Human Factors in Virtual Environments and Game Design, Vol. 96, 2023, 1–10
https://doi.org/10.54941/ahfe1003861

Mobile Game Design and Ergonomics: A Necessary Combination

Wiliam Machado de Andrade

Department of Media, The University of Adelaide, Adelaide, SA 5005, Australia

ABSTRACT

Games for mobile phones constitute a fast-growing industry, with technologies and business models that explore their portability and facilitated access. The human factors on mobile playing did not follow such a development. With devices using touchscreens to control the game, usability ignored the ergonomics of holding and interacting with handheld narratives in opposition to video game console controllers. This article studies mobile gaming ergonomics to understand how playing with a handheld device changes body alignment, pondering whether game design can lead to or avoid postural injuries in the long term. While console and desktop computer gaming are likely to occur in controlled settings, mobile gaming can happen in varied places and situations. Some games demand players to hold their devices with a single hand, making it difficult to distribute the weight and adjust the grip. Playing while standing up may cause arm and wrist fatigue while gamers try to achieve better visualization. In addition, small onscreen content can also prompt neck stretching, altering the body's axis. Even though the current literature reveals some concerns regarding video games and ergonomics, they commonly focus on the players but not on the game content. Thinking about the latter, is it possible to plan the game to reduce the risk of injuries when playing with a handheld device? As a first step toward a potential answer, the research investigates (1) the body risks when holding a smartphone; and (2) some distinct game features from other mobile operations that can aggravate potential injuries. The conclusions suggest some approaches to game design to reduce the risks in the long term, also attempting to make part of further discussions on ergonomics to make mobile gaming safer for the body.

Keywords: Mobile games, Game design, Game ergonomics, Smartphone risks, Touchscreen ergonomics

INTRODUCTION

Mobile gaming is currently the fastest growing segment of the game industry. Based on portability and business models that encourage users to download products with accessible prices or even for free, the options and audiences are numerous.

Whereas traditional game consoles and previous handheld gaming devices have dedicated controlling buttons, mobiles commonly rely on users touching the screen without a reserved area for inputs and other options. The interface incorporates those, making the products practical with facilitated learning.

Those factors favor mobile gaming with narratives using smartphone features, such as those Merbah, Gorce and Jacquier-Bret (2020) notice: one can

use their device in diverse ways and situations, from inside public transportation to formal working settings, with distinct body postures (standing up or while sitting).

However, the user's welfare and ergonomics did not follow the development and propagation of mobile phones and their downloadable products.

As mobiles became a ubiquitous tool of everyday life, users tend to adapt their bodies to positions they can better visualize the screening content and control narrative tasks, establishing a relation between the hand and the eyes that can force muscles and bones to adjust angles and weight distribution.

Such an adjustment may pose some risks. Syamala et al. (2018) and Eitivipart, Viriyarojanakul and Redhead (2018) estate that intense mobile use can lead to musculoskeletal injures, mainly when holding it below eye level, resulting in neck flexion that can involve other parts of the body in the process, thus causing discomfort and pain.

In the case of games, there are two factors to observe related to this scenario. The first is that gaming is usually longer than texting and internet browsing (the two main tasks the related literature normally analyses). The second is that playing mobile games may demand repetitive actions according to the narrative challenges.

Nguyen (2015) explains that a repetitive strain injury (RSI) can affect upper limbs and the back, altering the body's response to some activities and causing pain. Although not describing such for mobile games, one can imply that the prolonged playing hours with the recurrence of actions can lead to an RSI.

In addition to the neck and back, Gustafsson, Johnson and Hagberg (2010) describe excessive typing and piano playing as risks for the thumb and forearm; we can relate those to mobile gaming movements, which mostly rely on the thumb.

The long-term body effects are yet to be known, especially considering the early age some users engage with mobile games. On the other hand, we can think about short-term strategies to reduce the potential hazards, such as interface features and game content driven to ergonomics.

The present text aims at mobile gaming ergonomics, describing the potential body implications of prolonged and repetitive gaming while trying to control the narrative, pondering if game design and gameplay can work for ergonomics.

To that matter, not only the related (mostly about texting) literature is presented but also a brief discussion on gaming characteristics and potential strategies for future content.

FOUNDATION

The literature review on the risks of prolonged and repetitive use of mobiles reveals six interrelated topics that help to describe the scenario and understand it: hand issues, posture problems, performed tasks, fit, games as a separate field, and controllers.

Hand Issues

There are diverse ways to hold a smartphone, including doing so with one or two hands and vertical or horizontal orientation. Any decision changes weight distribution, grip, angle, and musculoskeletal strategies to maintain balance and interaction between fingers, hand and wrist (Cooley, 2017).

With the thumb as the main controller, there are risks of carpal tunnel syndrome (Nguyen, 2015) depending on how users operate the device.

Nguyen (2015) claims that users tend to hold and control mobiles single-handed while performing other activities, which restricts the thumb's touching range on the screens; options on the top corners are out of reach, potentially forcing unnatural wrist positions and stretching the thumb.

According to Eitivipart, Viriyarojanakul and Redhead (2018), such a picture alters the operation efficiency, demanding heavier loads of the joints, with more pressure on the carpal tunnel and compression of the median nerve, which can lead to or aggravate pain or result in hand numbness (Garosi, 2019).

To carpal tunnel syndrome, Nguyen (2015) adds the risk of de Quervain disease, which is the inflammation and compression of the median nerve and tendons, causing lateral pain on the wrist (on the side of the thumb).

The intensity of those conditions may depend on the hand and mobile sizes and operation nature (Trudeau et al., 2016).

Posture Problems

Hand positioning is not the only factor involved with holding a mobile device. Arms and shoulders are related to choosing a suitable body posture to interact with the devices. Merbah, Gorce and Jacquier-Bret (2020) also describe body strategies that involve the neck and the trunk according to the operating circumstances.

These authors conducted experiments on neck angle and flexion related to mobile usage, describing that it should not be over 20° to keep that limb within a safe range. Their research results, however, noted users with angles above the threshold, including a standing position of over 40°.

Neck pain is especially risky, as it can change the stability of the cervical spine and alter its rotation (Ning et al., 2015).

Neck flexion alters according to the task and setting. Garosi (2019) observed less muscular flexion when users had forearm and back supports for their mobile operation, which meets Gustafsson, Johnson and Hagberg's (2010) claims that standing positions result in more muscle activity of the trapezius. The latter also concludes that prolonged use poses risks to the cervical spine.

As support seems helpful, Liang and Hwang (2016) notice that users also try to lean on something (when possible) while standing up, as reaching equilibrium is more challenging.

Conversely, sitting may increase neck flexion as users try to maintain postural stability (Eitivipart, Viriyarojanakul and Redhead, 2018). In addition, Syamala et al. (2018) observe the highest neck flexion when the device rests on the lap without adequate support from the chair.

No studies compared different standing and sitting positions, as people have distinct habits to support their bodies and find stability, even though there may be some potential patterns according to the situation, such as the ones found by Liang and Hwang (2016).

Tasks

Most of the literature review describes users texting or internet browsing. About the former, Garosi (2019) states that typing activities result in more neck flexion than reading or watching videos, while Gustafsson et al. (2017) describe the thumb and forearm risks for such an activity adding, to the carpal tunnel syndrome, tendonitis and arthritis, due to excessive use.

Those authors also comment on different typing strategies, including doing so with one or two thumbs and using or not support. Conditions and tasks will result in diverse body postures, despite neck flexion being a regular feature.

Mobile gaming requires more research, which may present various levels of engagement, time demand and frequency of repetitive actions.

Fit

One of the reasons people may adapt to the device and not perceive the body is at risk while performing some tasks is fit.

As Cooley (2017) describes it, fit is a tactile vision, a perception that seeing and touching a mobile screened device are in such a close relationship that hand and device feel as one.

Cooley did not conceptualize fit as a musculoskeletal disorder origin, but it assists us on the reasons why the body adapts to the handheld device and not the other way around.

Games as a Separate Field

Mobile gaming activities are still an open field despite their rapid development. Even though they share certain practices with texting, a player shall notice its fit results in less self-conscious reactions of the body during a game.

As mobile games are unlikely to have a definite ending and present numerous strategies to make players keep playing, the amount of time one spends gaming is yet to be known. But observation makes us assume it is longer and more body-demanding than web browsing or texting.

In that regard, Merbah, Gorce and Jacquier-Bret (2020) observe that their experiments on texting and web browsing did not find relevant differences in body strategies opposing both tasks, revealing that the activities would last for short periods (around one minute), which is potentially different for gaming.

The rise of "touch-based games," as described by Torok et al. (2018, p. 33), brought unique features to smartphones and gaming. Some games rely on sliding the thumb instead of tapping. They do so by using the whole screen space, whereas typing has a reserved area. Sliding may force thumb flexion and make it repeat the movement numerous times, depending on the product.

In addition, controlling the narrative may incorporate sensors and accelerometers, changing the body posture according to the desired in-game action.

Ning et al. (2015) notice in their research that neck flexion was higher during gaming activities than reading ones on mobile. They considered the latter a more challenging task than the former, pondering if difficulty influences the tilting angle. To that thought, we assume that it will depend on the fit and engagement with the game, which grades of difficulty, alongside the narrative and connectedness with the player, may lead to different self-absorption levels and thus postures according to the time spent playing, following their conclusion more studies are required once their research used only one game title.

Controllers

Fit is a concept that also works for how players interact with their video game console controller (gamepad). Consoles have been available for longer than mobile gaming, which can provide some insights about posture and grip.

With exceptions, gamepads (like mobile phones) rely on the thumbs but regularly require gamers to use both hands, resembling the horizontal cradling of smartphones. Such a characteristic highlights a fundamental difference: the design of gamepad buttons always seeks availability, placing some of them where the fingers hold the device, making it possible to execute more functions than the thumbs could perform.

Conversely, Nguyen (2015) observes that no mobile operating system places all options within the thumb reach, regarded as the "functional area" (p. 04).

Another noticeable difference is that players are unlikely to play with their consoles in uncontrolled environments. Remote playing using a mobile to control the console is possible, but it does not seem to be the current norm of gaming.

Therefore, console games do not pose some of the challenges of mobile gaming, which circumstances may require the player to re-align the body to re-establish balance and equilibrium. Although some games explore motion capture technologies, the most common are console games played while sitting and with back support. As TV screens and desktop monitors have larger dimensions than phones, and players do not hold them while gaming, there is no need for similar neck stretching.

Gamepads offer some benefits, but they are not perfect. Torok et al. (2018) observe that their design follows a gaming tradition from the history of consoles, whereas Parisi (2015) ponders if it is a branding strategy with players. In that case, it is doubtful players will have the chance to use more ergonomic controllers. Moreover, some studies describe unsuitable sitting positions while video gaming, making us conclude it is not only a matter of how to hold the device but also self-conscious adequate body alignment for both gamepads and mobiles.

ADDITIONAL GAMING FACTORS

The literature review exposes the musculoskeletal risks and the need to understand how some tasks may increase them.

In the case of games and potential harm to the body, some features of mobile products require attention and future research.

For instance, despite the assumption that holding the device with two hands is better than having one, as it provides better weight distribution and grip, mobile games are unlikely responsive. Several titles count only on vertical or horizontal orientation, forcing the player to follow along with what it displays. In addition, Liang and Hwang (2016) claim that holding the device vertically (or "portrait orientation") is the favorite method adopted by users.

Another game demand is repetition: grinding (Cartwright and Hyde, 2022) is a known game term for repeating similar tasks to earn extra points or resources within a game narrative. That in-game strategy, however, leads the body to perform the same movement repeatedly, regardless of the action being in or out of the thumb's reach.

Such an action, which we could relate to RSI risks, may be worsened by the touchscreen's sensibility; As Nguyen (2015) notes, not all devices interpret touch the same way, and some require more pressure than others. Players may need to use some force while grinding, certainly getting the muscles fatigued quicker.

Fatigue may also be a problem depending on the screen size, as it influences one's ability to hold the smartphone keeping an adequate position (even more if using a single hand). Zhu and Li (2016) claim users ignore fatigue and keep operating the device, overusing their thumbs.

To those factors, our active observation can add three others. The first is that some mobile screens lose sensibility at the edges. They are, for some games, a relevant part of the narrative, making players use different pressure techniques and repeating the action in short periods to reinforce the input.

The second, as previously mentioned, is that many games do not require tapping but sliding. Thumbs will keep moving continuously, with different pressure and screen areas, potentially forcing tendons and muscles to unnatural performances.

The third is about the sensors; some games use accelerometers as controlling possibilities. For instance, a racing game may simulate turning the driving wheel when tilting the phone. When a real-world car is making a curve, the image from the windshield should not tilt with the same rotation angle as the driving wheel, as it is mostly perpendicular to the ground. Console simulators follow such a principle. But when one turns a mobile, the image on the screen does not maintain its perpendicular relation with the ground; it does it with the base of the device, making it rotate according to the turn.

If players wish to keep looking at it from the same relative axis, they need to tilt the neck and cervical spine, flexing them not only toward the screen but also to the sides, following the in-game turn.

The cervical cost of doing so repeatedly and without proper body preparation is unknown.

DISCUSSION

The problems raised drive a set of potential recommendations. Research has tested some of them. For example, Merbah, Gorce and Jacquier-Bret (2020) suggested that the least harmful posture is while sitting and at a table, which provides support. For mobile gamers, that seems to be the least adopted one, as they play on the go or in adverse situations when another action guides the setting (waiting, on public transportation, as a second screen, among others).

Not only will the whole body adapt to those, potentially stressing the neck and the cervical spine, but the device design can open doors for hand injuries, according to its weight and size. Nguyen (2015) explain that, for a right-hand user, movements with the thumb going from the top-left of the screen to the bottom-right are the most difficult ones, as Trudeau et al. (2016) ratify it by claiming the top-right and bottom-left are areas to provide better performances. From our experience, depending on the size of the hand, the top corners are unachievable on both sides.

These are external device features; on the internal ones, about the interface, Eitivipart, Viriyarojanakul and Redhead (2018) observe that more important than the screen dimensions are the location of the buttons and their size. As smaller they get, the more muscle activity they demand.

Smaller buttons also require more neck flexion, so users can see the option they want to tap. That may explain Garosi's (2019) research description of large numbers of users flexing the neck and having the wrists "in an unnatural position" (p. 02) while using large touch screens, aggravated when users let the device rest on their lap.

Users can personalize where the buttons are and choose from larger or smaller ones according to their personal preference. But device configuration is not necessarily straight forward to all users, nor their awareness of the long-term consequences their decisions may result.

Button size and distance from the eyes establish an ongoing interaction between neck and forearm. While standing up, users are likely to bring the device closer to their eyes, reducing neck flexion but increasing the arm's fatigue. More so if the screen is large, which may also make the phone heavier. Syamala et al. (2018) suggest that having the mobile at eye-level and using arm rests may alleviate this ever-attempting balance reach.

For mobile gaming, some of the potential solutions are not under consideration by the players. Playing while sitting and with available arm rests is a characteristic of console or desktop playing using a gamepad or a mouse and a keyboard. Mobiles are a convenient and portable machine with easy access in uncontrolled conditions.

For those cases, there is not much to do regarding screen size, shape, and weight. But we can suggest interface features with larger buttons and reachable thumb position when the game is on portray mode (favoring one-hand control).

Interactive content should be avoided at all corners, as they lose sensitivity and force the user to repeat the input.

Producers should consider limited sliding and repetition, as they cause fatigue. Games encouraging grinding could find loyalty strategies that would

not make players keep flexing thumbs and forcing the wrist to perform potentially rewarded actions.

Lack of game responsiveness should be compensated for by interface decisions that could avoid continuously overusing one thumb. Not all narratives are suitable for landscape orientation, nor playing with two hands is an alternative for every user. But how to generate inputs is under the developers' control, who can benefit from future studies on the functional area.

Timed actions are also a subject that require understanding for potential application. Prolonged gaming can increase the injury risks. Planning and pacing narratives for pauses (with narrative inputs, such as cut scenes or offering certain information or tips) may motivate users to rest before resuming playing.

Sensors and accelerometers can stimulate users to realign the body, and those could be a part of the gameplay.

These are some opportunities to explore, as (currently) no universal internal or external design works as a solution for all the risks and environmental gaming variables, which require future studies on mobile gaming.

CONCLUDING THOUGHTS

Available research and literature suggest proceedings for mobile phone operation, but gaming still requires studies to understand prolonged use, grinding and levels of engagement with the narratives that shape fit.

Yet, it is possible to make some recommendations toward ergonomics to reduce injury risks, in accordance with Merbah, Gorce and Jacquier-Bret (2020) thoughts. For them, users should look for body support and avoid prolonged use.

Trudeau et al. (2016) describe the differences holding the device with two hands instead of one, which is the preferable holding strategy from the literature, just as having the device at eye level while keeping a sitting position avoiding neck and cervical spine flexion.

Following those, although not thinking exclusively in gaming, players should ideally play for a brief time using arm rests while operating the device horizontally with both hands.

Such a posture and conditions are in contrast with the ones observed in on-the-go circumstances (e.g., on public transport), such as users barely counting with any support and playing with one hand (vertical orientation) for as long as the trip lasts, neck and cervical spine flexed with the wrist continuously compensating changes in balance.

Interfaces are also in opposition to what is considered ideal. While Nguyen (2015) discusses reachability of the screen options and the better layout for a right-hand user as an arch from the left corner to the upper right, games use various parts of the screen regardless, including ads that require users to close them by tapping buttons on the top parts (thus harder to achieve) as small as 3mm (about 0.12 in) of diameter on a 4.7-inch screen.

Parallel to Parisi's (2015) conclusion on gamepads that companies prefer to explore the familiar thumb activity than try (with exceptions) new forms to use the body as an input, mobile phone companies and game developers

favor audience familiarity designs instead of testing innovative approaches on ergonomics, disregarding the body cost.

In that sense, Cooley (2017) claims that clever design is the one that provides controlling effortlessly. We can assume previous operations play a relevant role on knowing where the options are and what they can do. Changing those may pose some challenges to the user but may be a price worth paying for the future of one's body.

ACKNOWLEDGMENT

The author would like to thank The University of Adelaide's Department of Media and School of Humanities for the support. This paper was only possible due to the School's Research Maintenance Fund.

REFERENCES

Cartwright, P., & Hyde, R. (2022). Virtual coercion and the vulnerable consumer: 'loot boxes' as aggressive commercial practices. Legal Studies, 42(4), 555–575. https://doi.org/10.1017/lst.2022.7.

Cooley, H. R. (2017). It's All about the Fit: The Hand, the Mobile Screenic Device and Tactile Vision. The Screen Media Reader. https://doi.org/10.5040/9781501311680.ch-030.

Eitivipart, A. C., Viriyarojanakul, S., & Redhead, L. (2018). Musculoskeletal disorder and pain associated with smartphone use: A systematic review of biomechanical evidence. Hong Kong Physiotherapy Journal, 38(02), 77–90. https://doi.org/10.1142/s1013702518300010.

Garosi, E. (2019). Smartphone and Musculoskeletal Risk Factors: A Systematic Review. Ergonomics International Journal, 3(1). https://doi.org/10.23880/eoij-16000193.

Gustafsson, E., Johnson, P. W., & Hagberg, M. (2010). Thumb postures and physical loads during mobile phone use – A comparison of young adults with and without musculoskeletal symptoms. Journal of Electromyography and Kinesiology, 20(1), 127–135. https://doi.org/10.1016/j.jelekin.2008.11.010.

Gustafsson, E., Thomée, S., Grimby-Ekman, A., & Hagberg, M. (2017). Texting on mobile phones and musculoskeletal disorders in young adults: A five-year cohort study. Applied Ergonomics, 58, 208–214. https://doi.org/10.1016/j.apergo.2016.06.012.

Liang, H.-W., & Hwang, Y.-H. (2016). Mobile Phone Use Behaviors and Postures on Public Transportation Systems. PLOS ONE, 11(2), e0148419. https://doi.org/10.1371/journal.pone.0148419.

Merbah, J., Gorce, P., & Jacquier-Bret, J. (2020). Interaction with a smartphone under different task and environmental conditions: Emergence of users' postural strategies. International Journal of Industrial Ergonomics, 77, 102956. https://doi.org/10.1016/j.ergon.2020.102956.

Nguyen, P. (2015). A Study of One-handed Interaction of Large Smartphones: GUI Changes for Better Ergonomics. Master's thesis, Department of Computer Science and Media Technology Gjøvik University College.

Ning, X., Huang, Y., Hu, B., & Nimbarte, A. D. (2015). Neck kinematics and muscle activity during mobile device operations. International Journal of Industrial Ergonomics, 48, 10–15. https://doi.org/10.1016/j.ergon.2015.03.003.

Parisi, D. (2015). A counterrevolution in the hands: the console controller as an ergonomic branding mechanism. Journal of Games Criticism.

Syamala, K. R., Ailneni, R. C., Kim, J. H., & Hwang, J. (2018). Armrests and back support reduced biomechanical loading in the neck and upper extremities during mobile phone use. Applied Ergonomics, 73, 48–54. https://doi.org/10.1016/j.apergo.2018.06.003.

Torok, L., Pelegrino, M., Trevisan, D., Montenegro, A., & Clua, E. (2018). Smart controller: Introducing a dynamic interface adapted to the gameplay. Entertainment Computing, 27, 32–46. https://doi.org/10.1016/j.entcom.2018.03.001.

Trudeau, M. B., Asakawa, D. S., Jindrich, D. L., & Dennerlein, J. T. (2016). Two-handed grip on a mobile phone affords greater thumb motor performance, decreased variability, and a more extended thumb posture than a one-handed grip. Applied Ergonomics, 52, 24–28. https://doi.org/10.1016/j.apergo.2015.06.025.

Zhu, R., & Li, Z. (2016). An Ergonomic Study on Influence of Touch-screen Phone Size on Single-hand Operation Performance. MATEC Web of Conferences, 40, 09001. https://doi.org/10.1051/matecconf/20164009001.