The Effects of an Occupationally Embedded Exercise on Bilaterally Assisted Supination in Persons With Hemiplegia

David L. Nelson, Kathy Konosky, Kathleen Fleharty, Ruth Webb, Kristin Newer, Virginia P. Hazboun, Cheryl Fontane, Brian C. Licht

Key Words: cerebrovascular disorders • neurodevelopmental therapy • therapeutic exercise

Objectives. Occupationally embedded exercise is a central idea in the profession of occupational therapy. This experiment compared the effect of an occupationally embedded exercise involving a simple dice game with a rote exercise in persons with stroke with pronator spasticity. Both exercise conditions involved bilaterally assisted supination, consistent with the neurodevelopmental model of practice.

Methods. The sample consisted of 14 men and 12 women post-cerebrovascular accident with a mean age of 68.4 years (SD = 11.2) at six clinical sites in California, Texas, and Michigan. Subjects had pronator spasticity, full passive range for supination after a brief warm-up, and no functional supination. After random assignment for experimental condition, the subjects engaged in two sets of 10 repetitions of bilaterally assisted supination in either the occupationally embedded condition (dice game) or the rote condition (no game). A pen recorder electronically documented degrees of rotation of the handle that was grasped during the exercise.

Results. The occupationally embedded exercise resulted in significantly more handle rotation (requiring more supination) than the rote exercise, t (24) = 2.28, p (one tailed) < .05. The effect size was large.

Conclusion. This study advances the experimental analysis of therapeutic occupation in the area of occupationally embedded exercise. Clinicians are urged to consider the multidimensional nature of occupationally embedded exercise.

In her Eleanor Clarke Slagle lecture, Trombly (1995) heralded a new era for research in occupational therapy, with a focus on the study of one of the basic principles of the profession: the use of occupation to enhance human movement. Citing Nelson's (1988) terminology, Trombly tried to "spark an explosion of research" (p. 960) to investigate the effects of occupational forms on meaning, purpose, occupational performance, and adaptation.

The idea that occupation can facilitate therapeutic exercise is an ancient one. The Greek physician Galen (ca. 200 A.D.) wrote, "The best exercises of all are those which cannot only train the body but also delight the mind" (as cited in Licht, 1984, p. 6). Early practitioners of occupational therapy who faced the many casualties of World War I applied this principle in their efforts to restore the motor skills of veterans with disabilities. Bird T. Baldwin (1919), who was director of occupational therapy and chief psychologist at Walter Reed Hospital in Washington, D.C., stated:

Occupational therapy is based on the principle that the best type of
The idea of embedding therapeutic exercise within occupation, 1993). A principle of occupation must be explored activity). The building of an experimental science of embedded exercise (sometimes referred to as purposeful activity). The building of an experimental science of therapeutic occupation is an incremental process (Nelson, 1993). A principle of occupation must be explored incrementally across different populations and across different dependent variables. Populations studied included:

- Patients with hand disorders (King, 1993), with multiple sclerosis (Mathiowetz, 1991), with traumatic brain injury (Sietsema, Nelson, Mulder, MerKat-Scheidel, & White, 1993), and with stroke (Hsieh, Nelson, Smith, & Peterson, 1996)

The dependent variables in these studies included:

- Heart rate (Bakshi et al., 1991; Bloch et al., 1989; Kircher, 1984; Steinbeck, 1986; Thibodeaux & Ludwig, 1988)
- Number of exercise repetitions (Bakshi et al., 1991; DeKuiper et al., 1993; Hsieh et al., 1996; King, 1993; Lang et al., 1992; Miller & Nelson, 1987; Steinbeck, 1986; Yoder et al., 1989)
- Duration of exercise (Bloch et al., 1989; Kircher, 1984; Miller & Nelson, 1987; Thibodeaux & Ludwig, 1988)
- Perceived exertion (Bakshi et al., 1991)
- Electromyogram readings (Steinbeck, 1986)
- Blood pressure (Bakshi et al., 1991)
- Visually guided motor skill (Licht & Nelson, 1990)
- Learning to operate a prosthesis (Yuen et al., 1994)
- Choice of type of exercise (Mullins et al., 1987)
- Affective meanings (Bloch et al., 1989; Miller & Nelson, 1987)
- Speed and distance of kicking (DeKuiper et al., 1993)
- Kinematics of feeding (Mathiowetz, 1991) and of reach (Wu et al., 1994)
- Extent of reaching ability (Sietsema et al., 1993)

Only one of the studies has focused on the stroke population, the population most often seen by occupational therapy practitioners (American Occupational Therapy Association, 1991). In a study of persons with hemiplegia due to stroke, Hsieh et al. (1996) compared three experimental conditions: materials-based exercise (throwing a ball at a target) versus imagery-based exercise (imagining the same kind of throw at a target) versus rote exercise. They found that subjects engaged in more exercise repetitions in the materials-based and imagery-based conditions than in the rote condition. Only one additional study (Sietsema et al., 1993) has dealt with a therapeutic exercise that is especially relevant to the motor control issues of persons who have experienced cerebral vascular accidents (CVAs). Sietsema and colleagues investigated the reaching patterns of subjects with hemiparesis secondary to traumatic brain injury (similar in many respects to the reaching patterns of persons with hemiplegia secondary to stroke). They found that reaching distance was greater in the context of a game than in rote exercise.

Stroke is the leading cause of disability among adults, particularly older adults, in the United States (Sullivan, 1992). The disabilities resulting from stroke are often a combination of sensorimotor, cognitive, and psychosocial disabilities. Spasticity and mixed patterns of flaccidity and spasticity frequently appear on the hemiplegic side. In the upper extremity, a common pattern of spasticity includes scapular retraction, shoulder adduction, internal rotation, elbow flexion, forearm pronation, wrist flexion, ulnar deviation, and finger flexion (Caillet, 1981; Davies, 1985).

To inhibit spasticity, adherents of the neurodevelopmental model of practice frequently recommend bilaterally assisted movement of the upper extremities (Davies, 1985; Wilcock, 1986). In bilaterally assisted movement for spasticity, the noninvolved extremity moves the involved extremity slowly and steadily against the spasticity through the therapeutic range. Concerning pronator spas-
ticity, Wilcock recommended:

When patients are seated, the arm supported in front of them, they should be encouraged to pronate and supinate the forearm. If the patient is unable to achieve this voluntarily, they should be shown how to assist the hemiplegic arm and hand with the sound one. (p. 154)

The present study integrates the neurodevelopmentally inspired suggestion of Wilcock (1986) with the concept of occupationally embedded exercise. Can occupational embedding enhance a neurodevelopmental exercise? For the occupationally embedded exercise, the first author developed a simple dice game that provided (a) the opportunity for bilaterally assisted supination throughout the range; (b) proper positioning to support the occupational performance; (c) automated measurement of the extent of movement; and (d) experimental control so that a randomly assigned comparison group could engage in exactly the same pattern of movement without the occupational form of the game. Given occupational therapy’s widespread acceptance of the principle of occupationally embedded exercise, and given the results of recent research (especially Sietsema et al., 1993), the following directional hypothesis was made: Subjects experiencing the occupationally embedded form of the supination exercise (dice game condition) will rotate the handle further than subjects in the rote supination exercise (no game condition).

Method

Subjects

Eight occupational therapists recruited subjects at their places of employment in California, Michigan, and Texas in accordance with a written protocol developed by the first author for this study. Subject selection criteria were unilateral hemiplegia caused by a first and only CVA, duration since onset of the stroke of between 9 days and 7 months, and age of at least 45 years. Potential subjects were further screened for (a) pronator spasticity; (b) full passive range of supination after brief warm-up exercise; (c) no functional supination; (d) ability to grasp a 3-cm dowel bilaterally with overlapping fingers; (e) no contraindications to supination exercise; and (f) sufficient visual perception and comprehension to participate in the experimental conditions as evaluated by the ability to match playing cards by number.

Thirty potential subjects met the inclusion criteria; however, data were excluded for two subjects who did not complete the procedure because of pain or grasp problems. Additionally, the data on two other subjects were excluded because of procedural problems identified before data examination. Six therapists at clinical sites in California, Michigan, and Texas provided usable data (two therapists with seven subjects each, two with four subjects each, one with three subjects, one with one subject). The final sample consisted of 14 men and 12 women, with a mean age of 68.4 years (SD = 11.2). The mean duration poststroke was 53.5 days (SD = 51.9), and the ratio of left hemiplegia to right hemiplegia was 15:11. There were no significant differences between the groups assigned to the two experimental conditions in terms of age, duration poststroke, gender, or side of hemiplegia.

In an attempt to increase the power of the experiment, the original design identified the degree of spasticity for each subject as a potential covariate. We expected that pronator spasticity would be negatively correlated with supination, regardless of experimental condition. Each therapist rated spasticity on a 7-point scale, and independent raters at each site confirmed the reliability of measurement. However, the degree of spasticity did not correlate with the dependent variable (r = .01); therefore, it was not useful as a covariate.

Apparatus

Figure 1 depicts the apparatus developed for the study for the occupationally embedded exercise condition. When the handle is rotated to approximately 40°, the first of three colored dice (red, blue, yellow) falls noisily down the wooden chute; the last die falls at about 90°. Figure 2 depicts the apparatus as set up for the rote exercise condition. The cap on the handle weighs approximately the same as the three dice.

Rotation of the handle is met with little resistance because of the ball bearings in the lazy Susan connecting the handle to the frame. A rotary potentiometer (Radio Shack # 271 342)1 embedded in the center of the handle converts the angular displacement of the handle into directly proportional electrical signals. An impedance-matching amplifier matches the output of the potentiometer to the input of a Linseis LM242 one-channel pen recorder. Because of a linear relationship between degrees of rotation and centimeters of pen deflection, the circuit was designed to be calibrated so that 90° of rotation in one direction leads to pen deflection of 3 cm in the opposite direction.

1Manufactured by Tandy Corporation, 401 NE 35th Street, Ft. Worth, Texas 76106.

Before each data collection period, the therapist conducted a calibration procedure (at 0° and at 45° and 90° in both directions) to determine the exact relationship between handle rotation and pen deflection for that subject’s data. In 24 of 26 cases, 90° of rotation led to 3 cm of pen deflection. In the other 2 cases, a deflection of 3.1 cm occurred, and the data were corrected accordingly. This calibration procedure corrected for any variation across the six machines used (one per therapist). The pen recorder’s paper drive was set to operate at 20 cm/min.

Procedure

Each occupational therapist serving as data collector followed a written protocol in administering all experimental procedures. Subjects were randomly assigned in a stratified balanced way (Schwartz, Flamant, & Lellouch, 1980) to ensure that none of the clinical sites would provide a disproportionate number of subjects to either experimental condition. The therapist at each site classified the subjects into one of four categories by gender and side of hemiplegia. The first subject in each category (e.g., the first woman with left hemiplegia at a particular site) was randomly assigned to either the occupationally embedded condition or to the rote condition; the second subject in the same category (e.g., the second woman with left hemiplegia at that site) was automatically assigned to the opposite condition. Preliminary data analysis indicated that there was no significant correlation between the order of testing at each site and scores on the dependent variable.

On entering the testing site (each participating facility’s regular treatment area), the subject was engaged in preliminary exercises as recommended within the neurodevelopmental model of practice (Davies, 1985). These exercises involved bilateral self-ranging of the upper extremities and trunk, with the subject’s fingers interlocked so that the involved thumb was on top. Three repetitions were performed for each of the following: (a) reaching between knees to floor, (b) reaching forward, (c) reaching toward uninvolved side, (d) reaching toward involved side, and (e) moving wrist from ulnar deviation to radial deviation. Next, the therapist positioned the subject at an adjustable table to perform the bilaterally assisted supination exercise; positioning sometimes required raised seating. The therapist then secured the subject’s involved arm in the trough of the apparatus perpendicular to the shoulder and with approximately 40° of shoulder flexion.

For the occupationally embedded condition, the therapist moved the rotary handle of the apparatus in the appropriate direction and said, “Today you’re going to exercise your arm by playing a game with this handle.” Placing the dice in the top of the handle, the therapist demonstrated how to make the dice fall and showed the subject that the object of the game was to get doubles (e.g., double sixes) or three in a row (e.g., three, four, five). The therapist then assisted the subject in gaining firm bilateral grasp of the handle, with the affected thumb on top. While saying, “Here’s how you get your arm exercise while playing a dice game,” the therapist manually guided the subject through the motion until all three dice dropped. Slow and steady movement was...
encouraged, and elevation of the uninvolved shoulder with tining of the trunk was discouraged. The presence or absence of doubles or three in a row was pointed out. After a second trial of manual guidance, the therapist said, “Now I'd like you to do it 10 times by yourself. Get all three dice out. I'll count, and let's see if you can get some doubles.” Slow and steady movement was reemphasized. At this point, the therapist no longer touched the subject in any way; data collection was discontinued for any subject who lost grasp during the 10 trials. The therapist counted the trials and reported on the presence or absence of doubles or three in a row after each repetition. At the end of the 10 trials, the subject took a 3-min break, with the therapist assisting him or her in releasing the handle. After the break, grasp was reinstated, and 10 additional trials were completed as before.

For the rote exercise condition, all procedures were identical to those in the occupationally embedded exercise condition except for a few aspects of the apparatus (see Figure 2) and in the therapist’s instructions. In this condition, the therapist said, “Today you’re going to exercise your arm by using this handle.” As in the other condition, the therapist demonstrated full turning of the handle, and the subject achieved the movement with manual guidance. After each repetition in two sets of 10 trials, the therapist reported the count, as is frequently done in rote exercise. The therapist made comments appropriate to the situation (e.g., “That’s the way to exercise that arm,” “One more to go”). The purpose of these comments was to ensure that the amount of verbal interaction was equivalent between the two experimental conditions.

Results
Preliminary analysis indicated good reliability (repeatability) for the measurement of degrees of handle rotation across the 20 trials for the 26 subjects, with intraclass correlation coefficient = .85. The mean degrees of handle rotation were computed, which was moderately skewed in a negative direction (i.e., most scores tended to be relatively high with only a few scores in the lower part of the range; see Table 1). Additionally, as indicated by the standard deviations, the variance of the rote exercise condition was somewhat greater than that for the occupationally embedded condition; therefore, the raw data were transformed by squaring each subject’s score (Buchner & Findley, 1990).

With alpha set at the .05 level (one tailed), the t test on the transformed data revealed significance, $t(24) = 2.26, p = .016$. As recommended by Buchner and Findley (1990), a $t$ test was then run on the original, untransformed data, $t(24) = 2.28, p = .016$. Thus, with these data, skewness and transformations made little difference.

The effect size was calculated on the original, untransformed data, as recommended by Cohen (1988), with $d = .885$. Cohen argued that a $d$ at this level indicates a “large” (p. 26) effect size. In summary, the superiority of the occupationally embedded exercise over the rote exercise was significant, with a large effect on the dependent variable.

Another way of describing the results is to consider the percentage of trials (each subject had 20 trials) that resulted in 90° of rotation. In the occupationally embedded exercise group, 68% of the 280 trials resulted in 90° rotation, whereas 46% of the 240 trials in the rote exercise group resulted in 90° rotation.

Additional analysis revealed that there were no significant differences among the six data collection sites in terms of degrees of handle rotation, $F(5, 20) = .34, p = .88$. These findings indicated that the experimental procedures among the sites were comparable.

Discussion
The results support the proposition that an occupationally embedded exercise can enhance a specific pattern of therapeutic exercise in bilaterally assisted supination. Despite the presence of pronator spasticity, subjects rotated a cylindrical handle further in the context of a game than in the rote exercise condition. In doing so, they engaged in a pattern of bilaterally assisted exercise that is recommended within the neurodevelopmental model of practice.

The occupationally embedded exercise involved a multidimensional occupational form (dice) to which the subjects might have assigned meanings and purposes to several different factors. One possible source of enhanced meaning is that the dice game provided feedback directly related to the subject's performance. We synthesized the

### Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Occupationally Embedded Exercise</th>
<th>Rote Exercise</th>
<th>Skewness</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degrees of handle rotation</td>
<td>95.3 12.2</td>
<td>81.9 17.6</td>
<td>-.80</td>
<td>2.28*</td>
</tr>
<tr>
<td>Square of degrees of handle rotation</td>
<td>9223 2355</td>
<td>6995 2675</td>
<td>-.25</td>
<td>2.26*</td>
</tr>
</tbody>
</table>

$n = 14$
$n = 12$
$p < .05$
occupational form so that the third die would fall out of the handle at approximately 90°; our prediction was that the anticipated impact of the third die falling out of the handle would add purpose to the performance of full supination throughout the range. In contrast, the occupational form of the rote exercise provided less performance-related feedback; the subject could observe the rotation of the handle, but no specific impact occurred at full range of motion (i.e., no die fell to mark the achievement).

A second explanation for superior performance in the occupationally embedded condition involves an analysis of each subject's sensory experience. It is one thing to recognize that the subject received feedback (one aspect of perceptual meaning); it is also important to analyze the sensory qualities of that feedback (additional aspects of perceptual meaning). We synthesized the occupational form in the occupationally embedded condition so that the dice and the felt at the bottom of the ramp would have varying, bright colors and so that the dice would make a noisy, irregular sound as they fell down the wooden ramp. We predicted that subjects would find these aspects of the form to be visually and auditorially arousing and pleasing compared with the rote exercise condition with its monotone.

A third explanation relates to an analysis of the symbolic meanings persons assign to the occupational forms within their culture. We synthesized the occupationally embedded condition so that most subjects would recognize it as a popular game in our culture. The object of many common dice games is to roll doubles or three in a row. Hence, our instructions and verbal feedback regarding the game were important aspects of the occupational synthesis. We predicted that most of the subjects would recognize the type of game and find some meaning in it. We also anticipated that they would have fun while engaging in an exercise that is otherwise not much fun.

Given the study design, it is impossible to say which of the three explanations, or which combination of the three, is correct. Indeed, different subjects might well have found different patterns of meaning in the same occupational form (e.g., the game quality might have added purpose for one person, whereas someone else might have sought out the feedback). Future experiments should tease out the salient factors in the occupational forms, in the types of subjects, and in their interactions. For example, a game condition incorporating feedback could be compared with a no game condition involving the same physical feedback. We also recommend future studies similar to this one in which a common rote exercise is compared with a multidimensional occupational form under controlled conditions.

Because of its multidimensional nature, occupationally embedded exercise is a powerful and complex tool for clinical occupational therapy practice. We recommend that occupational therapy practitioners engage in a clinical reasoning process that is similar to the occupational synthesis demonstrated in this experiment. The occupational therapist considers the potential of the occupational form for feedback, for sensory stimulation, and for symbolic meaning within our culture. The therapist analyzes a multitude of physical factors (e.g., size, weight, texture, distance, sounds) and sociocultural factors (e.g., rules, roles, typical uses) when synthesizing an occupational form for a person with complex sensorimotor, perceptual, and cognitive characteristics. For example, a trip to the supermarket can provide rich feedback to performance and multiple sensory cues in a naturalistic setting.

The main difference between occupational synthesis in clinical practice and occupational synthesis in research is that the orientation of the therapist is to the individual, not to the group as in a controlled research project. The therapist whose patient does not experience a game, like the dice game in this study, as fun (e.g., the patient sees it as frivolous or associated negatively with gambling) has the opportunity to resynthesize the occupational form to meet the unique needs of the patient. Unlike the quantitative researcher, the therapist can and should collaborate with the patient in the occupational synthesis. Together, they can choose among the many forms made available by our culture—from self-care to work to play—in helping the patient find meaning and purpose in the occupational therapy process.

The neurodevelopmental model of practice increasingly emphasizes the importance of everyday situations as the ideal context for therapeutic intervention (Davies, 1985). Motor learning, a different model of practice frequently recommended for the treatment of hemiplegia, also places a strong emphasis on naturalistic contexts for therapeutic intervention (Carr & Shepherd, 1987). These endorsements by currently popular models of practice are consistent with the ideas of some of the founders of the occupational therapy profession.

**Limitations**

The main limitation of this study was overrotation of the handle to more than 90° in many cases. Therefore, one cannot say that only supination was involved. Other possible biomechanical movements contributing to overrotation include (a) lateral tilting of the trunk toward the involved side with elevation of the noninvolved shoulder; (b) external rotation of the involved arm; and (c) the
pushing of the handle into the thenar crease in combination with radial deviation. Lateral tilting of the trunk was discouraged in the experimental procedures preceding the actual data collection, and the arm trough tended to lessen external rotation of the involved shoulder. However, we made a conscious decision not to make the testing situation so artificial that it bore no resemblance to actual clinical situations. Although verbal instructions to avoid compensatory movement and arm troughs with hook-and-loop straps are common in clinical settings, an apparatus to restrain the entire body except for the involved forearm would be obtrusive and extremely artificial. Even though the movement measured in this study was not purely supination, this type of movement is characteristic of what clinicians seek to elicit in occupational therapy. Indeed, radial deviation and external rotation are desirable movement patterns to counteract the typical pattern of spasticity.

The original research plan was for each participating therapist to collect data on eight subjects, but this proved impossible within a reasonable time frame. We also planned to use a covariate to reduce error due to individual differences among subjects, but the planned covariate was not correlated with the dependent variable. However, the small sample size, the use of multiple sites, and the lack of a covariate did not threaten the validity of this experiment. Small sample sizes, variability across sites and testers, and individual differences tend to cause Type II errors (false nonsignificant results), not Type I errors (false significant results). In this study, a Type II error did not take place; the difference between groups was significant. The effect size of the independent variable was large enough to overcome unsystematic error, even with limited degrees of freedom. As for Type I error, the random assignment of subjects to experimental conditions within each site and the use of carefully crafted protocols are strong arguments that the comparison between the two conditions was fair. All subjects were treated equivalently, except for the independent variable. Indeed, if a researcher can demonstrate significant effects across sites and across data collectors while controlling against Type I error, a stronger case can be made for the external validity of the study than if a single site is used.

Conclusion
The core of our profession is the use of occupation as therapy. For more than 70 years, occupational therapists have applied this principle to the enhancement of movement skills. This study provides experimental support for this principle in persons with stroke, the most frequently seen population in occupational therapy today.

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645


