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Designing Mobile Game Input Unreachability: Risks When Placing Items Out of the Functional Area

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ABSTRACT

When planning controls for mobile games and gamified apps, designers consider how gamers access features and where to display them. With users potentially operating their devices single-handed, content producers have been using design approaches based on the screen area a thumb can reach when the hand supports the device, with different degrees of difficulty. Depending on the screen size, some parts are out of the thumb's reach, requiring operation with the assistance of the other hand or changing grip when possible. Despite the common facilitated access to relevant game resources within the area, some items are intentionally placed in unreachable zones, trying to make gamers take longer until they can access them, thus increasing displayed content exposure. These hard-to-reach options are inputs to mute, forward, or close in-game advertising and in-app purchase offers. They disregard the potential uncommon thumb actions one may adopt to tap them. This paper studies single-handed thumb reachability in mobile games and the ads they display to identify how their screen design can provide different levels of performance and body safety to access specific content and then understand whether items out of the thumb's reach can lead to potential risks for the gamer. While game design should contribute to interaction and comfort, promotional features seeking monetization have strategies to avoid or delay interaction, with risks of interfering with performance or thumb injuries.

Keywords: Mobile gaming risks, Mobile device interface thumb reachability, Mobile screen design human factors, Functional area of the thumb

INTRODUCTION

Human Factors Gaming with a smartphone is a widespread practice using mobile technologies. The products have facilitated access on application (app) stores, which offer many of them for free. Other apps use a gamified approach, i.e. adapting their content to the mechanics of games.

Current monetization techniques use in-game advertising to profit with the free app. Users exchange some of their time and attention to promoted content, which is the one paying for the development and download. Some games and gamified apps use the same strategy and offer in-narrative products by creating game breaks or challenges that require virtual items players may purchase.

To prolong the exposure of the user to promotional messages, the ads may place controlling options, such a mute, forward and (most importantly) close, in screen areas not easily reached when the device is unimanually operated with a single thumb. In some cases, not even with two hands.

Such a practice goes against design discussions about convenient access of on-screen inputs. While authors propose or refute a mobile screen functional area (and its various names) according to the thumb's reachability and hand grip while holding a device, publishers explore the unfunctional area, the one that requires the users to change how they hold their phones (potentially affecting performance) and the number of taps to interact with the promotional content that impedes playing until closed.

As a result, users may need to adopt awkward and prolonged hand movements, increasing the number of taps on the touchscreen, so they resume gaming. Literature has described the risk of injuries when overusing thumbs, a scenario the ads and their hard-to-interact apparatus may worsen.

The relationship of game design and body consequences still needs research. However, some of the risks are well-known. The purpose of this paper is to describe whether in-game ads are leading users to change grips and frequency of tapping that can pose risks for the thumb, identifying where the controlling inputs are and their association with the thumb's reachability and grip.

To verify the location of the controls of in-game ads, the research recorded 160 interstitial, video, and interactive advertised content displayed on free games upon playing.

To understand whether the place where they stand is adequate for the user from a design perspective, the research relied on authors discussing holding and touchscreen tapping strategies, crossing information with others presenting injury risks due to excessive smartphone usage.

Even though the works on thumb usage on smartphones are more related to texting, it is possible to associate such activities with gaming and expand some of the considerations to its particularities, such as the ads and the input locations that exceed the standard soft keyboard ones.

As a conclusion, it is possible to assume that game and gamified app designers try to place interactive items at the player's convenience, whereas ads try the contrary, regardless of the potential resulting risks for the users.

FOUNDATION

Smartphone interfaces and mobile risk injuries have been subjects of continuing studies since those devices gained popularity and increased the number of users.

In 2011, Steve Hoober and Eric Berkman published an influential book on designing content for mobile phones according to how users access information on their devices. Although not thinking about games (they were more limited than in the current time), the proposed guidance was related to various applications and strategies, such as design presenting information in a way that was easy to understand, margin limits of content and screen, and hierarchy of displayed elements.

Button size and directions on on-screen gestures (such as tapping and dragging) controls were a concern for those authors, who described the risks of fatigue and injury due to repetition (p. 352) and the minimum dimension for inputs (p. 521).

During that period, Berolo, Wells, and Amick III (2011) shared those thoughts by describing associations "between hand-held device use and upper extremity musculoskeletal symptoms" (p. 371), also describing potential problems when loading the thumb's musculature. They presented data about time spent with a mobile device and pain in the middle and base of the thumb (p. 376).

Years later, Ahmed et al. (2022), when studying smartphone addiction, also found a greater incidence of hand pain (for those who reported any) on the thumb and its base.

In 2013, Hoober published a new text describing how users held their (now touchscreen) devices, mostly mentioning portrait orientation with a single hand and thumb operation, two hands and single thumb, or two hands and two thumbs, claiming the former to be the predominant method. Despite understanding people would shift their holding strategies depending on the situation, he presented an illustration that described the screen area a thumb could reach with different degrees of difficulty when users held their devices with one hand.

The zone covered by the thumb would also work for cases when both hands cradled the device, increasing its reach. If the index finger touched the screen while the other hand supported the device, there was no reaching limitation.

Even though the screens were smaller ten years ago (thus, all areas assumed to be reachable when operating unimanually), Hoober suggested designers not to consider placing items in the upper-left corner (one of the harder-to-reach areas) as it was necessary for more understanding of users' preferences to explore such.

Bergstrom-Lehtovirta and Oulasvirta (2014) studied Hoober's model alongside other proponents of smartphone screen design related to reachability, naming as "the functional area of the thumb" (p. 1991) what users could access single-handed with the device in portrait orientation. They considered a parabolic curve motion of the thumb and its relationship with the index finger (holding the device at the back of it). The grip also determined the reachable areas and performance. The authors suggested that interface inputs "should not be placed to the predicted extrema of the thumb's reach" (p. 1992), as changing grips frequently could interfere with the interaction.

In search of a design understanding of the screen coordinates, Eardley et al. (2017) also studied hand grip and the functional area, noting that users tend to adapt their holding strategy according to the sort of interaction with the phone. Kim, Jung, and Im (2014) proposed research on an interface with "optimal controllability" (p. 265), offering a diagram with a diamond shape above the centre of a portrait screen but not touching the edges as a "preferable control zone" (p. 272), noting potential alterations due to the screen size. Xiong and Muraki (2016) developed a "thumb coverage area" (pp. 142–143) upon observing different age groups of users and distinct thumb sizes, presenting a different zone than the previous authors.

With new insights on the functional area (and facing larger phone screens than previous studies), Hoober started reflecting on hand anatomy and its possibilities, refuting his early illustration by presenting six ways people commonly held and operated their devices (2017a). Having in mind constant changes in grip and orientation, instead of describing a functional area, he claimed there was an accuracy chart of operation, being (on portrait orientation) the vertical extended centre of the screen the most accurate and the corners the least, with a gradual transition between them.

According to him, users preferred to visualize and interact with items in the centre of the screen, even scrolling content on it. Interestingly, he presented further thoughts about the suggested 10mm button size from his 2011 work to 7mm if in the centre and 12mm if in the corners, even though Hoober did not consider those dimensions perfect, and users frequently missed the tapping target.

Accuracy touch replaced the original thumb's reachable zone. Yet, Hoober suggested secondary items in the upper and lower edges and presented a new illustration depicting the corners as inaccurate spots and recommending avoiding the boundaries (2017b).

Hoober's latest book kept those conclusions and suggested that larger devices should count on larger icons (2021). He described the corners as inaccurate regions, proposing a tap area users would access regardless of the holding strategy. The concept of the tap area was like the accuracy one but smaller and farther from the edges.

METHOD

Considering the functional area located at the centre of the screen with a predominantly vertical spread towards the edges (but not reaching them) as a replacement for the original concept of the thumb zone, it is possible to conclude that the remaining parts are the unfunctional area.

Regardless of the shifts in holding strategies, certain products drive users to specific phone orientations and grips, also influencing interaction (mostly requiring the thumbs). For instance, non-responsive games such as Electronic Arts' Real Racing 3 (a mandatory two-hand grip landscape-only title based on accelerometers and one thumb), Kabam's Marvel Contest of Champions (a mandatory two-hand grip landscape-only title that requires both thumbs), and Outfit7's Talking Tom Gold Run (a portrait-only primarily one-hand grip driven to one-thumb controlling) use different input options that lead holding the device in specific or favoured ways.

They also have unrestrictive zones for tapping or swiping in common, meaning that the user can perform the controlling actions where they prefer on the screen (e.g., Real Racing 3 breaks the car upon tapping on any non-menu area) without an interface presenting anchored inputs. Touchscreen smartphones recognize the gestures and react accordingly, not limiting the inputs to a specific place.

Except for some of their reserved (for information or other options) areas, such an approach allows players to choose their preferred touching area to

tap or swipe, with no need to try to force or flex their thumbs or change the grips. Design on game affordances provides players with adaptive controls.

Other games, such as King's Candy Crush Soda, mostly use the centre of the screen, spreading interactive corners to areas that may exceed the functional limits, depending on the user's hand size, keeping the gameplay with a single-thumb control and unimanual grip.

The in-game situation of these titles indicates that interfaces consider the functional zone and the hand comfort by positioning items under the thumbs' reach or by letting players choose where to input controlling information, leaving most of the centre for such actions.

Another type of content, however, may do the opposite.

In-game voluntary (the ones the player chooses to access in exchange for rewards) or involuntary (the ones that pop up during games or in between levels or events) ads seem to explore out-of-single-thumb reachable areas by placing the options to close, mute, or forward their message within the unfunctional area, making it harder for players to access those and prolong exposure to the displayed content.

Research conducted for this paper observed 160 interstitials (game breaks displayed full screen, according to Rosenfelder, 2023), rewarded videos (the ones requiring watching and offering in-game benefits, id.), and in-narrative built-in (those that are part of the game and offer some exchange from the gamer) voluntary or involuntary ads from varied free games or gamified products (e.g. Duolingo) available at Apple's App Store (without Arcade subscription) during one week in February 2024. The idea was to investigate if the inputs to return to the games or to mute their sounds were reachable during an unimanual and single-thumb situation, also considering the potential difficulty in bimanual cases.

As banner ads do not halt the gaming experience, this text excluded them.

The strategy was to record the ads according to when games displayed them. For that reason and thinking on the efforts to control them while playing, the research did not eliminate redundant ads, as they required new interactions regardless of the content being the same.

The research also recorded the number of sequential parts of ads displayed after the player tapped the closing option. Doing so was necessary as some ads presented such an option suggesting that the user only needed to tap it once, returning hands and thumbs to the original cradling position to realize the ad opened a new message with another closing option.

Exploring the unfunctional area may work in opposition to controlling the narrative by using the expanded centre of the screen, thus potentially risking overuse or awkward movements of thumbs and wrists.

The following results demonstrate the frequency of using the unfunctional area and its features.

RESULTS

Games and gamified apps displayed different sorts of ads. They were either from external advertisers (products unrelated to the narrative) or internal

(optional features producers offer for the gamer to use within the played narrative).

The research accessed both, following what the games presented to the player regardless of the origin. Even though the results considered them altogether, there were some noticeable differences, depending on the title and communication strategy.

For example, from the 160 ads, only one (0.62%) could close the promoted item within the portrait orientation functional area. Although closer to the bottom of the screen (with a certain margin before the edge), that unique case was an in-narrative promotional content offering the player to start a new secondary challenge or to keep playing the regular game. It was also the only time the closing input was not an "X" or a forward symbol but by the word "later" as a button.

From the other 159, 130 (81.25% of the total) ads had the closing option in the top-right corner (close to the edge) of the screen, regardless of the phone orientation. Other 11 (6.88%) were in the top-right but within any orientation functional area (placed lower than the previous ones). These were all internal ads.

Not all ads were responsive. In some cases, despite playing a landscape game, the ad would be in portrait mode.

Two (1.25%) ads displayed the closing option as an "X" in the top-left corner.

Gaming found 14 (8.75%) ads that closed themselves automatically after playing their videos. They were from the same advertiser and perhaps not as planned by the publisher. Despite some of them having the "X" button, it closed the video once pressed, but a black screen with a countdown took its place to resume the game only when it was over. In addition, the content was adapted to a portrait mode when it was landscape content (switching orientation did not make any difference).

The research did not include those for the controlling location count, despite occasionally presenting the "X" in the top-right corner of the landscape content (thus, not close to the top-right edge of the screen, as the video was vertically at the centre).

The research did not consider the advertising companies responsible for the external ads. However, as most of the internal content also placed the closing input in similar locations, it is possible to conclude that there is a pattern to such an option, even though publishers can locate it anywhere while making their products.

Producers likely know well where to display easy or hard-to-access items. For instance, when the responsive Candy Crush Soda was in landscape orientation, it shifted the area under gaming interaction to the right, as it was going to be closer to the right thumb once the centre as a functional area worked better in portrait orientations (landscape would make the centre farther from the thumbs).

Back to the ads, not all had mute or forward options. Some were one image with no video or audio, hence having only the closing option. Internal ads with any motion or sound planned the content to blend with the visual and sound style and did not display forward or mute options.

External ads with videos or interactive demos offered options to forward and mute. None were in the functional area. As non-excluding results (some titles had both or all the three buttons), twenty-five games had the mute input at the bottom-left corner, twenty-three at the top-left corner, and one at the bottom-right corner.

Forwarding was possible by tapping the top-left corner in thirteen games and the top-right corner in eleven titles. Most cases with the top input led the forwarded content to other parts of the ad, potentially replacing the button with a countdown that later allowed the "X" option.

Some ads displayed sequential messages, using up to four screens players needed to close until they returned to the game. Tapping the forward and the "X" icons did not mean immediately closing the message, and some even opened the dedicated link from the app store to download the advertised product, requiring users to reject it (or eventually accept it) before resuming the game.

What may favour the message can be detrimental to the body. As Mustafaoglu et al. (2021) describe, repetitive usage of the thumbs can cause pain and musculature disorders.

Conversely, most of the "get" and "install now" buttons or website links (e.g. "open" and "shop now") on external ads were within the functional area or the thumb zone (closer to the right edge). One advertiser had a "play now" input in the top-right corner (below the "X"), which was a unique case. That ad reserved the functional area for interaction with the demo of the promoted product.

Internal advertising used the functional area to display options to buy or spend in-game resources, download promotional content, or access external videos for rewards.

Observing the input locations may lead to the conclusion that one must access out-of-reach inputs to control the exposure to ads. Immediate spending or opening link options facilitated access related to the centre or expanded centre of the screen.

How to present the options was also related to content exposure and thumb usage. Promotional content was evident, but closing ads were not always so. The "X" was sometimes opaque, blending with the content behind it, thus not entirely visible.

The size of the closing input also had potential issues. On a 5.4 screen, the "X" button with the largest dimensions (assumed as the button interactive size with its circular background) was 5mm in diameter. The smallest was an "X" approximately 1.5mm in length and height over a circle close to 2mm. Distinct from Kim and Lee's (2015) suggestion of a 3mm distance between keys (which is possible to relate to the distance from the margins as well), this case was 2mm away from the right edge of the screen.

Lee et al. (2015) evaluated button sizes, concluding that their dimensions affected the tapping time, having the smallest one with 4mm. If smaller target sizes negatively interfere with performance, one can assume something with half that size attempts to hinder tapping.

Small inputs require precision or repeated attempts to achieve the desired outcome, potentially increasing the time spent on the activity and the number of taps, thus increasing injury risks.

DISCUSSION

While Hoober claimed that shifting how to hold a phone to be a customary practice and using the thumbs to reach something at the edges causes no discomfort, there was little association in his writings about the performed activities with phones and the potential consequences of prolonged usage. In addition, not all content is responsive or reminds users to change or pause what they are doing.

It is worth noting that when the interface studies mentioned here began, smartphones had bezels, providing a non-blind spot when covered by the base of the thumb, thus offering a smaller screen and a more accessible area. Lee et al. (2018) observed that larger display sizes may have caused operational difficulties and interfered with the grip. In that case, reaching the top-right corner also became unimanually harder and out of the reach of the left thumb in bimanual situations when the left hand is supporting the base of the phone.

Games can take several hours and frequently enforce an orientation and interaction method. According to Lai, Chiu, and Law (2014), repetitive gaming actions can increase the risk of injury. Mustafaoglu et al. (2021) state that wrists and hands are among "the body parts with the highest prevalence of pain" (p. 75) related to smartphone addiction. Benites-Zapata, Jiménez-Torres, and Ayala-Roldán (2021) have found associations between smartphone hours usage per day and de Quervain's disease.

Research for this paper did not find literature comparing thumb usage between texting apps and games.

About the former, Yu et al. (2021) claimed that actions when the input is small (being 3x5mm or 5x3mm the smallest dimensions they tested) resulted in more errors, demanding repeating the action.

Repeating due to error may be detrimental to the thumb. However, texting occurs at the bottom of the screen, where the soft keyboard pops up with a vertical margin to facilitate the grip and the thumb's reach when operating the device with a single hand. The one used for this paper had each alphabet key of 5x7mm. Although two had no margin to the side edges, they were larger than the closing "X" buttons displayed by games and gamified apps.

The location near the edges, frequency, and compact dimensions of the inputs seem to deliver laborious operation even when both hands interact with the device in portrait orientation, as the second thumb is unlikely to increase vertical reachability when the corresponding hand is providing support for the device. Changing the grip to reach the target may lead to repetitive awkward poses. Not obtaining immediate results may prolong them.

As texting is a known cause of injury with such features, it is possible to assume that internal and external in-game ads also present risks once the thumbs are already engaged with the narrative when they must reach the corners with small inputs.

In addition, texting and game times may differ, as the latter presents rewarding mechanisms to keep the player committed to the product.

Wang et al. (2019) conducted experiments on prolonged mobile gaming and repetitive thumb action, finding risks of musculoskeletal disorders, recommending that players should limit gaming to 20 minutes and strategize less thumb movement.

McLaughlin et al. (2023) reported data from previous research on the rupture of the tendon, "enlarged median nerve, thumb pain at rest, and decreased pinch strength" (p. 185) due to cell phone addiction and excessive gaming while presenting other potential risks.

Ads can extend gaming time, as gamers need to interact with them to resume playing, sometimes doing so several times due to missing the target because of the input size, location, visibility, or the sequential content that opens other parts of the message when the previous one closes or forwards.

Discussions of the functional area/thumb zone/covered area have not focused on games, even though they are "the most downloaded app category across both Apple's App Store and Google Play" (Rosenfelder, 2023). While the literature frequently approaches texting, games and ads still require research.

CONCLUSION

Free games and gamified apps offer easy access based on their content and monetization strategies, which include advertising in-narrative features or external companies. It is a mechanism that allows gamers to download and use the products, assuming no financial cost, exchanging their time and attention to the interstitial, video, or interactive message.

The user decides to download and play the games. It is not a compulsory system with forced actions towards the player.

Yet, considering that smartphone users potentially spend hours a day playing with their devices, game developers and advertisers should be not only aware that "users are becoming increasingly intolerant of mobile ads" (Mor-Samuels, 2022) but also that their designs have out-of-game implications, including body comfort.

It is not about paying for the game to access ad-free content. It is about considering what gamers need and how to provide it safely. Understandably, advertisers wish for prolonged exposure to the message. However, how to do so may have unilateral consequences for the users.

On the design size, even if there is no thumb zone, and functional areas may change according to different device holding and grip strategies, 81.25% of top-right corner closing inputs indicate an unfunctional area, which usage inhibits a quick interaction.

Controlling various parts of the screen following a player gesture (or responsive games adapting content to the thumb's reach when the orientation shifts) indicates that producers plan how to facilitate input for playing or make it more difficult due to exposure to ads. They must also consider that the thumb "is good at grasping but not good for repetitive movement" (Eapen et al., 2018, p. 203).

Sequential screens of ads that appear after tapping the closing or forwarding option keep demanding thumbs and grip to change, affecting performance and increasing the number of movements required by the player. Some cases had up to four screens in sequence, all waiting for the input to move on.

The current text had a one-device usage and a few free games played as limitations. More research may reveal differences between smartphone application stores and publishers. The relationship between games and ads also needs more studies.

Yet, from the body perspective, little is known about the relationship in-game and game advertising design have with repetitive and prolonged awkward actions players may adopt to interact with the content. Related literature, however, describes the risks of injury and potential musculoskeletal issues.

With texting as a starting point, research needs to understand better mobile gaming habits, including their association with thumbs and grip. Not only thinking about the device size and the screen area but also about the content presented to the player and how it unfolds to other actions, such as interacting with the ads.

Designing for the user's comfort and body adequacy does not mean harming the advertisers' messages. Players accept well to have the products for free by giving some of their time and attention while facing the digital and mobile challenges. However, controlling screen content should not differ due to the origin and purpose of the message nor the importance of players' safety when doing so.

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