# Computerized Training for Executive Functions: The Effect of Feedback Availability

**Nirit Gavish**
ORT Braude College
nirit@braude.ac.il

**Hagit Krisher**
ORT Braude College
hevenzur@braude.ac.il

## Abstract

Training Computerized training systems offer a promising new direction in the training of executive functions, in part because they can easily be designed to offer feedback to learners. Yet feedback is a double-edged sword, serving a positive motivational role while at the same time carrying the risk that learners may become dependent on the feedback they receive. The current research suggests that computerized training systems may take advantage of the motivational effects of feedback without the unwanted risk by making feedback available while not requiring trainees to access it. Specifically, we hypothesized that the mere availability of feedback would improve performance even if trainees never or almost never made use of it. We tested this hypothesis using a simple puzzle completion task, putting the focus on executive functions by instructing participants to complete each puzzle with a minimal number of rotations and moves. Two training sessions in which the availability of feedback was manipulated were followed by a transfer test and a visual perception test. The results show that the availability of feedback improved performance, in terms of the smaller number of excess moves performed during both the training sessions and the transfer task.

**Keywords**: Executive function, Feedback, Training, Computerized system.

## Introduction

Executive functions are the high-level cognitive skills – e.g., attention, self-control, working memory, and abstract thinking – involved in planning, organizing, and executing lower-level cognitive tasks (Miyake et al., 2000). Several studies have examined computerized training programs for the improvement of executive functions – part of a trend that has seen the proliferation of computerized training systems aimed at improving cognitive skills in general (Owen et al., 2010). An important question that must be addressed when designing computerized training systems in general, and for executive functions specifically, concerns the provision of feedback to trainees during the training. Feedback can improve performance by providing the trainee with information that can serve as a basis for error correction (Salmoni, Schmidt, & Walter, 1984). On the other hand, several studies have suggested that learners may become dependent on the feedback they receive, and in consequence fail to take in or effectively use other sources of information.

Given the potential negative effects of feedback, it might appear that feedback in cognitive training systems should be avoided. But feedback also serves a motivational role, by offering psychological encouragement during the skill acquisition period (Arps, 1920; Crawley, 1926; Diserens & Vaughn, 1931; Elwell & Orindley, 1938; Locke, 1966; Locke & Bryan, 1969; Smode, 1958). The motivational power of feedback seems to vary depending on the type of feedback, negative or positive, but in general, constructive feedback is thought to increase motivation not only by strengthening learners' belief that they are capable of achieving the desired goal (Hattie & Timperley, 2007), but also by making the task more interesting and enjoyable (Hung, Huang, & Hwang, 2014). This suggests that feedback might be of benefit after all.

The findings described above raise the question of whether it may be possible to harness the positive motivational effects of feedback without risking the potential negative effects by providing trainees with the opportunity to access feedback, but not requiring them to do so. That is, the mere possibility of receiving feedback, even though the trainee may never actually take advantage of this offer, may improve the trainee's performance over time. Indeed, this motivational effect may be especially dominant in training systems for executive functions because of the strong apparent link between executive functions and motivation, and between such functions and emotion.

The current study addressed the hypothesis that having the opportunity to receive feedback would improve performance even among trainees who chose not to take up the feedback offer, with the driving force behind this effect assumed to be the motivational effects of the feedback option. We tested the hypothesis among 76 undergraduate students using a puzzle replication task.

## Method

### Design and Experimental Task

Several tasks were evaluated from a computerized training system developed by Mindri (http://www.mindri.com). The chosen task was a simple puzzle replication task using a variety of geometric shapes (see Figure 1). Trainees were invited to two training sessions, held a week apart, in each of which they were asked to complete four 4-piece puzzles and eleven 9-piece puzzles. In the second session they were also given a transfer test, which required them to complete five 16-piece puzzles using a set of identical geometric shapes (see Figure 2). To ensure that trainees would focus on improving their executive function skills, they were instructed to complete each task as efficiently as possible (i.e., using the smallest possible number of rotations and moves). They were also told that their payout for the session would depend on their performance across the entire set of tasks.

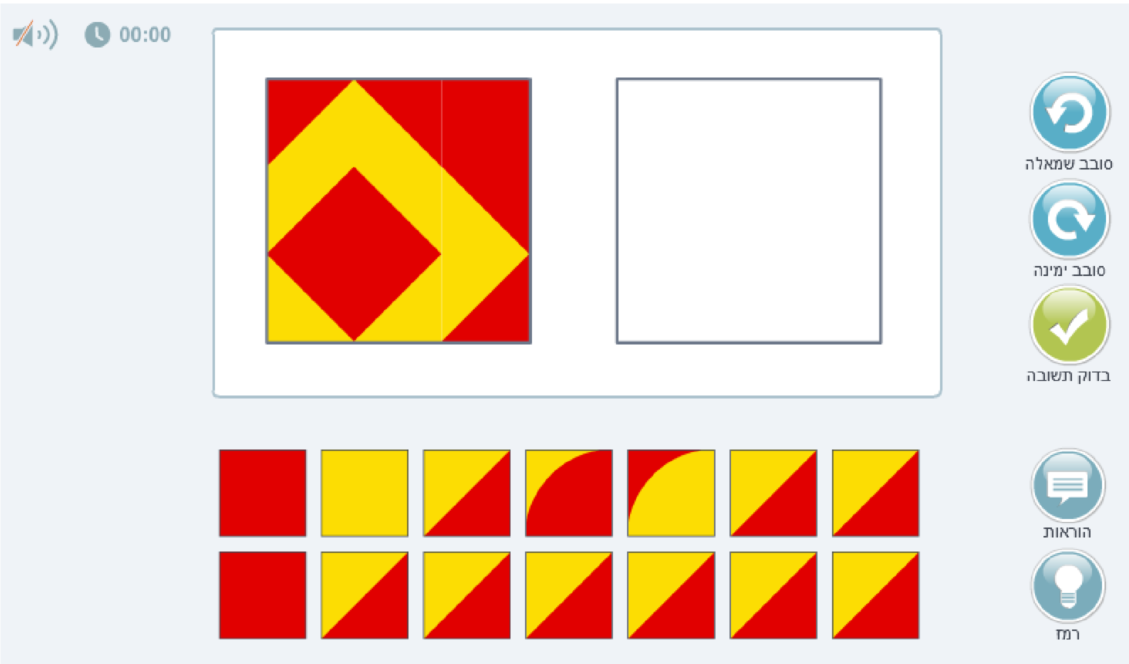


**Figure 1. The experimental puzzle completion task**

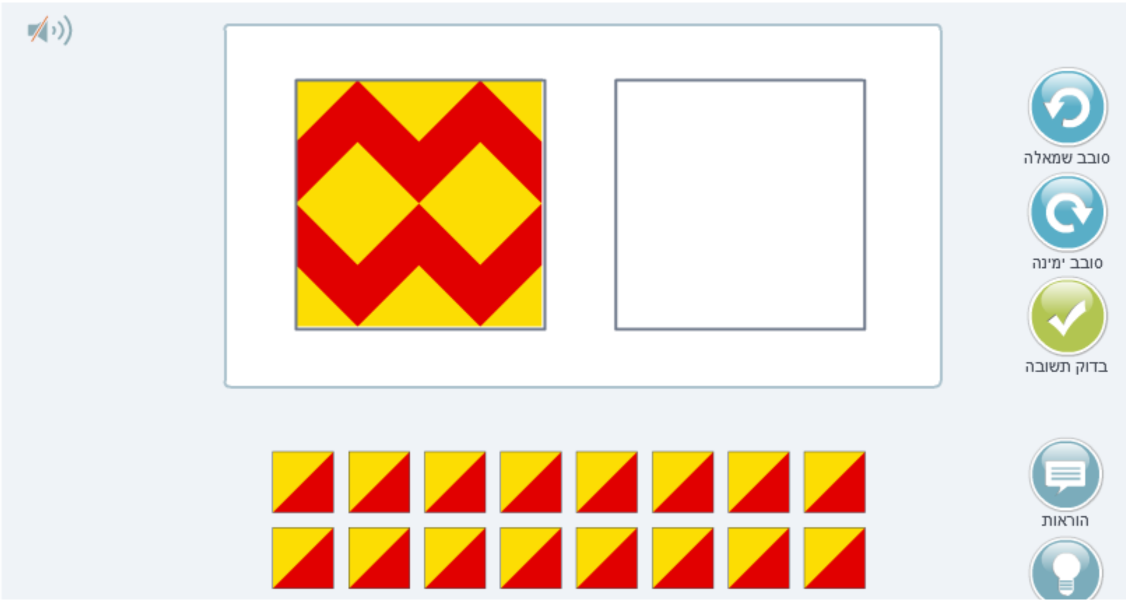


**Figure 2. The transfer test task**

Participants were randomly assigned to two between-participants groups: with and without the option of receiving feedback (the Feedback and No Feedback groups respectively). The feedback option showed participants the most efficient way to complete their most recent move. Because the task was relatively simple, most trainees with the feedback option chose to use it only once, or not at all. The data of trainees who used the feedback option more than once were excluded from the analysis (see below).

The experiment initially followed a 2X2 factorial design that would have compared the effects of two types of feedback: specific feedback on individual moves (Feedback/No Feedback) and more general feedback about the participant's overall strategy (Strategy/No Strategy). Half the participants in each feedback condition were told that an expert trainer had evaluated their performance in the first session and had prepared strategies that would help them improve their performance. The strategies were very short and very general (e.g., "Try to think through your moves and carefully consider whether a piece matches before placing it in the frame. This will improve your efficiency"). A manipulation check showed that the strategies produced no significant effects. Hence, we decided not to include this manipulation as an independent variable.

## Participants

Participants initially included 88 undergraduate students (59 males, 29 females) from ORT Braude College, Israel. Forty-three participants (31 males, 12 females) were randomly assigned to the Feedback group, and 45 participants (28 males, 17 females) to the No Feedback group. Twelve participants in the Feedback group were excluded from the analysis because they used the suggested system's feedback at least twice in at least one of the two sessions. Hence, the final sample comprised 76 participants, of whom 31 (21 males, 10 females) were in the Feedback group.

## Results

The main dependent measures in both the main task and the transfer test were the number of excess rotations and moves performed when completing the puzzles. These were calculated by subtracting the minimum required rotations and moves for each puzzle from the number actually performed. Task duration was also calculated, although participants were not instructed to complete the task as fast as possible.

To analyze the results for the main tasks, a repeated-measures ANOVA was conducted, with feedback condition (Feedback/No Feedback) as the between-participants independent variable and the training session (first or second) as the within-participants independent repeated measure. Separate ANOVAs were conducted for the transfer test and the pencil-and-paper visual perception test, with feedback condition as the between-participants independent variable.

### Main Task

With respect to excess moves in the main task, the effect of training session was significant ($F(1,74) = 4.74$, $p = 0.03$, partial eta squared = 0.06): participants made fewer excess moves in the second session ($M = 17.12$, $SE = 3.57$) compared to the first session ($M = 21.26$, $SE = 3.97$). The effect of feedback condition was also significant ($F(1,74) = 6.23$, $p = 0.02$, partial eta squared = 0.08): participants in the Feedback group made fewer excess moves ($M = 10.08$, $SE = 5.62$) compared to the No Feedback group ($M = 28.30$, $SE = 4.66$). The interaction between training session and condition was not significant ($F(1,74) = 0.65$, $p = 0.42$, partial eta squared = 0.01). The results are shown in Figure 3.

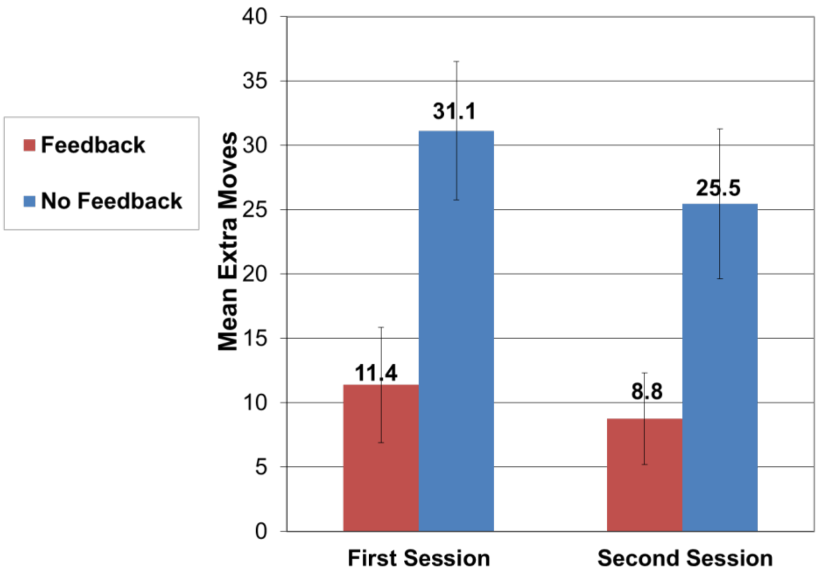


**Figure 3. Training sessions, excess moves: Mean excess moves for each session and group (with standard error bars)**

The question arises whether the results would have been similar had we included those participants who were dropped from the analysis because they took advantage of the feedback option twice or more in either session (suggesting that they might have been weaker performers). We therefore ran a second repeated measures ANOVA with the addition of these 12 participants. The results confirmed the previous findings. Again, the effect of training session was significant ($F(1,86) = 5.40$, $p = 0.02$, partial eta squared = 0.06), with fewer excess moves made in the second session ($M = 17.59$, $SE = 3.16$) compared to the first ($M = 21.37$, $SE = 3.46$). The effect of condition was also significant ($F(1,86) = 7.54$, $p = 0.01$, partial eta squared = 0.08), with fewer excess moves made in the Feedback condition ($M = 10.66$, $SE = 4.59$) compared to the No Feedback condition ($M = 28.30$, $SE = 4.49$). As before, the interaction between training session and condition was not significant ($F(1,86) = 1.36$, $p = 0.25$, partial eta squared = 0.02).

With respect to excess rotations, the effect of training session was significant ($F(1,74) = 33.87$, $p < 0.001$, partial eta squared = 0.31): fewer excess rotations were performed in the second session ($M = 17.56$, $SE = 2.65$) compared to the first ($M = 28.97$, $SE = 3.30$). The effect of condition was not significant ($F(1,74) = 2.42$, $p = 0.12$, partial eta squared = 0.03), nor was the interaction between training session and condition ($F(1,74) = 0.29$, $p = 0.66$, partial eta squared = 0.003). The results are depicted in Figure 4.

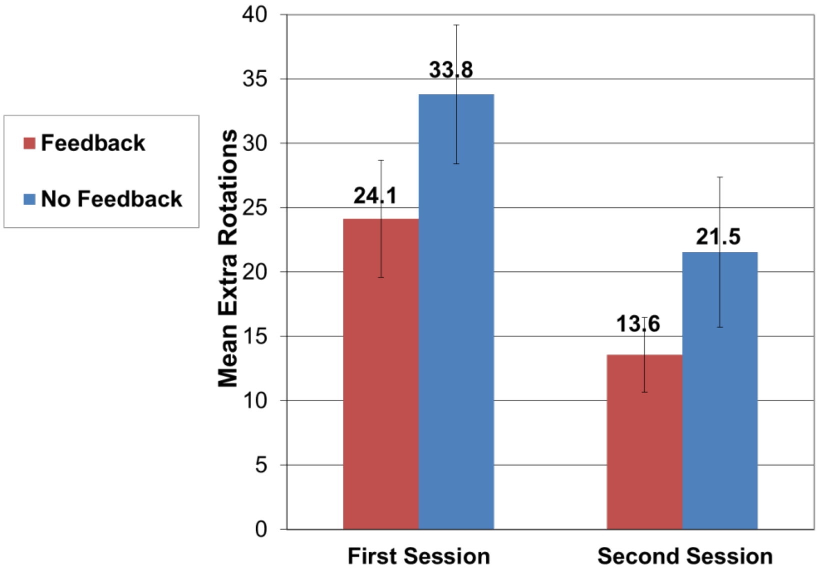


**Figure 4. Training sessions, excess rotations: Mean excess rotations for each session and group (with standard error bars)**

The pattern of results for mean duration is similar to the pattern for mean extra rotations .The effect of training session was significant ($F(1,74) = 125.96$, $p < 0.001$, partial eta squared = 0.63): participants needed less time to complete the task in the second session ($M$ = 505.49 seconds, $SE$ = 16.70) compared to the first ($M$ = 667.26 seconds, $SE$ = 23.64). The effect of feedback condition was not significant ($F(1,74) = 3.01$, $p = 0.09$, partial eta squared = 0.04), nor was the interaction between training session and condition ($F(1,74) = 0.27$, $p = 0.61$, partial eta squared = 0.004). The results are shown in Figure 5.

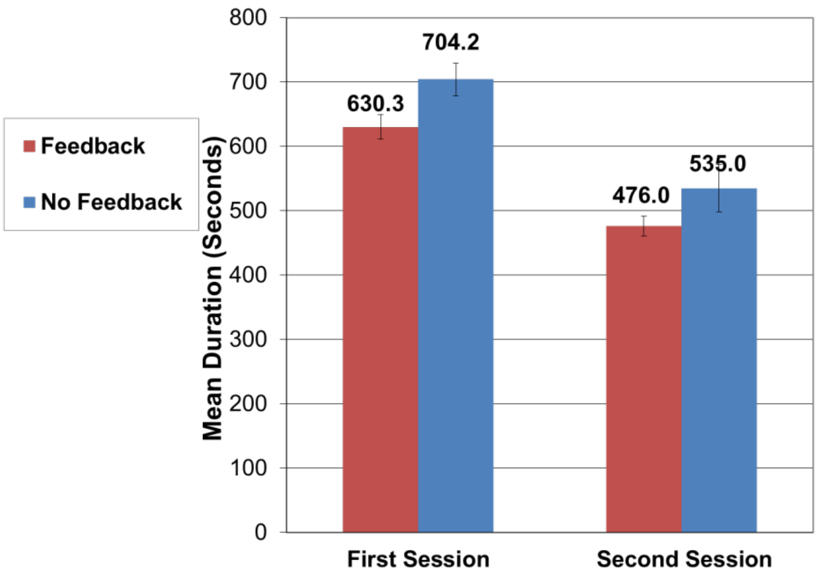


**Figure 5. Training sessions, task duration: Mean duration for each session and group (with standard error bars)**

## Transfer Test Results

In the transfer test, the effect of feedback condition on excess moves was very close to significance ($F(1,74) = 3.75$, $p = 0.057$, partial eta squared = 0.05): fewer excess moves were made in the Feedback condition ($M = 6.16$, $SE = 4.08$) compared to the No Feedback condition ($M = 16.42$, $SE = 3.39$). As before, to evaluate whether excluding the participants who took advantage of the feedback option twice or more in either session affected the results, we ran a second ANOVA with the addition of these 12 participants. In this analysis the effect of feedback group was even more significant ($F(1,86) = 6.46$, $p = 0.01$, partial eta squared = 0.07), with fewer excess moves in the Feedback condition ($M = 4.98$, $SE= 3.22$) compared to the No Feedback condition ($M = 16.42$, $SE = 3.15$).

The effect of feedback condition on mean excess rotations in the transfer test was not significant ($F(1,74) = 0.17$, $p = 0.68$, partial eta squared = 0.002).

The effect of feedback condition on mean duration was not significant ($F(1,74) = 1.91$, $p = 0.17$, partial eta squared = 0.02).

## Discussion and Conclusions

Overall, the current findings suggest that in computerized training systems for executive functions, simply making feedback available, even if most trainees are likely to make little use of it, can have strong influence on both training and performance. This finding should be evaluated further using other tasks and in other domains, to examine its robustness for future computerized training system design recommendations and guidelines.

The current findings are interesting in light of research about the extent to which priming – i.e., exposing individuals to a particular stimulus – can affect participants' behavior and performance in different situations. For example, Bargh, Chen, and Burrows (1996) found that "participants whose concept of rudeness was primed interrupted the experimenter more quickly and frequently than did participants primed with polite-related stimuli," while "participants for whom an elderly stereotype was primed walked more slowly down the hallway when leaving the experiment than did control participants" (p. 230). Steele and Aronson (1995) showed that African Americans who were primed with a negative stereotype about their intellectual ability performed more poorly in intellectual tests than similar black participants who were not so primed. Likewise, Dijksterhuis and Van Knippenberg (1998) reported that priming the stereotype of a professor or the trait "intelligent" improved participants' performance on a general knowledge test, while priming the stereotype of soccer hooligans or the trait "stupid" reduced their performance. In a similar manner, the mere knowledge that feedback is available may prime trainees with the motivational effect of feedback, creating a psychological state of mind that may improve training and transfer.

## Acknowledgments

This research was supported in part by the Research Committee of ORT Braude College, Israel.

## References

Arps, G. F. (1920). Work with KR versus work without KR. *Psychological Monographs, 28(125)*.

Bargh, J. A., Chen, M., & Burrows, L. (1996). Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. *Journal of Personality and Social Psychology, 71(2),* 230-244.

Crawley, S. L. (1926). An experimental investigation of recovery from work. *Archives of Psychology, 13*.

Dijksterhuis, A., & Van Knippenberg, A. (1998). The relation between perception and behavior, or how to win a game of trivial pursuit. *Journal of Personality and Social Psychology, 74(4),* 865.

Diserens, C. M., & Vaughn, J. (1931). The experimental psychology of motivation. *Psychological Bulletin, 28(1),* 15-65.

Elwell, J. L., & Orindley, G. S. (1938). The effect of knowledge of results on learning and performance. *British Journal of Psychology, 29,* 39-53.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77(1)*, 81-112.

Hung, C. M., Huang, I., & Hwang, G. J. (2014). Effects of digital game-based learning on students' self-efficacy, motivation, anxiety, and achievements in learning mathematics. *Journal of Computers in Education, 1(2-3)*, 151-166.

Locke, E. A. (1966). The motivational effects of knowledge of results: The influence of goal-setting. *Silver Spring, MD: American Institutes for Research*.

Locke, E. A., & Bryan, J. F. (1969). Knowledge of score and goal level as determinants of work rate. *Journal of Applied Psychology, 53(1),* 59-65.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49-100.

Owen, A. M., Hampshire, A., Grahn, J. A., Stenton, R., Dajani, S., Burns, A. S., Howard, R. J., & Ballard, C. G. (2010). Putting brain training to the test. *Nature, 465,* 775-779.

Salmoni, A. R, Schmidt, R. A., & Walter, C. B. (1984). Knowledge of results and motor learning: A review and critical appraisal. *Psychological Bulletin, 5,* 355-386.

Smode, A. F. (1958). Learning and performance in a tracking task under two levels of achievement information feedback. *Journal of Experimental Psychology, 56(4),* 297-304.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69(5),* 797-811.