Differentiating in-Game Frustration from at-Game Frustration using Touch Pressure

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ABSTRACT
Games are engaging in part because players experience competence from overcoming challenges. Although this process can feel frustrating, it is often experienced as a positive frustration that results in further engagement. Motivating frustration can be difficult to differentiate from the disheartening frustration that occurs when games are poorly designed or are much too difficult, yet understanding this difference is important for designers to make informed decisions on how to address player experience problems. We conducted an experiment to determine whether touch pressure from game interaction can differentiate between motivating in-game frustration and disheartening at-game frustration. Our results showed that although in-game and at-game frustration were of similar magnitude, enjoyment was higher and attribution was more internal for in-game frustration. Both peak pressure and mean pressure were also higher for in-game frustration, showing the potential of touch pressure as a game experience evaluation metric.

Author Keywords
Touch pressure; games; frustration; player experience.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
People now spend more time and money playing digital games than on other leisure media, such as listening to music or watching movies [12,13]. There are several theories that explain why games are so engaging – the most prevalent (self-determination theory [32]) suggests that one reason games are motivating to play is because players experience a feeling of competence from overcoming in-game challenges [33]. Repeatedly trying (and failing) to beat game elements can feel frustrating, but then triumphing over the challenge is rewarding [2]. This type of *motivating frustration* (in which players want to persevere and overcome in-game challenges) can be called *in-game frustration* [16] and is desirable in a game. However, frustration during game play is not always positive. For example, players can be so frustrated by poor game controllers or a ridiculously difficult boss that they 'rage quit' and potentially do not return to play again. This type of *disheartening frustration* (in which players disengage from game play) can be called at-game frustration [16] and is something that game designers want to avoid in their game design. Designers try to avoid negative frustration by using good design principles and by employing iterative evaluation throughout the design lifecycle to identify frustrating moments that can be balanced or fixed during development.

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There are several methods to infer frustration during gameplay. Researchers can visualize player death locations [11,4], or quitting behavior; can observe players [22] and look for signs that are based in physiology (e.g., red face, sweating) or behavior (e.g., agitation, swearing); can ask questions that explicitly ask players to recall frustrating moments [6]; or can record physiological signals that indicate negative arousal [23]. However, these methods either do not scale for use after commercial release or have a resolution too low to trigger adaptation. In addition, although these methods may indicate that a player is frustrated, they do not differentiate whether players will be motivated or disheartened as a result. Knowing whether the experienced frustration is motivating or disheartening is vital for game researchers and designers to be able to choose a course of action – for example, whether the in-game challenge should be reduced or whether the controls need to be fixed.

The problem that we address is that by using standard approaches for detecting frustration, researchers cannot reliably differentiate between motivating frustration that may encourage players to overcome in-game challenges and disheartening frustration that may result in players quitting. Previous research has shown that the pressure that players exert on controller buttons increases with increasing game difficulty [34]. As such, we propose that although the magnitude of frustration may be similar, the pressure exerted by players during touch-based game interaction will differentiate between these two types of frustration. Specifically, we hypothesized that motivating in-game frustration will result in greater touch pressure (reflecting engagement) and disheartening at-game frustration will result in lower touch pressure (reflecting disengagement).

To differentiate frustration type using touch pressure, we designed a game that allowed us to vary the in-game challenge and responsiveness of the input controls. We created four experimental conditions: a training condition, in-game frustration (created through challenging obstacles), at-game frustration (created through unresponsive and laggy controls), and an easy condition (created through boring and repetitive obstacles) that was used as a comparison condition. In a study with 42 participants, we gathered data on player experience from several validated scales. We also collected touch pressure; however, because pressure-sensitive displays are not ubiquitous, we operationalized touch pressure as the size of the finger contact area, which can be sensed using a standard touch-sensitive display.

Our results showed that:

- There was no difference in the frustration ratings between the motivating and disheartening conditions, showing that the two types were similar in terms of the magnitude of experienced frustration;
- Players perceived in-game frustration as more difficult and attributed it more internally, which shows that our experimental manipulation of game challenge was successful at eliciting different experiences and that players blamed the system more for their performance during at-game frustration.
- In-game frustration was rated as more enjoyable than at-game frustration, which lends support to the distinction between positive motivating frustration and negative disheartening frustration.
- Competence, attribution, and difficulty were significant predictors of enjoyment; whereas frustration was not, suggesting that the root cause of the frustration (i.e., in-game or at-game) yields different experiences that could result in feeling motivated or disheartened.
- Most importantly, players pressed harder on average and also had higher peak pressures when the frustration was derived from in-game challenges (i.e., challenging level design) as opposed to at-game challenges (i.e., laggy controls), showing that motivating frustration can be objectively differentiated from disheartening frustration through an analysis of touch pressure.

Our results differentiate in-game and at-game frustration using subjective measures (e.g., enjoyment, attribution). More notably, our research is the first that we know of to use touch pressure to objectively distinguish between these interaction patterns. Understanding the degree of frustration is important for designers to create adaptive games; however, understanding the orientation of the frustration is equally important for making decisions on how to address the player experience problems through game design changes or difficulty adaptations. By using touch pressure to differentiate between in-game and at-game frustration, game designers will have a continuous and high-resolution indicator of player experience that complements the useful and robust tools already in the game user research toolbox.

RELATED WORK

In this section, we present an overview of positive and negative frustration in games and how it is measured along with an overview of touch input and touch pressure input in games, and how touch pressure is measured.

Frustration in Games

Frustration in game play can either be positive for player experience or negative for player experience, and researchers have suggested several ways of describing this distinction.

Positive frustration arises under various circumstances. For example, players may be positively frustrated when in-game challenges are slightly beyond a player's abilities – such as when playing against an opponent who is slightly superior in skill [1,2]. Players may also be positively frustrated when they do not know exactly what needs to be done to complete an in-game challenge [16]. Gilleade and Dix call this *in-game frustration*, defined as "a failure to know how a challenge is to be completed" [16]. Nyland and Landfors call this positive frustration, defined as frustration whose cause can be entirely ascribed to the player [28]. This desirable frustration has been argued as either originating from a particular source [16] or being attributed to the player [28]. We argue a distinction based on the resulting outcome of the frustrating experience. As such, we define *positive frustration as frustration that motivates the player to engage further with the game, i.e., motivating frustration*. Designers create positive frustration by producing well-balanced games with difficulty levels, by providing in-game assists either explicitly (e.g., health packs) or covertly (e.g., bullet magnetism) [36], by implementing dynamic difficulty adjustments that tailor to an individual's performance [18], or by scaffolding players to learn the mechanics and controls at an appropriate pace [20].

Negative frustration, on the other hand, arises when challenges are well beyond a player's capabilities (e.g., the enemy is too strong and the player has no chance of beating it) [6,36], the competition in multi-player games is unbalanced (e.g., the opponents have much greater skill and the player gets badly beaten) [36], or the game or controls do not behave in a way that the player expects (e.g., the mappings of the controller buttons to in-game actions are non-standard or unintuitive) [16,33]. Gilleade and Dix call this *at-game frustration* [16], defined as a "failure to operate the input device," which could be caused by poor command mapping, unresponsive input, complex input patterns, or the player's skill level. Nyland and Landfors call this negative frustration, whose cause can be attributed to the game itself [28]. We define *negative frustration as frustration that motivates the player to disengage with the game, i.e., disheartening frustration*. Designers try to avoid at-game frustration by using good design principles and by employing iterative evaluation throughout design to identify frustrating moments that can be balanced or fixed during development.

Although good design and iterative evaluation should help to avoid at-game frustration, it may also occur in a well-designed but poorly balanced game. Ijsselsteijn et al. [19] note that while in-game frustration can add to the satisfaction of completing a challenge, if it becomes too much, it may negatively impact player experience. As a result, they suggest that there is a need for real-time indicators of frustration [19]. In addition, we suggest that knowing whether the experienced frustration is motivating or disheartening is vital for game researchers and designers to be able to choose a course of action – for example, whether the in-game challenge should be reduced or whether the controls need to be adapted.

Measuring Frustration

There are several methods to infer frustration during gameplay. Researchers can visualize player death locations (indicating in-game chokepoints) [11,4], or quitting behavior; however, this only works after-the-fact and cannot be used to trigger an intervention. Researchers can infer frustration by observing players and looking for signs that are based in physiology (e.g., red face, sweating) or behavior (e.g., agitation, swearing); however, this requires a researcher to observe all gameplay and doesn't scale to dynamically adapt games in real time. Researchers can ask survey questions that explicitly ask players to recall frustration within a game [6,33], but the resolution of this method is low. Researchers can record physiological signals that detect arousal through, for example, heart rate or galvanic skin response [23]; however, this requires participants to be connected to expensive sensors and does not work for players in their natural environments. In addition, although these methods may indicate the degree of frustration experienced by a player, they do not differentiate whether players will be motivated or disheartened.

Touch in Games

In this section, we discuss touch as input, touch as an evaluation approach, and how to measure touch pressure.

Touch as Input

With the advent of smartphones, touch interaction has become a predominant mode of interaction with mobile systems. Although game controller or mouse/keyboard interactions still comprise the majority of game input, touch input continues to gain prominence through mobile gaming – recent estimates suggest that 35% of U.S. gamers play on a smartphone [13]. And although touch-based game interaction may be viewed as non-standard, research by Watson et al. [37] demonstrated that experience in a targeting game improved when using a multi-touch display over a mouse. In particular, participants experienced greater positive affect, felt more competent, in control, related to other people, and immersed when using touch input. They also showed that the results could not be explained by the intuitiveness of the controls, by discussing their findings within the framework of needs satisfaction [32,33].

Although touch is a common in-game interaction, touch pressure has not been leveraged as an input approach in the context of games. Several mobile gaming devices have pressure-sensitive screens (e.g., Wii U, 3DS); however, neither device exposes an application programming interface (API) to developers that would allow them to incorporate touch pressure as input mechanism. As the new iPhones have pressure-sensitive screens and allow developers to access this parameter, we may see an increase in the number of games that incorporate touch pressure as an input approach. Outside of the context of games, Cechanowicz and Gutwin [8] give several design examples of how click pressure exerted on a mouse could augment interactions with a computer interface. For example, they suggest that increased pressure could bypass dialog box confirmations or unlock locked folders. Similarly, Ramos and Balakrishnan [31] present several designs and a framework of how pressure exerted by a stylus on an interactive display could be used to augment interactions. Ramos and Balakrishnan also explored integrated panning and zooming using input pressure of a stylus while sliding in x-y space [30].

Touch as Evaluation

As opposed to being used as input to a game, the quality of touch interaction can also be used to evaluate interaction with a system. Pressure on game controller devices has been proposed to be linked to frustration. Sykes and Brown found that pressure on a gamepad increases with emotional arousal [34], while Octavia et al. showed that pressure exerted on a joystick indicates frustration [29]. Outside of the context of games, researchers have shown that frustration can be predicted by pressure exerted on chairs [35], keyboards [17,35], mice [9,21,17,35], and trackpads [25,26]. As such, touch pressure seems to be a good candidate for measuring frustration. In a study with touch gestures in Fruit Ninja played on an iPod, Gao et al., [15] found that pressure features discriminated frustration from excitement, relaxation, and boredom, whereas features related to stroke speed discriminated between levels of arousal. Using these features, the authors created a model that differentiated between low and high arousal and between low and high valence with 89% accuracy. Although indicative that great touch pressure should indicate frustration, this work does not differ between motivating and disheartening frustration.

Integrating Touch Pressure into Interaction

Most touchscreens afford a constrained 2-dimensional input space in which x- and y- locations are translated into on-screen actions. Touch pressure could act as a third dimension to this space. Using specially designed hardware that senses touch pressure, prior research has shown touch pressure to be useful for augmenting touch input, for example to speed up typing [5] or create more flexible gestures [31]. Because displays that have pressure-sensing capabilities are not yet ubiquitous, Ramos and Balakrishnan also suggest using the size of a fingertip's contact area with a touchscreen as a proxy for pressure [30]; this approach was also used by Gao et al. [15] in their examination of emotion during play of a touch-base game on an iPod and by Hernandez et al. [17] to operationalize pressure on a mouse through contact area.

EXPERIMENT

We conducted an experiment to determine whether pressure can differentiate between at-game and in-game frustration.

Game Design

The goal of our work was to differentiate between in-game and at-game frustration using both objective and subjective measures, and thus the game chosen for our experiments had to be able to be manipulated in terms of generating both kinds of frustration. Also, as with all games used in controlled experiments, we had to balance the need to get into the game quickly (unlike, for example, a complicated role-playing game) with the need to feel engaged. Finally, our game also required repeated touch input so that we could determine whether the pressure of touch input changed with frustration. As such, we wanted to choose a casual game – defined as games that are "fun, quick to access, easy to learn and require no previous special video game skills, expertise or regular time commitment to play" [7, pg. 3] – that used touch input regularly during the game. To meet these requirements, we chose an infinite runner game for our experiment. Infinite runners, also called endless runners, represent a very popular game type available on mobile devices (e.g., Temple Run [39]). We developed a game based on a version downloaded from the Unity 3D asset store [40]. Our game, called *City Run*, is very similar to commercial games, but developing our own version gave us the flexibility needed to introduce touch gestures to control the avatar, to introduce different types of frustration into the game, and to implement all of the touch event and game event logging needed to answer our research questions.

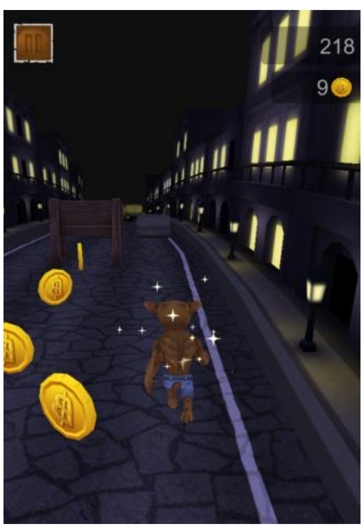

Figure 1. Our infinite runner game, called City Run.

In City Run, players control an avatar that runs along an infinite track, which is divided into three lanes (see Figure 1). As the avatar runs down the track, players must collect coins and avoid obstacles through a combination of jumping, ducking, and switching lanes. These avatar movements are accomplished using touch gestures: swiping left and right to switch lanes, swiping up to jump, and swiping down to duck. If the avatar hits an obstacle, it loses ten coins to a minimum of zero, but continues running. The avatar moves at a fixed speed, which increases over the course of the game. Rather than procedurally generating the obstacles (which would then be different each time the game was played), we scripted the locations and types of obstacles by hand-designing short patterns of obstacles. We created 11 patterns: 1 easy pattern with few obstacles, 8 medium patterns with a manageable numbers of obstacles, and 2 hard patterns with high numbers of obstacles. We then created the levels by piecing together a series of patterns. To create an easy level, we used the single easy pattern repeatedly. In the medium level, we used only the medium patterns. To create the hard level, we used half medium patterns and half hard patterns.

Frustration Conditions

To facilitate our manipulation of frustration, we modified the game to add three configurable parameters. *Input Lag* allowed us to introduce a configurable amount of lag to the touch input, meaning that the game's reaction to a player touching the screen could be delayed by an adjustable amount. *Input Fail* allowed us to introduce a configurable amount of failure into the gesture recognizer; failure was implemented as a specified percentage of the user's gestures on the touch screen simply being ignored by the game. *Difficulty* allowed us to adjust the difficulty of the game itself. We created three discrete levels of difficulty by varying the number of obstacles that the user had to avoid. This is similar to the way in which comparable commercial games create higher levels of difficulty.

Using these parameters, we created the following five experimental conditions.

1. **Training:** no modifications to the game, medium difficulty level
2. **Lag (at-game):** for each gesture the response was delayed by a random amount between 0 and 300ms, medium difficulty level
3. **Fail (at-game):** 1 of every 10 gestures were ignored, medium difficulty level
4. **Easy:** the appearance of obstacles was infrequent and repetitive compared to the other conditions
5. **Hard (in-game):** the appearance of obstacles was very frequent compared to the other conditions

A small pilot study helped to determine that the lag and fail conditions yielded very similar patterns of behaviour, and thus we only considered the Training, Easy, Lag, and Hard conditions moving forward with our full experiment. Our hypothesis was that lag would yield disheartening at-game frustration and game difficulty (i.e., hard) would yield motivating in-game frustration. The easy condition was included as a comparator and the training condition introduced players to the game mechanics and input. As such, our full experiment used four conditions: Training, In-game frustration (i.e., Hard), at-game frustration (i.e., Lag), and the Easy condition as the baseline.

In each condition, the game lasted until the player reached a fixed in-game distance of 800, which translated into approximately two minutes of play time. We chose this distance because it kept the duration of the entire experiment manageable, and also because it reflects the typical length of casual game play levels for mobile phone games.

We used a within-subjects design so participants played each condition. All participants began with the Training condition, and the order of presentation of the remaining three conditions was controlled using a Latin Square.

Participants and Procedure

We had 42 participants in the study (20 females, aged 18-49). Of our participants, 33 reported playing videos games at least once per week, and 37 reported playing mobile games on a phone or tablet previously. Participants were recruited though mailing lists at the University of Saskatchewan.

After providing informed consent, participants were introduced to the game and played the Training condition. Following completion of the game play, participants filled out a series of game experience questionnaires (see Measures section) about the condition they just played. This approach was repeated for the three remaining experimental conditions (presented in a Latin Square). Following all four conditions, participants completed a background survey that collected information on their basic demographics and game playing experience. We then debriefed participants on the nature of the experiment, and compensated them with $10.

The experiment was conducted on a Microsoft Surface Pro 3 computer using a connected multitouch-enabled monitor (positioned horizontally on the desktop) with a resolution of 1920x1080. Halfway through the experiment, we switched to the integrated screen of the Surface (resolution of 2160x1440), as we found that the pressure sensitivity of the touch monitor was inferior to the Surface. Because of the within-subjects design, in which we compare participants' performances to themselves across conditions, the fact that the technology was different for about half of the participants is not a major issue in our analyses; however, we return to this aspect in the discussion of the limitations of the study.

The game required that the computer use Windows 8 or higher. We instrumented the game so that each game event (e.g., obstacle hit) was logged to a file, each touch event was logged to a file, and we generated a summary log of overall game performance and touch pressure for ease of analysis. The experiment was conducted in a private room in a laboratory at the University of Saskatchewan.

Measures

We collected subjective measures of experience and objective measures of touch pressure.

Player Performance & Experience

We gathered the following validated measures of experience.

Perceived competence was gathered using the Player Experience of Needs Satisfaction (PENS) instrument [33]. Participants rated their agreement (on a 5-point scale from strongly disagree to strongly agree) with three items related to how well they felt they demonstrated mastery over the game's challenges (e.g., "I feel very capable and effective when playing"). The scale had good internal consistency (Cronbach's α=0.81).

Intuitive control was gathered also using PENS and reflects how well the game controls support interaction with the system. Three items (e.g., "When I wanted to do something in the game, it was easy to remember the corresponding control") rated on a 5-point scale from strongly disagree to strongly agree exhibited good internal consistency (Cronbach's α=0.69).

Enjoyment was measured using the interest-enjoyment subscale of the Intrinsic Motivation Inventory [24]. Five items (e.g., "Playing the game was fun") rated on a 5-point scale from strongly disagree to strongly agree exhibited good internal consistency (Cronbach's α=0.88).

Internal attribution was measured using three items (e.g., "The score of the round was mostly caused by things other than myself": recoded) adapted from [10]. Measured using a 5-point scale from strongly disagree to strongly agree, the Attribution scale exhibited good internal consistency (Cronbach's α=0.81). Attribution was collected to determine whether participants felt that their performance was attributable more to internal causes (e.g., skills and abilities) or more to external causes (e.g., game mechanics, system) [10]; a higher number indicates more internal attribution.

Difficulty was measured using the single item "How difficult was the game you just played?", rated on a 5-point scale from easy to hard.

Subjective performance was rated using the single item "How well do you think you did at the game?", rated on a 5-point scale from poor to excellent.

Frustration was measured using the single item "How frustrated did you feel with the game?", rated on a 5-point scale from not at all frustrated to very frustrated.

Touch Pressure

A pressure gesture generally follows a normal distribution over time – pressure increases to a peak and then decreases. We operationalized touch pressure metrics in three ways.

Peak pressure considers the peak of each individual touch gesture in a condition and averages those for an indicator of the central tendency of peak pressure.

Average pressure takes the average pressure of each gesture and returns the mean of those for an indicator of central tendency of average pressure.

We also considered the overall pressure – operationalized as the average of all pressure values in a condition, but found that it was almost identical to average pressure, and thus we only report average pressure.

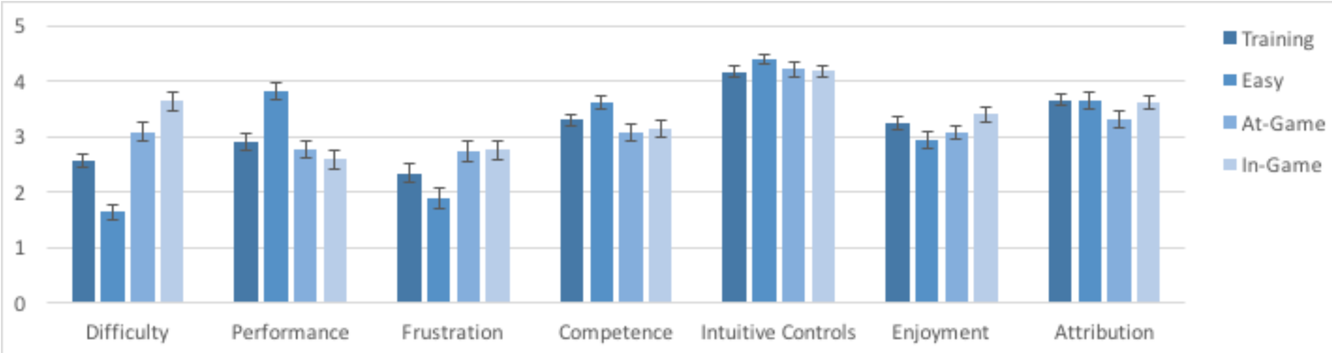

Figure 2. Means (±SE) of the subjective measures on a 5-pt scale (higher number indicates greater value).

Demographics
Demographic information was collected at the end of the study, including participant age, sex, gaming frequency, gaming devices used, and touchscreen experience.

Data Analyses
All data analysis was performed with IBM SPSS Statistics 24. It was important that participants included in the analyses were able to control the game with a base level of competence, thus we removed outlier participants who were three standard deviations below the mean on both subjective performance and objective performance (i.e., score). This resulted in the removal of a single participant who rated themselves as very low competence in all conditions and whose game score ranged between 0 and 18 (for comparison, the average score in the Training condition was 146). We performed a Multivariate Analysis of Variance with condition (easy, at-game, in-game) as a within-subjects factor on the subjective scales, (difficulty, frustration, performance, competence, intuitive controls, enjoyment, and attribution) and the touch pressure data (average pressure, average peak pressure). When the sphericity assumption was violated, we used the Greenhouse-Geisser correction.

RESULTS
We first present the results of player experience followed by the results from the touch data.

Player Experience
Our results showed main effects of condition on Competence ($F_{2,80}$=7.0, p=.002, η^2=.15), Enjoyment ($F_{2.85,64.5}$=5.8, p=.008, η^2=.13), Attribution ($F_{2,80}$=3.02, p=.05, η^2=.07), Frustration ($F_{2,80}$=13.1, p≈.000, η^2=.25), Difficulty ($F_{1.74,69.7}$=42.9, p≈.000, η^2=.52), and Performance ($F_{2,80}$=17.1, p≈.000, η^2=.30). See Figure 2. There were no main effects of condition on intuitive control ($F_{2,80}$=2.3, p=.105) or overall score ($F_{2,80}$=0.5, p=.624).

Participants felt less frustrated in the easy condition than in the in-game (p≈.000) or at-game (p≈.000) conditions. There was no difference in subjective frustration between in-game and at-game (p=.897). Similarly, participants felt more competent and that they performed better in the easy condition than the in-game (competence: p=.008; performance: p≈.000) or at-game (competence: p=.002; performance: p≈.000) conditions, with no differences between in-game and at-game (competence: p=.686; performance: p=.460). These results suggest that both in-game and at-game frustration yielded similar levels of frustration and that those two conditions did not produce differing levels of perceived performance or competence.

In terms of perceived difficulty, players felt that the in-game condition was more difficult than the at-game condition (p=.004), which was in turn more difficult than the easy condition (p≈.000), suggesting that the condition designed to yield in-game frustration was perceived as more challenging than the condition designed to yield at-game frustration. These results are expected as the frustration that arose from increasing the game's challenges (the in-game condition) should translate into an experience of a difficult game; whereas the frustration that arose from the game feeling laggy should not translate into an experience of difficulty.

In terms of the player experience, participants enjoyed the in-game condition more than the easy condition (p=.009) or the at-game condition (p=.003), with no differences observed between easy and at-game (p=.366). This suggests that in-game frustration yielded an enjoyable play experience, whereas at-game frustration yielded a less enjoyable play experience – even though there were no differences in the perceived levels of frustration for these two conditions.

Finally, participants attributed the cause of their performance more externally in the at-game condition than the easy condition (p=.029) or in-game condition (p=.035), but there was no difference between easy and in-game (p=.969). This suggests that regardless of actual performance, participants do not differentiate in their attribution of the cause of that performance when the game is easy or more challenging (attributing success and failure internally), but do distinguish when the game is affected by laggy controls (attributing more externally – likely to the system). Players attribute more externally for at-game frustration and more internally for in-game frustration.

Touch Pressure
In terms of the touch pressure data, we found a main effect of condition on both the average touch pressure ($F_{2,80}$=5.2, p=.008, η^2=.11) and the average peak pressure ($F_{2,80}$=4.5,

p=.014, η^2=.10). In both cases, the results show that the in-game condition yielded more pressure than the at-game condition (average: p=.039; peak: p=.049) or the easy condition (average: p=.008; peak: p=.011), with no differences between the at-game and easy conditions (average: p=.190; peak: p=.247). These results suggest that participants press harder when they experience in-game frustration derived from the game's challenges than when they experience at-game frustration as a result of laggy controls. See Figure 3 (note that although the error bars seem large, it is due to using two different displays in the study; because participants were compared to themselves in a repeated-measures test (from a within-subjects design), the differences in display sensitivity affect the standard error and means, but not the statistical tests).

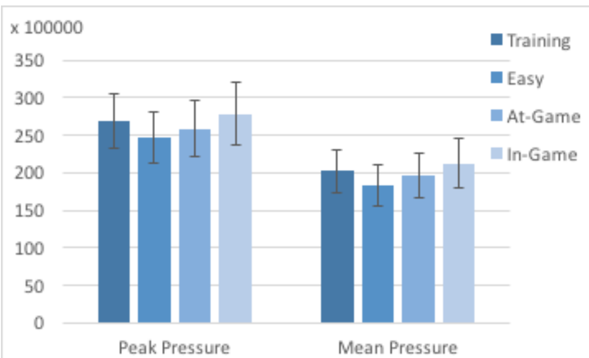

Figure 3. Means (±SE) of the peak and average pressure.

Predicting Enjoyment

Our results suggest that although frustration levels are similar for the in-game and at-game frustration conditions, the experience of participants varies depending on the source of the frustration. To determine the relative predictive value of the experiential variables on perceived enjoyment of the game, we conducted a hierarchical regression analysis in which we first entered the player satisfaction of needs variables (i.e., competence, intuitive control) and in a second step entered the variables frustration, difficulty and attribution. We began with the needs satisfaction variables because of the large body of work that suggests how satisfaction of needs during play translates into increased game enjoyment (e.g., [3]).

As shown in Table 1, perceived competence predicts enjoyment in the first step, whereas intuitive control did not. This is not surprising in our data set because we saw little variance in intuitive control overall. In the second step, both game difficulty and attribution predict enjoyment; however, frustration does not play a significant role. This reaffirms the idea that the amount of frustration is not as important in determining enjoyment as the source of that frustration. When the frustration stems from challenging in-game activities toward which players can internally attribute their performance (i.e., feel that the cause of their success is within themselves), the game is still enjoyable. On the other hand, when similar levels of frustration stem from problems or issues with the game environment that are not part of the game's mechanics or challenges, the game is less enjoyable.

Table 1. Unstandardized β values, t-statistic, and p-values for individual predictors of game enjoyment. R(m) and P(m) refer to the R and significance of the overall model fit for each step.

	Predicting Enjoyment				
	β	*t*	*p*	*R(m)*	*P(m)*
Step One	**Player Experience of Need Satisfaction (PENS)**				
Competence	0.543	6.80	**<.001**	0.526	**<.001**
Intuitive Control	-0.170	1.56	0.121		
Step Two	**Difficulty, Attribution, and Frustration**				
Difficulty	0.213	3.59	**<.001**	0.663	**<.001**
Attribution	0.252	3.49	**0.001**		
Frustration	0.003	0.05	0.963		

DISCUSSION

In this section, we summarize the results and provide possible explanations for the patterns of behavior that we observed. We then describe implications for the design and evaluation of games and other media, followed by a discussion of the limitations and future opportunities enabled by the research.

Summary and Explanation for Results

As expected, the easy condition was rated as least difficult, with the best performance, lowest frustration, and highest competence. In terms of differentiating between in-game and at-game frustration, people found the level of frustration to be similar in the in-game and at-game conditions; however, they found that in-game frustration was perceived as more difficult and more enjoyable than at-game frustration. They also attributed more internally for in-game frustration than at-game frustration and pressed harder on average and also at the peak when the frustration was derived from in-game challenges (i.e., challenging level design) as opposed to at-game annoyances (i.e., laggy controls). Finally, competence, attribution, and difficulty were significant predictors of enjoyment, whereas frustration was not.

We did not see any differences in the ratings of intuitive control between the conditions and it was also not a predictor of enjoyment. This is not surprising as the interface to the game was the same in each condition – players made directional gestures to jump, duck, and switch lanes. As such, we would expect their ratings of intuitive controls to not vary with the amount of game challenge. We may have expected the lack of responsiveness in the at-game condition to affect ratings for intuitive control; however, the participants were rating the input mappings and not the laggy response. This was also made clear in that players attributed their performance more externally in the laggy condition – suggesting that they perceived that it was the system's fault that they did not perform well and not their own fault.

Contextualizing within Current Literature

The idea that games offer different types of challenges, which result in different types of experiences has been established. Gilleade and Dix differentiated between in-game and at-game frustration [16] as frustration that is derived from the game's challenges versus frustration that stems from an inability to operate the game controls. Nyland and Landfors [28] distinguish between positive and negative frustration depending on the attribution of the source of that frustration (user or game respectively). Lazzaro [22] differentiates between four types of fun in games, referring to hard fun (i.e., in-the-moment personal triumph over adversity), easy fun (i.e., curiosity), serious fun (i.e., relaxation and excitement), and people fun (i.e., amusement). In describing hard fun, she notes how the in-game challenges focus a player's attention and reward their progress, which creates emotions such as frustration and fiero – a feeling of personal triumph. In self-determination theory, Ryan et al. [33] describe that games have motivational pull because they allow people to experience a sense of mastery over challenges (i.e., competence) by offering choice and volitional engagement (i.e., autonomy), in an environment that supports connections to other players and characters in the game (i.e., relatedness). The act of volitionally overcoming challenges creates a sense of competence, even if frustration at the failure of repeated attempts is experienced along the way.

Touch Pressure as an Indication of Frustration

Our results show that when frustration stems from challenging in-game activities, and players are able to internally attribute their performance (i.e., feel that the cause of their success in the game is within themselves), the game experience is enjoyable. On the other hand, when similar levels of frustration stem from problems or issues with the game environment that are not part of the game's mechanics or challenges, the game experience is less enjoyable. As such, it isn't the degree of frustration experienced by the players, but the source of that frustration that is more important for determining future engagement.

More importantly, we showed that touch pressure (both average pressure and peak pressure) can differentiate between an enjoyable type of frustration and a less enjoyable type of frustration. Players pressed harder when the frustration was experienced as a result of in-game challenges. When the frustration was experienced at the game itself, the players pressed less hard – similar in degree to the pressure exerted in the easy condition. Although we cannot say for certain, the lower pressure in the laggy response condition may have been prompted by a feeling of disengagement from the participants. This disengagement may have been the driving factor behind not pressing as hard when frustrated with the game.

Implications for Design and Games User Research

Games offer players a relatively risk-free environment in which they can try new things and fail multiple times before experiencing the joy of triumphing over adversity. Differentiating between the negative frustration that arises when players are challenged well beyond their capacity or when controls do not operate as expected, and the positive frustration that results from getting so close to overcoming a challenge before failing and trying again is essential for game designers and researchers. The negative frustration should be prevented through better game design, better game balance [36], or scaffolding player skill development [20]. The positive frustration should be maintained so long as it does not start to turn into negative frustration. Our results move toward a method of distinguishing in real-time whether a player is positively frustrated through in-game challenges or whether they are negatively frustrated by poor design. If designers can detect these states during game play, they can provide games that better adapt to a player's emotional state and ability – which would ultimately create more engaging and successful games.

Although our work is grounded in the need for frustration detection in game user research, there are also applications beyond games. There are many productivity applications that could offer assistance if they detected that a user is struggling or could adapt the interface if it is detected that a user is overwhelmed [14]. Although we cannot generalize our results beyond games, there is an opportunity to determine how touch pressure can be used a metric for evaluation in serious applications.

Limitations and Future Work

Our research provides initial support for the idea that touch pressure is valuable for differentiating between types of frustration in gameplay. There are limitations in the generalization of our results and many opportunities afforded by the work.

First, as discussed in the methods section, we did not use a pressure-sensitive display, but operationalized pressure as the contact area of the finger. We chose this approach because touch-sensitive displays are prevalent, but true pressure-sensitive displays are only now becoming more accessible, which makes our method more practical for application. However, the accuracy of this method may vary on different devices because the resolution of touch digitizers varies. Further, contact area is more commonly used in differentiating between fingertips and palms, which requires a very low degree of accuracy, reducing the incentive for device manufacturers to increase the accuracy of touch digitizers. Device manufacturers also rarely document the specifications of their touch digitizers, making it difficult to know how well our method of pressure sensing will perform across all devices. The initial display that we used in our study is not as sensitive as Microsoft's Surface, which we switched to part way through collecting our data. As we used a within-subjects design, we compared participants' performance to themselves, and the display was kept consistent for an individual participant. However, future work should use the most sensitive displays.

Second, we adjusted difficulty to create in-game frustration using two factors – the number of obstacles and the repetitiveness of obstacles. It is possible that are results are driven by one of these factors – that people press harder when they are more engaged through novelty or more engaged through challenge. Future research should deconstruct the increased pressure further – we showed that pressure was higher in the more challenging and more enjoyable condition; however, investigating the source of the enjoyment and how variations in that source affect touch pressure would be valuable.

Third, along these lines, we investigated touch pressure in the context of a popular genre of mobile games – an infinite runner game. The infinite runner uses gestures (i.e., swiping) and investigating whether our results extend to other interaction techniques (e.g., tapping, pinching, marking) is an important future extension of our work.

Finally, we looked at touch pressure as an objective measure of player experience. Although we characterized the data in the subjective experience of players, comparing the information provided by touch pressure with other objective data sources (e.g., logging and visualization of game events [11], player physiological responses [23], eyetracking [38], or posture sensing [27]) would further help game user researchers characterize player experience using objective and continuous real-time metrics.

CONCLUSION

Frustration in game play can be both a motivating and positive source of engagement for players and a disheartening and negative reason to quit. There are various methods of determining the frustration level of people playing games; however, the existing methods are either too low in resolution (e.g., survey data), do not scale for games after release (e.g., observation), or require expensive sensors that are not appropriate for use in people's homes (e.g., physiology). In this paper, we describe an objective and non-disruptive method for differentiating between types of frustration in a touch-based game – by using the average or average peak pressure of the touch gestures.

We demonstrated how touch pressure can be used to detect the positive challenging frustration that is desired in game design. Used in combination with other existing methods, player frustration and its type can be characterized, yielding opportunities for game designers to adapt their systems and create more engaging and successful games.

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