The Use of a Game to Promote Arm Reach in Persons With Traumatic Brain Injury

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This study tested a principle of occupational therapy and motor learning theory in the context of neurodevelopmental treatment techniques. Ten trials of occupationally embedded intervention (playing Simon, a computer-controlled game) were compared with 10 trials of rote arm-reach exercise. A counterbalanced design was structured so that each subject experienced each condition one week apart. Subjects were 17 men and 3 women with traumatic brain injury who exhibited mild to moderate spasticity in the upper extremity. Maximum distance from hip to wrist during active reach of the affected extremity was measured by digitization of videotape with the Motion Analysis™ EV-3D system. Results indicated that the use of the game elicited significantly more range of motion than the rote exercise ($t(19) = 5.77, p < 0.01$). These results support the use of an occupationally embedded intervention for persons with traumatic brain injury and add to the theoretical base of occupational therapy.

A fundamental concept in occupational therapy is that the activity (occupation) must be interesting and must intrinsically promote the correct movement. For therapy to be occupational, practice must focus on the interrelationships of mind, body, and environment (Christiansen & Salum, 1991; West, 1984).

A systematic study of occupation requires a functional definition of occupation. Nelson (1988) defined occupation as the relationship between occupational form (context) and occupational performance (actions). Particular meanings of occupations depend on one's developmental structure, and occupational performance depends on one's purpose. This focus on occupational performance as a mechanism for adaptation is consistent with the historical view of occupational therapy.

A skillful synthesis of the occupational form requires consideration of all of the following components: physical stimuli, including materials, environmental surroundings, human context, and temporal context; and sociocultural reality depending on social or cultural norms (Nelson, 1988). Altering any of these components can influence occupational performance.

Literature Review

Seven recent research studies have examined occupational performance as a dependent variable and synthesized occupational forms as the independent variable. One condition of the independent variable involves exercise in the context of occupation. The term occupationally embedded exercise is used to describe exercise that occurs as a by-product of pursuing task-specific goals (Nelson & Peterson, 1989; Yoder, Nelson, & Smith, 1989). The other condition involves simple exercise done for its own sake. Nelson and Peterson (1989) used the term rote exercise.
exercise to describe this alternative to occupationally embedded exercise. According to Nelson and Peterson, rote exercise refers to the calisthenic-like, simple, repetitive movement patterns that typically involve mental focus on the exercise as opposed to focus on occupational processes.

A study by Kircher (1984) and an extended replication study by Bloch, Smith, & Nelson (1989) compared heart rates and exercise duration of women college students jumping rope and jumping in place without a rope. Subjects who jumped with a rope had significantly higher heart rates than subjects who jumped without a rope, and both studies concluded that the subjects’ perceived exertion was less when jumping with a rope than when jumping without a rope. The authors in both studies claimed that these results indicated a higher level of motivation in subjects who jumped with a rope than in those who jumped without a rope.

Steinbeck (1986) studied frequency of repetitions elicited from college students in two different exercise contexts. One context compared a bulb-squeezing exercise that suspended a table-tennis ball with a rote bulb-squeezing exercise. The other context compared a pedaling exercise that operated a drill press with a rote pedaling exercise. The frequency of repetitions in both occupationally embedded exercises was significantly greater. Steinbeck concluded that the occupationally embedded exercises were more motivating than the rote exercises.

Heck (1988) compared the duration of tolerance of pain from electrical stimuli in college students who were duplicating patterns with a blunt stylus with duration of pain tolerance of those performing a rote tracing exercise with a blunt stylus. Subjects performing the occupationally embedded exercise tolerated pain significantly longer than those performing the rote exercise. Mullins, Nelson, and Smith (1987) studied elderly nursing home residents’ choice of subsequent exercise after performing a stenciling activity and after performing the same type of exercise without stenciling materials. Results were not statistically significant, and the authors suggested that the men in the study might have been less motivated by the stenciling than were the women.

Miller and Nelson (1987) and Yoder et al. (1989) compared exercise repetitions elicited by stirring cookie dough with those elicited by rote stirring. The first study involved college students, the second involved women who lived in nursing homes. Miller and Nelson obtained results on the evaluation factors of the Osgood semantic differential that approached statistical significance ($p = .052$) in favor of stirring cookie dough. Yoder et al. found that stirring cookie dough elicited significantly more exercise repetitions ($p = .012$) than performing the rote exercise.

The seven articles reviewed above focus on the core concept of occupational therapy: the inherent value of occupation. None of the studies applied this concept to rehabilitation of persons with traumatic brain injury. Can occupations enhance the motor performance of clients with profuse cognitive and physical impairments? The steady increase in brain injuries and the increased survival rate of persons with severe injuries present major challenges to occupational therapists (Dow, 1989). The extensive rehabilitation after brain injury involves physical, sensory integrative, cognitive, psychosocial, and behavioral aspects.

Motor control is one performance component that affects all occupational performance areas. Motor control can be assessed after the client begins functioning at level IV to V of the Rancho Los Amigos scale of cognitive functioning (Malkmus, Booth, & Kodimer, 1980). A client at this level is confused and unable to focus attention on an activity without frequent redirection. When spasticity develops, abnormal posture and movement patterns impede occupations. A typical pattern of spasticity includes the following:

- Retraction and depression of scapula
- Adduction and internal rotation of shoulder
- Flexion of elbow, wrist, and fingers
- Pronation of forearm
- Ulnar deviation of wrist
- Adduction of fingers
- Lateral flexion of neck and trunk toward involved side
- Posterior pelvic tilt
- Extension of hip, knee, and ankle
- Internal rotation of thigh. (Bobath, 1979)

Research in motor learning supports the idea that occupationally embedded intervention improves motor control. Bernstein (1967) promoted the concept that purposeful movement is organized to solve motor problems. Motor problems are challenges to the neuromuscular system that arise from interaction with the external environment (Sabari, 1991). Bernstein (1967) also introduced the concept of degrees of freedom, the number of individual components of movement that are free to vary and need to be controlled. Motor control is the ability to control these degrees of freedom. Persons with traumatic brain injury often do not dissociate the various degrees of freedom. For example, they tend to reach forward by using the whole shoulder instead of protracting the scapula.

Feedback from the occupation is necessary for reacquisition of motor skills. "It is through such action with feedback from both the human and nonhuman objects that an individual comes to know the potential and limitations of self and the environment and achieves a sense of competence and intrinsic worth" (Fidler & Fidler, 1978, p. 306). Kielhofner and Burke (1980) emphasized the importance of feedback in completing the open sys-
tem's cycle of input, throughput, and output. Feedback includes knowledge of results and knowledge of performance. Knowledge of results is feedback about the outcome of movement and knowledge of performance is feedback about the nature of movement (Schmidt, 1988).

Sabari (1991) emphasized feedback in her framework for the integration of a motor relearning program with a neurodevelopmental treatment perspective. She combined motor learning research and the works of Carr and Shepherd (1987) with Bobath treatment techniques. Eggers (1983) creatively applied neurodevelopmental treatment techniques within occupationally embedded intervention. The combination of these techniques provides both intrinsic and extrinsic feedback to facilitate occupational performance. Neurodevelopmental positioning and handling techniques provide intrinsic feedback by reminding clients with brain injuries how nondysfunctional postural alignment and functional movement patterns feel (Bobath, 1971). Postural alignment, which is essential for functional movement, can be learned only in the context of task performance (Carr & Shepherd, 1987).

Neurodevelopmental treatment begins with establishing an appropriate base of support for the client, shifting his or her center of gravity, and aligning the posture to allow for both stability and mobility (Bobath, 1979). The combination of neurodevelopmental treatment with occupationally embedded intervention occurs naturally because everyday occupations require the client to establish a proper base of support. After establishing this base of support, the client uses feedback from the occupational form to establish memory traces of relearned movements.

**Purpose**

This study applied motor learning theory and a principle of occupational therapy in the context of neurodevelopmental treatment techniques for persons with traumatic brain injury. The purpose of this study was to compare the movements elicited by occupationally embedded intervention with those elicited by rote exercise. The occupationally embedded condition was leaning forward and reaching out the affected arm to play Simon™, a computer-controlled game that challenges the player to repeat its sequences of flashing lights and sounds by pressing colored lenses (see Figure 1). This game was chosen because it facilitated nondysfunctional movement patterns while allowing subjects to succeed and be challenged. All subjects were able to press the lenses with their affected hands. Other games, such as checkers and cards, could not have been used as easily because some subjects could not open and close their affected hands.

The Simon™ game was easily understood, provided immediate visual and auditory feedback, and required no contrivance. The rote exercise condition consisted of leaning forward and reaching out the affected arm on command (see Figure 2). Neurodevelopmental handling and positioning techniques were performed by the fourth author, who is certified in neurodevelopmental treatment to promote postural alignment and functional movement. Would occupationally embedded intervention promote greater range of motion (i.e., trunk inclination, shoulder flexion, and elbow extension) than pure exercise? The hypothesis was that range of motion would be greater in the occupationally embedded exercise than in the rote exercise condition.

**Method**

**Subjects**

The sample of this study was composed of 20 adults (17 men and 3 women) who had sustained traumatic brain injury...
injury. Subjects' ages ranged from 22 to 54 years (M = 31.6 years, SD = 7.6) and the number of years since the injury ranged from 1 to 15 (M = 6, SD = 4.1). All subjects were medically stable and functioning at level IV or V to VII on the Rancho Los Amigos scale of cognitive functioning (Malkmus et al., 1980). All subjects had mild to moderate spasticity; 11 had an involved right arm, 7 had an involved left arm, and 2 had equal bilateral upper extremity involvement. Seventeen subjects used wheelchairs; 3 subjects used canes. All subjects were receiving services at one of three rehabilitation facilities in Grand Rapids, Michigan. Subjects were evaluated and referred by therapists at the rehabilitation facilities.

Apparatus

The research was conducted at the subjects' rehabilitation facility. Materials used during the experiment included a chair 18 in. wide, 20 in. deep, and 17 in. high with an additional 15-in. backrest, a work table 22 in. by 15 in. with adjustable height, and a Simon™ game. Subjects had 2 1/2 in. adhesive reflectors attached to their skin at the shoulder, elbow, and wrist, and to their pants at the hip. The adhesive reflectors were attached at the following anatomical landmarks to define segment centers of mass positions from videotaped data: the acromion process of the scapula, the greater tuberosity of the humerus, the olecranon process of the ulna, the styloid process of the ulna, and the iliac crest. The hip reflector was placed after the iliac crest was palpated through the pants. To control for any shifting of clothing, the hip measurement was taken when the subject was positioned in proper alignment.

Each session was videotaped with a camera placed 6 ft from the subject and perpendicular to the sagittal plane. Movements were measured by a videotaped biomechanical analysis with Motion Analysis™ equipment. This computerized analysis digitizes movements by assigning x and y coordinates at a rate of 60 frames per sec. Range of motion measurements included trunk inclination, shoulder flexion, and elbow extension. The total movement (leaning forward and reaching) was measured by the maximum distance between the hip and the wrist, and the related maximum distance between the scapula and the wrist was also measured.

Procedure

A counterbalanced research design was structured so that each subject was seen on two days one week apart. Ten subjects were asked to reach out their hands in a rote manner during the first session and to play Simon™ during the second session; session activities for the other 10 subjects were reversed. A counterbalanced design is powerful because it compares subjects with themselves under both conditions. Subjects had diverse characteristics (e.g., arm length, contractures, etc.), and this design eliminated error due to individual differences. Each session took approximately 20 min and involved a warm-up with neurodevelopmental positioning and handling techniques. The session followed Bobath's (1979) guidelines and incorporated the sequence presented in the Adult Hemiplegia Bobath Certification Course by Neurodevelopmental Treatment Association, Inc. (Davis, 1985).

The therapists (the third and fourth authors) achieved an appropriate base of support by rotating the subject's hips into anterior pelvic tilt. This anterior tilt prepared the subject for arm reach by allowing the necessary mobility in the hips, trunk, and scapula. After achieving trunk mobility and control, the therapists promoted shoulder girdle separation by opening their hands over the scapula and applying pressure laterally, medially, then upward. The subject was then positioned in proper alignment to help normalize tone. The head was in midline, the hips were in anterior pelvic tilt, the shoulders were over the hips, and the knees were over the feet. All functional movements began from this position.

The therapists then facilitated the movement pattern required for the arm reach exercise by moving the shoulder joint into forward flexion. The subject was moved through the motion required for the exercise to elicit maximum range of trunk flexion, shoulder flexion, and elbow extension. While the subject was held in this position, the table was positioned in front of him or her with the center of the palm at the center of the table and with the subject's hand 3 in. above the table to match the height of the Simon™ game. For the occupationally embedded condition, the center of the Simon™ game was placed at the center of the table. After repositioning the subject in proper alignment, one therapist instructed the subject to perform the arm reach exercise.

For the rote exercise condition, she said, “I would like you to lean forward and reach out your affected hand 10 times like this.” She then demonstrated one repetition. For the occupationally embedded condition, she said, “I would like you to lean forward and reach out your affected hand 10 times to play Simon like this.” She then demonstrated one repetition. No more than three prompts were provided whenever the subject hesitated over 3 sec. If a subject assisted the reach of the involved extremity with the noninvolved extremity, the subject was reminded not to do so, and the trial did not count. When subjects in the rote exercise condition hesitated, the therapist said, “Can you reach out your hand some more without feeling too uncomfortable?” When subjects in the occupationally embedded condition hesitated, the therapist said, “Can you play Simon some more without feeling too uncomfortable?”


Motion Analysis™ Corporation, 3650 North Laughlin Rd., Santa Rosa, CA 95403, 707-579-6500, 800-753-6746.
Results

Each repetition was analyzed separately. Due to technical difficulties with the video camera, one subject’s last repetition was cut off, and the next subject’s first two repetitions were missing. To analyze the data, the cells for the missing repetitions were supplied with the means of the remaining repetitions for that subject. A t test was conducted to check for a significant difference between the means of those who did the rote exercise first and the means of those who did the rote exercise second. Another t test was done to investigate order effects in the game condition. Neither t test was statistically significant at the .05 level, so there were no significant order effects.

Range of motion across both conditions is shown in Table 1. Results indicated a significant difference in favor of the occupationally embedded condition (t (19) = 5.77, p < .001 according to the t test for paired samples). Subjects playing the game leaned forward and reached an average of 12.22 cm. farther, and their related scapula-to-wrist measurement was an average of 3.52 cm. greater than it was during the rote exercise. No statistical test was done on the scapula-to-wrist measurement because it was highly correlated to the main dependent variable, the hip-to-wrist measurement. Subjects’ reaching patterns were fairly consistent during both conditions. The stable range of motion across the 10 trials in both conditions indicated no significant trend.

Discussion

When spasticity develops, early occupational therapy intervention is essential to maintain function and promote motor relearning. A well-known characteristic of the early phase of motor skill learning is that concentration is necessary to process the information needed to perform (Fitts & Posner, 1967; Marteniuk, 1979). Therefore, a major challenge is to structure occupations that require the use of the client’s involved spastic arm while invoking his or her optimum motivation. Mosey (1986) emphasized this need for structuring occupationally embedded exercise because “performance components are not acquired through random activity or mindless exercise; rather they are acquired through active, goal-directed interaction with the environment” (p. 234).

This study supported the hypothesis that the occupationally embedded intervention promoted more range of motion than did rote exercise. The flashing lenses and sounds of the Simon™ game provided motivating feedback to enhance performance, and the game promoted more enthusiasm and increased attention span. Subjects required less cuing during the occupationally embedded condition and many subjects continued playing Simon™ after they had completed 10 repetitions.

This research enhances the knowledge base of occupational therapy. Whereas the studies previously reviewed involved healthy elderly persons or healthy college students, this study focused on intervention for persons with traumatic brain injury, a growing population on which few studies are available. This study was also different because it quantified the quality of movement elicited by occupation.

A limitation of this study was that the therapists (third and fourth authors) administering the independent variable were aware of the theoretical background and the hypothesis. The mitigating factors were training and the use of a script. Because qualitative research is reductionistic, this study could not consider all individual differences in volitional and habitual subsystems. Although one game was used for control purposes, we cannot assume that one intervention is appropriate for all clients with brain injuries. A holistic treatment approach considers clients’ personal interests and choices.

Future research could examine whether occupationally embedded intervention promotes more repetitions or more nondysfunctional movement patterns than does rote exercise in persons with spasticity. Replication of this study will strengthen the hypothesis and similar studies could test other neurologically involved populations. The effects of neurodevelopmental treatment on functional movement could also be studied. Motion Analysis™ and other computerized systems open doors for exciting new research by allowing us to quantify occupational performance. Such systems can also address velocity, acceleration, and smoothness of movement.

Many fruitful opportunities for occupational therapy research involve biomechanical analysis of movement patterns. Mathiowetz (1992) analyzed the motor performance of persons with and without multiple sclerosis while they performed activities of daily living in impoverished, partial, natural, and simulated conditions. McPherson et al. (1991) compared the arm movements in four sitting positions elicited by persons with and without cerebral palsy. Kluzik, Fetters, and Coryell (1990) studied the effects of neurodevelopmental treatment on the smoothness of arm reach in children with spastic quadriplegia. Similar research providing quantitative data about the quality of movement can strengthen the scientific base of occupational therapy.

Table 1

<table>
<thead>
<tr>
<th>Range of Motion (cm)</th>
<th>Game</th>
<th>Rote Exercise</th>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Hip to wrist</td>
<td>71.60</td>
<td>19.46</td>
</tr>
<tr>
<td>Scapula to wrist</td>
<td>54.16</td>
<td>10.45</td>
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2Not analyzed by inferential statistics because it is a component of the other variable and therefore related in a nonindependent fashion.

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References


