Exploring the Pace of an Endless Runner Game in Stationary and Mobile Settings

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Abstract

We explore the effects of pace of an endless runner game on user performance, preference, enjoyment, and engagement in stationary and mobile settings (while walking). Results revealed that game pace affects performance in both settings. The number of attempts increases and the total score decreases exponentially with increasing pace. Enjoyment, engagement, and preference are unaffected, yet most users prefer a slower pace while walking. These findings encourage further research on how to manipulate game pace based on the player's mobility status and physiological state to improve the mobile gaming experience.

Author Keywords

Video game; mobile game; mobile phone; game pace; walking; running; workout.

CSS Concepts

• **Human-centered computing → Human computer interaction (HCI)**; Smartphones; User studies.

Introduction

Mobile games are becoming increasingly popular among smartphone users. A recent market research predicted up to 30% growth in the global mobile games market from 2012 to 2021 [22]. This work focuses on games played while on the move, specifically while walking.

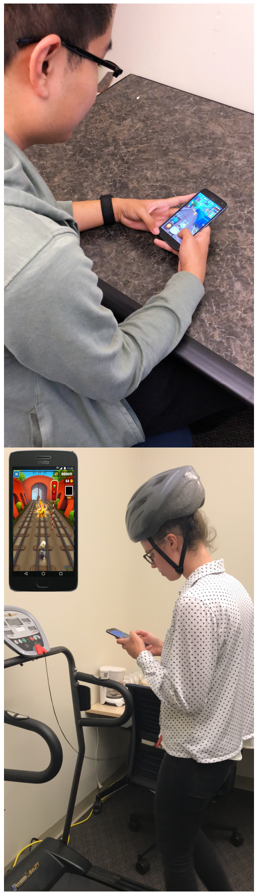

Figure 1. Two participants playing Subway Surfers [33] in (top) stationary and (bottom) mobile settings (walking on a treadmill). The image in the inset (top-left corner) illustrates the game and the device used in the user study.

While there is no reliable data on how often this gaming practice happens, the pervasive use of phones while walking [4] and mobile gaming practices suggests that it is not uncommon. It is evident that walking affects mobile phone usage and vice versa. Users tend to walk slower and deviate from a straight line while using a mobile phone [24,28]. Texting and talking on a phone also affects treadmill workout sessions by reducing walking speed by 10% [26]. Interestingly, users' mobile phone performance (in particular target acquisition) is usually unaffected while walking at a 40-80% of one's preferred speed on a treadmill [8].

The safety of using mobile phones while walking has been the concern of several studies [11,14,20], concluding that there is a higher accident risk for those who use mobile phones while walking *"especially for those who are playing games"* [11]. This is related to the immersive capabilities of games. They can push contextual contingencies to the background, which may ultimately put the players more at risk. Several designs have been explored outside the realm of games, such as *assistive technologies* that provide additional feedback to make walking and texting safer [5] and *architectural interventions* that separate sidewalk lanes for mobile users [7,34]. There are also *software adaptations* to facilitate the dual task of walking and mobile use, such as changing volume, vibration, and alerts depending on whether the user is walking, seated, or running [32], and increasing font size while walking to improve text selection and reading [29].

Many have studied the effects of latency on the gamer's performance [17], and the possibility of using games for physical activities [16], measuring attention-based abilities [3], and in planned exercise [1,2,12]. The most relevant to this work is an attempt to control player arousal by adjusting game difficulty based on the player's physiological state [23]. A study with a car-racing game revealed that manipulating car speed provides a higher control of arousal levels than changing road visibility or vehicle steering.

Here, we explore the possibility of changing the *game pace* (game action and narrative development) to facilitate gaming while walking, and how that would enhance and impact the mobile gaming experience. We work under the assumptions that: i) there is a connection between game pace and the player's engagement and interest (an optimal pace keeps the players engaged and invested, while a too fast or slow pace risks the players falling behind or losing interest) and that ii) a slower pace can potentially make mobile gaming safer by reducing the chance of accidents (bumps, slips, trips, and falls) and health risks due to increased levels of energy expenditure, heart rate, and exertion [21,31].

Experiment

This study explored the effects of game pace on user performance, preference, enjoyment, and engagement in stationary and mobile settings.

Apparatus

We used a Motorola Moto G^5 Plus smartphone (150.2×74×7.7 mm, 155 g) at 1080×1920 pixels in the study (Figure 1). We used a Fitness Reality TRE5000 electric treadmill to simulate walking, which is a common practice in controlled studies (e.g., [6,8,13,27,33]). We also used a third-party app called GameGuardian [36] to control game pace by altering the game's internal clock.

Figure 2. Screenshots of the Subway Surfers game: (top) the character is running away from the inspector by avoiding oncoming obstacles, and (bottom) the inspector caught the character, resulting in a "game over".

Subway Surfers

The study used the *Subway Surfers* [15] endless runner game since it is one of the most downloaded mobile games in the world [10]. This game starts with a police inspector chasing a character for spraying graffiti on a train (Figure 2). The player controls this running character by swiping *up*, *down*, *left*, or *right* to avoid crashing into oncoming obstacles, such as moving trains, poles, tunnel walls, and barriers. Getting caught or crashing into obstacles results in a "game over". Players collects points by evading crashes and collecting various items along the way, such as coins and score multipliers. The pace of the game increases with increasing levels to make the gameplay more challenging.

Game Pace

We investigated three game paces in the study: *slow*, *default*, and *fast*. The first slowed down the default pace by 0.7x and the last sped it up by 1.3x. We used this mapping in all levels. These paces were selected based on a pilot study, where 6 participants (3 female, 3 male) played the game in a seated position in three faster (1.3x, 1.6x, and 1.9x) and three slower (0.1x, 0.4x, and 0.7x) paces. Results identified 0.7x and 1.3x as the paces that least affected the gameplay.

Walking Speed

The treadmill was set on 1.0 mph (~1.6 km/h) during the mobile setting. This rate was based on a prior study that showed that users usually maintain a walking speed between 0.9 and 1.2 mph (1.5 and 2 km/h) when using mobile phones [19].

Participants

Twelve participants took part in the study. Their age ranged from 19 to 25 years (M = 22.33, SD = 2.09). Six of them were female, six were male. All of them were experienced mobile gamers with at least 2 years of experience (M = 7.5, SD = 3.28). Nine of them had played Subway Surfers before participating in the user study. They all received US $10 for their participation.

Design and Procedure

We used a within-subjects design. The independent variables were *setting* and *pace*, and the dependent variables were the following performance metrics.

- **Attempts** represents the total number of attempts made per condition. An attempt is counted from the start/restart of a game to "game over".
- **Score** represents the average "total" score per condition. If a player makes three attempts in a condition, then the total score of that condition is the sum of the points scored at each attempt.

All participants started with the default pace as it was the baseline. All other conditions were counterbalanced to eliminate the effect of learning. In summary, the design was: 12 participants × 2 settings (stationary and mobile) × 3 game paces (slow, default, fast) × 5 minutes (at least) = 260 minutes (at least), excluding practices and questionnaire.

In the study, all participants played Subway Surfers in slow (0.7x), default, and fast (1.3x) conditions in both stationary and mobile settings. First, we explained the study procedure to all participants and collected their consents and demographics. We then asked the ones who had never played the game before to play it in the default pace for about three minutes. We included this practice block to make sure that all participants were moderately familiar with the game, to mitigate unfamiliarity effects on performance or preference. The main study started after that, where participants were asked to play the game for at least five minutes in each condition. However, we allowed them to finish a level if the game was not over by the allocated time. All participants started the game at the first level. They were asked to restart the level in cases of "game over" before the allocated time. We used a stopwatch to keep record of the time. We also recorded the total score per condition; and perceived engagement with the game by observing the player's body language, facial expression, and willingness to complete a level.

Appropriate safety measures were taken during the mobile condition. All participants were asked to attach the treadmill safety key to their clothing and wear a bike helmet to prevent injuries in case of an unexpected slip, trip, or fall (Figure 1). Besides, there were mandatory breaks between the conditions to prevent exhaustion for using the treadmill.

Quantitative Results

Participants spent on average 33.8 minutes (SD = 2.7) exclusively playing the game. A complete study session took from 45 to 60 minutes, including breaks and questionnaire. A Shapiro-Wilk test failed to reject the null hypothesis for the dependent variables ($p > .05$) that the sample came from a normally distributed population. A Mauchly's Test of Sphericity indicated that the assumption of sphericity was not violated for the dependent variables ($p < .05$). Hence, we used a repeated-measures ANOVA for all analysis.

Attempts

An ANOVA identified a significant effect of pace on attempts ($F_{2,11} = 39.9$, $p < .0001$). However, there was no significant effect of setting ($F_{1,11} = 1.30$, $p > .05$) or pace × setting ($F_{2,22} = 0.72$, $p > .05$). A Tukey-Kramer Test revealed that the three examined paces were significantly different both within and between settings. Evidently, there were strong correlations between the data and exponential trendlines: $R^2 = 0.99$ for both settings (Figure 3).

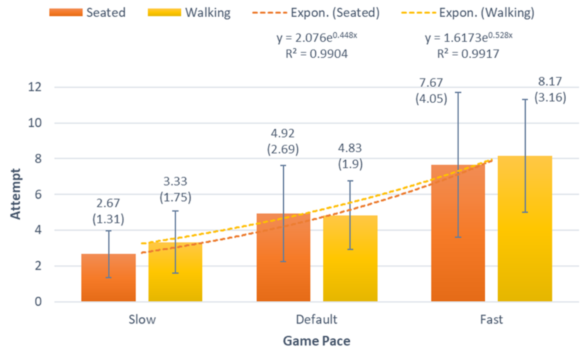

Figure 3. Average attempts per condition fitted to exponential trendlines. The values inside the brackets and the error bars represent standard deviations.

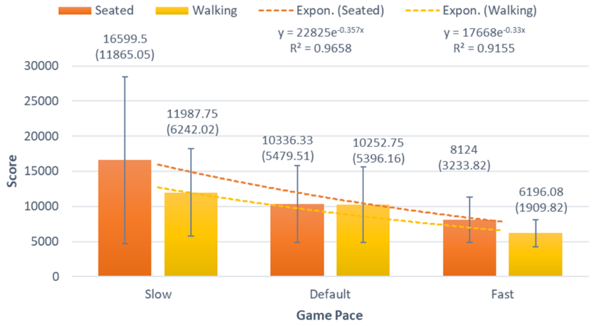

Figure 4. Average score per condition fitted to exponential trendlines. The values inside the brackets and the error bars represent standard deviations.

Score

An ANOVA identified a significant effect of pace on score ($F_{2,11} = 7.91$, $p < 0.005$). There was also a significant effect of setting ($F_{2,11} = 4.92$, $p < .05$), but not of pace × setting ($F_{2,22} = 1.24$, $p > .05$). A Tukey-Kramer Test identified three distinct groups: slow × seated, fast × seated, and fast × walking. Like with attempts, there were strong correlations between the data and exponential trendlines: $R^2 = 0.96$ and $R^2 = 0.92$ for the stationary and mobile settings, respectively (Figure 4).

Qualitative Results

Upon completion of the study, participants were asked to complete a short questionnaire where they could rate and comment on their preference and enjoyment of the game on 7-point Likert scales. A Friedman Test was used to analyze all non-parametric data.

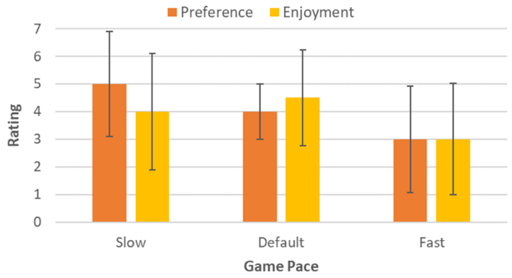

Figure 5. Median preference and enjoyment scores for the examined paces in the mobile setting on a 7-point Likert scale, where 1 to 7 represented "strongly agree" to "strongly disagree". Error bars represent ±1 standard deviation.

Preference and Enjoyment

A Friedman Test failed to identify a significant effect of pace on preference in the mobile setting ($\chi^2_{(2)} = 5.68$, $p = .05$). But 75% ($N = 9$) participants preferred either the slow or the default pace while walking. A Friedman Test also failed to identify a significant effect of pace on enjoyment in the mobile setting ($\chi^2_{(2)} = 2.23$, $p = .33$). Figure 5 shows the median preference and enjoyment scores for the three paces while walking. Interestingly, most participants (67%, $N = 8$) responded that they would prefer playing games that compensated for their mobility status and physiological states by changing game pace, one (8%) said that he would not, while the remaining participants (25%, $N = 3$) were neutral.

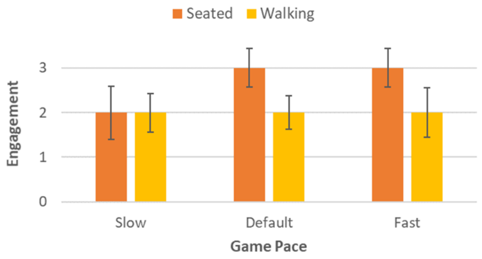

Figure 6. Median perceived engagement rating per condition on a 3-point Likert scale, where 1 to 3 represented "not engaged" to "engaged", respectively. Error bars represent ±1 standard deviation.

Engagement

To rate gameplay engagement, a researcher observed the players' body language, facial expression, and willingness to complete a level (Figure 6). A Friedman Test identified a significant effect of pace × setting on engagement ($\chi^2_{(5)} = 26.53$, $p < .0001$). There was a significant effect of pace on engagement in the stationary setting ($\chi^2_{(2)} = 12.8$, $p < .005$), but not while walking ($\chi^2_{(2)} = 0.2$, $p > .05$).

Discussion

Results showed that game pace affects both attempts and score in both stationary and mobile settings. The number of attempts increases and the total score decreases exponentially with increasing pace. In the mobile setting, participants required 31% fewer attempts to achieve a 14% higher score with the slow pace than the default pace

Qualitative data revealed that the enjoyment and engagement ratings were comparable between different game paces in the mobile setting. Further, participants did not prefer a particular pace significantly more than the others. This must inspire researchers to further investigate if tweaking game pace can improve user performance in mobile settings without affecting their preference. A near significant difference ($p = .05$) in preference between different paces also demands further investigation to find out whether this reaches significance with a larger sample. The fact that most participants (67%) liked the idea of manipulating pace and wanted to play games that change pace based on their physiological state is encouraging.

It is interesting that participants yielded a comparable performance in the stationary and mobile settings. It contradicts an existing theory in cognitive psychology that suggests that *"dual-task performance is severely and persistently constrained by a central cognitive bottleneck"* [9,25,35]. This could be because the cognitive bottleneck was not reached in the study. It is also possible that the participants, who were experienced mobile gamers, had mastered the skill of performing the two examined tasks (playing mobile games and walking) in parallel without impacting the performance of either. This aligns with an alternative theory that suggests that *"skilled procedural decision making and response selection for two or more tasks can proceed at the same time under adaptive executive control"* [18,30]. However, it is unclear whether this observation will persist in the real-world since we used treadmill in the mobile condition that did not require participants to keep an eye on a constantly changing environment [5]. Further exploration is needed to fully understand this phenomenon.

Conclusion

We found out that game pace affects performance in both stationary and mobile settings. Although no relationship between pace and enjoyment, engagement, preference was identified, most players prefer a slower pace while walking.

Future Work

In the future, we will conduct further studies to identify any relationships between game pace and performance, preference, enjoyment, and engagement in different mobile settings and physiological state. We will also develop custom games. Although we did not observe any issues during the study, it is possible that the third-party app used to manipulate pace had caused glitches and deviations leading to a less pleasant gameplay. We will use a larger sample and a more structured method to measure various human factors. The goal will be to develop a theoretical model that can be used to design mobile games that can adapt to the gamer's physiological state to provide her with a better gaming experience. Further, we will explore the effects of mobile games on walking performance to identify the extent to which players can perform both tasks well in the playing-walking dual-task scenario. The safety of playing games while walking will also be studied. Finally, we will explore if there is a relationship between game pace and latency, and whether this relationship can be exploited to improve mobile gaming experience.

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