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RESEARCH ARTICLE

DIGITAL GAMES AND BEYOND: WHAT HAPPENS WHEN PLAYERS COMPETE?

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Appendix A

Proof Proposition 1

We first show that the contest model has a unique Nash equilibrium (t_1^*, t_2^*) where $t_1^* = t_2^* = t$ is the solution to the following equation:

$$\frac{\mu_1\mu_2}{(\mu_1 + \mu_2)^2} = tc'(t) \tag{2}$$

Taking the first-order derivative of player 1's total expected utility (1) with respect to their effort level t_1, we have $\frac{\partial u_1}{\partial t_1} = \frac{\mu_1\mu_2 t_2}{(\mu_1 t_1 + \mu_2 t_2)^2} - c'(t_1)$. A necessary condition for t_1 to be optimal is that $\partial u_1 / \partial t_1 = 0$, which implies (a): $\frac{\mu_1\mu_2 t_2}{(\mu_1 t_1 + \mu_2 t_2)^2} = c'(t_1)$. This necessary condition is also sufficient because of the second-order derivative $\frac{\partial^2 u_1}{\partial {t_1}^2} = -2\frac{{\mu_1}^2\mu_2 t_2}{(\mu_1 t_1 + \mu_2 t_2)^3} - c''(t_1) < 0$. Similarly, we see that the necessary and sufficient condition for t_2 to be optimal is (b): $\frac{\mu_1\mu_2 t_1}{\mu_1 t_1 + \mu_2 t_2} = c'(t_2)$. Let t_1^* and t_2^* be the solution to equations (a) and (b). t_1^* and t_2^* are the best responses to each other and therefore constitute a Nash equilibrium.

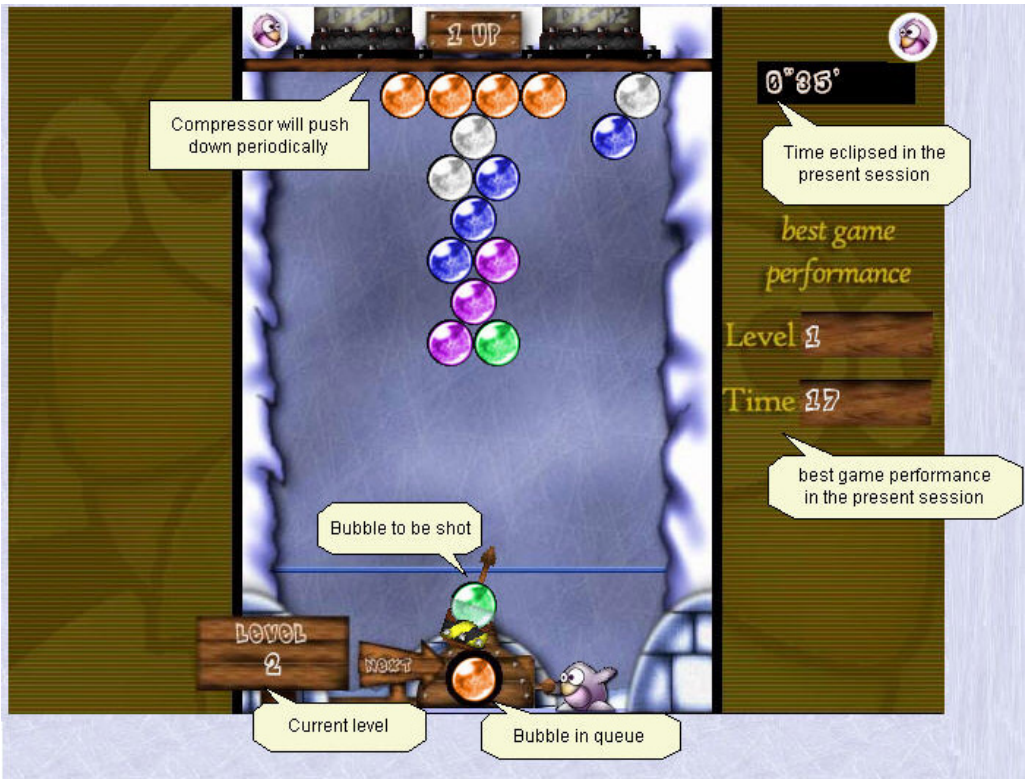
Combining conditions (a) and (b), we have (c): $t_1 c'(t_1) = t_2 c'(t_2)$. For (c) to hold, we must have $t_1 = t_2$. This is because if $t_1 > t_2$, we have $t_1 c'(t_1) > t_2 c'(t_2)$, which makes condition (c) impossible. Substituting $t_1 = t_2$ into (a) and (b) and reorganizing terms, we obtain the condition (2).

Because (2) has a unique solution (note that is monotonically increasing), the Nash equilibrium for the tournament must also be unique.

To see the result in Proposition 1, denote $\lambda = \mu_2/\mu_1$. The equilibrium effort level $t_1^* = t_1$ satisfies $\frac{\lambda}{(1+\lambda)^2} = t_1 c'(t_1)$. The derivative of $\frac{\lambda}{(1+\lambda)^2}$ with respect to λ is $\frac{(1-\lambda)}{(1+\lambda)^2}$, which is equal to (less than, greater than) zero if $\lambda = 1$ ($\lambda > 1, \lambda < 1$). This indicates that $t_1 c'(t_1)$ reaches maximum at $\lambda = 1$, increases with λ when $\lambda < 1$, and decreases with λ when $\lambda > 1$. The same holds for $t_1^* = t_1$ player 1's equilibrium effort level because $t_1 c'(t_1)$ is a monotonically increasing function of t_1.■

Appendix B

Screenshot of the Frozen Bubble Game



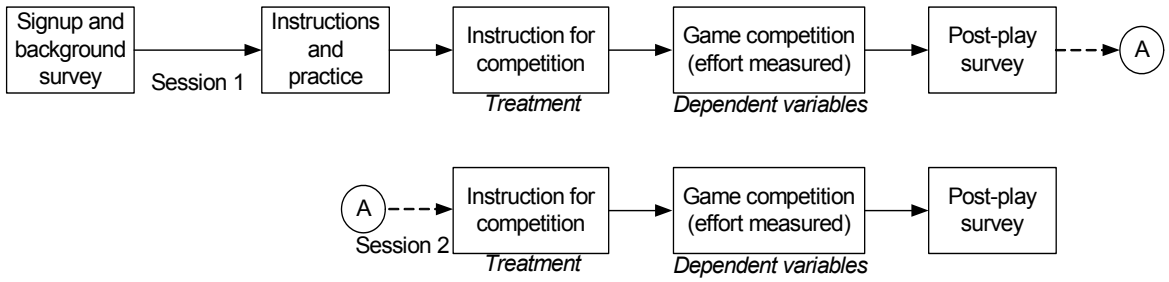
Appendix C

Selected Background Questions

- Game playing experience: On average how many hours a week do you play computer games?
- Computer usage: On average how many hours a day do you use a computer?

Appendix D

Experimental Procedures and Scripts



D1. Practice Instructions

Welcome to this session where you will be playing a computer game. We thank you and appreciate your participation and attendance. Our interest is to study game-playing behaviors to improve the design of computer games. Hence, you have been invited to play a tournament that includes two sessions.

The following pertains to the practice session and instructions on how to play the game. Your successful participation in the formal experiment is built on your effort and performance in the practice session. Please read carefully and make sure you understand each instruction before you start. If you have questions, ***please raise your hand***.

- We will allow you to play for a full 10 minutes to get familiar with the game.
- After 10 minutes, the system will end the practice session automatically.
- Your score in the practice session will be automatically recorded and used in the subsequent formal tournament sessions.

- In this game, your objective is to **clear bubbles on the screen before they reach the bottom** (the compressor pushes them down periodically). Once a bubble hits the blue line at the bottom, you will lose the game.
- The right side of your playing screen displays the clock and your best game performance, which is the number of levels you achieved and time used for the best game you have played so far.
- After you finish all 4 levels, you can start a new game by pressing the fire key (UP).

- The goal of the game is to reach the highest level in the shortest time. The higher the level you achieve, the better your performance. Given the highest level achieved, the less time you use, the better your performance.
- Since you can play multiple games in a session, **only the best game performance will be recorded**. For example, if you play three games in a session and reached level 3 in 95 seconds in the first game, level 2 in 80 seconds in the second, and level 4 in 190 seconds in the third, then your best game performance is level 4 in 190 seconds.

D2. Competition Session Instructions

Now, we will start the formal competition session. Please take this session seriously and follow the instructions carefully as this has important consequences for our understanding of game-playing behavior.

- When you decide to stop, you have to click the "FINISH" button. The system will NOT stop you automatically.
- If you finish everything early, please wait there and be quiet until the session ends.

Your task during this session is to play with a competitor we will assign to you. The competition is between you and your competitor.

- To simulate the online gaming environment, before you start the game, we will disclose to you the skill level of your competitor in relation to your skill; that is, we will tell you if your competitor's skill level is higher or equal or lower than yours. Because of privacy considerations, we will not be able to disclose his/her name.
- As you play the game, you will get feedback on how well you are playing against your competitor via a flashing sentence at the bottom of the playing screen.
- We will announce all the winners after the tournament is over, i.e., after both sessions.
- Winning is determined by the highest level reached in the best performance game, time used in the best performance game, and the number of games played.
- We calculate a score using a formula that will lower your winning chance if you play many more games after you have reached your best winning chance against your competitor.

D3. Manipulation Check Question

Understanding of Treatment Condition
Your competitor's skill level is most likely _____ than yours (seven-point Likert scale; ranked from 1 (*Much Lower*) to 4 (*About the same*) to 7 (*Much Higher*))

Appendix E

Measurements for Enjoyment and Arousal

Enjoyment (Cronbach's alpha = 0.81) Source: (Epstein and Harackiewicz 1992; Tauer and Harackiewicz 1999)	**Factor Loadings**
This computer game is very interesting	0.92
This computer game is very enjoyable	0.83
Arousal (Cronbach's alpha = 0.94) Source: (Broach et al. 1995)	**Factor Loadings**
The computer game makes you feel active	0.86
The computer game makes you feel excited	0.83
The computer game makes you feel stimulated	0.87
The computer game makes you feel lively	0.83
The computer game makes you feel activated	0.89

References

Broach, V. C., Page, T. J., and Wilson, R. D. 1995. "Television Programming and its Influence on Viewers' Perceptions of Commercials: The Role of Program Arousal and Pleasantness," *Journal of Advertising* (24:4), pp. 45-54.

Epstein, J., and Harackiewicz, J. 1992. "Winning Is Not Enough: The Effects of Competition and Achievement Orientation on Intrinsic Interest," *Personality and Social Psychology Bulletin* (18:2), pp. 128-138.

Tauer, J., and Harackiewicz, J. 1999. "Winning Isn't Everything: Competition, Achievement Orientation, and Intrinsic Motivation," *Journal of Experimental Psychology* (35:3), pp. 209-238.