The Use of Player-centered Positive Reinforcement to Schedule In-game Rewards Increases Enjoyment and Performance in a Serious Game

Aniket Nagle[1*], Peter Wolf[1], Robert Riener[1,2], Domen Novak[3]
[1]*Department of Health Sciences and Technology, ETH Zurich, Zurich*
{aniket.nagle, peter.wolf, robert.riener}@hest.ethz.ch
[2]*Spinal Cord Injury Center, Balgrist University Hospital, Zurich*
[3]*Department of Electrical and Computer Engineering, University of Wyoming, Laramie*
dnovak1@uwyo.edu

Abstract

Among the methods used to increase enjoyment and performance in serious games, reward schedules, i.e., determining when in-game rewards should be given, have not been sufficiently explored. In the present study, we designed a simple memory training serious game and compared two methods of scheduling rewards, both based on the paradigm of positive reinforcement: fixed ratio schedule, in which rewards were given after a fixed number of correct responses, and variable ratio schedule, in which rewards were given after an unpredictable number of correct responses. To account for the variability in player preference for rewards, a player-centered sub-mode was included in both schedules by adjusting the schedule ratio according to player preference for rewards. The effectiveness of this approach was tested by comparing it against two more sub-modes: one which used a predetermined ratio, and another which set the ratio to the opposite of player preference. The game was put online and tested with 210 participants. Enjoyment, performance, duration of gameplay, and likelihood to play again were significantly higher in the player-centered sub-mode than the other sub-modes. On average, the variable-ratio schedule was better in the outcome measures than the fixed-ratio schedule. The results highlight the importance of in-game rewards, and indicate that giving rewards according to a player-centered variable-ratio schedule has the potential to make serious games more effective.

Keywords: *serious games; enjoyment; performance; reward schedules; positive reinforcement; player-centered design;*

1. Introduction

Serious games are games meant for purposes other than entertainment [1], finding uses in areas like learning [2], education [3], training [4][5] and rehabilitation [6]. Although the goal of a serious game is to provide a functional benefit rather than to entertain the player, enjoyment is a crucial game component, since enjoyable serious games result in a better functional outcome [7-9] and have a higher replay value [10]. Among the approaches used to increase enjoyment in serious games, such as dynamic adaptation of game elements [11-13], competition [14], and psychophysiology [15], in-game rewards remain relatively unexplored. The lack of systematic studies on game rewards in serious games might be due to rewards being considered a form of extrinsic motivation and hence detrimental to task performance [16]. However, the role of rewards in motivation is still a topic of debate [17], with multiple meta-analyses challenging the notion that rewards are detrimental to intrinsic motivation [18][19]. Additionally, rewards remain an integral part of commercial computer games [20], where they come in various forms like high score, experience points, feedback messages, unlocking mechanisms, etc. [20]. Therefore, in-game rewards were studied in the present work.
An important consideration that affects the potency of rewards is the reward schedule, i.e. determining *when* rewards should be given. Some rewards like high score are displayed

continuously, while others, like feedback messages, are given after good user performance. A general way of treating reward schedules is through the paradigm of positive reinforcement, which is a technique of increasing the probability of a behavior by giving a reward as a consequence of that behavior [21]. Positive reinforcement occurs naturally in everyday life, such as when a company gives a bonus to its high performing employees to encourage similar performance in the future, or when a teacher verbally praises a high-scoring student to encourage similar academic performance in the future. Positive reinforcement has been associated with an increased propensity to play a game [22] and has been used as a reward system both in game [23-25] and non-game [26] contexts. It thus has a potential to be used in serious games also. Although the idea of using positive reinforcement to schedule rewards in serious games has been proposed before [27-29], there is a lack of empirical studies about its effect on enjoyment and performance.
In the positive reinforcement paradigm, rewards can be scheduled in two distinct ways: interval schedules, in which rewards are given at particular time intervals, and ratio schedules, in which rewards are given after a specified number of user actions [30]. Ratio schedules, owing to their support for higher response rates [31] and suitability to games [23][25], were evaluated in the present study. Two types of ratio schedules were compared: 1) fixed-ratio schedule, where a reward is given after a fixed number of responses, and 2) variable-ratio schedule, where a reward is given after an unpredictable number of responses [30]. The latter involves an element of uncertainty which has been a factor of improved engagement in learning games [32]. The variable-ratio schedule was therefore hypothesized to be more effective.
Another factor that needs to be considered when empirically evaluating the effectiveness of reward schedules is the variability in preference for frequency of rewards among different players [33][34]. It was hypothesized that participants who like rewards more would enjoy a mode of gameplay which scheduled rewards frequently. Such gameplay tailoring fits the broad paradigm of player-centered game design, which has been used to adapt game elements to suit players' preferences and needs [28][35-37]. The effectiveness of ratio schedules depends on the specific ratio chosen [38][39]. Setting the ratio too low might result in a drop in performance between rewards [40], and setting it too high might lead to users getting frustrated and stopping the game altogether [41]. Therefore, the ratio was set according to participants' preference for rewards. In order to determine the effectiveness of such a player-centered approach, the two ratio schedules were divided into three sub-modes each: player-centered, in which the initial ratio was set according to participants' preference for rewards, opposite-preference, in which the initial ratio was set opposite to participants' preference for rewards and preset, in which the ratio was set to a predetermined value (Fig. 1). The three sub-modes were then compared, together with the two schedules, variable-ratio and fixed-ratio.

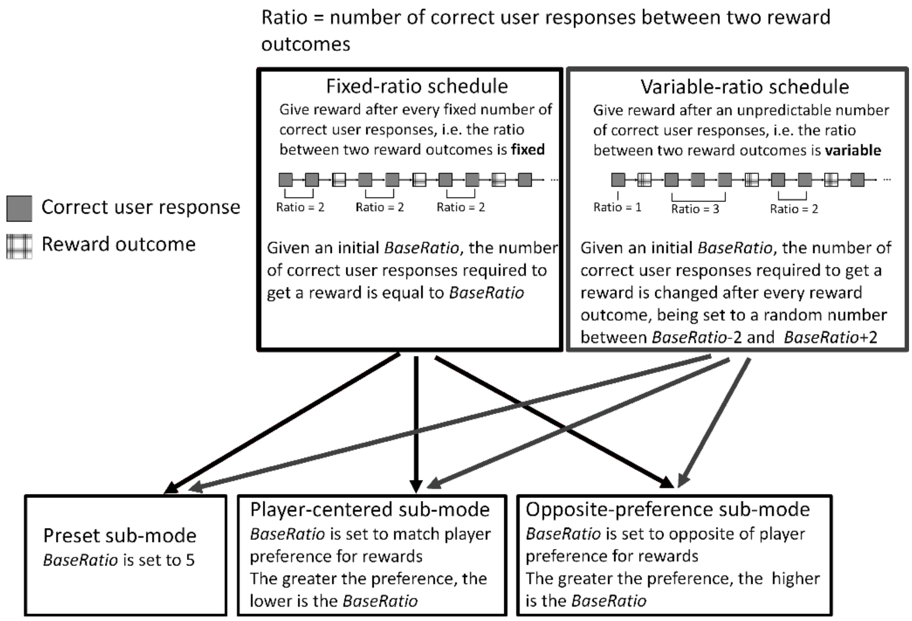

Figure 1. Schematic of the fixed-ratio and variable-ratio schedules, and the three sub-modes: preset , player-centered, and opposite-preference.

A simple working memory training game was designed as a testbed to empirically evaluate the effect of the two ratio schedules and the three sub-modes. It was hypothesized that:

H1. Participants in the variable-ratio schedule will experience higher enjoyment, perform better, play the game for a longer duration, and will be more likely to play the game again than participants in the fixed-ratio schedule.
H2. Participants in the player-centered sub-mode will experience higher enjoyment, perform better, play the game for a longer duration, and will be more likely to play the game again than participants in the other sub-modes.

2. Materials and methods

The serious game was put online on a university server and participants were invited to play the game by posting on game forums, sending an email on university mailing lists, etc. 210 participants took part in the study (122 males, 71 females, 17 unknown; mean age = 33.6 years, SD = 6.8 years). Owing to the anonymous nature of the study, the age and sex figures are not completely reliable.
Upon going to the game website, participants were first informed about the study, and asked to click on a button if they agreed to participate. Subsequently they were asked for their age and sex (both optional), and the following two reward preference questions:

1) How much do you care for in-game rewards?
2) How frustrated would you be if the game did not reward you for your good performance?

These had to be answered on a scale from 0 to 100, with 0 representing “don’t care at all” / “not frustrated at all”, and 100 representing “care a lot” / “frustrated a lot”. The answers to the two questions were averaged and normalized to give a number CARE_FOR_REWARDS with a value between 0 and 1. This value was used to divide the two basic schedules of fixed-ratio and variable-ratio into player-centered and opposite-preference sub-modes, by setting the BaseRatio in two different ways, as follows:

Player-centered: BaseRatio = Floor(3 + 4*(1 – CARE_FOR_REWARDS))
Opposite-preference: BaseRatio = Floor(3 + 4*CARE_FOR_REWARDS)

For example, a participant in the player-centered sub-mode who fully cared for rewards (CARE_FOR_REWARDS = 1) would get a BaseRatio of 3, which meant that the participant would get rewards after every 3 correct responses in case of fixed-ratio schedule, or after a variable number of responses in the range [3-2, 3+2] in case of variable-ratio schedule. One possible problem with the two reward preference questions could be that participants might not be able to always self-assess their true preference for rewards, and so the two questions might not be an accurate reflection of reward preference. An a-posteriori analysis was therefore performed to partially check the validity of participants’ self-assessment by correlating answers to the two questions with enjoyment in the player-centered and opposite-preference sub-modes.
The constants 3 and 4 and the range of +/- 2 in the ratio computation were chosen from pilot studies done internally. The preset sub-mode used a predetermined BaseRatio of 5 (Fig. 2). A seventh, baseline mode that gave no rewards was also included. After participants answered the rewards and frustration questions, they were randomly assigned to one of the 7 modes and the game was started. Participants could quit at any point, either by clicking on the GUI quit button, or by simply closing the browser window. 22 participants did not complete the study, but instead quit the game by closing the browser window, and were therefore not included in the final analysis. They played on average for 294 seconds, which was almost half the final gameplay duration average of 511 seconds. Thus, discarding these 22 participants was unlikely to have significantly affected the overall analyses.
The serious game used in this study consisted of a single sequence recall task, similar to ones used to train working memory [42]. The task consisted of memorizing a sequence of characters (either letters or numbers) and recalling the sequence in the same order, by moving a humanoid character through several stages of options (Fig. 3). At each stage, three options were displayed in the form of spheres containing characters (Figure 3b) and participants had to choose the correct character for the current position in the sequence by moving a keyboard-controlled humanoid figure through the appropriate sphere (Figure 3c). Once participants passed the character at the final position, the result was displayed (“Correct” / “Incorrect”) and a new round was started. Each successful round counted as one correct response in determining whether to supply reinforcement or not (Fig. 2). The initial length of the sequence was 5 characters for all modes, and was capped at a maximum of 9, that number being a well-known upper limit on the number of items humans can hold in their working memory [43].

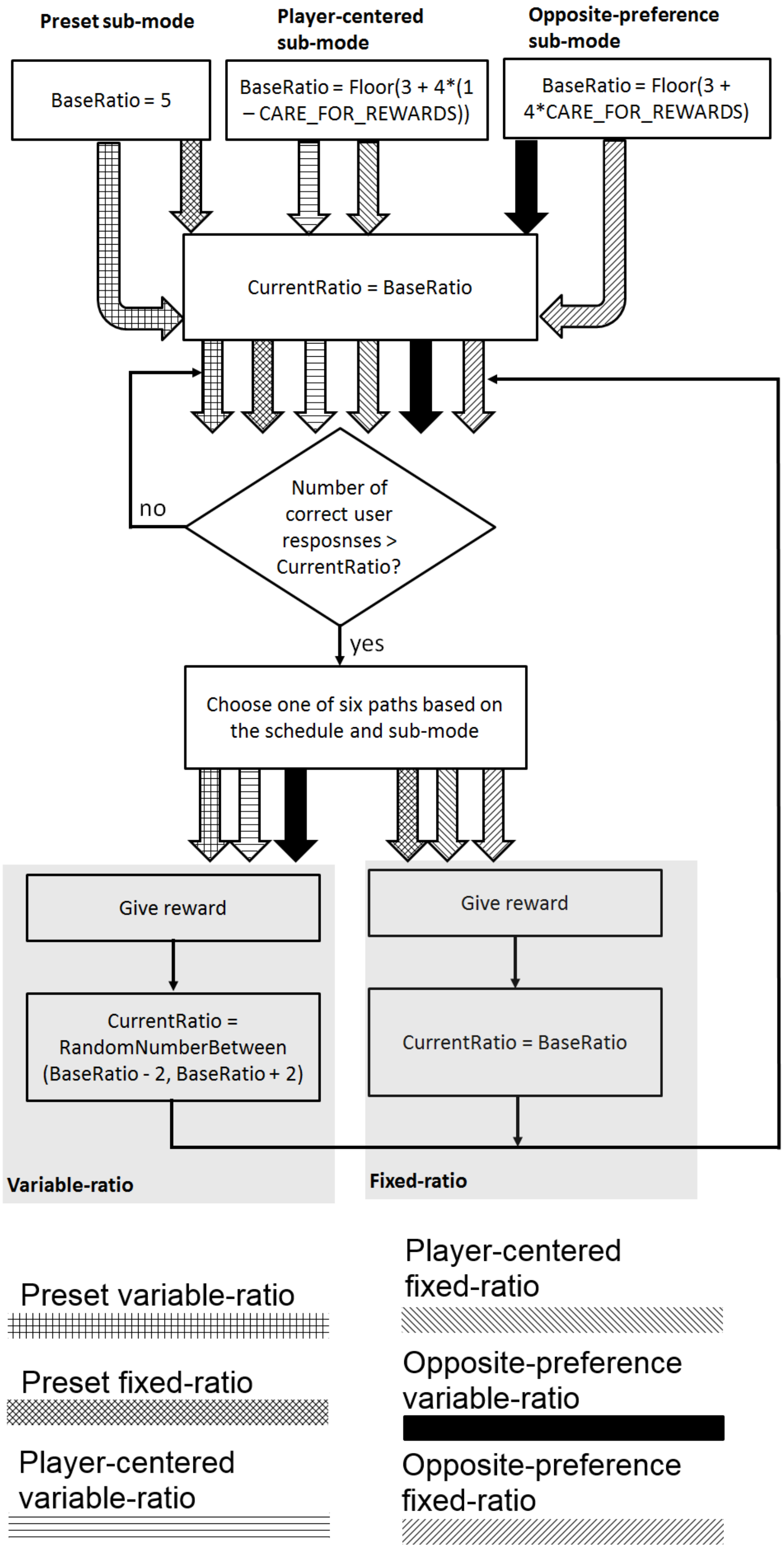

Figure 2. Flow of control through the various combinations of schedules and sub-modes.

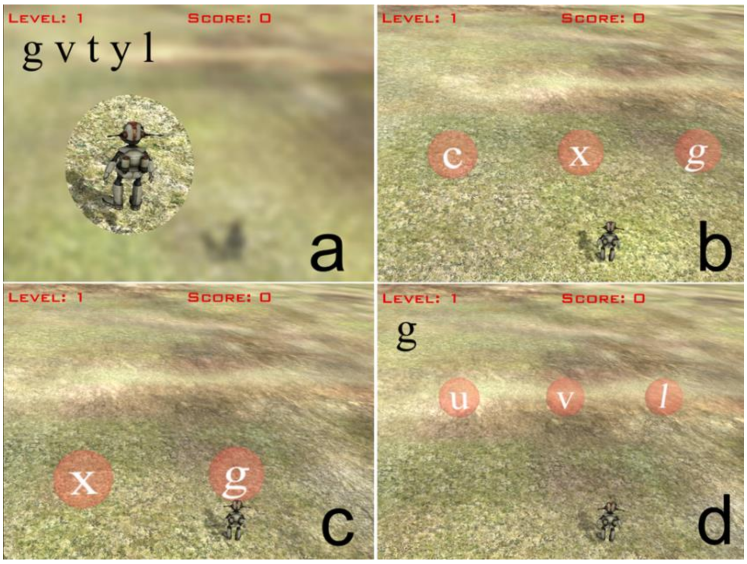

Figure 3. Screenshots of the serious game used in the present study. The different panels show various stages of completing a round, in which a sequence of characters has to be memorized and recalled. (a) The sequence to be memorized shown in the top left corner. Also seen is the humanoid figure, which the player controls and moves around to perform actions. (b) The first stage with three spheres, with one correct character 'g'. (c) Walking towards the 'g' sphere. (d) Upon going through the 'g' sphere, the recalled sequence up to the current point appears on the top left, and three new spheres are spawned.

Reinforcement was supplied in the form of in-game rewards that consisted of three components: a large increase in the game score, the option to play a card-matching mini-game, and the number of characters to memorize being increased by 1; all three components were awarded at once (Table 1). The mini-game consisted of six pairs of cards hidden behind 12 slots. Cards would be revealed for a few seconds by clicking on the respective slots. Two cards could be revealed at once, and if they were a matching pair, would stay revealed. The game was finished when all six pairs were revealed.

Table 1. The three components of in-game rewards used in the serious game, along with a rationale for each. All three components were awarded together.

Reward	***Rationale***
Large increase in the game score	Score, though an abstract quantity, has been a ubiquitous feature of video games, and is known to act as a factor of motivation [44].
The option to play a bonus card-matching mini-game.	Bonus gameplay features that are unlocked at certain points following a prolonged duration of good performance is a commonly used technique in video games to sustain enjoyment [45].
The number of characters to memorize being increased by 1	Increasing the number of characters allowed participants to challenge themselves at a higher difficulty level, potentially keeping them interested in the game [46].

Five outcome measures were defined to test for the two hypotheses:
1) Enjoyment: This was a self-reported measure, derived from the following post-game question: "How much did you enjoy this game?", which participants had to answer on a scale from 0 to 100. 0 represented "did not enjoy at all" and 100 represented "enjoyed a lot".
2) Willingness to play the game again: This was an ordinal outcome, derived from the following post-game question: "Would you play this game again?", to be answered as a choice between "no", "maybe" and "yes". The three answers were coded as 0, 1 and 2 respectively for analysis.
3) Performance: This was computed as:

$$\frac{100}{N}\sum_{i=1}^{N}\left(p(i)-\frac{1-p(i)}{c(i)}\right)$$

Here,

N = number of rounds

c(i) = length of sequence in round *i*

p(i) = 1, if round *i* finished successfully, else 0

The above metric thus computed the percentage of maximum possible performance, with a penalty factor for unsuccessful rounds, proportionate to sequence length at that point.

4) Duration of gameplay: This was recorded as the sum of the duration of each round, excluding the time spent in playing the mini-game. There was no minimum length threshold on gameplay duration in order to be included in the analysis, and neither was there an upper cap on game length, with participants being free to play as long as they wished.

5) Number of rounds played: This was recorded and correlated to duration of gameplay, in order to assess whether participants spent most of the time playing rounds, or if they were distracted.

A 2 (schedule type: variable-ratio and fixed-ratio) x 3 (sub-mode: preset, player-centered, opposite-preference) factorial design was used. Two-way ANOVA's were applied to examine the effect of schedule type and sub-mode on the four scalar outcome measures of enjoyment, performance, duration of gameplay, and number of rounds played. Additionally, ordinal regression analysis was performed to examine the effect of schedule/sub-mode on the ordinal measure of willingness to play the game again.

3. Results

3.1 Primary outcome measures

On average, enjoyment, performance, duration of gameplay, and number of rounds played were the highest in the player-centered variable-ratio mode (Fig. 4). Two-way ANOVA's were conducted to examine the effect of schedule type (fixed-ratio / variable-ratio) and sub-mode (preset/player-centered/opposite-preference) on the four scalar outcome measures (Table 2).

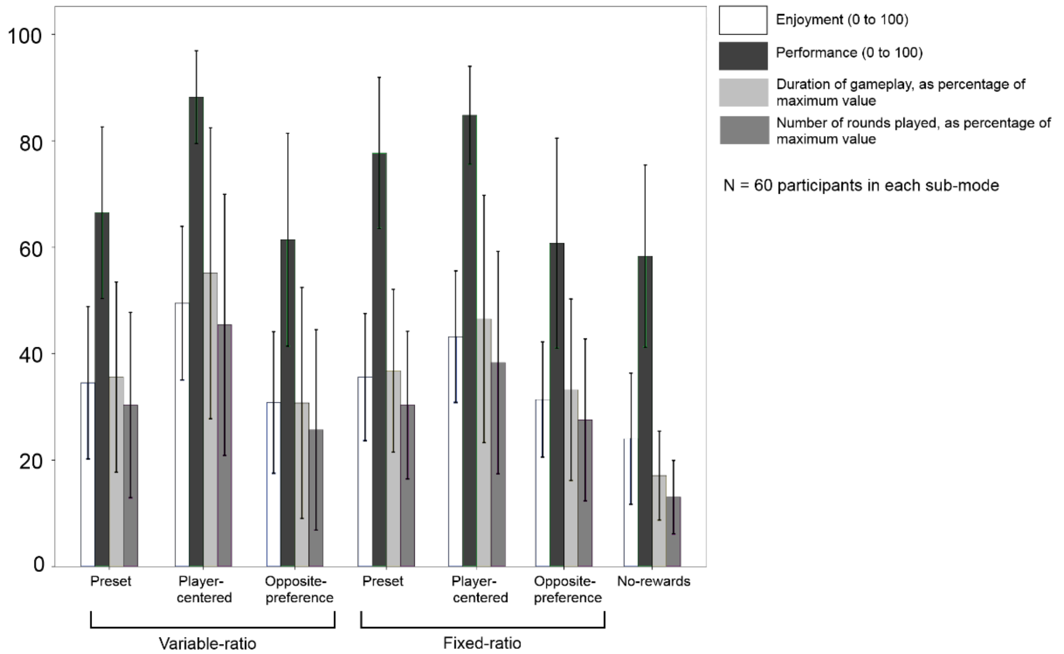

Figure 4. Mean and standard deviation for enjoyment, performance, duration and gameplay and number of rounds played for the 7 modes. Duration of gameplay and number of rounds played are normalized as percentage of the maximum value for the sake of graphical depiction.

None of the outcome measures exhibited significant main effects of schedule or significant interactions between schedule and sub-mode; there was, however, a significant main effect of sub-mode for all the measures (Table 2). Post-hoc comparison using the Tukey HSD test revealed that all the four scalar measures were significantly higher in the player-centered sub-mode than the preset sub-mode and opposite-preference sub-mode (Fig. 5).
Pearson product-moment correlations were run to determine the relationships between enjoyment, duration of gameplay, performance and number of rounds played (Table 3). A linear regression established that number of rounds played could statistically significantly predict duration of gameplay, $F(1, 208) = 3312.64$, $P < .0001$ and number of rounds played accounted for 94.1% of the explained variability in duration of gameplay. The regression equation was:

Duration of gameplay = [49.238 + 31.975 * (number of rounds played)] seconds

Table 2: Results of two way ANOVA to examine the effect of schedule type and sub-mode on enjoyment, duration of gameplay, performance and number of rounds played.

Source		***Enjoyment***	***Performance***	***Duration of gameplay (seconds)***	***Number of rounds played***
Schedule (variable-ratio / fixed-ratio) df: 1, 174	F	.651	1.092	.278	.384
	P	.421	.298	.599	.536
	η_p^2	.004	.006	.002	.002
Sub-mode (preset / player-centered / opposite-preference) df: 2, 174	F	22.418	41.375	13.510	10.728
	P	< .0001	< .0001	< .0001	< .0001
	η_p^2	.205	.322	.134	.110
Schedule x sub-mode df: 2, 174	F	1.520	3.860	1.269	.948
	P	.222	.231	.284	.390
	η_p^2	.017	.042	.014	.011

df = degrees of freedom
η_p^2 = partial eta squared

Table 3: Pearson correlation coefficients and P values for correlations between enjoyment, duration of gameplay, number of rounds played and performance.

	Duration of gameplay (seconds)		***Number of rounds played***		***Performance***	
	r	**P**	**r**	**P**	**r**	**P**
Enjoyment	.284*	< .0001	.285*	< .0001	.255*	< .0001
Duration of gameplay			.970*	< .0001	.308*	< .0001
Number of rounds played					.281*	< .0001

n = 210
*Statistically significant at the P < .05 level

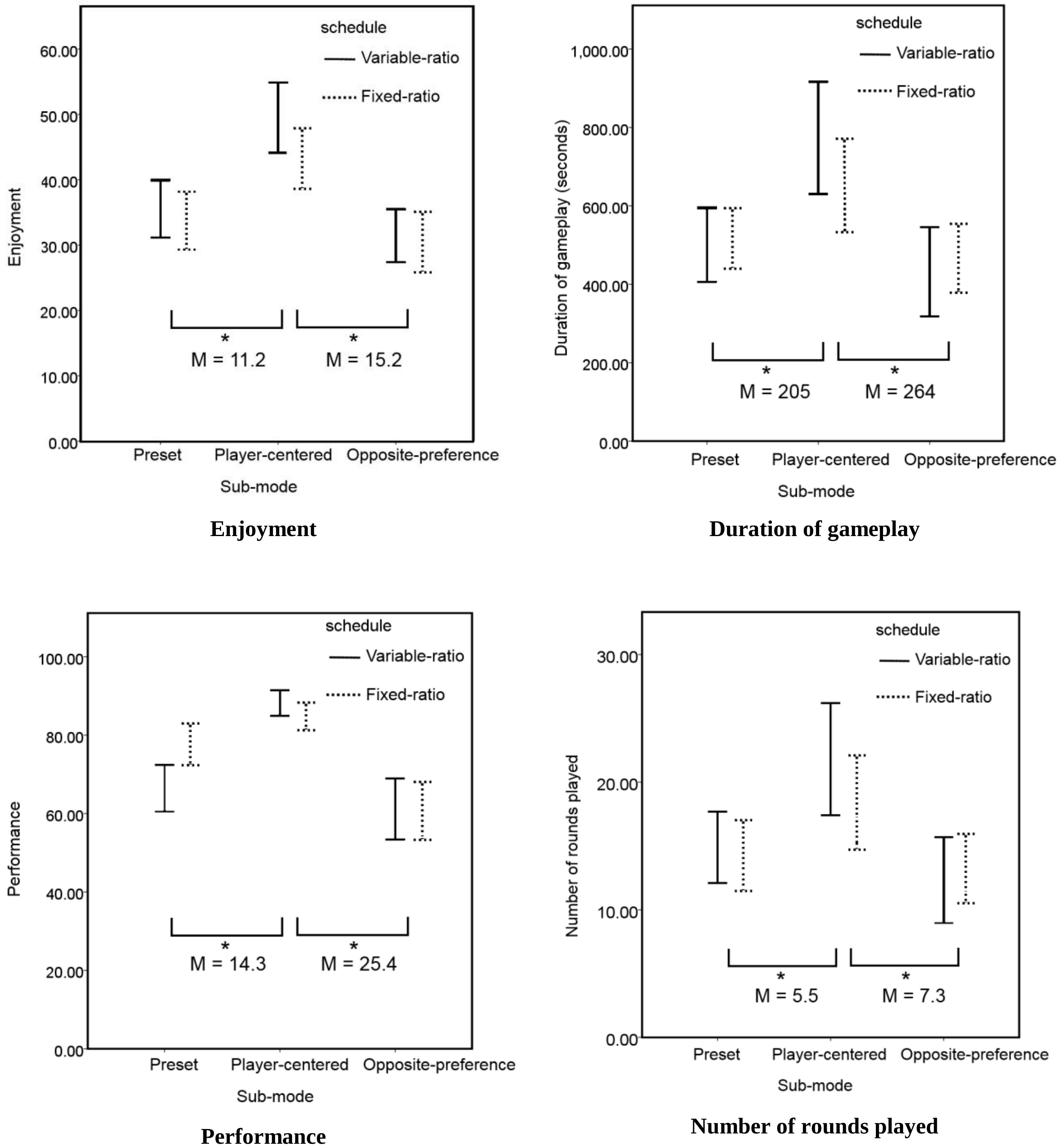

Figure 5. Estimated marginal means with 95 % CI error bars for enjoyment, duration of gameplay, performance and number of rounds played. Results of post-hoc comparison using the Tukey test between the player-centered sub-mode and the other two sub-modes are also shown, along with mean difference (M). Statistically significant differences at the P < .05 level are indicated with *.

A cumulative odds ordinal logistic regression with proportional odds was run to determine the effect of sub-mode and schedule on willingness of participants to play the game again. Sub-mode was able to significantly predict willingness to play the game again, over and above the intercept-only model, $\chi^2(2) = 15.606$, $p < .0001$. The odds of participants in the preset sub-mode playing the game again was 1.84 (95% CI, .921 to 3.692) times that of participants in the opposite-preference sub-mode, although the effect was not statistically significant, $\chi^2(1) = 2.984$, $p = .084$. On the other hand, the odds of participants in the player-centered sub-mode playing the game again was 4.082 (95% CI, 2.015 to 8.271) times that of participants in the opposite-preference sub-mode, a statistically significant effect, $\chi^2(1) = 15.24$, p = < .0001. Schedule (variable-ratio / fixed-ratio) could not significantly predict willingness to play the game again, χ^2 (1) = .812, $p = .368$.

3.2. Validation of the two reward preference questions

CARE_FOR_REWARDS, derived by averaging the answers to the two reward preference questions, was used to set the reward ratio in the player-centered and opposite-preference sub-modes. As mentioned previously, one possible problem with using the two questions to set the ratio could be that participants might not be able to fully self-assess their true preference for rewards. An a-posteriori analysis was therefore performed to partially validate the two questions. Pearson product-moment correlations were run to determine the relationship between CARE_FOR_REWARDS and enjoyment in the player-centered and opposite-preference sub-modes. CARE_FOR_REWARDS was significantly positively correlated to enjoyment in the player-centered sub-mode ($r = .621$, $P = .001$) and significantly negatively correlated to enjoyment in the opposite-preference sub-mode ($r = -.384$, $P = .002$). Additionally, CARE_FOR_REWARDS was related to enjoyment by a quadratic polynomial in the player-centered sub-mode and a cubic polynomial in the opposite-preference sub-mode (Fig. 6).

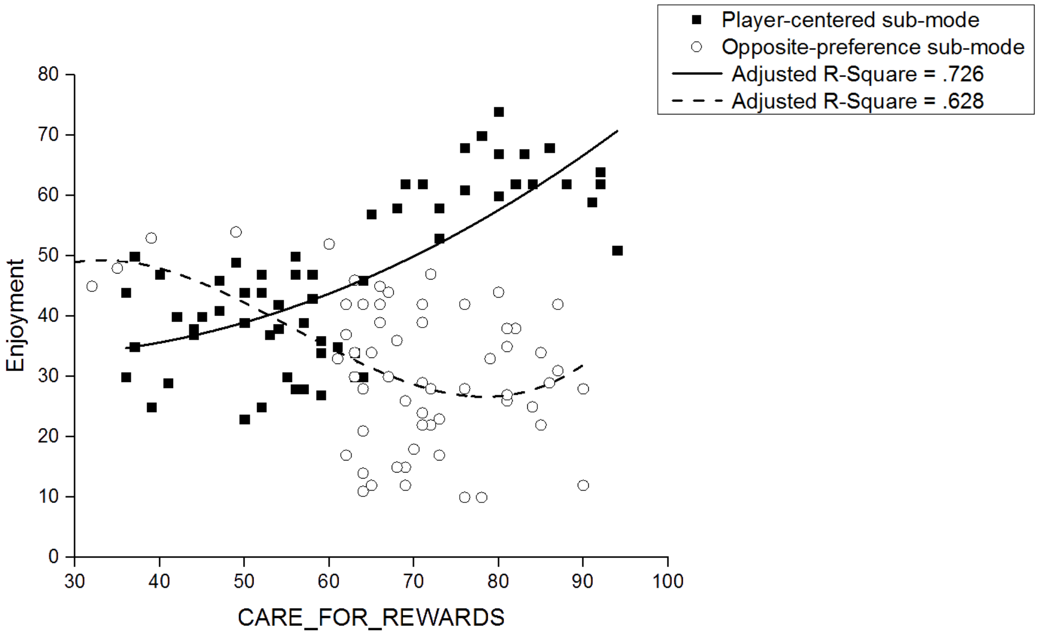

Figure 6. Scatterplot of post-game self-reported enjoyment values and CARE_FOR_REWARDS for participants in the player-centered and opposite-preference sub-modes.

4. Discussion and conclusions

A serious game containing a simple working memory task was augmented with fixed-ratio and variable-ratio reward schedules, and each schedule was divided into three sub-modes each: preset, player-centered, and opposite-preference. Participants in the player-centered sub-mode experienced higher enjoyment, performed better, played for a longer duration, and were more likely to play again than participants in the other sub-modes, confirming **H2**, and suggesting that taking into account player preference for rewards is indeed more effective than ignoring the preference. In general, the number of rounds that participants played was highly positively correlated to duration of gameplay, indicating that participants did spend most of the recorded gameplay time in playing rounds. This, taken together with the moderate positive correlation between enjoyment and duration of gameplay, confirms the viability of the latter as a measure of effectiveness of the sub-modes. No significant differences were observed in any of the outcome measures between variable-ratio and fixed-ratio schedules, and thus **H1** was not fulfilled. On average, however, enjoyment and duration of gameplay were higher in the sub-modes with variable-ratio schedule than the sub-modes with fixed-ratio schedule (Fig. 4). One reason for this might be the implicit uncertainty involved in variable-ratio; such uncertainty is known to be attractive to humans [47], especially in games [32, 48]. Variable-ratio being better than fixed-ratio also confirms other findings in non-game contexts [49][50], although we emphasize that the superiority of variable-ratio in the present study was not statistically significant. Compared to the other modes, giving no rewards fared worst, especially compared to player-centered variable-ratio, in which participants enjoyed on average twice as much as the no-rewards mode and played the game three times as long (Fig. 4).

The relationship between the reward preference value CARE_FOR_REWARDS and enjoyment indicated that the more players cared for rewards, the more they enjoyed the sub-mode that set the ratio according to their preference (player-centered), and the less they enjoyed the sub-mode that set the ratio opposite to their preference (opposite-preference) (Fig. 6). Additionally, CARE_FOR_REWARDS was positively and negatively correlated to enjoyment in the player-centered sub-mode and opposite-preference sub-mode respectively. These results suggest that the value obtained by the two reward preference questions does, to some degree, reflect player preference for the reward ratios. Eliciting reward preference from players could be made more robust by having a pre-test phase in which players are exposed to different game versions with different reward ratios and then asked about their favorite.

This study has some limitations. Firstly, the serious game considered contained only a single task, and thus only one behavior had to be reinforced. In complex serious games, there might be multiple and parallel user actions, and determining which behavior to reinforce could become more complex. However, reward schedules have been used in commercial video games [23][25], and some of those techniques could be applied to larger serious games. Secondly, the anonymous, online nature of the study meant that the population of participants was likely skewed towards one that plays games regularly. Additionally, participants' mean age of 33.6 years was quite below the average age of the target population of memory training games, which is typically above 65. This young age profile may explain the low enjoyment values reported by participants, which generally were at or below the midpoint on the enjoyment scale (Fig. 4). However, the desire to train cognitive functions is an important factor of motivation among elderly users when playing cognitive training games [5], and so the enjoyment values are expected to be higher in the target population.

Despite its limitations, the present study emphasizes the importance of in-game rewards, especially if scheduled according to positive reinforcement principles. Augmenting a variable-ratio schedule with a player-centered design was able to elicit high levels of enjoyment and performance from participants, and therefore could be a viable reward scheduling method in serious games. A possible direction for future research would be to evaluate the long-term effect of scheduling rewards according to player-centered variable-ratio on functional outcomes of serious games. There has been an increasing shift away from the old approach of treating extrinsic rewards as negatively impacting task motivation, and towards rewards being considered not wholly detrimental to motivation in all situations [18][19]. The results of the present study suggest that investigating the effects of not only the nature of rewards but also the way they are scheduled is a feasible avenue for future research.

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References

[1] Abt C. C., Serious games: University Press of America, 1987.

[2] Wouters P., van der Spek E. D., and Van Oostendorp H., "Current practices in serious game research: A review from a learning outcomes perspective," Games-based learning advancements for multisensory human computer interfaces: techniques and effective practices, pp. 232-255, 2009. http://dx.doi.org/10.4018/978-1-60566-360-9.ch014

[3] Graafland M., Schraagen J. M., and Schijven M. P., "Systematic review of serious games for medical education and surgical skills training," British Journal of Surgery, vol. 99, pp. 1322-1330, 2012. http://dx.doi.org/10.1002/bjs.8819

[4] Connolly T. M., Boyle E. A., MacArthur E., Hainey T., and Boyle J. M., "A systematic literature review of empirical evidence on computer games and serious games," Computers & Education, vol. 59, pp. 661-686, 2012. http://dx.doi.org/10.1016/j.compedu.2012.03.004

[5] Kueider A. M., Parisi J. M., Gross A. L., and Rebok G. W., "Computerized Cognitive Training with Older Adults: A Systematic Review," PLoS ONE, vol. 7, p. e40588, 2012. http://dx.doi.org/10.1371/journal.pone.0040588

[6] Rego P., Moreira P. M., and Reis L. P., "Serious games for rehabilitation: A survey and a classification towards a taxonomy," in Information Systems and Technologies (CISTI), 2010 5th Iberian Conference on, 2010, pp. 1-6.

[7] Blunsdon B., Reed K., McNeil N., and McEachern S., "Experiential learning in social science theory: An investigation of the relationship between student enjoyment and learning," Higher education research and development, vol. 22, pp. 43-56, 2003. http://dx.doi.org/10.1016/j.compedu.2010.02.003

[8] Gomez E. A., Wu D., and Passerini K., "Computer-supported team-based learning: The impact of motivation, enjoyment and team contributions on learning outcomes," Computers & Education, vol. 55, pp. 378-390, 2010. http://dx.doi.org/10.1080/0729436032000056544

[9] Mitchell T. J., Chen S. Y., and Macredie R. D., "The relationship between web enjoyment and student perceptions and learning using a web-based tutorial," Learning, Media and Technology, vol. 30, pp. 27-40, 2005. http://dx.doi.org/10.1080/13581650500075546

[10] Giannakos M. N., Chorianopoulos K., Jaccheri L., and Chrisochoides N., "“This Game Is Girly!” Perceived Enjoyment and Student Acceptance of Edutainment," in E-Learning and Games for Training, Education, Health and Sports, ed: Springer, 2012, pp. 89-98. http://dx.doi.org/10.1007/978-3-642-33466-5_10

[11] Bellotti F., Berta R., De Gloria A., and Primavera L., "Adaptive experience engine for serious games," Computational Intelligence and AI in Games, IEEE Transactions On, vol. 1, pp. 264-280, 2009. http://dx.doi.org/10.1109/TCIAIG.2009.2035923

[12] Peirce N., Conlan O., and Wade V., "Adaptive educational games: Providing non-invasive personalised learning experiences," in Digital Games and Intelligent Toys Based Education, 2008 Second IEEE International Conference on, 2008, pp. 28-35. http://dx.doi.org/10.1109/DIGITEL.2008.30

[13] Westra J., Dignum F., and Dignum V., "Modeling agent adaptation in games," in BNAIC 2008 Belgian-Dutch Conference on Artificial Intelligence, 2008, p. 381.

[14] Bin-Shyan J., Chien-Hung L., Yen-Teh H., Tsong-Wuu L., and Cheng-Yu L., "Using Game-Based Cooperative Learning to Improve Learning Motivation: A Study of Online Game Use in an Operating Systems Course," Education, IEEE Transactions on, vol. 56, pp. 183-190, 2013. http://dx.doi.org/10.1109/TE.2012.2207959

[15] Suttie N., Louchart S., Lim T., and Ritchie J., "Towards a Biocybernetic Approach for Serious Games Real-time Psychophysiological Inferences for Adaptive Agents in Serious Games," Procedia Computer Science, vol. 15, pp. 316-317, 2012. http://dx.doi.org/10.1016/j.procs.2012.10.092

[16] Deci E. L., Koestner R., and Ryan R. M., "A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation," Psychological bulletin, vol. 125, p. 627, 1999. http://dx.doi.org/10.1037/0033-2909.125.6.627

[17] Pierce W. D., Cameron J., K. Banko M., and So S., "Positive effects of rewards and performance standards on intrinsic motivation," The Psychological Record, vol. 53, p. 4, 2012.

[18] Cameron J., Banko K. M., and Pierce W. D., "Pervasive negative effects of rewards on intrinsic motivation: The myth continues," The Behavior Analyst, vol. 24, p. 1, 2001.

[19] Eisenberger R., and Cameron J., "Detrimental effects of reward: Reality or myth?," American psychologist, vol. 51, p. 1153, 1996. http://dx.doi.org/10.1037/0003-066X.51.11.1153

[20] Wang H., and Sun C.-T., "Game reward Systems: gaming experiences and social meanings," Research Paper, Department of Computer Science, National Chiao Tung University, Taiwan, 2011.

[21] Reynolds G. S., "A primer of operant conditioning.(Rev ed)," 1975.

[22] Chumbley J. and Griffiths M., "Affect and the computer game player: the effect of gender, personality, and game reinforcement structure on affective responses to computer game-play," CyberPsychology & Behavior, vol. 9, pp. 308-316, 2006. http://dx.doi.org/10.1089/cpb.2006.9.308

[23] Charlton J. P., and Danforth I. D., "Distinguishing addiction and high engagement in the context of online game playing," Computers in Human Behavior, vol. 23, pp. 1531-1548, 2007. http://dx.doi.org/10.1016/j.chb.2005.07.002

[24] Siang A. C., and Rao R. K., "Theories of learning: a computer game perspective," in Multimedia Software Engineering, 2003. Proceedings. Fifth International Symposium on, 2003, pp. 239-245.

[25] Yee N., "The psychology of massively multi-user online role-playing games: Motivations, emotional investment, relationships and problematic usage," in Avatars at work and play, ed: Springer, 2006, pp. 187-207. http://dx.doi.org/10.1007/1-4020-3898-4_9

[26] Domínguez A., Saenz-de-Navarrete J., de-Marcos L., Fernández-Sanz L., Pagés C., and Martínez-Herráiz J.-J., "Gamifying learning experiences: Practical implications and outcomes," Computers & Education, vol. 63, pp. 380-392, 4// 2013. http://dx.doi.org/10.1016/j.compedu.2012.12.020
[27] Linehan C., Kirman B., Lawson S., and Chan G., "Practical, appropriate, empirically-validated guidelines for designing educational games," in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 2011, pp. 1979-1988. http://dx.doi.org/10.1145/1978942.1979229
[28] Charles D., Kerr A., McNeill M., McAlister M., Black M., Kcklich J., et al., "Player-centred game design: Player modelling and adaptive digital games," in Proceedings of the Digital Games Research Conference, 2005.
[29] Fua K. C., Gupta S., Pautler D., and Farber I., "Designing serious games for elders," in 8th International Conference on the Foundations of Digital Games, Chania, Crete, Greece, 2013.
[30] Skinner B. F., Ferster C., and Ferster C. B., Schedules of reinforcement: Copley Publishing Group, 1997.
[31] Bradshaw C. A. and Reed P., "Relationship between contingency awareness and human performance on random ratio and random interval schedules," Learning and Motivation, vol. 43, pp. 55-65, 2012. http://dx.doi.org/10.1016/j.lmot.2011.11.002
[32] Howard-Jones P. A. and Demetriou S., "Uncertainty and engagement with learning games," Instructional Science, vol. 37, pp. 519-536, 2009. http://dx.doi.org/10.1007/s11251-008-9073-6
[33] Hariri A. R., S. Brown M., Williamson D. E., Flory J. D., de Wit H., and Manuck S. B., "Preference for immediate over delayed rewards is associated with magnitude of ventral striatal activity," The journal of Neuroscience, vol. 26, pp. 13213-13217, 2006. http://dx.doi.org/10.1523/JNEUROSCI.3446-06.2006
[34] Mischel W. and Grusec J., "Waiting for rewards and punishments: Effects of time and probability on choice," Journal of Personality and Social Psychology, vol. 5, p. 24, 1967. http://dx.doi.org/10.1037/h0024180
[35] Magerko B., Heeter Fitzgerald C., J., and Medler B., "Intelligent adaptation of digital game-based learning," in Proceedings of the 2008 Conference on Future Play: Research, Play, Share, 2008, pp. 200-203. http://dx.doi.org/10.1145/1496984.1497021
[36] Göbel S., Hardy S., Wendel V., Mehm F., and Steinmetz R., "Serious games for health: personalized exergames," in Proceedings of the international conference on Multimedia, 2010, pp. 1663-1666. http://dx.doi.org/10.1145/1873951.1874316
[37] Madeira R. N., Correia N., Guerra M., Postolache O., Dias A., and Postolache G., "Designing personalized therapeutic serious games for a pervasive assistive environment," in Serious Games and Applications for Health (SeGAH), 2011 IEEE 1st International Conference on, 2011, pp. 1-10. http://dx.doi.org/10.1109/SeGAH.2011.6165465
[38] Toppen J., "Effect of size and frequency of money reinforcement on human operant (work) behavior," Perceptual and motor skills, vol. 20, pp. 259-269, 1965. http://dx.doi.org/10.2466/pms.1965.20.1.259
[39] Tatham T. A., Wanchisen B. A., and Hineline P. N., "Effects of fixed and variable ratios on human behavioral variability," Journal of the Experimental Analysis of Behavior, vol. 59, pp. 349-359, 1993. http://dx.doi.org/10.1901/jeab.1993.59-349
[40] Griffiths R. R., and Thompson T., "The post-reinforcement pause: A misnomer," The Psychological Record, 1973.
[41] Pagulayan R. J., Keeker K., Wixon D., Romero R. L., and Fuller T., "User-centered design in games," The human-computer interaction handbook: fundamentals, evolving technologies and emerging applications, pp. 883-906, 2003.
[42] Baddeley A., "Working memory," Science, vol. 255, pp. 556-559, January 31, 1992 http://dx.doi.org/10.1126/science.1736359
[43] Miller G. A., "The magical number seven, plus or minus two: some limits on our capacity for processing information," Psychological review, vol. 63, p. 81, 1956. http://dx.doi.org/10.1037/h0043158
[44] Malone T. W., "What makes things fun to learn? Heuristics for designing instructional computer games," in Proceedings of the 3rd ACM SIGSMALL symposium and the first SIGPC symposium on Small systems, 1980, pp. 162-169. http://dx.doi.org/10.1145/800088.802839
[45] Hamari J., and Eranti V., "Framework for designing and evaluating game achievements," Proc. DiGRA 2011: Think Design Play, vol. 115, pp. 122-134, 2011.
[46] Csikszentmihalyi M., Flow: HarperCollins, 1991.

[47] Atkinson J. W., "Motivational determinants of risk-taking behavior," Psychological review, vol. 64, p. 359, 1957.
[48] Loftus G. R., and Loftus E. F., Mind at play: The psychology of video games vol. 14.
[49] Hopson J., "Behavioral game design," Gamasutra, April, vol. 27, 2001.
[50] Jablonsky S. F., and DeVries D. L., "Operant conditioning principles extrapolated to the theory of management", Organizational Behavior and Human Performance, vol. 7, pp. 340-358, 1972. http://dx.doi.org/10.1016/0030-5073(72)90021-9