A Novel Difficulty Mechanism based on HIIT for Self-control Training Game Design

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1 Introduction

Cognitive training has drawn attention from researchers for it can improve basic cognitive ability concerning individual well-being of living in the real world and various approaches have been utilized for this purpose. However, many studies showed that traditional training methods have been too time-consuming to gain significant effects. Therefore, we proposed a novel difficulty mechanism based on HIIT [4] (High intensity interval training) and conducted a study in a video game comparing it with mainstream traditional mechanisms: MICT (Moderate intensity continuous training, aka fixed-difficulty [3]) and DDA [2] (Dynamic difficulty adjustments). Our work motivates further7 studies into higher efficiency of cognitive training.

2 Related work

2.1 Mechanisms used in cognitive training

In the field of cognitive training, DDA and MICT are the majority of mechanisms used in existing methods. However, learning from a similar area of sports science to overcome the shortcoming of traditional mechanisms being too time-consuming has not drawn adequate attention from researchers. Therefore, to solve this critical problem, we targeted the HIIT concept for HIIT is a very highly efficient physical exercise. We believe it promising to improve current cognitive training by transforming the HIIT method into a HIIT style mechanism. Thus, the time-consuming problem may be solved.

3 Experiment

3.1 Experimental design

We proposed a HIIT style mechanism (Figure 1) by invoking cycles of high with low difficulty patterns. A comparative user study was used to evaluate the effectiveness of HIIT in a self-control training video game implemented with the Go-nogo paradigm [1]. The experiment conducted mainly used the stop-signal task as means of estimating training effects within subjects. Among three groups: HIIT, DDA, and MICT, 30 people were recruited and assigned randomly in the study (24 males and 6 females; aged from 18 to 32). Each group was assigned 10 participants and no break was given during the experiment game-play session. All participants are required to operate on the same PC in the designated experiment room.

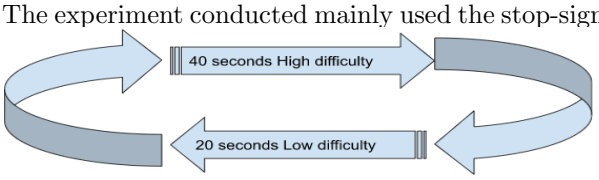

Figure 1. The HIIT style difficulty mechanism

3.2 Measures

The stop-signal task is used to evaluate training effects on self-control ability, in which the participants have to press the right arrow keys displayed on the screen as quickly as possible. The Intrinsic Motivation Inventory (IMI) measures enjoyment, perceived competence, efforts, tension, value, by which we could understand motivations of participants. Our used version of IMI has 30 questions to be rated on a 7-point scale of intensity. The player experience of need satisfaction (PENS) measures competence, autonomy, relatedness, presence, intuitive control, by which we could understand subjective game experience of participants. Our used version of PENS has 21 questions to be rated on a 7-point scale of intensity. Structured interviews we have used ask the participants about their competence, confidence, subjective difficulty and enjoyment.

3.3 Analysis tools

The data from pre and post tests, game-play and questionnaires are analyzed using repeated MANOVA to verify the trending of the training data within subjects (data sampled from the first day, the middle day, and the last day for game performance data; data sampled at the first day and last for pre-post data), and one-way ANOVA to verify between-subjects (data sampled from the first day and the last day) effects (analysis with $\alpha = 0.05$; post-hoc tests with Bonferroni correction were used if any).

4 Result

4.1 RQ1: HIIT version of the game was more effective overall?

To address RQ1, we used the stop-signal task as measurements of self-control ability. In terms of RTs (response time) in pre-post tests, in the H group, a repeated measure of MANOVA was performed to com-

pare the effect of the game training on reaction time before and after. There was a statistically (Figure 2) significant ($p=0.04 < 0.05$) difference in reaction time between before (M=559.96, SD=77.95) and after (M=528.52, SD=71.57). But, the D group showed no significant difference between before (M=534.14, SD=58.33) and after (M=519.06, SD=59.97). Likewise, no significance was found between before (M=557.37, SD=63.70) and after (M=539.85, SD=66.50) in the M group as well. This revealed that only response time of participants in the H group significantly decreased. In terms of SRs (success rate) in the pre-post test, results of MANOVA showed that for H, D, and M, they all showed no significance between before and after. At day0, the results of one-way ANOVA showed no significance between three groups. Also, at day8, no significance was found between three groups.

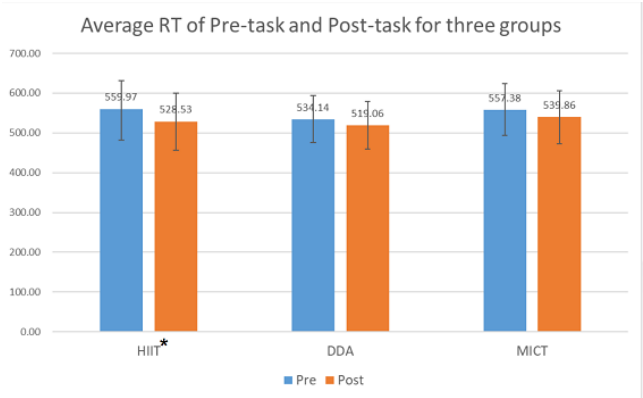

Figure 2. RT results

4.2 RQ2: HIIT style difficulty mechanism might sabotage the game experience of players?

At five sub-scales of IMI (enjoyment, competence, importance, tension, value). The results of comparisons of means for three groups at each scale were respectively : H (M=5.03, SD=1.31) > M (M=4.37, SD=1.00) > D (M=4.27, SD=1.60), M (M=5.17, SD=1.12) > D (M=4.55, SD=0.864) > H (M=4.07, SD=1.60), H (M=4.70, SD=0.68) > M (M=4.58, SD=0.91) > D (M=4.54, SD=1.00), M (M=3.56, SD=0.96) > D (M=3.42, SD=1.17) > H (M=3.20, SD=1.12), M (M=5.33, SD=1.32) > H (M=5.11, SD=0.83) > D (M=4.23, SD=1.68). But the results of one-way ANOVA on each sub-scale all showed no significance between three groups. Likewise, at five sub-scales of PENS (competence, autonomy, relatedness, immersion, intuitive controls). The results of comparisons of means for three groups at each scale were respectively : M (M=5.37, SD=0.76) > H (M=5.03, SD=0.76) > D (M=4.63, SD=1.11), H (M=4.60, SD=1.61) > M (M=3.97, SD=0.97) > D (M=3.30, SD=1.05), M (M=4.43, SD=0.86) > H (M=4.33, SD=1.01) > D (M=3.17, SD=1.06), M (M=3.80, SD=0.95) > H (M=3.77, SD=1.15) > D (M=3.32, SD=1.18), D (M=5.43, SD=0.79) > M (M=5.27, SD=1.74) > H (M=4.80, SD=0.85). And results of one-way ANOVA on each sub-scale showed that only significance ($p=0.01 < 0.05$) was observed in relatedness. We conducted a Bonferroni post-hoc test to further investigate this significance. And the results of H vs D, H vs M, D vs M showed that difference between H and M was insignificant, while other results of other comparisons like H vs D ($p=0.04 < 0.05$) and D vs M ($p=0.02 < 0.05$) were significant. However, this significance was not very explanatory, for our game was only a lab-game which lacked gameplay design and beautiful visual effects, sound effects etc.

5 Conclusion

We proposed and verified a novel difficulty mechanism based on the HIIT approach from sports science for cognitive training purposes, which is highly efficient to save time of users compared to traditional methods. It can also boost improvements of player skills quickly. All of those benefits above can also be achieved while rendering the game challenging and enjoyable. Despite so many benefits, more in-depth and detailed studies are required to further understand and generalize this mechanism, even commercialize it.

References

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