ORIGINAL ARTICLE

The Role of Order of Practice in Learning to Handle an Upper-Limb Prosthesis

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ABSTRACT. Bouwsema H, van der Sluis CK, Bongers RM. The role of order of practice in learning to handle an upper-limb prosthesis. Arch Phys Med Rehabil 2008;89:1759-64.

Objective: To determine which order of presentation of practice tasks had the highest effect on using an upper-limb prosthetic simulator.

Design: A cohort analytic study.

Setting: University laboratory.

Participants: Healthy, able-bodied participants (N=72) randomly assigned to 1 of 8 groups, each composed of 9 men and 9 women.

Interventions: Participants (n=36) used a myoelectric simulator, and participants (n=36) used a body-powered simulator. On day 1, participants performed 3 tasks in the acquisition phase. On day 2, participants performed a retention test and a transfer test. For each simulator, there were 4 groups of participants: group 1 practiced random and was tested random, group 2 practiced random and was tested blocked, group 3 practiced blocked and was tested random, and group 4 practiced blocked and was tested blocked.

Main Outcome Measures: Initiation time, the time from the starting signal until the beginning of the movement, and movement time, the time from the beginning until the end of the movement.

Results: Movement times got faster during acquisition ($P<.001$). The blocked group had faster movement times ($P=.009$), and learning in this group extended over the complete acquisition phase ($P<.001$). However, this advantage disappeared in the retention and transfer tests. Compared with a myoelectric simulator, movements with the body-powered simulator were faster in acquisition ($P=.004$) and transfer test ($P=.034$).

Conclusions: Performance in daily life with a prosthesis is indifferent to the structure in which the training is set up. However, practicing in a blocked fashion leads to faster performance; in novice trainees, it might be suggested to practice part of the training tasks in blocks.

Key Words: Artificial limbs; Learning; Rehabilitation.

PEOPLE WITH AN UPPER-EXTREMITY amputation often choose to have fitted a prosthesis but do not always use this prosthesis much in their daily life. Twenty to 40% of upper-extremity amputees do not use their prosthesis at all because of a low degree of functional use.[1-3] The functional use of an upper-limb prosthesis is not only determined by its function—that is, the technical possibilities—but also by its functionality, the way the amputee is able to handle the prosthesis. As has been shown previously, the latter aspect can be enhanced by training.[4,5] Consequently, by enhancing the functionality through training, the functional use of the prosthesis might increase.

Although the current training methods in the rehabilitation of upper-limb amputees appear effective, there seems to be room for improvement. For instance, Fraser[6] showed that people do not use their prosthesis in everyday life as they have been trained to. He found that while training of prosthetic use focused on learning to manipulate objects, amputees used their prosthesis only for support while using their sound hand for manipulation. This, combined with the high rate of nonuse, indicates that the effectiveness of current training can be increased. Moreover, it is known that quality of training determines the use of the prosthesis for the rest of one's life.[7] Therefore, training methods have to be developed in a way that functionality in everyday life will improve.

Several aspects of a training scheme can contribute to the efficiency of the training. The different tasks that amputees have to practice determine training efficiency to a large extent. Another important aspect is the structure of the training, which concerns the design in which practice tasks are presented. The structure of the training might be particularly relevant to improve the transfer of skills to tasks in daily life. What kind of training structure would most facilitate transfer to other skills and produce the greatest benefit for amputees? A concept often used to classify training structures when learning new skills is *contextual interference*, which refers to the effect of the degree of interference of order of practice on learning.[8] A low contextual interference involves practicing all trials of 1 task before the next task is introduced, commonly referred to as *blocked order*. High contextual interference involves practicing the trials of each task in random order.[9] In general, studies prove that practicing skills under high contextual interference—random order—enhances performance in transfer to other skills compared with practicing under low contextual interference blocked order[9,10]; it is assumed that making a new movement plan at each trial, which is required when training randomly, improves the effect of training on tasks that are not explicitly trained. Although most studies support the contextual interference effect[10] of enhanced performance in other skills when practiced in a random order, there is limited knowledge about whether the concept of contextual interference does apply to learning to handle an upper-limb prosthesis.

List of Abbreviations

ANOVA	analysis of variance

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Weeks et al[4] examined the practice schedule that elicited the greatest degree of learning in the training of an upper-limb prosthesis using the concept of contextual interference. In their experiment, able-bodied participants used a body-powered prosthetic simulator to study learning and transfer of prehension skills under low and high contextual interference. Results showed that the participants who practiced in a random order outperformed the participants who practiced in a blocked order. This effect of contextual interference was present in the transfer test but absent in the retention test. The latter unexpected lack of the contextual interference effect can probably be explained by the design of the blocked schedule Weeks[4] used during the acquisition phase; the schedule used for the blocked condition was repeated on 2 days, implying that this condition was not strictly blocked. Tsutsui et al[11] used a similar schedule—although not in a study with prostheses but a study of the contextual interference effect with a bimanual coordination task with able-bodied participants—and also showed a lack of a contextual interference effect. Tsutsui[11] reran the experiment comparing a strictly random with a strictly blocked order and then did find an effect of contextual interference. This indicates that an overall effect of contextual interference should be present if the order of practice is strictly applied. Thus, the lack of a contextual interference effect in the study of Weeks[4] might come from implementation of the blocked schedule. A key question of the present study is whether a contextual interference effect can be found in learning to handle an upper-limb prosthesis when the practice schedules are strictly applied.

The purpose of this study was to determine which order of practice tasks has the highest effect on performance with an upper-limb prosthesis. We therefore examined training with 2 types of prosthetic simulators, myoelectric and body-powered, using the concept of contextual interference in a strict order. It was hypothesized that random practice with the simulators would lead to better results in retention and transfer than blocked practice.

METHODS

Participants

Seventy-two able-bodied students (36 men, 36 women; mean age ± SD, 21.07±2.32y) volunteered to participate. All participants were right-handed, had normative or corrected to normative vision, and had no restrictions of the right arm or hand. Thirty-six participants used a body-powered prosthetic simulator and 36 participants used a myoelectric prosthetic simulator in the experiment. For each simulator, there were 4 groups of participants. Group 1 practiced randomly and was tested randomly, group 2 practiced randomly and was tested blocked, group 3 practiced blocked and was tested randomly, and group 4 practiced blocked and was tested blocked. For each of the 8 conditions (2 simulators, 4 groups) 9 men and 9 women were randomly assigned. The participants signed an informed consent at the start of the experiment. The study was conducted in compliance with the tenets of the Declaration of Helsinki for research in human subjects. Because we studied able-bodied, healthy participants, the study needed no review or approval of an ethics committee by our institution.

Apparatus

Two simulators were developed to resemble closely a body-powered and a myoelectric upper-limb prosthesis for a below-elbow amputation (fig 1).

Each of the simulators consisted of a conventional prosthetic hand (Otto Bock)[a] attached to an open cast in which the hand

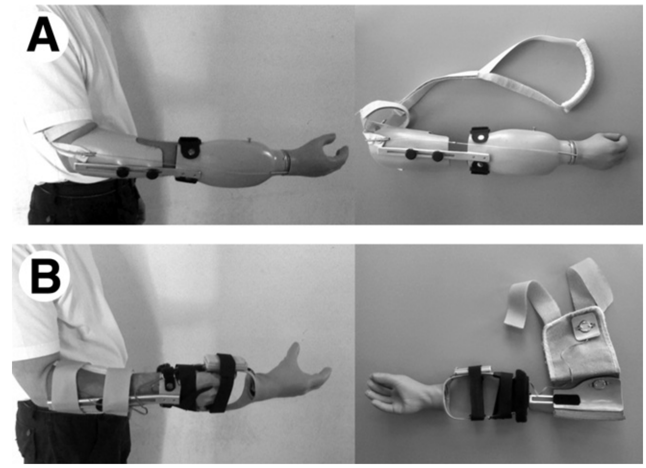

Fig 1. (A) The body-powered simulator and (B) the myoelectric simulator.

could be placed. The cast extended into a splint along the forearm, adjustable in length. The splint could be attached to the arm using a self-adhesive (Velcro) sleeve. The simulator was not attached to the sound hand to prohibit facilitating control, which mimicked a prosthesis worn by an amputee as closely as possible. The hand of the body-powered simulator was connected to a cable, attached to a harness system fitted around the contralateral shoulder. This harness was adjustable to create an appropriate tension of the string to open and close the hand with motions of the torso, shoulders, and arm. The myoelectric simulator was powered and controlled by changes in electric muscle activity, detected by 2 electrodes placed on the dorsal and palmar flexors in the lower arm, which controlled an electric motor in the hand. The exact positions of these electrodes were determined after palpation of the most prominent contraction of muscle bellies of the dorsal and palmar flexors. Subsequently, these locations were marked to place the electrodes. These positions determined where the electrodes were attached to the inside of the self-adhesive sleeve that was folded around the arm. Hand opening was accomplished by activity of the dorsiflexors, while the hand closed by activity of the palmar flexors. To mimic the use of a prosthesis as closely as possible, the participants were instructed not to move the hand, because when one is amputated, the muscles can contract only isometric. It is hardly possible not to move the hand when contracting dorsal and palmar flexors; therefore, the hand was fixated with self-adhesive sleeves to prevent most of the movements.

A task board (60×60cm), fixed to a table, indicated the start and end positions of the tasks. All tasks were started and finished by pressing the space bar of a keyboard, which was used as a start-stop button. The keyboard was positioned at the right of the participant, at 30cm from the midline and 3cm from the edge of the table at which the participants were seated. At the beginning of every trial, the task to be executed was presented on a computer screen positioned at the left side of the table.

Design

On the first day, the participants had to execute 3 tasks, each consisting of 20 trials. The order of practice was either random or blocked, with task order in the blocked schedule counterbalanced within groups—implying that within those groups, 6