On the Impact of Competitive Gameplay on Text Entry Performance - A Study Based on a Mobile Typing Game

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ABSTRACT

Text entry is a fundamental part of human computer interaction and typing games are a popular way to train and improve text entry skills. To assess the impact of competitive gameplay on text entry performance we conducted a public app store trial. For this purpose TypeClash, a competitive multiplayer mobile typing game was designed, developed and publicly distributed. The results demonstrate a significant effect of competitive gameplay mechanics on text entry performance regarding both speed and accuracy, with competitive gameplay resulting in better text entry performance.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; **Empirical studies in ubiquitous and mobile computing**.

KEYWORDS

serious games, typing games, competition, text entry, text input

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1 INTRODUCTION

Text entry is a fundamental part of how we interact with our contemporary computing systems, whether it be on desktop or mobile devices. As such, the ability to enter text is a crucial skill for users in order to operate their devices effectively and efficiently. To help people train and improve their text entry skills, typing games have been a popular training tool for several decades. Typing games typically provide activities intended to practice and improve typing skills and embed them in fun and engaging gameplay mechanics in order to make practice more motivating and entertaining. Their primary purpose commonly being focused on training and education, typing games can be considered a form of serious games, which are defined as games with a primary purpose other than pure entertainment [5, 14].

Given the importance of text entry as an essential building block of human computer interaction, the evaluation of text entry methods and their performance measurement has been the subject of extensive HCI research. To this end, some researchers have been using typing games as a means to conduct their experiments (see section 2.2). Typing games might be considered an opportune or "natural" match for these kinds of research, as their typical core gameplay loop is well aligned with the typical core task of text entry experiments, which generally task participants with transcribing predefined phrases, chosen from a representative phrase set, as quickly and accurately as possible. However, when using serious games as an apparatus for research purposes, it is necessary to carefully balance research objectives and methodology with game design, as different gameplay mechanics and game design choices could potentially influence or distort the results, posing a threat to the validity of collected data.

This paper examines the effect of a particular gameplay mechanic, specifically competitive multiplayer gameplay, on text entry performance in a mobile typing game named TypeClash. TypeClash was publicly released on Apple's App Store and Google Play Store for crowd-sourced data acquisition. The results demonstrate a statistically significant effect of competitive gameplay on both text entry speed and accuracy. These results can help game designers creating typing games for educational and training purposes, as well as researchers utilizing typing games for experimental purposes, to better understand the impact of game design choices regarding competitive gameplay on player performance.

2 RELATED WORK

2.1 Effects of Competitive Play in Games

Prior research examined the effects of competitive gameplay in various gaming domains with largely positive, but sometimes conflicting results. Vorderer et al. [21] discuss the role of competition for the enjoyment of video games and relate it to interactivity (specifically the necessity to act on possibilities) and social competitive processes, the latter of which this study focuses on. Weibel et al. [22] examined the experiential effect of playing against human or computer-controlled opponents and found that "the type of opponent [...] has a strong influence on playing experiences", with human opponents resulting in stronger feelings of presence, enjoyment and flow. In the domain of serious educational games, Cagiltay et al. [3] examined the effect of competition on learning

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in a serious game. They found that competition enhances learning and motivation and concluded with the recommendation that "game designers should incorporate the element 'competition' [...] to facilitate learning". Investigating competition as a gamification element for learning, Sepehr et al. [18] observed a detrimental effect on students' satisfaction and enjoyment when losing a competition, but still regarded competition to be a key element to motivate students. In the domain of exergames, Song et al. [19] examined the effects of competition and competitiveness on motivation in exercise videogames. They found that a "competitive context provided positive exergame experiences to competitive individuals, whereas it had detrimental effects for less competitive participants". Nunes et al. [15] evaluated the difference between single player and competitive multiplayer game modes in an immersive virtual running environment and showed that competition significantly improved performance. While most studies highlight the positive effects of competition on player experience, motivation or performance, the results by Sepehr et al. [18] and Song et al. [19] show that competition can also lead to detrimental effects and its use warrants caution.

2.2 Typing Games in HCI Research

Mobile typing games have been utilized for scientific purposes and to conduct research on text entry behaviour and performance in prior research. To teach people shape writing, a novel touchscreen text entry technique, Kristensson and Zhai [11] developed a training game and defined their design goals for the game to be efficient, fun and challenging. Relying on informal user feedback, the authors found their results encouraging. Rudchenko et al. [17] developed Text Text Revolution, a typing game to improve text entry on mobile touchscreen keyboards in two ways: by providing targeting practice to users and by generating training data for key-target resizing as a side effect of playing the game. Text Blaster by Vertanen et al. [20] is a multiplayer shoot'em up game for investigating performance and design aspects of touchscreen text entry mechanisms. Without measuring the specific effects of competitive gameplay mechanics on text entry performance, the authors found that the competitive nature of gameplay encouraged players to enter text both quickly and accurately and hypothesized "that these properties might make Text Blaster an ideal platform for conducting both laboratory and crowdsourced text entry experiments". Employing a public app store trial approach similar to the one presented in this paper, Henze et al. [9] developed a typing game to collect more than 47 million keystroke events from 72,945 installations. They concluded that their "studies have a low internal validity but, compared to common lab studies, a very high external validity" because of the large number of participants and the data being collected in real life contexts from users' own devices. Hyper Typer by Wimmer et al. [23] is a mobile typing game for measuring text entry performance employing a public app store trial approach, with its goal being ongoing data collection on a large scale in the real world. They concluded that serious games are a promising way for crowd-sourcing HCI research and discussed issues such as limited internal validity and low data quality as well as challenges related to reach and distribution. While not specifically presented as a game, Zhang et al. [24] described their text entry task as "game-like", with a variable scoring mechanism relative to desired objectives (speed or accuracy) in order to induce different cognitive sets among participants.

3 GAME DESIGN AND DEVELOPMENT

3.1 Design Process

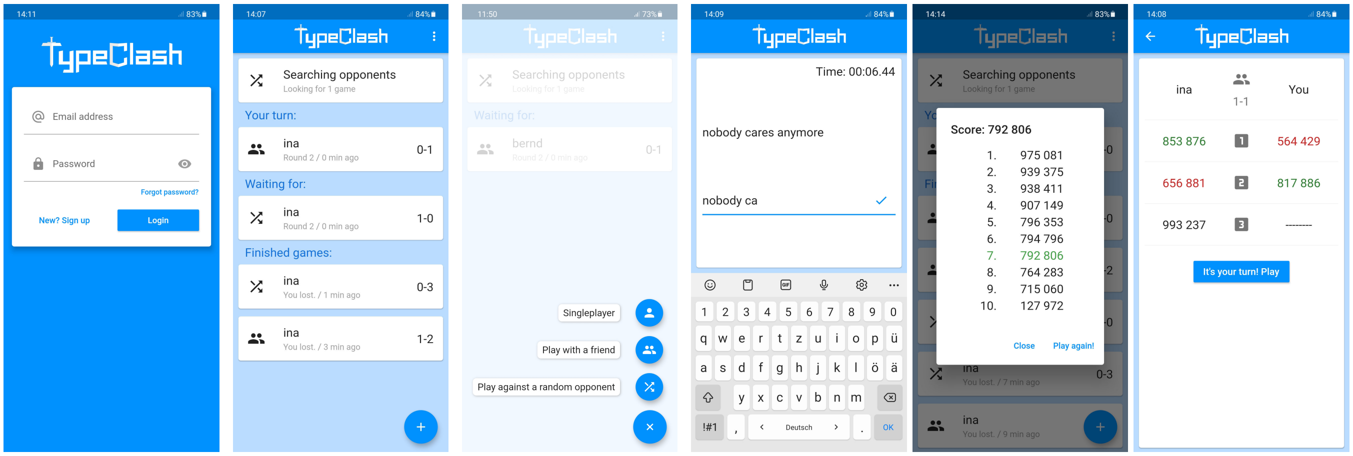
For the purposes of this study a mobile typing game for iOS and Android named TypeClash was developed. Designing and developing a serious game for research purposes is a challenging and laborious task that requires expertise in both game design and research methodology. In order to ensure the validity of results, the game design and research objectives must be carefully aligned and balanced. To this end, the Human Computing to Video Games model [4] proposes a design process to facilitate this goal: Researchers first deconstruct their research objectives into desired outputs before integrating the research activities into the game loops. The desired outputs of TypeClash are text entry performance metrics such as words per minute or error rates which are well established in text entry evaluation methodology.

The core gameplay loop of TypeClash consists of the transcription of predefined phrases, which is similar to both existing typing games as well as recommendations and related work in the field of text entry evaluation. In line with recommendations on text entry evaluation [10], players are tasked with transcribing predefined phrases "as quickly and accurately as possible". Phrases for transcription are selected from the English language phraseset for text entry evaluation by MacKenzie & Soukoreff [12] and presented in the upper half of the game screen above the text input field (see Figure 1d), a layout which has proven itself suitable [16]. In contrast to some other typing games (e.g. [9]), the game does not implement its own custom virtual keyboard, but presents players with the same system keyboard that they are already familiar with in order to facilitate realistic text entry behaviour. Predictive text entry features such as auto-correction and auto-completion were disabled for the purposes of this study.

The game adopts the unconstrained text entry evaluation paradigm defined by the following three requirements as described by Wobbrock [13]: All printable characters are accepted as legitimate input during transcription (specifically including incorrect characters), using backspace is the only means of correcting errors and no intrusions affect text entry. Some typing games violate this paradigm by prohibiting incorrect inputs or ignoring incorrect characters, presumably to provide a more fluid gameplay experience. However, Rudchenko et al. [17] observed that artificially constraining text input influences the player's text entry behaviour to slow down and type more carefully.

3.2 Game Design and Gameplay

Upon launching the game, players are presented with a screen where they can register a new account or login with an existing account (see Figure 1a). During the registration process players must select a publicly visible username. After signing up or logging in, players are presented with the game's homescreen, which contains a list of ongoing games (see Figure 1b). Players can start a new (single player or multiplayer) game from this screen (see Figure 1c). A menu accessible through the button in the top right corner of



(a) Sign Up **(b) Game List Menu** **(c) New Game** **(d) Gameplay** **(e) Scores** **(f) Match scores**

Figure 1: Screenshots of TypeClash

the homescreen allows players to log out, manage or delete their account and to share the game with others using messaging apps or social media.

TypeClash supports both single player and multiplayer game modes. In both single- and multiplayer game modes, players are presented with the same gameplay screen (see Figure 1d). In single player mode, upon finished transcription, players are presented with a highscore list (see Figure 1e) to provide feedback on the player's performance and players can start a new game directly from this highscore list.

In multiplayer mode, players can challenge other players in a competitive match. Players can either challenge a specific player (such as friends or players they have played with before) using their username, or they can challenge anonymous opponents randomly drawn from the playerbase. Incoming challenges are displayed in the game list on the homescreen (see Figure 1b). Players can decline incoming challenges and challenges are automatically declined if they are not accepted within 72 hours. Multiplayer matches facilitate asynchronous, turn-based gameplay, where players take turns transcribing a total of three phrases each across three rounds. Both players are presented with the same phrase for transcription in each round to ensure a fair challenge. After a round is completed, players are presented with a results screen, highlighting the winner of the current game round (see Figure 1f). The overall match winner is determined using the best-of-three principle. After finishing a competitive multiplayer game, players can immediately challenge their opponent to a rematch. The game utilizes push notifications to inform players about incoming multiplayer match requests, when it is their turn in an ongoing match and when a match is finished. In addition, players receive a push notification when their opponent has been waiting on their turn for 24 and 48 hours respectively.

The game was developed using Flutter as a cross-platform app for both iOS and Android. The game uses Firebase for account creation, account management and push notifications. Text entry performance data is collected inside a PostgreSQL database, using a custom Spring application via REST API.

4 STUDY METHODOLOGY

Facilitating a public app store trial approach [7, 8], TypeClash was publicly released for the purposes of ongoing data collection without the need for direct supervision. The game was released on both Apple's App Store (for iOS devices) and Google Play Store (for Android devices) in order to reach as large an audience as possible and to lower the barrier of participation. While this approach limits experimenters' control of experimental procedure, it provides the benefit of reaching participants in their natural, everyday environment, thus potentially increasing reach and external validity of results [7]. To ensure informed consent for data collection from players, the research purposes of the game were prominently described in the app store listings. In addition to its public release, the game was disseminated among the authors' social circle with the request for further distribution among potentially interested parties.

To assess text entry performance the game collects the following performance measures for text entry speed and error rate metrics [13, 23]:

- Words per Minute (WPM): "Measure of entry rate, based on common assumption that one word consists of 5 characters."
- Adjusted Words per Minute (ADJ.WPM): "Adjusted WPM entry rate penalized by uncorrected errors." A penalty exponent of 1.0 is used in our calculation.
- Total Error Rate (TER): "Proportion of incorrect-not-fixed and incorrect-fixed characters to the total number of characters entered, equal to the sum of corrected and uncorrected error rates."
- Corrected Error Rate (CER): "Proportion of incorrect-fixed characters to the total number of characters entered."
- Uncorrected Error Rate (UER): "Proportion of incorrect-not-fixed characters to the total number of characters entered."

None of these metrics are directly exposed to players within the game as they might be confusing for a general audience unfamiliar with text entry evaluation methodology. Instead, players are presented with a synthetic score based on text entry speed and error

Game mode	Single player	Multiplayer	p
n	1464	1194	
WPM	46.9 (16.3)	52.2 (15.1)	**< 0.01**
ADJ.WPM	44.6 (15.7)	50.3 (15.1)	**< 0.01**
TER	8.82 % (8.16)	7.10 % (7.30)	**< 0.01**
CER	3.95 % (7.33)	3.33 % (6.19)	**< 0.05**
UER	4.87 % (5.12)	3.77 % (4.88)	**< 0.01**

Table 1: Comparison of text entry performance between single player and multiplayer modes (mean values, standard deviation in parentheses).

Match state	Decided	Undecided	p
n	244	154	
WPM	50.8 (15.8)	53.7 (14.3)	**< 0.05**
ADJ.WPM	48.6 (15.6)	52.3 (14.4)	**< 0.01**
TER	8.11 % (7.58)	6.44 % (6.93)	**< 0.05**
CER	3.62 % (6.16)	3.60 % (6.27)	= 0.864
UER	4.48 % (5.49)	2.85 % (4.05)	**< 0.01**

Table 2: Comparison of text entry performance in third-round transcriptions between decided and undecided match states (mean values, standard deviation in parentheses).

rates. This score is also used in highscore lists and to determine the outcome of multiplayer matches. In addition to these metrics, the game also stores operating system, device language, timestamp, duration, game mode, score, presented and transcribed phrase for each transcription.

5 RESULTS

5.1 Data Acquisition and Data Cleansing

Following its public release, a total of 97 installations of the game (40 Android, 57 iOS) were registered over a two month time span. Of those, 67 TypeClash accounts were registered and a total of 1614 single player games (consisting of a single transcription) and 265 multiplayer matches (consisting of 6 transcriptions for a finished match) were played.

Due to the voluntary nature of participation and unsupervised gameplay, the collected data was thoroughly examined and cleaned up for subsequent analysis. Of the 265 multiplayer games, 57 were prematurely terminated and excluded from further analysis. In addition, transcriptions with no discernible relation to the presented phrases were removed by filtering transcriptions with an uncorrected error rate (UER) greater than 30 % before manual inspection and filtering of the remaining phrases. The final resulting dataset after data cleansing consists of 1464 transcriptions from single player games and 1194 transcriptions from 199 multiplayer matches.

5.2 Analysis by Game Mode

To assess the impact of single player and multiplayer game modes on typing performance, all valid transcriptions that remained after data cleansing were compared (see Table 1).

In single player mode, average text entry speed WPM is 46.9 words per minute (SD = 16.3) and ADJ.WPM 44.6 words per minute (SD = 15.7) when adjusting for uncorrected errors with a penalty exponent of 1.0. Average error rates are total error rate TER 8.82 % (SD = 8.16), corrected error rate CER 3.95 % (SD = 7.33) and uncorrected error rate UER 4.87 % (SD = 5.12). In multiplayer mode, average text entry speed WPM is 52.2 words per minute (SD = 15.1) and ADJ.WPM 50.3 words per minute (SD = 15.1). Average error rates are total error rate TER 7.1 % (SD = 7.3), corrected error rate CER 3.33 % (SD = 6.19) and uncorrected error rate UER 3.77 % (SD = 4.88).

A comparison of game modes using an independent samples t-test showed a significant effect of game mode on text entry speeds WPM ($t(2656) = 8.554, p < 0.01$) and ADJ.WPM ($t(2656) = 9.520, p < 0.01$).

Error rates were compared using a Mann-Whitney U Test ($n_{single} = 1464$, $n_{multi} = 1194$) as visual inspection using Q-Q plots did not support the assumption of normal distribution. The comparison of error rates showed a significant effect of game mode on total error rate TER ($U = 756508.5, z = -6.009, p < 0.01$), corrected error rate CER ($U = 835395, z = -2.223, p < 0.05$) and uncorrected error rate UER ($U = 749984.5, z = -6.520, p < 0.01$).

These results show that players' text entry performance, regarding both speed and accuracy, was significantly better when playing in competitive multiplayer mode compared to single player mode.

5.3 Analysis by Match State

As described in section 3.2, the winner in multiplayer matches is determined based on the best-of-three principle - as such, a match's outcome is already decided if the same player wins the first two consecutive rounds. However, the third and final round is always played out in the game, even in matches that have already been decided. To assess the effect of these two different match states (decided, where one player is already the certain winner, and undecided, where both players can still achieve victory), the third rounds of multiplayer matches were analysed (see Table 2).

Out of 199 finished multiplayer matches, 122 matches were already decided after the first two rounds, whereas 77 were still undecided, resulting in 244 transcriptions from decided and 154 transcriptions from undecided rounds. In decided rounds, average text entry speed WPM is 50.8 words per minute (SD = 15.8) and ADJ.WPM 48.6 words per minute (SD = 15.6). Average error rates are total error rate TER 8.11 % (SD = 7.58), corrected error rate CER 3.62 % (SD = 6.16) and uncorrected error rate UER 4.48 % (SD = 5.49). In undecided rounds, average text entry speed WPM is 53.7 words per minute (SD = 14.3) and ADJ.WPM 52.3 words per minute (SD = 14.4). Average error rates are total error rate TER 6.44 % (SD = 6.93), corrected error rate CER 3.60 % (SD = 6.27) and uncorrected error rate UER 2.85 % (SD = 4.05).

A comparison of match states using an independent samples t-test showed a significant effect of match state on text entry speeds WPM ($t(396) = -1.876, p < 0.05$) and ADJ.WPM ($t(396) = -2.365, p < 0.01$). Error rates were again compared using a Mann-Whitney U Test ($n_{decided} = 244$, $n_{undecided} = 154$) and showed a significant effect of match state on total error rate TER ($U = 16275.5, z = -2.267, p < 0.05$) and uncorrected error rate UER ($U = 15686, z = -2.934, p <$

Opponent relationship	Specific	Random	p
n	1044	150	
WPM	52.4 (15.0)	51.0 (16.0)	= 0.291
ADJ.WPM	50.5 (15.0)	49.3 (15.6)	= 0.391
TER	7.05 % (7.09)	7.51 % (8.62)	= 0.694
CER	3.18 % (5.81)	4.35 % (8.29)	= 0.899
UER	3.86 % (4.97)	3.16 % (4.19)	= 0.159

Table 3: Comparison of text entry performance between specific and random opponents (mean values, standard deviation in parentheses).

0.01), but not corrected error rate CER (U = 18617.5, z = -0.171, p = 0.864).

These results show that players' text entry performance was better when a match was still undecided in the third round and when both players still had a chance to win. Players were significantly faster and made less errors overall, but seemingly were not willing to expend effort on correcting more errors (as expressed by corrected error rate CER).

5.4 Analysis by Opponent Relationship

As described in section 3.2, in multiplayer mode, players could either challenge specific other players such as friends that were already familiar to them, or random, anonymous players. To assess whether the relationship between opponents had an impact on text entry performance the two groups of specific and anonymous opponents were compared (see Table 3).

Out of 199 finished multiplayer matches, 174 matches (resulting in 1044 transcriptions) were played between specific opponents and 25 matches (resulting in 150 transcriptions) were played between random, anonymous opponents. Against specific opponents, average text entry speed WPM is 52.4 words per minute (SD = 15.0) and ADJ.WPM 50.5 words per minute (SD = 15.0). Average error rates are total error rate TER 7.05 % (SD = 7.09), corrected error rate CER 3.18 % (SD = 5.81) and uncorrected error rate UER 3.86 % (SD = 4.97). Against random opponents, average text entry speed WPM is 51.0 words per minute (SD = 16.0) and ADJ.WPM 49.3 words per minute (SD = 15.6). Average error rates are total error rate TER 7.51 % (SD = 8.62), corrected error rate CER 4.35 % (SD = 8.29) and uncorrected error rate UER 3.16 % (SD = 4.19). A comparison of opponent relationships showed no significant effect of opponent relationship on text entry speeds and error rates.

6 DISCUSSION

The results demonstrate a statistically significant effect of competitive multiplayer gameplay on text entry performance, regarding both speed and accuracy. Players appear to expend additional effort when facing an opponent in a multiplayer match. As such, competitive multiplayer gameplay is a suitable design choice when striving to motivate players to perform text entry tasks at the height of their capabilities. Considering that many text entry experiments urge participants to enter text as quickly and accurately as possible rather than at a leisurely or convenient pace, it can be assumed that researchers are generally interested in measuring text entry performance at peak performance levels. To this end, we encourage researchers to consider the use of competitive gameplay mechanics in order to achieve this goal. While outside the scope of this paper, competitive gameplay might have a similar effect on other HCI research tasks (e.g. pointing or steering tasks) and we plan to examine this in our future work.

Due to the unsupervised nature of data collection it is only prudent to consider the possibility of confounding factors other than gameplay mode having influenced the results. For example, it is possible that people with better typing skills, or at least more confident in their typing skills, might be more strongly drawn to the competitive playing mode, whereas less skilled typists might be more drawn to single player mode. However, we believe that the analysis of decided and undecided match states (see section 5.3) supports the assumption that players are indeed motivated to perform better in order to win, as the results show significantly better performance (for all metrics except corrected error rate) for undecided game rounds compared to decided game rounds.

Nevertheless, the use of competitive gameplay mechanics warrants caution and careful deliberation as its effects might vary depending on player personality. Players respond to various gameplay mechanics differently based on their preferences, expectations and motivation and several models to classify player personality types exist [1, 2, 6]. Based on Bartle's taxonomy [1], so-called "killers", who are primarily driven by direct competition and a desire to win, should be most strongly motivated by competitive gameplay mechanics, whereas "achievers", "explorers" and "socializers" might be less motivated or even deterred by it. This would be in line with the results by Song et al. [19], who observed a detrimental effect of competition on less competitive participants in the domain of exergames.

The analysis of different player relationships (specific vs. random opponents) revealed no significant effect. It should be noted, however, that the sample size for random opponents (n = 150) was significantly smaller than for specific opponents (n = 1044), and thus this aspect requires further investigation. At the same time, this difference in sample sizes indicates that players were more strongly inclined to challenge other players they already knew or played with before rather than random, anonymous opponents.

7 CONCLUSION

In this paper we present the results of our research on the impact of competitive gameplay on text entry performance. We designed, developed and released a mobile typing game named TypeClash to facilitate a public app store trial and crowd-source data collection. Over a two month time span, a total of 2658 phrase transcriptions were collected for subsequent analysis. The results demonstrate a significant effect of competitive multiplayer gameplay on text entry performance regarding both speed and accuracy, with competitive gameplay resulting in better text entry performance. We recommend that game designers and researchers consider competitive gameplay as a suitable gameplay mechanic to motivate and increase player performance in typing games.

TypeClash, the game developed for the purposes of this study, remains a viable platform for further research on mobile text entry behaviour by way of public app store trials. In the future we plan to expand on our research by examining the effects of other gameplay mechanics on mobile text entry performance, by investigating the effects of competitive gameplay on tasks other than mobile text entry performance and by more comprehensively studying the effects of competitive gameplay on different player personality types.

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