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ARTICLE REVIEW:

Design and evaluation of Calcularis computer-based training to enhance numerical cognition

Käser, T., Baschera, G., Kohn, J., . . . von Aster, M. (2013). Design and evaluation of the computer-based training program Calcularis for enhancing numerical cognition. Frontiers in Psychology, 4, (489) 1–13. http://dx.doi.org/10.3389/fpsyg.2013.00489

Käser et al. (2013) examined the computer-based training program, Calcularis, for children who have difficulties learning mathematics. The authors report the results of the pilot implementation of this program. Calcularis was developed from the core elements of an earlier program "Rescue Calcularis" (Kucian et al., 2011). Calcularis provides a more complete training of mathematical skills, combining the training of basic numerical cognition with arithmetical abilities. The program user model enables adaptation to support individuation based on each student's level of mathematical skill.

Program and Study Design

The authors hypothesized that students engaged in the pilot would exhibit significant training effects for spatial number representation and arithmetical performance. They also expected increased motivation by providing an attractive computer-based learning environment and adapting the difficulty level to the individual child.

The program combines the training of basic numerical cognition with training of different number representations and their interrelations, and arithmetical abilities. Calcularis is based on the following design principles:

- Design of numerical stimuli that includes different modalities (*** - three – 3) shown simultaneously at the end of each trial.
- The control function in the program improves the efficacy of the learning process by using each child's responses to determine the level and speed of progress of the tasks. By employing a hierarchical progression for the tasks, early fundamental skills used in initial tasks are building blocks for more advanced training.
- Children are taught conceptual knowledge before going over to automation training. For example, an arithmetic operation is first introduced and explained. The arithmetic operation and its solution are then modeled using stimuli and finally, mental calculation is trained

The training program consists of 10 different games that are associated with the presented skills. By varying the numbers used in the games, there are 81 different task difficulty levels. The authors described four basic game types used in the training program.

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- **Ordering.** Ordering is a support game in "Number Representations," which trains ordinal number understanding. A sequence of numbers is displayed for 5 seconds. Children need to decide if the sequence was sorted in ascending order.
- **Landing.** This is the main game in "Number Representations," which trains spatial number representation. A purple cone must be directed to the position of a given number on a number line (with indicated center), using a joystick. Numbers are presented in verbal or Arabic notation. In another option the cardinality of a given point set and the position of this quantity on the number line have to be estimated. This game is representative of Number line development.
- **Slide Rule.** This is a support game for "Arithmetic Operations." It introduces addition and subtraction using the part–whole concept. An operation task is presented to the child, as well as a number line and a glass case containing a number of blocks (according to the first number of the task). The size of the glass case must be changed such that it contains the result of the task.
- **Plus and Minus.** This is a support game in "Arithmetic Operations." An arithmetic operation in Arabic notation must be modeled using colored blocks (one, ten, and 100). Different strategies can be used to find the answer.

The effects on 41 elementary school children in grades 2–5 were examined in the evaluation of the pilot. Participants were assigned to a training group (n = 20, 65% females) who completed a 12-week training or a wait group (n = 21, 66.6% females) who started with a 6-week wait period. Groups were matched on age, gender, and intelligence. Mathematical performance was evaluated before the training, after 6 weeks, and then after 12 weeks. Training sessions were 20-minutes, five times a week. Mathematical performance was measured with the Heidelberger Rechentest (HRT 1–4; Haffner, Baro, Parzer, & Resch, 2005), a timed paper-pencil test with addition and subtraction sections. Several computer-based tests were used: Arithmetic (AC), where subjects solve a series of addition and subtraction tasks; Number Line test involving line positioning of Arabic numbers; Non-symbolic magnitude comparison (NC), size comparison of two sets of dots; Estimation, this task presents subjects with sets of dots and they need to decide if the set is less or greater than 50. At the end of the training, participating children completed a feedback questionnaire where they rated each game for likability. They also rated the overall training, how difficult it was, and if they believed the training helped them.

Results and Summary

The Calcularis training program pilot was evaluated for efficacy, as well as the practicality and adaptability.

- Student feedback confirmed that the adaptation and estimation of their knowledge were sufficient.
- The scaffolding of the program works on the assumption that each student starts with a different amount of mathematical knowledge and shows deficits in different areas and adapts to differences.
- Participants generally demonstrated large improvements in deficit areas after training.

A comparison of mathematical performance pre- and post-training indicates positive training effects in mathematical skills. Children significantly improved their subtraction skills during the 6-weeks of training: They were able to solve more complex subtraction problems (medium–large effect in the computer-based subtraction test) and solve subtraction tasks faster (large effect in HRT: 30% improvement). When compared to performance on subtraction tasks, student exhibited less improvement on addition tasks, this progress was significant. Children also were able to locate a number on a number line more accurately after training. Specifically, in the number range between 0 and 10, the errors were reduced by 33% after 6 weeks.

The feedback questionnaire results also support the improvement of mathematical performance measured with the external tests. On average, students reported that training had improved their mathematical performance. The subjective feeling of improvement and learning success expressed might also enhance positive self-concepts and motivation. Participants indicated that they liked to train with the program. This demonstrates that the computer is an attractive medium for children and in line with previous studies the authors conducted (Kucian et al., 2011).

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