mobile app wherein the ad is hosted (*Adaptive Interaction*).

Design rationale of Perceptive Ads was informed by a preliminary study with $N = 15$ participants. Prior to the preliminary study, we ensured that all participants were acquainted with a news app and a game app by asking each participant to use the apps for at least one week. Only participants who used the apps at least 3 times were invited to attend the preliminary study. Participants were showed ads using Perceptive Ads and conventional ad placements while using the apps. We encouraged participants to think aloud during the session. Based on participants' feedback, we improved Perceptive Ads design as reported below.

3.2.1 Whole Ad Placement for Apps having Low User Interactivity + Low Disruption Impact.

Perceptive Ads uses *Whole Ad* strategy to place ads in apps requiring low level in user interactivity requirements and having low disruption impact. In this type of apps, as the main functionality of the app can be resumed at any time without interfering with the final outcome, ad interactions are increased by providing intuitive gesture capabilities [5, 53, 62] that allow the user to interact with the ad. Perceptive Ads relies on touchscreen gestures to dynamically allocate the screen position and the size of the spot in which the ad will be displayed [28, 50] and to collect feedback about the ad that can be used later to profile the user.

Fig. 3a shows the proposed approach. An ad is initially shown using a minimalistic and visual representation of the content, e.g., company logo, or product shape, at a position within an occlusion-free zone. Once the ad appears, the user can drag the ad across the screen without interfering with the functionality of the underlying app. If the user is interested in the ad and wants to see its content in more details, the user can use pinch gesture to manipulate the ad to cover a larger (or smaller) proportion of the screen. Alternatively, double-tapping gesture can be used to quickly toggle between the maximized and minimized forms of the shown ad. The user can also completely remove the ad by swiping either left or right (explained later). The functionality of the underlying mobile app remains detached from the ad, which means that if the user decides to view the ad, the app continues to run normally in the background. Once the ad disappears, or is removed by the user, the user can resume interactions with the underlying app normally. Naturally, the user can resume the app once the ad is put aside.

Perceptive Ads also integrates a mechanism for users to provide feedback on the shown advertisements. Our feedback strategy is inspired by the popular swipe left or right paradigm. Specifically, when the user swipes the advertisement to the left edge, the ad is perceived as irrelevant to the user. When the ad is swiped to the right edge, this is interpreted as positive feedback. In both cases, the ad disappears from the screen and the user can resume interactions with the underlying app. If the user does not swipe the ad to either side, the advertisement will remain visible until it times out. By analyzing touchscreen gestures applied to an ad, Perceptive Ads makes it possible to measure how the ad is perceived by the user and to derive fine-grained metrics about its effectiveness. For instance, Perceptive Ads can be used to capture any correlations between the size of the ad, and the time it is interacted with. By granting an ad the ability to be manipulated by the user (in terms of rendering location and size) and by collecting feedback from the user, our proposed strategy aims to reduce the annoyance caused by displaying in-app ads while improving its effectiveness.

3.2.2 Segmented Ad Placement for for Apps having High User Interactivity + High Disruption Impact.

In apps characterized by high level of user interactivity and disruption impact, Perceptive Ads limits ad interaction capability to texture-switching (see below) to minimize competition with user's app interactions. Perceptive Ads divides the overall message of an ad into segments (Fig. 3b). Segments are embedded into selective objects of the apps, for example, background objects, objects at the sides of the screen, or objects in the areas that are not interacted with, and sequentially displayed when the texture switching is triggered manually or adaptively. Interactive objects that are susceptible to high disruption impact should be excluded or minimally chosen for ad embedding because the result of unexpected texture switching would severely disrupt the user attention and impede the user from completing the task. For example, it is up to the app designer/developer to decide whether incoming obstacles in a fast-paced shooting game are to be excluded or embedded with ad segments, in the latter case, ad segments should be sparingly embedded into incoming obstacles or within the area that is not interacted with. In another example, bonus objects of a game app, e.g., bonus coins in the Flappy Bird[6] game, can be chosen for ad segment integration in a random way or based on rules defined by app designers. Not all app objects are suitable for embedding ad segments. Defining which app's objects are suitable for being embedded with ad segments is best to be handled by mobile app developers, who understand well about their apps' objects and app objects' behaviors.

With Segmented Ad strategy, ad segments cannot be moved across the screen as they could in the Whole Ad strategy. Interactions with ad segments happen locally instead. Perceptive Ads implements a texture-switching mechanism that enables switching between an ad segment and the app's texture of an object. When the object texture is switched into an ad, the app's object can be granted with actions that are relevant for the ad, such as a triggering event that supports incentives for the user (e.g., discount coupons). Depending on the interaction allowances of an embedded ad object, texture switching occurs manually or adaptively. In manual texture switching, interactive ad-embedded objects (e.g., bonus coins in a game app) are switched to respective ad segments (e.g., a promotional burger ad) when they are interacted by the user. Adaptive texture switching for non-interactive (e.g., background objects) and interactive objects is based on the level of user interactivity with the app such that the texture switching does not compete with user attention. The frequency of texture-switching is lower for novice users who focus their attention on learning the app and its content, in comparison to that for expert users who easily manoeuvre the app. For example, sprites of pipes in the Flappy Bird game can be switched to show the embedded ad segments when the user progresses through the game (Fig. 6b). Determining optimal frequency for texture switching is beyond the scope of this paper.

The potential of our approach lies in the ability to transmit ad message incrementally during app usage. It captures the attention of users through repetitive patterns, similarly to how memory cues are used to improve recall [63]. This can be used to reinforce the impact of each segment in user attention and facilitate the process of putting together all the segments to understand the overall message of the ad. Naturally, determining the right split of the message and placing each of them at the right stage of the app interaction is a critical design consideration, which should ideally take into account the individual user's usage of the app. We use a history-based approach, where app usage session information is collected and analyzed to determine the right split of the message.

Overall, Perceptive Ads uses the detected level of user interactivity and disruption impact to arrive at an ad placement decision. Whole Ads/Segmented Ads strategy is used for apps with low/high level in user interactivity and disruption impact. The adaptation of ad presentation to meet with different app genres and a multitude of app's objects makes it essential to involve app developers in the design process of ads. Design choices are now split between ad designers who focus primarily on visual design of the ad [40] and app developers focus mainly on making user interaction with app and its hosted ads harmonious. App developers can inform designers which app objects are suitable to host ads/ad segments. If necessary, developers can also pre-determine the absolute/relative locations where the ads should be displayed or when it is a good time to show the ads in order to minimize disruptions impact on user-app interaction, thus reducing user annoyance. This information can be generalized and captured in *boundary* objects [32, 57] which serve as abstract containers to be used by ad designers in the process of ad decomposition and to test the ads/ad segments they design.

3.3 Implementation

We implemented a prototype of our Perceptive Ads strategy using a client-server architecture: a cloud-based server and a client running a personalized ad service and an in-app handler. Fig. 5 shows an overview of the architecture of Perceptive Ads. In the following we describe our prototype implementation in detail.

3.3.1 Cloud-based Ad-App Server.

The server implements the *Data Manager* functionality that manages the pools of ads and apps that subscribe for selected ads, and disseminates processed ads to clients. The *Data Manager* contains *Data Analyzer*, *Content*

[6]http://www.dotgears.com/

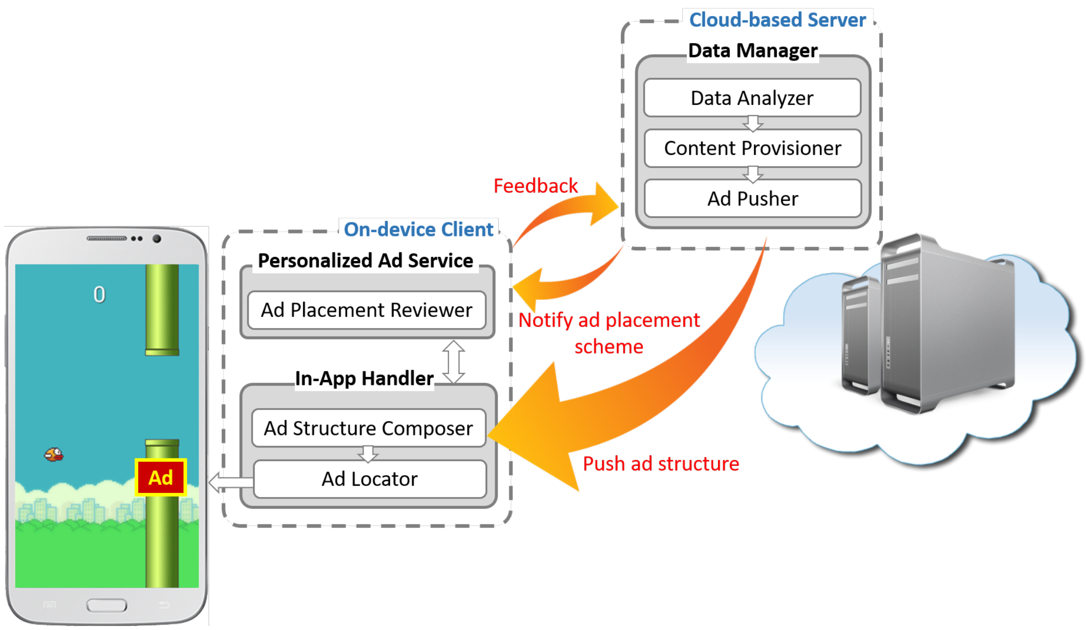


Fig. 5. Perceptive Ads framework.

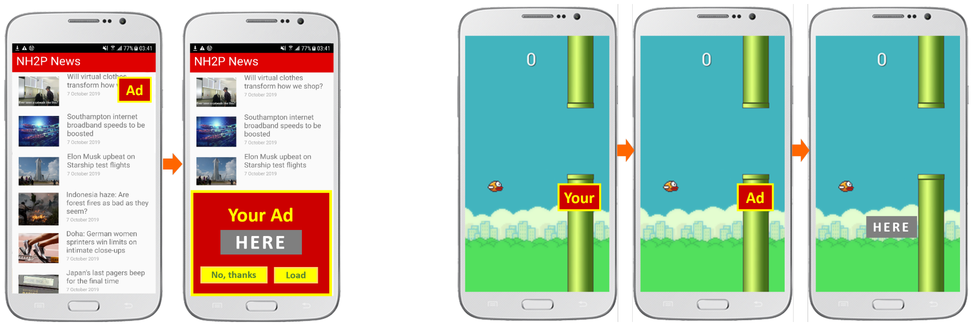
Provisioner and *Ad Pusher* components. The *Data Manager* decides the ad placement strategy for each app-ad pair based on the default level of user interactivity that the app requires whereas the *Data Analyzer* processes the ad to be fetched. The decision about ad placement strategy defines the structure of the ad: the ad will be transformed to match a specific ad placement mechanism (e.g., serving ad as a whole or as segments). Apps having low level of user interactivity will be assigned a minimalistic presentation of the ad whereas for apps with high level of user interactivity the *Content Provisioner* splits the message of the ad into segments and assigns a sequence to each of them. Decisions about ad placement strategy could be overridden by the Personalized Ad Service (see below) based on the user's profile. Finally, the server uses the *Ad Pusher* component to send the ad as notification messages to devices, such that an ad can be incrementally fetched by the client. This reduces network load by preventing too many simultaneous requests from the same client to the server.

3.3.2 On-device Client.

Personalized Ad Service implements *Ad Placement Reviewer* which reviews and revises, if necessary, the ad placement strategy proposed by the server based on the user's interactivity profile recorded by the client. For some apps, the actual level of user interactivity between a user and the selected app could be different from the default level of user interactivity required by the app. For example, the Sudoku game[7] – a logic-based number placement game – could be considered a low interactivity app for ones but high interactivity app for others if time constraint is applied to the game. The Personalized Ad Service communicates the outcome of this review – whether to keep the ad placement plan prescribed by the server or to change the ad placement strategy to match the actual level of user interactivity of the user with the app – as feedback for personalized ad prescription to the server.

In-App Handler serves the ad using the decided ad placement strategy and the ad materials fetched from the server. It implements an *Ad Structure Composer* and an *Ad Locator* component. The *Ad Structure Composer* receives the

[7] http://www.sudoku-space.com/sudoku.php



(a) (b)

Fig. 6. Perceptive Ads placement in terms of user interactivity: (a) low interactivity: an ad is appeared in minimalist representation (left) or expanded representation (right), (b) high interactivity: ad segments are showed sequentially. The actual ad content is replaced with the text "Your Ad HERE" in this figure to avoid any misimpression.

JSON-format structure of the ad from the server. A low interactivity app requires at least two ad files: a minimalistic ad format and a full content about the ad. A high interactivity app requires a collection of small images that are used to replace the texture of objects inside an app. Each small image is an intermediate object that is pre-processed by the server to match a particular object in the app and that can be displayed without extra processing. *Ad Structure Composer* further describes in detail the attributes for the prescribed ad placement strategy (e.g., location path, displaying sequence) and specifies a set of available actions that can be triggered when a user interacts with a segment (e.g., vibration, sound and screen intensity, among others). The *Ad Locator* component is responsible for synchronizing the ad with the execution flow of the app, monitoring interaction of the users with the ad (e.g., moving, tapping ad), and collecting relevant information (e.g., coordinates of the ad in the screen, session time of the app). This information is later utilized to tune the process of displaying ads based on user preferences by the Personalized Ad Service.

4 EXPERIMENTAL SETUP

We evaluate Perceptive Ads in a user study that addresses the following goals: 1) to determine how the interactivity of the user is affected when ads are included into the flow of the app and how this impacts the user's experience, and 2) to measure how effective the shown ads are.

4.1 Apps Selection

To demonstrate the potential of Perceptive Ads strategy in a naturalistic setting, we developed a custom news reader mobile app (Fig. 6a) and instrumented the mobile game app *Flappy Bird* using our framework. The news reader app serves as an example of apps with low levels in both interactivity requirements and disruption impact whereas the Flappy Bird game serves as an example of apps demanding high levels of interactivity and disruption impact. We chose the 2 apps because they represent two distinct but typical levels of interactivity widely used in day-to-day smartphone apps today. The interactivity of the news reader app is probably the most typical one and familiar with app consumers: news updates, trends apps, e-commerce apps, etc. are all basically taking the scrollable viewing/reading that allows user-paced and user-controlled content consumption. The interactivity of Flappy Bird is another typical case where relatively timely, repeated user inputs (e.g., tapping, typing) keep the user highly engaged throughout the app, seen mostly in games and other popular smartphone apps such as way-finding apps, drawing apps, social messaging apps, etc.

We systematically conducted a controlled user study with $N = 16$ participants wherein ad effectiveness and user perception towards ad served with Perceptive Ads were compared to those served with conventional ads. More insights about ad effectiveness and user perception towards ad placement in low and high levels of interactivity are investigated in a post-study probe with $N = 8$ participants. The participants in the two studies had no overlap.

4.2 Main User Study

Participants. $N = 16$ participants (11 males) consisting of researchers, students and administration staff at a University took part in our user study. The mean age of all participants was 30.3 years (SD=6). All but one participants have prior experience of using mobile apps served with conventional ads. The sole participant with no prioer experience was given additional time to get acquainted to apps served with conventional ads.

Experiment Design. The study follows a 2 x 2 within-subject design with ad placement strategies (CA: conventional ads, PA: Perceptive Ads) and levels of interactivity (LI: low interactivity, HI: high interactivity) as independent variables, resulting in 4 conditions: LI+CA, LI+PA, HI+CA and HI+PA (Table 1). We use news reader and game apps as representative examples of apps requiring low and high interactivity respectively. With each instance of these apps was randomly served one ad from the ad pool (size=7) using the conventional ad placement technique or Perceptive Ads strategy, 4 app-ad combinations are formed: news+CA, news+PA, game+CA and game+PA. The 7 ads were from well-known commercial brands including McDonald's, H&M, Adidas, Spotify, Heinz, Toyota and DHL, chosen from categories of food, clothing, footwear, media entertainment, transportation and services. By presenting well-known ads from non-controversial companies with an overall positive image to participants (instead of a mixture of variable brand familiarity), we can minimize the effect variations in brand perception would have on ad recognition and perceptions [23]. This helps to minimize potential effects from ad selection on ad effectiveness. In the news reader app, Perceptive Ads shows an ad as minimalist representation when it first appears (Fig. 6a: left) and as expanded representation (Fig. 6a: right) when user interacts with the ad using the pinch gesture or double-tap gesture. In the Flappy Bird game, Perceptive Ads shows different ad segments at different time during the game play (Fig. 6b). To provide a baseline for comparison, we instrumented our apps with conventional mobile ad placement techniques.

To obtain insights on whether the strategy alleviates or not the inclusion of mobile ads to some extent, two different types of experiments were conducted: one to measure how effective the ad is in transmitting the message to advertise, and the other to determine how the interaction of the user is affected when ads are displayed. Descriptive statistics including mean, standard deviation, frequency percentage are used for the data analysis.

Procedure. Participants were divided into 4 groups. Participants in each group were subjected to the same set of 4 conditions (Table 1a) in counterbalanced order to avoid any possible order effect. At the start of the experiment, we briefly explained our proposed approach on a general level without mentioning the contents of the ads shown to the participants. Each participant was exposed to each different condition on average for three minutes. Participants were encouraged to think out loud as they interacted with the app. After each condition, participants filled in a questionnaire about their familiarity and their experience in using the app wherein the ad was served. After completing all experiment conditions, participants were showed a possible response set of ad images (size=21) and asked to indicate which ad they had seen in each condition. The possible response set was composed of 7 test ads and 14 ads from the same categories of food, clothing, footwear, media entertainment, transportation and services that 7 test ads belong to. Presenting participants with multiple ad images of the same category was to eliminate the chance of participants' indication of a correct ad shown in the test condition just by remembering its category. Participants rated their perception about the ads in terms of annoyance, disruptiveness, ad manipulation as well as potential benefits brought by interacting with the ads on a 5-point Likert-style response scale (1: Strongly disagree,

Conditions	Description
LI+CA	Low interactivity + Conventional ad placement
LI+PA	Low interactivity + Perceptive Ads placement
HI+CA	High interactivity + Conventional ad placement
HI+PA	High interactivity + Perceptive Ads placement

(a)

Conditions	Description
LI+WA	Low interactivity + Whole Ad
HI+SA	High interactivity + Segmented Ad

(b)

Table 1. Experiment conditions used in (a) user study and (b) post-study probe

2: Disagree, 3: Neutral, 4: Agree and 5: Strongly agree). Basic demographic information about age and gender of participants were also collected in this questionnaire. Each session took approximately 30 minutes.

4.3 Post-study Probe

Since high interactivity apps (e.g., the game app) require more attention – thus susceptible to disruption, and timely interactivity from users, we segmented the ad into segments and integrated them into the flow of the game (HI+SA). These ad segments are sequentially shown as the game progresses, some of which embedded into the game objects that give bonuses in game upon receiving the user's interaction (e.g., tapping on an ad segment). Characterized by discrete and non real-time interactivity, low interactivity apps (e.g., the news reader app) allow more rooms for occasionally interacting with ad, so Perceptive Ads initially serves the ad as an icon at the screen location where the user less likely interacts with app content (e.g., the upper middle or right corner of the screen) in the news reader app (LI+WA). With simple touch gestures such as dragging, swiping, double tapping, the user could move, dismiss, or toggle the ad content between icon view and detailed view.

A post-study probe was conducted in order to understand in more detail about user perception and ad effectiveness when ads were served using the above two Perceptive Ads' adaptive ad placement strategies based on the level of user interactivity and disruption impact. $N = 8$ participants were introduced the 2 conditions (Table 1b). The procedure for this post-study probe was similar to that of the main study, but using only apps having ads served using the 2 strategies of Perceptive Ads: news+WA and game+SA. The post-study probe concluded with open-ended discussion.

5 RESULTS

Highlights of our results are the following:

- *Perceptive Ads* significantly improved ad effectiveness and user perception in comparison to conventional ad placement mechanisms (Section 5.1).
- User annoyance was significantly reduced by 43.75% (Section 5.2), while ad effectiveness was improved by 37.5% (Section 5.3).
- Besides annoyance and effectiveness, our framework demonstrates to be effective in significantly reducing disruption caused by ads (Section 5.4) and maintaining positive user engagement with ads (Section 5.5).
- The robustness of Perceptive Ads was demonstrated on both low and high levels of user interactivity and disruption impact. Insights were gained on the impact of Perceptive Ads strategies (Section 5.6).

5.1 Overall Performance

We first compare the overall difference of using Perceptive Ads (PA) and conventional ad (CA) placements. In terms of the balance between ad effectiveness and user annoyance, Perceptive Ads reduces user annoyance towards ads by 43.75% (Fig. 7a) while at the same time increasing advertisement effectiveness by 37.5% (Fig. 7b). Disruptiveness

	CA			PA		
Feature	**Median**	**Mean**	**SD**	**Median**	**Mean**	**SD**
Annoyance	4	3.88	0.619	3	3.06	0.854
Effectiveness	0	0.37	0.492	1	0.75	0.440
Disruption	4	3.62	0.885	4	3.56	0.727
Usefulness	2	2.31	0.873	4	3.38	1.147
Control	2	2.37	1.455	4	3.56	1.031

(a)

	LI+PA			HI+PA		
Feature	**Median**	**Mean**	**SD**	**Median**	**Mean**	**SD**
Annoyance	4	3.25	1.389	3	2.88	1.458
Effectiveness	1	0.88	0.354	1	0.75	0.463
Disruption	3	3	1.069	2	2.38	1.302
Usefulness	4	4	0.926	3	2.75	0.886
Control	4	4	0.926	2	1.88	0.641
Benefits	4.5	4.25	0.886	3	3	1.069

(b)

Table 2. Results statistics. (a) Perceptive Ads (PA) vs. Conventional Ads (CA) placement. (b) Low Interaction + Perceptive Ads (LI+PA) vs. High Interaction + Perceptive Ads (HI+PA).

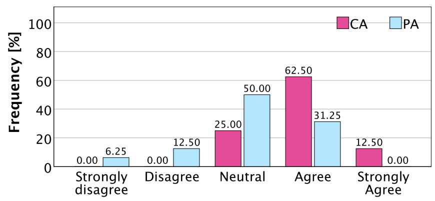
presents a similar response for both strategies, with Perceptive Ads causing lower disruption than conventional ad (Fig. 7c: Perceptive Ads: 56.25%, conventional ad: 62.50%). When analysing the perceived usefulness of ad interaction, 62.50% of the participants perceived the usefulness of interacting with Perceptive Ads whereas only 6.25% of participants felt it may be useful to interact with conventional ad (Fig. 7d). Similarly, for perceived sense of control, 43.75% participants perceived they have more controls over Perceptive Ads in comparison to conventional ad (Fig. 7e). These participants indicated that the perception of being able to control the ad placement contributes to reduce their negative perception towards ads. Descriptive statistical distribution is reported in Table 2.

5.2 User Annoyance

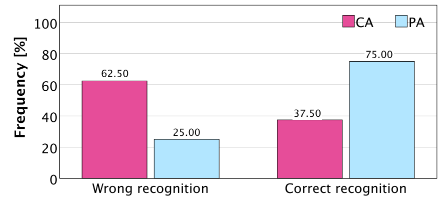
Capturing user's annoyance was based on participants' rating on a 5-point Likert scale (1: Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree and 5: Strongly agree) in response to the statement "The ad annoyed me" stated in the post-task questionnaire. Quantitative analysis shows that 75% participants felt annoyed with conventional ad (Median = 4, Mean = 3.88, SD = 0.619) whereas only 31.25% participants perceived annoyance with Perceptive Ads (Median = 3, Mean = 3.06, SD = 0.854). Two-sample Wilcoxon signed-rank test indicates there is a significant effect of ad technique on annoyance (z = -2.484, p = 0.013) with a large effect size (r = 0.621). Also the number of participants with neutral perception towards ad placement is higher with Perceptive Ads strategy (50%) than with the conventional ad (25%) strategy. Notably, 18.75% participants indicated that they did not feel annoyed towards Perceptive Ads placement and interaction whereas all participants either felt annoyed or neutral towards conventional ad placements. The positive movement in user perception from being annoyed to neutral and eventually to not being annoyed demonstrates the effectiveness of Perceptive Ads over conventional ad placement.

5.3 Ad Effectiveness

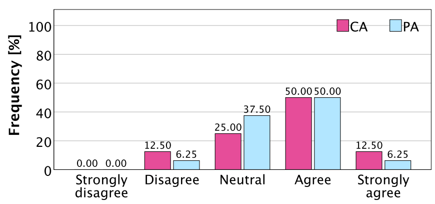
Effectiveness was measured based on participants' recognition of the ads shown in a particular test condition (0: wrong recognition, 1: correct recognition). Specifically, 21 ad images, of which 7 ads were shown randomly to participants in the controlled experiments, were presented to participants. Participants were asked to recognize the ads encountered during the use of the apps for the question: "Which of the following ads did you see during the task...?". Note that ads were randomly introduced to participants in each condition and the questionnaire was presented to participants after all tasks were completed. Advertisement effectiveness is increased by 37.5% when using Perceptive Ads (Median = 1, Mean = 0.75, SD = 0.44) compared to the conventional ad (Median = 0, Mean = 0.37, SD = 0.492). Wilcoxon test is applied to assess whether advertisement efficiency is higher for perceptive or conventional technique. Interestingly, results demonstrate a significant difference (z = -3.464, p = 0.001) with a large effect size (r = 0.612). Throughout the experiment, we observed that the users' initial stance towards any appearance of ads during the use of the apps was to ignore them regardless of the format of the ads. The



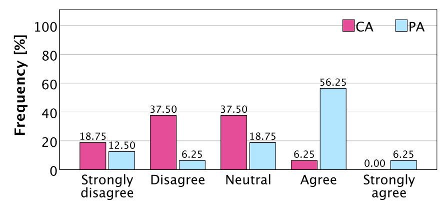
(a) Participants' responses to the statement "The ad annoyed me" (z = -2.484, p = 0.013, r = 0.621)



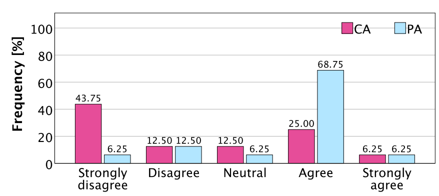
(b) Ad effectiveness measured by participants' responses to the question: "Which of the following ads did you see during the task...?" (z = -3.464, p = 0.001, r = 0.612)



(c) Participants' responses to the statement "The ad disrupted my usage of the app" (z = -0.176, p = 0.86, r = 0.044)



(d) Participants' responses to the statement "Being able to interact with the ad was useful" (z = -2.571, p = 0.01, r = 0.643)



(e) Participants' responses to the statement "I was able to control the viewing of the ad" (z = -2.223, p = 0.026, r = 0.556)

Fig. 7. Conventional ads vs. Perceptive Ads: (a) rating of participants' annoyance (b) ad effectiveness measured by participants' ability to recognize correct ads shown in the experiment, (c) rating of ad disruption on app usage, (d) rating of participants' perception on the usefulness of ad interaction, and (e) rating of participants' perceived sense of control over ad placement. CA: conventional Ads, PA: Perceptive Ads.

pre-conceived notion of the ads being disruptive and something to be avoided is understandable as it must have formed over time, in most cases through encountering various ads in the past.

5.4 Ad Disruption

Measure of ad disruption was based on participants' rating on the 5-point Likert-style response scale (1: Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree and 5: Strongly agree) in response to the statement "The ad disrupted my usage of the app" stated in the post-task questionnaire. 62.5% (Median = 4, Mean = 3.62, SD = 0.885) of the participants indicated that conventional ad placement disrupted their interaction with the app whereas 56.25%

(Median = 4, Mean = 3.56, SD = 0.727) of participants responded that Perceptive Ads caused disruption (Fig. 7c). There was no significant difference observed between ad placement techniques and perceived ad disruption (z = -0.176, p = 0.86, r = 0.044). However, evidences of reduced level of distraction with Perceptive Ads were found numerous times in the open-ended comments after the tasks: *"Less distracting"* (P2 of group 1), *"Less distraction"* (P4 of group 1, P4 of group 2), *"The game ads were not distractive"* (P3 of group 2), *"It is movable so I'm not distracted"* (P1 of group 4), *"It wasn't disturbing with the usage of the app. They weren't as annoying as in the conventional way"* (P2 of group 4), *"... less distracting and less wasted space. For the game, at least the ads were integrated into the game's elements, rather than a disruptive overlay."* (P4 of group 4).

5.5 Providing a Means for Users to Engage with Ads

Providing a means for users to find more information about the advertised products or brands and eventually purchase them is critical in advertising. With advertisers are typically concerned with getting their advertisement message reached target users, tapping or clicking on an ad would direct the user to advertiser's website. While this approach works well for users who are interested with ads, those who are not would find in-app ads nuisance. In fact, only 15.63% of participants tapped on ads placed by conventional ad. Reasons for not interacting with ads include: having no interest in ads (e.g., *"...generally not interested in ads on app"* – P3 of group 1), distrust (e.g., *"privacy concerns, worry about malware or viruses"*–P4 of group 4, *"I think it will open another view"* – P2 of group 1), or detest (e.g., *"I do my best to avoid ads."* – P3 of group 3) towards ads.

With the new ad presentation and adaptive interactivity, Perceptive Ads drew participants' attention on what it could do. Participants expressed how much they agree to the statement "Being able to interact with the ad was useful" on the 5-point Likert-style response scale (1: Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree and 5: Strongly agree). 62.50% (Median = 4, Mean = 3.38, SD = 1.147) participants perceived the usefulness of interacting with Perceptive Ads whereas only 6.25% (Median = 2, Mean = 2.31, SD = 0.873) of participants felt it may be useful to interact with conventional ads (Fig. 7d). Wilcoxon test indicates that the difference between the technique is significant (z = -2.571, p = 0.01) with a large effect size (r = 0.643). Participants explained that the ads drew their attention due to relevant advertised content (e.g., *"Some sales events for something I have being looking for"*–P1 of group 4), uniform presentation between the shown ad and the app interface (e.g., *"it blends with app*–P1 of group 1). Interestingly, knowing that initial interactions with ads would not immediately direct them to the ad targeted action (e.g., opening up a website of the advertised product/company), participants felt more at ease to explore the ad's behaviors and its content. As P4 of group 4 commented, *"You can open it if you're curious, but move it almost entirely off the screen if you are not, or when you are done looking at it."*. This implies an opportunity for neutralizing bias in ad engagement, by designing multi-level content for ad and making ad interaction transparent to users, it affirms that the reason for an ad existence in the mobile app is for raising user awareness about the advertised content, which can be explored further based on the user's level of interest.

Participants' perceived sense of control over ad placement was captured through their responses on the 5-point Likert-style response scale (1: Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree and 5: Strongly agree) to the statement "I was able to control the viewing of the ad". 75% (Median = 4, Mean = 3.56, SD = 1.031) participants expressed their strong sense of control over the placement and the view of Perceptive Ads through ad interaction. 31.25% (Median = 2, Mean = 2.37, SD = 1.455) participants conveyed that they could manually control the viewing of the ads served by conventional ad placement technique. Their common ways include the use of two thumbs to block the view of the banner app shown at the bottom of the screen, quickly closing the popup ad, or not looking at the ad region at all. Wilcoxon test indicates there is a significant effect of ad technique on control (z = -2.223, p = 0.026) with a large effect size (r = 0.556). Being able to make choice over what to do with the placement of ads increase user acceptance towards the co-location of ads with app content.

In summary, qualitative and quantitative analyses show that Perceptive Ads significantly reduces user annoyance and improves ad effectiveness compared to conventional ad placements. There is statistically significant evidence that participant's sense of control over ad placement and perceived usefulness of ad interaction were realized when ads were placed using Perceptive Ads in comparison to conventional ad placement. Although participants perceived either way of ad placement as a disruption to their usage of the app, positive user perception and perceived usefulness of ad interaction influence participants' acceptance of in-app ads. This is consistent with findings in marketing research which suggest that perceived usefulness has significant impact on user's intention to accept mobile advertising, thus helping to retain mobile app users [27].

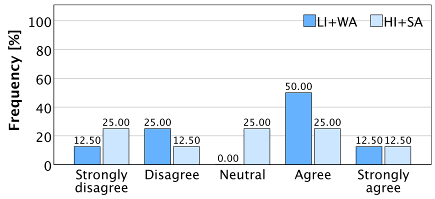
5.6 Post-study Probe

To further demonstrate the potential of our method, we perform a follow up evaluation of Perceptive Ads where compare the whole and segmented advertisement strategies against each other.

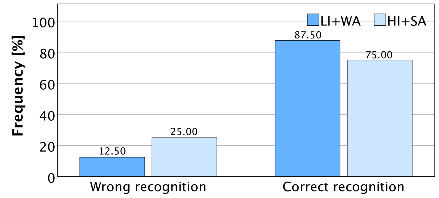
User Annoyance and Ad Effectiveness. Results of the post-study probe are showed in Fig. 8. From the figure, 62.5% (Median = 4, Mean = 3.25, SD = 1.389) of participants perceived annoyed with ad placement in the news reading app, 37.5% (Median = 3, Mean = 2.88, SD = 1.458) of participants felt annoyed with ad placement in the game app. Majority of participants commented that embedding ad segments into the app objects in the game app (Segmented Ad) created a sense of surprise and curiosity about the ad segments, making the participants feel less annoyed towards ads in comparison to seeing a floating icon-form ad in the news reading app (Whole Ad). However, just as P7's commented, *"but I am uncertain about the Ad. The reason is my attention was divided, while focus on the main content (game) make it hard to spot precisely the content of the Ad"*, focusing on the high demanded temporal interactions with the game made it difficult to comprehend the overall ad message for some participants. Quantitative results show that 87.5% (Median = 1, Mean = 0.88, SD = 0.354) and 75% (Median = 1, Mean = 0.75, SD = 0.463) of participants correctly recognized the ads served using Whole Ad placement and Segmented Ad placement respectively (Fig. 8b). When compared against each other, no statistically significant effects were found for ad effectiveness (z = -0.577, p = 0.564, r = 0.204) or user annoyance (z = -0.828, p = 0.408, r = 0.293).

Ad Disruption. Fig. 8c shows that 62.5% (Median = 2, Mean = 2.38, SD = 1.302) of participants did not perceive Segmented Ad placement to disrupted their interaction with app content as *"it is obviously (an) advertisement, nothing to do with me, I just focus on my game"* (P1 of group 2). 25% (Median = 3, Mean = 3, SD = 1.069) of participants indicated that Whole Ad placement disrupted their interaction with the app because *"it forced me to drag to hide"* (P2 of group 1). Participants positively perceived the integration of ad segments into the flow of the game app as bringing additional information (e.g., *"I may go for that McDonald's burger deal after this game"* – P7 of group 3) that they may need without taking additional screen space in comparison the insertion of the ad icon – even in minimalistic format – atop the app content. Insignificant effect was found (z = -1.186, p = 0.236, r = 0.420) between the ad placement technique and participants' perceived ad disruption.

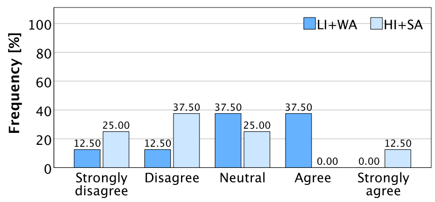
Ad Engagement. With Whole Ad placement, Perceptive Ads enable participants to interact with an ad shown within a low-interactivity app whereas the degree of interaction with the segmented ad shown in a high-interactivity app is minimal. Participants did not feel interacting with ad rendered using the Segmented Ad technique useful because that would impact the interaction quality with app content, unless ad segments are highly relevant to the app content (Fig. 8d). In addition, high level of user interactivity with app content made it difficult for participants to *'link'* ad segments together. This impeded participants' comprehension of the overall meaning of ad message. Quantitative results show that 87.5% (Median = 4, Mean = 4, SD = 0.926) of participants rated that it was useful in interacting with the ad using Whole Ad placement whereas 12.5% (Median = 3, Mean = 2.75, SD = 0.886) of participants perceived the interactions with Segmented Ad placement useful. Examples of participants' comments include: *"I am more focused on the news after moving the ad out of the way"* (P2 of group 1), or *"...with this one (ad in the news app), I can see more details of the advertisement or just hide it away"* (P7 of group 3). Strong



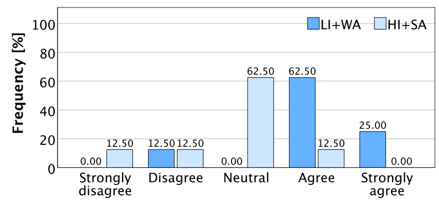
(a) Participants' responses to the statement "The ad annoyed me" (z = -0.828, p = 0.408, r = 0.293)



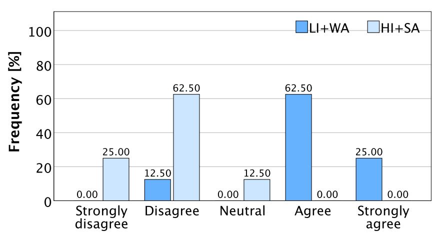
(b) Ad effectiveness measured by participants' responses to the question: "Which of the following ads did you see during the task...?" (z = -0.577, p = 0.564, r = 0.204)



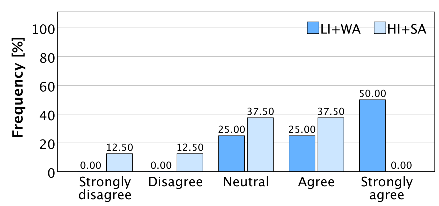
(c) Participants' responses to the statement "The ad disrupted my usage of the app" (z = -1.186, p = 0.236, r = 0.420)



(d) Participants' responses to the statement "Being able to interact with the ad was useful" (z = -2.428, p = 0.015, r = 0.858)



(e) Participants' responses to the statement "I was able to control the viewing of the ad" (z = -2.555, p = 0.011, r = 0.903)



(f) Participants' responses to the statement "Flexible placements of the ad helped me to regain device screen space" (z = -2.428, p = 0.015, r = 0.858)

Fig. 8. Whole Ads (WA) vs. Segmented Ads (SA): (a) rating of participants' annoyance (b) ad effectiveness measured by participants' ability to recognize correct ads shown in the experiment, (c) rating of ad disruption on app usage, (d) rating of participants' perception on the usefulness of ad interaction, and (e) rating of participants' perceived sense of control over ad placement, and (f) rating of participants' perception on benefits of ad placement. LI: low interactivity, HI: high interactivity.

significant effects (z = -2.428, p = 0.015, r = 0.858) identified by Wilcoxon test indicates that participants had more favourable attitude towards Whole Ad placement than Segmented Ad placement.

From participants' feedback, being able to minimise and to move the shown ad to the device screen sides offered a sense of control over the ad placement. Fig. 8e shows 87.50% (Median = 4, Mean = 4, SD = 0.926) of participants perceived they have control over ad placement using Whole Ad approach. No participant perceived any control on Segmented Ad placement. Wilcoxon test shows a strong significant effect between ad placement technique and perceived sense of control (z = -2.555, p = 0.011, r = 0.903). Notably, majority of participants commented that the capability to interact with ads is a significant factor in mitigating their annoyance towards ads.

One of the chief benefits of Perceptive Ad placement strategy is its ability in reclaiming the screen space otherwise permanently occupied by the ad. 75% (Median = 4.5, Mean = 4.25, SD = 0.886) of participants perceived the benefits brought by the interaction with Whole Ad placement to make it *"less wasted my phone screen which is already small"* (P5 of group 1), whereas 37.50% (Median = 3, Mean = 3, SD = 1.069) of participants perceived the benefits of Segmented Ad placement because *"the ad parts become graphics of the game instead of a popup"* (P6 of group 4). Strong significant effect of ad placement technique on perceived ad benefits is found with a Wilcoxon test (z = -2.428, p = 0.015, r = 0.858).

Results of the post-study probe show that presenting an ad as a whole cf. series of ad segments has equal impact on user perception and ad effectiveness. By empowering users to be in control of ad placement, Whole Ad strategy was found to stimulate higher perceived usefulness of ad interaction, perceived sense of control over ad placement and perceived benefits of ad placement strategy than Segmented Ad strategy. However, it is not recommended to apply Whole Ad strategy for every type of app. Recall that with Perceptive Ads placement, promoting or constraining ad interaction requires consideration in both of the level of user interaction with the app content and the level of disruption impact. Whole Ad strategy is suitable for apps with low level of user interaction and disruption impact. Segmented Ad strategy should be considered for apps characterized by high level of user interaction and disruption impact.

6 DISCUSSION

Balancing Segmentation and Interactivity. For applications with high interactivity requirements, Perceptive Ads segments the ad into a small, icon-sized visual representation of the product, its textual information and the price, and allocates these elements in the appropriate stages of the app. While this was well-suited for the game mechanics employed in Flappy Bird, other applications may require alternative ways to segment and present advertisements. We envision that this step can be automated through tools that collect feedback from the user's interactions and rely on AI-based models to identify best segmentation and presentation formats.

Acceptance of Ad Segments. Embedding ad segments into app's objects and scenes divided opinion among participants. Most participants supported the idea, such as *"This one is in the best form of ad I can imagine. It mixed into the game without much distraction."* (P4 of group 2) and *"I like it when ads are placed as part of the game design, it looks realistic even."* (P2 of group 2). However, some participants preferred to have a clearer separation between ads and app content unless there is strong relationship between them, for example, *"the ads were integrated into the game's elements, but ultimately still didn't add anything substantive to the game's world."* (P4 of group 4). Integrating ads into app's flow and logic requires not only the matching of user interface (*"If it is a text only ad relevant to the app and if it is clearly written in the same style as the app."* – P2 of group 2) and interaction between app and ad (*"If it blends with app"* – P1 of group 1), but also user's incentives (*"Bonuses and perks relating to use of the app"* – P2 of group 1).

Ad Behaviour and User's Control. With existing in-app advertisements, users are forced to interact with (potentially undesirable) advertisements for fixed periods of time. As we demonstrated, lack of control over ad placement can lead to frustration and annoyance during app usage. Our proposed Perceptive Ads provides a new mechanism that enables app users to control the ad placement within the app – even if users have no control over which ads would be shown to them. We showed that allowing some level of control over ad placement reduces user annoyance while improving advertising effectiveness. By minimizing user annoyance and frustration, Perceptive Ads helps users to cope with ads served in mobile apps, which in turn helps mobile app developers retain their users. Our work also shows that this facilitates positive user engagement with the app and its embedded ads.

Target groups. Perceptive Ads has been designed primarily to benefit end-users and app developers while also taking into consideration the needs of other stakeholders, including advertisement providers and the advertisers. Our work shows that the trade-off between annoyance and effectiveness of ads can be regulated to reduce app usage disruption toward users. We also demonstrate that Perceptive Ads provide more flexibility for developers to control the behavior of ads within applications, such that the developer can regulate ad interactions with users. However, Perceptive Ads also provides indirect benefits to other groups, such as advertising companies and advertisement distribution entities. Our results showed higher effectiveness for the advertisements than in conventional strategies, which helps to motivate advertisers and advertisement companies to adopt our approach. As ads become more noticeable by users, the rate in which ads are clicked, explored, and criticized by users increases. This suggests that advertising companies can tune their designs to make them more attractive for different audiences. At the same time, distribution entities can also experience an improvement in monitoring effectiveness of ads without changing their underlying metrics and channels that quantify such metrics, e.g., clicks or other forms of interaction.

Acceptability of Ads. Generally, any ads, regardless of their form or interactivity, will be disliked by most users. While our Perceptive Ads sought to minimise this prevalent dislike of ads, there will be users who may prefer other types of ad mechanisms. Indeed, there are users that are willing to pay a subscription fee to avoid interacting ads. Our Perceptive Ads provides an alternative to minimize the disruption of ads caused during app usage. In addition, there will be app developers who might not be open for integrating Perceptive Ads within their applications, and advertisers who may be skeptical about ad effectiveness when ad messages are presented in a different way than in more traditional, currently adopted formats. While Perceptive Ads has the potential to improve the effectiveness of ads, especially compared to current state-of-the-art placement strategies, we would like to emphasize that Perceptive Ads is not meant to replace existing ad placement techniques, rather it is an alternative solution to deal with the problem of ads in apps.

Room for Improvements. Our results demonstrated the effectiveness of Perceptive Ads in two application case studies. Naturally there is more work to extend and generalize the framework for other types of apps. For example, integrating the proposed approach within the mobile app development life-cycle would require more effort. In our current implementation, the app objects embedded into ad segments need to be determined by app developers. This process can be partially automated using segmentation algorithms and logging how users interact with the different interface components. While this can increase the effort of developers, the lower disruption caused by our strategy combined with its high effectiveness should motivate developers to carry out these operations. Another potential optimization is to use interface logging to customise for different applications or users the area where the advertisements are shown.

Design Implications for Advertisement Strategies. While Perceptive Ads were seen as less intrusive or annoying while enhancing the effectiveness at the same time, the nature of our one-off usability experiment as conducted in the study means it does not capture a long-term impact of such an ad strategy. Was it effective due to its inherent quality of the strategy proposed or due to its novelty to the users? As P1 of group 3 commented: *"The advertisements were not too invasive, but this might depend on the fact that I have never seen this type of advertisements and I found them curious."* These may imply that advertisement mechanisms for mobile apps should change their dynamics periodically before users get so used to them and take them for granted, so that ads can be perceived more distinctively and have the most influence over users. This warrants a future research to ascertain the effectiveness of ad strategies when exposed to the users for an extended period of time.

Implementation and Scalability. Compared to existing advertisement models, our proposed mechanism does not induce extra processing cost or memory load on the mobile device. The utilization of push notifications and small size files provides Perceptive Ads an advantage over existing methods as ads can be incrementally fetched from a remote location. Moreover, when compared to same execution conditions (network and device), the utilization of intermediate objects by our framework can accelerate even further the loading of an ad in a mobile app as the device does not have to perform any additional process over the ad. Our study demonstrates that users are willing to adapt to new methods for receiving ads. However, the inclusion of those in the life cycle of an app can be very costly if they need to be changed too often. While this is not a problem for large companies, it could become a potential threat for small-scale developers. As a result, mobile apps will need to be designed/integrated with an ad insertion mechanism in such a way as to require minimum additional resources and updates as the ads evolve over time. Although this paper took on the ad placement strategies mainly as a design problem, wider issues on the low-cost and scalable solutions that embrace the strategies will need to be considered for it to become successful.

Monitoring User Attention and Interactivity. Our experiments showed Perceptive Ads to be effective when the level of user interactivity and attention demand can be uniquely quantified. However, in some cases the level of attention and interactivity may be difficult to capture and the appropriate level can vary across different actions and/or across devices. As an example, when using Netflix or another movie streaming service, interactivity demands are mostly low, but attention levels vary depending on user activity. When the user is browsing the service catalogue, both attention and interactivity levels tend to be low. Once the user starts to watch a programme, the attention level increases while interaction levels decrease even further. However, when the user uses a smartwatch as an input device to control the browsing/playback of the movie shown on a separate display screen [42], user interactivity is captured by the smartwatch whereas the smart display draws user attention. Adapting to this type of situations would require integrating different types of services for monitoring user activity as well as user attention. For example, many smartphones analyse images from front-facing camera to detect whether the user's eyes are looking toward the screen or away from it. Such functionality could be combined with touch-screen input monitoring to obtain better estimates of the user's interaction and attention levels.

Ad Placement and Presentation in Multi-device Usage. Perceptive Ads strategy studied in this paper is for visual engagement and evaluated in the context of using a single mobile device. Along with the growing use of multiple devices [14] come additional usability issues related to dynamic changes in device membership [44]. Determining which device shows the ad when the user keeps switching his/her attention to different devices would require further research, and similarly there is a need for information on whether differing presentation modes are required on the different devices to make the advertisements more noticeable. An example for such situation is when the user mainly interacts with the app on one device (e.g., looking at the arrow symbols in a wayfinding app running on the smartwatch while walking) while occasionally accessing the same app on another device (e.g., pulling out the phone for detailed information and map using the same wayfinding app). Minimizing user annoyance while maintaining ad retention in multi-device usage requires further research that addresses additional design considerations, such as, ad distribution and shifting among devices.

Other Domains. Thus far we have exclusively focused on mobile advertising. However, our results have potential impact on interface design in other domains also. One such example is in the area of computer-supported collaborative learning where the design factors of Perceptive Ads can be applied in designing *shifting cues* that guide spontaneous shifts in user interactions between personal devices and devices in the environment [43]. Another example is the design of visual memory cues. Improving the effectiveness of visual memory cues without disrupting the user's task or causing user annoyance is essential for many other application domains, e.g., for aiding individuals with cognitive disabilities or enhancing long-term learning processes.

7 SUMMARY AND CONCLUSIONS

While ads have become a key mechanism to monetize mobile application development and reward developers, they can also severely hamper user experience. We have shown that this trade-off can be mitigated, at least partially, without sacrificing on user experience. Specifically, we developed Perceptive Ads as a new advertisement placement strategy that considers interactivity and disruption impact as decision factors for determining optimal advertisement placement in mobile apps. This allows Perceptive Ads to tailor the presentation of advertisements – and the interactions linked with each advertisement – according to the characteristics of the user and the application hosting the ad. The key intuition in Perceptive Ads is to place the advertisements in regions where they are salient, but do not hamper interactions, and to design interactions with user's current task in mind. Through a user study with $N = 16$ participants, we demonstrated that our approach improves advertising effectiveness, reduces user's frustration levels, and improves control over advertisements compared to conventional mobile app placement strategies. Our work provides a foundation for designing intelligent advertising strategies that consider all stakeholders in the mobile app ecosystem and that provide added value to each of them. Beyond advertising, our strategy can be adopted for designing more effective visual cues, e.g., for supporting learning or for enhancing human memory.

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REFERENCES

[1] Lauri Aalto, Nicklas Göthlin, Jani Korhonen, and Timo Ojala. 2004. Bluetooth and WAP push based location-aware mobile advertising system. In *Proceedings of the 2nd international conference on Mobile systems, applications, and services*. ACM, 49–58. https://doi.org/10.1145/990064.990073

[2] Micah Adler, Phillip B Gibbons, and Yossi Matias. 2002. Scheduling space-sharing for internet advertising. *Journal of Scheduling* 5, 2 (2002), 103–119. https://doi.org/10.1002/jos.74

[3] Maximilian Altmeyer, Kathrin Dernbecher, Vladislav Hnatovskiy, Marc Schubhan, Pascal Lessel, and Antonio Krüger. 2019. Gamified Ads: Bridging the Gap Between User Enjoyment and the Effectiveness of Online Ads. In *Proceedings of Conference on Human Factors in Computing Systems (CHI '19)*. ACM, New York, NY, USA, Article 182, 182:1–182:12 pages. https://doi.org/10.1145/3290605.3300412

[4] Jeff Avery, Daniel Vogel, Edward Lank, Damien Masson, and Hanae Rateau. 2019. Holding Patterns: Detecting Handedness with a Moving Smartphone at Pickup. In *Proceedings of the 31st Conference on l'Interaction Homme-Machine (IHM '19)*. Association for Computing Machinery, New York, NY, USA, Article Article 7, 7 pages. https://doi.org/10.1145/3366550.3372253

[5] Gilles Bailly, Jörg Müller, Michael Rohs, Daniel Wigdor, and Sven Kratz. 2012. ShoeSense: a new perspective on gestural interaction and wearable applications. In *Proceedings of the Conference on Human Factors in Computing Systems (SIGCHI'12)*. ACM, 1239–1248. https://doi.org/10.1145/2207676.2208576

[6] Hrvoje Benko, Andrew D. Wilson, and Patrick Baudisch. 2006. Precise Selection Techniques for Multi-touch Screens. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI '06)*. ACM, New York, NY, USA, 1263–1272. https://doi.org/10.1145/1124772.1124963

[7] Joanna Bergstrom-Lehtovirta and Antti Oulasvirta. 2014. Modeling the Functional Area of the Thumb on Mobile Touchscreen Surfaces. In *Proceedings of Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 1991–2000. https://doi.org/10.1145/2556288.2557354

[8] Humayun Kabir Chowdhury, Nargis Parvin, Christian Weitenberner, and Michael Becker. 2010. Consumer attitude toward mobile advertising in an emerging market: An empirical study. *Marketing* 12, 2 (2010), 206–216.

[9] Mark D Corner, Brian N Levine, Omar Ismail, and Angela Upreti. 2017. Advertising-based Measurement: A Platform of 7 Billion Mobile Devices. In *Proceedings of the 23rd Annual International Conference on Mobile Computing and Networking (MobiCom'17)*. ACM, 435–447. https://doi.org/10.1145/3117811.3117844

[10] Niranjan Damera-Venkata and José Bento. 2012. Ad Insertion in Automatically Composed Documents. In *Proceedings of the 2012 ACM Symposium on Document Engineering (DocEng '12)*. ACM, New York, NY, USA, 3–12. https://doi.org/10.1145/2361354.2361358

[11] Esther David and Rina Azulay. 2012. No More Damaging Ads on Your Own Webpage – Strategy Proof Mechanisms for Ad Placement. In *Proceedings of the The 2012 IEEE/WIC/ACM International Joint Conferences on Web Intelligence and Intelligent Agent Technology - Volume 02 (WI-IAT '12)*. IEEE, Washington, DC, USA, 140–145. https://doi.org/10.1109/WI-IAT.2012.147

[12] Sanorita Dey, Brittany Duff, Niyati Chhaya, Wai Fu, Vishy Swaminathan, and Karrie Karahalios. 2020. Recommendation for Video Advertisements based on Personality Traits and Companion Content. In *Proceedings of the ACM International Conference on Intelligent User Interfaces (IUI 2020)*.

[13] Motahhare Eslami, Sneha R. Krishna Kumaran, Christian Sandvig, and Karrie Karahalios. 2018. Communicating Algorithmic Process in Online Behavioral Advertising. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Article 432, 13 pages. https://doi.org/10.1145/3173574.3174006

[14] Huber Flores, Agustin Zuniga, Farbod Faghihi, Xin Li, Samuli Hemminki, Sasu Tarkoma, Pan Hui, and Petteri Nurmi. 2020. COSINE: Collaborator Selector for Cooperative Multi-Device Sensing and Computing. In *IEEE International Conference on Pervasive Computing and Communications (PerCom 2020)*.

[15] Ari Freund and Joseph (Seffi) Naor. 2002. Approximating the Advertisement Placement Problem. In *Proceedings of the 9th International IPCO Conference on Integer Programming and Combinatorial Optimization*. Springer-Verlag, Berlin, Heidelberg, 415–424. http://dl.acm.org/citation.cfm?id=645591.660074

[16] Krzysztof Gajos and Daniel S. Weld. 2004. SUPPLE: Automatically Generating User Interfaces. In *Proceedings of the 9th International Conference on Intelligent User Interfaces (IUI '04)*. ACM, New York, NY, USA, 93–100. https://doi.org/10.1145/964442.964461

[17] Cuiyun Gao, Yichuan Man, Hui Xu, Jieming Zhu, Yangfan Zhou, and Michael R. Lyu. 2017. IntelliAd: Assisting Mobile App Developers in Measuring Ad Costs Automatically. In *Proceedings of the 39th International Conference on Software Engineering Companion (ICSE-C '17)*. IEEE Press, Piscataway, NJ, USA, 253–255. https://doi.org/10.1109/ICSE-C.2017.123

[18] Tom Geller. 2014. How Do You feel? Your computer knows. In *Communications of the ACM.*, Vol. 57. https://doi.org/10.1145/2555809

[19] Michael C Grace, Wu Zhou, Xuxian Jiang, and Ahmad-Reza Sadeghi. 2012. Unsafe exposure analysis of mobile in-app advertisements. In *Proceedings of the fifth ACM conference on Security and Privacy in Wireless and Mobile Networks (WISEC '12)*. ACM, 101–112. https://doi.org/10.1145/2185448.2185464

[20] Jiaping Gui, Stuart Mcilroy, Meiyappan Nagappan, and William G. J. Halfond. 2015. Truth in Advertising: The Hidden Cost of Mobile Ads for Software Developers. In *Proceedings of the 37th International Conference on Software Engineering - Volume 1 (ICSE '15)*. IEEE Press, Piscataway, NJ, USA, 100–110. http://dl.acm.org/citation.cfm?id=2818754.2818769

[21] Jiaping Gui, Meiyappan Nagappan, and William GJ Halfond. 2017. What Aspects of Mobile Ads Do Users Care About? An Empirical Study of Mobile In-app Ad Reviews. *arXiv preprint arXiv:1702.07681* (2017).

[22] Parissa Haghirian, Maria Madlberger, and Andrea Tanuskova. 2005. Increasing advertising value of mobile marketing-an empirical study of antecedents. In *Proceedings of the 38th Annual Hawaii International Conference on System Sciences (HICSS'05)*. IEEE, 32c–32c. https://doi.org/10.1109/HICSS.2005.311

[23] Muhammad Hamid, Shahid Rasool, Asif Ayub Kiyani, and Farman Ali. 2012. Factors affecting the brand recognition; An exploratory study. *Global Journal of Management and Business Research* 12, 7 (2012), 75–82.

[24] Steven Hoober. 2013. How do users really hold mobile devices. *Tillgänglig http://www. uxmatters. com/mt/archives/2013/02/how-do-users-really-hold-mobile-devices. php (Hämtad 2015-02-11)* (2013).

[25] Nataliya Hristova and Gregory MP O'Hare. 2004. Ad-me: wireless advertising adapted to the user location, device and emotions. In *Proceedings of the 37th Annual Hawaii International Conference on System Sciences (HICSS)*. IEEE, 10–pp. https://doi.org/10.1109/HICSS.2004.1265673

[26] Selim Ickin, Kai Petersen, and Javier Gonzalez-Huerta. 2017. Why Do Users Install and Delete Apps? A Survey Study. In *International Conference of Software Business (ICSOB'17)*. Springer, 186–191. https://doi.org/10.1007/978-3-319-69191-6_13

[27] S Jafari, Gh Jandaghi, and Hadi Taghavi. 2016. Factors influencing the intention to accept advertising in mobile social networks. *Marketing and Management of Innovations* 1 (2016), 57–72.

[28] Hans-Christian Jetter and Harald Reiterer. 2013. Self-Organizing User Interfaces: Envisioning the Future of Ubicomp UIs. (2013).

[29] Sunjun Kim, Jihyun Yu, and Geehyuk Lee. 2012. Interaction Techniques for Unreachable Objects on the Touchscreen. In *Proceedings of the 24th Australian Computer-Human Interaction Conference (OzCHI '12)*. Association for Computing Machinery, New York, NY, USA, 295–298. https://doi.org/10.1145/2414536.2414585

[30] Ravi Kokku, Rajesh Mahindra, Sampath Rangarajan, and Honghai Zhang. 2011. Opportunistic alignment of advertisement delivery with cellular basestation overloads. In *Proceedings of the 9th International Conference on Mobile Systems, Applications, and Services (MobiSys'11)*. ACM, 267–280. https://doi.org/10.1145/1999995.2000021

[31] Effie Lai-Chong Law, Virpi Roto, Marc Hassenzahl, Arnold POS Vermeeren, and Joke Kort. 2009. Understanding, scoping and defining user experience: a survey approach. In *Proceedings of the Conference on Human Factors in Computing Systems (SIGCHI'09)*. ACM, 719–728. https://doi.org/10.1145/1518701.1518813

[32] Charlotte P Lee. 2007. Boundary negotiating artifacts: Unbinding the routine of boundary objects and embracing chaos in collaborative work. *Computer Supported Cooperative Work (CSCW)* 16, 3 (2007), 307–339.

[33] Yiqun Li, Yiqun Li, Kong Wah Wan, Xin Yan, and Changsheng Xu. 2005. Real Time Advertisement Insertion in Baseball Video Based on Advertisement Effect. In *Proceedings of the 13th Annual ACM International Conference on Multimedia (MULTIMEDIA '05)*. ACM, New York, NY, USA, 343–346. https://doi.org/10.1145/1101149.1101221

[34] Bin Liu, Suman Nath, Ramesh Govindan, and Jie Liu. 2014. DECAF: Detecting and Characterizing Ad Fraud in Mobile Apps. In *Proceedings of the 11th USENIX Conference on Networked Systems Design and Implementation (NSDI'14)*. USENIX Association, Berkeley, CA, USA, 57–70.

[35] Qi Liu, Yong Ge, Zhongmou Li, Enhong Chen, and Hui Xiong. 2011. Personalized travel package recommendation. In *2011 IEEE 11th International Conference on Data Mining (ICDM)*. IEEE, 407–416. https://doi.org/10.1109/ICDM.2011.118

[36] Haiping Ma, Huanhuan Cao, Qiang Yang, Enhong Chen, and Jilei Tian. 2012. A habit mining approach for discovering similar mobile users. In *Proceedings of the 21st international conference on World Wide Web (WWW'12)*. ACM, 231–240. https://doi.org/10.1145/2187836.2187868

[37] Claire Cain Miller. 2010. YouTube ads turn videos into revenue. *New York Times* 2 (2010).

[38] Ben Miroglio, David Zeber, Jofish Kaye, and Rebecca Weiss. 2018. The Effect of Ad Blocking on User Engagement with the Web. In *Proceedings of the 2018 World Wide Web Conference (WWW '18)*. ACM, Republic and Canton of Geneva, Switzerland, 813–821. https://doi.org/10.1145/3178876.3186162

[39] Anik Mukherjee, R. P. Sundarraj, and Kaushik Dutta. 2017. Apriori Rule–Based In-App Ad Selection Online Algorithm for Improving Supply-Side Platform Revenues. *ACM Transactions on Management Information Systems (TMIS)* 8, 2-3, Article 10 (July 2017), 28 pages. https://doi.org/10.1145/3086188

[40] Brad Myers, Sun Young Park, Yoko Nakano, Greg Mueller, and Andrew Ko. 2008. How designers design and program interactive behaviors. In *2008 IEEE Symposium on Visual Languages and Human-Centric Computing*. IEEE, 177–184.

[41] Suman Nath. 2015. Madscope: Characterizing mobile in-app targeted ads. In *Proceedings of the 13th Annual International Conference on Mobile Systems, Applications, and Services (MobiSys'15)*. ACM, 59–73. https://doi.org/10.1145/2742647.2742653

[42] Ngoc Thi Nguyen and Hyowon Lee. 2017. "Hop-to-Select" Traverse with Gestural Input in an Eye-off Interaction. In *Proceedings of the 29th Australian Conference on Computer-Human Interaction (OZCHI '17)*. Association for Computing Machinery, New York, NY, USA, 597–601. https://doi.org/10.1145/3152771.3156180

[43] Ngoc Thi Nguyen and Hyowon Lee. 2019. Device Transition: Understanding Usability Issues in Shifting a Device During a Task. In *Design, User Experience, and Usability. User Experience in Advanced Technological Environments*, Aaron Marcus and Wentao Wang (Eds.). Springer International Publishing, Cham, 178–191. https://doi.org/10.1007/978-3-030-23541-3_14

[44] Ngoc Thi Nguyen and Hyowon Lee. 2019. Understanding Usability Challenges in Shifting between Multiple Devices during a Task. In *2019 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*. IEEE, 3–8. https://doi.org/10.1109/PERCOMW.2019.8730756

[45] Petteri Nurmi, Antti Salovaara, Andreas Forsblom, Fabian Bohnert, and Patrik Floréen. 2014. PromotionRank: Ranking and Recommending Grocery Product Promotions Using Personal Shopping Lists. *ACM Transactions on Interactive Intelligent Systems (TiiS)* 4, 1, Article 1 (April 2014), 23 pages. https://doi.org/10.1145/2584249

[46] Antti Oulasvirta, Anna Feit, Perttu Lähteenlahti, and Andreas Karrenbauer. 2017. Computational Support for Functionality Selection in Interaction Design. *ACM Transactions on Computer-Human Interaction (TOCHI)* 24, 5, Article 34 (Oct. 2017), 30 pages. https://doi.org/10.1145/3131608

[47] Justin W Owens, Barbara S Chaparro, and Evan M Palmer. 2011. Text advertising blindness: the new banner blindness? *Journal of usability studies* 6, 3 (2011), 172–197.

[48] Rosalind W. Picard. 1997. *Affective Computing*. MIT Press, Cambridge, MA, USA.

[49] Irena Prochkova, Varun Singh, and Jukka K Nurminen. 2012. Energy cost of advertisements in mobile games on the android platform. In *Proceedings of the Sixth International Conference on Next Generation Mobile Applications, Services and Technologies (NGMAST'12)*. IEEE, 147–152. https://doi.org/10.1109/NGMAST.2012.32

[50] Roman Rädle, Hans-Christian Jetter, Jens Müller, and Harald Reiterer. 2014. Bigger is not always better: display size, performance, and task load during peephole map navigation. In *Proceedings of the Conference on Human Factors in Computing Systems (SIGCHI'14)*. ACM, 4127–4136. https://doi.org/10.1145/2556288.2557071

[51] Anand Ranganathan and Roy H. Campbell. 2002. Advertising in a Pervasive Computing Environment. In *Proceedings of the 2Nd International Workshop on Mobile Commerce (WMC '02)*. ACM, New York, NY, USA, 10–14. https://doi.org/10.1145/570705.570708

[52] Marc Resnick and William Albert. 2014. The impact of advertising location and user task on the emergence of banner ad blindness: An eye-tracking study. *International Journal of Human-Computer Interaction* 30, 3 (2014), 206–219. https://doi.org/10.1080/10447318.2013.847762

[53] Simon Robinson, Parisa Eslambolchilar, and Matt Jones. 2008. Point-to-GeoBlog: gestures and sensors to support user generated content creation. In *Proceedings of the 10th international conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI '08)*. ACM, 197–206. https://doi.org/10.1145/1409240.1409262

[54] John P Rula, Byungjin Jun, and Fabian Bustamante. 2015. Mobile AD (D): Estimating Mobile App Session Times for Better Ads. In *Proceedings of the 16th International Workshop on Mobile Computing Systems and Applications (HotMobile'15)*. ACM, 123–128. https://doi.org/10.1145/2699343.2699365

[55] Mehul K Sanghavi, Michael Froimowitz Greenzeiger, and Ravindra Phulari. 2017. Interaction-aware advertising for minimizing banner blindness. US Patent 9,652,782.

[56] Stephan Sigg, Eemil Lagerspetz, Ella Peltonen, Petteri Nurmi, and Sasu Tarkoma. 2019. Exploiting usage to predict instantaneous app popularity: Trend filters and retention rates. *ACM Transactions on the Web (TWEB)* 13, 2 (2019), 13. https://doi.org/10.1145/3199677

[57] Susan Leigh Star and James R Griesemer. 1989. Institutional ecology,translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social studies of science* 19, 3 (1989), 387–420.

[58] Ralf Terlutter and Michael L. Capella. 2013. The Gamification of Advertising: Analysis and Research Directions of In-Game Advertising, Advergames, and Advertising in Social Network Games. *Journal of Advertising* 42 (2013), 95–112. https://doi.org/10.1080/00913367.2013.774610arXiv:1111.6189v1

[59] Gabriele Tolomei, Mounia Lalmas, Ayman Farahat, and Andrew Haines. 2019. You must have clicked on this ad by mistake! Data-driven identification of accidental clicks on mobile ads with applications to advertiser cost discounting and click-through rate prediction. *International Journal of Data Science and Analytics* 7, 1 (2019), 53–66. https://doi.org/10.1007/s41060-018-0122-1

[60] Melody M Tsang, Shu-Chun Ho, and Ting-Peng Liang. 2004. Consumer attitudes toward mobile advertising: An empirical study. *International Journal of Electronic Commerce* 8, 3 (2004), 65–78. https://doi.org/10.1080/10864415.2004.11044301

[61] Demetrios Vakratsas and Tim Ambler. 1999. How advertising works: what do we really know? *The Journal of Marketing* (1999), 26–43.

[62] Robert Walter, Gilles Bailly, and Jörg Müller. 2013. Strikeapose: revealing mid-air gestures on public displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 841–850.

[63] Stuart Webb. 2007. The effects of repetition on vocabulary knowledge. *Applied linguistics* 28, 1 (2007), 46–65. https://doi.org/10.1093/applin/aml048

[64] Wolfgang Woerndl, Christian Schueller, and Rolf Wojtech. 2007. A hybrid recommender system for context-aware recommendations of mobile applications. In *2007 IEEE 23rd International Conference on Data Engineering Workshop*. IEEE, 871–878. https://doi.org/10.1109/ICDEW.2007.4401078

[65] Moonhee Yang, David R. Roskos-Ewoldsen, Lucian Dinu, and Laura M. Arpan. 2006. The Effectiveness of In-Game Advertising: Comparing College Students' Explicit and Implicit Memory for Brand Names. *Journal of Advertising* 35 (2006), 143–152. https://doi.org/10.2753/JOA0091-3367350410

[66] Li Zhang, Dhruv Gupta, and Prasant Mohapatra. 2012. How expensive are free smartphone apps? *ACM SIGMOBILE Mobile Computing and Communications Review* 16, 3 (2012), 21–32. https://doi.org/10.1145/2412096.2412100

[67] Wen Zhou. 2004. The choice of commercial breaks in television programs: the number, length and timing. *The Journal of Industrial Economics* 52, 3 (2004), 315–326. https://doi.org/10.1111/j.0022-1821.2004.00228.x

[68] Hengshu Zhu, Enhong Chen, Kuifei Yu, Huanhuan Cao, Hui Xiong, and Jilei Tian. 2012. Mining personal context-aware preferences for mobile users. In *2012 IEEE 12th International Conference on Data Mining (ICDM)*. IEEE, 1212–1217. https://doi.org/10.1109/ICDM.2012.31

[69] Agustin Zuniga, Huber Flores, Eemil Lagerspetz, Petteri Nurmi, Sasu Tarkoma, Pan Hui, and Jukka Manner. 2019. Tortoise or Hare? Quantifying the Effects of Performance on Mobile App Retention. In *The World Wide Web Conference (WWW'19)*. ACM, 2517–2528. https://doi.org/10.1145/3308558.3313428