Effect on Gait of Motor Task Learning Acquired in a Sitting Position

RONALD H. SEITZ
and CAROL L. WILSON

The purpose of this study was to ascertain the importance of learning a motor task in a sitting position and its influence on gait. Thirty-one healthy subjects, divided into three groups, were asked to learn a synchronous heel-up-heel-down rhythm task in a sitting position and to reproduce the rhythm during their gait cycle on three separate occasions over a three-day period. This study provided evidence that training of a subject in a sitting position produced a nonspecific influence during ambulation. The inability to obtain an exact transfer of learning from a sitting position to gait and its implication to the specificity principle of learning are discussed. Some subjects had difficulty maintaining their performance over the three-day period. This finding was attributed in part to the influence of proactive and retroactive inhibition. Mat activities, therefore, seem to have a very limited impact on modifying gait. The clinical implications of these findings are presented.

Key Words: Gait, Motor skills, Physical therapy.

The challenge of physical therapy is to improve the client's functional performance. For example, hemiplegic ambulation is characterized by slowed cadence,\(^1\) asymmetrical weight bearing,\(^1,2\) and the initial ground contact with the forepart of the affected foot rather than the heel.\(^2\) In rehabilitation, the physical therapist attempts to correct the abnormalities in the gait pattern in addition to the overall speed of ambulation. The efficient and effective application of therapeutic intervention is an important determinant of the quality of the client's physical functioning.

Several treatment approaches currently are used to modify a client's functional performance. One such technique is the use of recumbent activities to improve the quality of gait. For example, both the Brunstrom\(^1\) and the neurodevelopmental treatment\(^4\) approaches advocate facilitation of lower extremity components of gait in the supine position to achieve more functional gait patterns. Techniques that advocate mat activities to improve ambulation are based on the assumptions 1) that a person can transfer or generalize motor performance practiced in one position to another similar activity performed in a different position and 2) that what is learned will have a lasting, beneficial influence.

Even though the information gained from the study of healthy individuals is limited as to the specific conclusions that can be extrapolated to persons with disabilities, the information provides general trends of human behavior that may be useful in application to persons with disabilities. In healthy individuals, the benefit of generalizing motor skills performed in a recumbent position to those performed in an upright position is questionable. Smith, in his review of the generality and specificity principles of gross motor skills, found more evidence favoring the specificity principle, which holds that a poor relationship exists between different motor tasks.\(^5\) For example, the ability to play baseball has little to do with the ability to play tennis. Not only does the ability to perform one skill have low predictability for the ability to perform another skill, Nelson found that transfer of gross motor learning also was highly specific.\(^6\) For example, the ability to play baseball would not lead to an increased ability to play tennis. Thus, the ability to perform a component of the gait patterns in a supine position may have little to do with the ability to perform that component during gait. Although this information strongly supports the specificity principle, the question as to which principle, specificity or generality, has the greatest effect on motor learning has not been decided conclusively. Results from studies that tested for the specificity of motor learning under fatigued and nonfatigued conditions are not supportive of the specificity principle.\(^7,8\)

The position of the patient during training is only one factor influencing the efficiency and the lasting benefit of physical therapy. Other considerations are the effects of proactive and retroactive inhibition. Do previously established behaviors have a negative impact on the acquisition of new behaviors (proactive inhibition) and does learning occurring after a behavior has been established interfere with retention of the newly established behavior (retroactive inhibition)? The influence of learning one motor task on the subsequent acquisition of other motor skills has not been established.\(^9-11\) Research in verbal learning, however, indicates several factors that influence the acquisition and retention of skills. One factor is the similarity of the material. Underwood demonstrated that subjects who learned two lists of words varying in similarity learned similar words faster than dissimilar words but had more difficulty retaining the words.\(^12\) Another factor

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Mr. Seitz is Clinical Instruction Supervisor, Department of Physical Therapy, Leon S. Peters Rehabilitation Center, Fresno Community Hospital and Medical Center, PO Box 1232, Fresno, CA 93715 (USA).

Ms. Wilson is a staff physical therapist, Department of Physical Therapy, Leon S. Peters Rehabilitation Center.

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is how well the behavior is learned before attempts to change the behavior are undertaken. The more established a behavior is, the harder it is to change.13 This finding also has been confirmed in studies of motor learning. Purdy and Lockhart found that initial performance of gross motor skills was a valuable index of future performance of the same task.14 Additionally, Adams, reviewing the literature on motor performance, found that the amount of original learning is related to retention of a motor skill.15 A final factor is interpolated learning. After a specific task has been established, retention will be affected adversely if a similar activity is performed immediately after the task.13

Generality of motor performance from one position to another and the interference of learning that occurs outside therapy are important factors influencing the effectiveness of physical therapy. The purposes of this study were 1) to determine the influence of a person's motor learning performed in one position on the performance of a similar task in another position and 2) to determine whether retroactive and proactive inhibition influence a person's ability to learn and retain motor skills. Because physical therapists attempt to influence their patients' activities from a sitting position, we assessed the influence of rhythm learning on gait with subjects learning in a sitting position. The activity of gait also was chosen because it is a well-established behavior used extensively in daily routines.

Using healthy subjects, we hypothesized that if a motor task emphasizing a sequentially timed motor response was learned in a sitting position in a 10- to 15-minute period, learning would have an influence on gait effective over a three-day period. We further hypothesized that the acquisition and retention of motor skills would be subject to the influences of proactive and retroactive inhibition. We used a 10- to 15-minute training period because this is not an unusual amount of time for a therapist to spend training one component of a skilled sequence.

METHOD

Subjects

Thirty-one adults (25 women, 6 men) without orthopedic, neurological, or other medical problems related to their ability to participate in this study were the subjects. All subjects signed an informed consent statement. Their average age was 27 years, with a range of 21 to 40 years. The subjects were recruited from the staff of the physical therapy and occupational therapy departments of the Leon S. Peters Rehabilitation Center where the study was conducted. All subjects were naive as to the purposes of the investigation.

Equipment

A gait analyzer that measured the heel-down and heel-off pattern of one leg was built specifically for this project. It consisted of 1) a Medtronic* heel switch and 2) an integrated circuit, which disregarded the first 10 times the heel switch was closed and then activated two electronic stopwatches. One stopwatch (timer one) was activated when pressure was applied to the heel switch and deactivated when the pressure on the heel switch was released. This sequence was conducted from step 10 to step 19, thus giving a cumulative heel-down time for these 10 steps. The other stopwatch (timer two) was activated with heel pressure on step 10 and deactivated with heel pressure on step 20. Thus, the second timer gave the total time for the subject to take 10 steps with the right foot. The circuit was built to disregard the first 10 steps to eliminate variance in gait caused by the start of walking.

Rhythm training for subjects in a sitting position was accomplished by a device, also constructed specifically for this project, that trained the heel-up–heel-down rhythm that might occur in gait. A pressure-sensitive heel switch, constructed of two thin pieces of metal separated by a thin piece of polyurethane foam, was attached to an integrated circuit device. The circuit operated two green lights positioned vertically 1.5 cm apart, one red light, and one (2.5 cm) buzzer (Fig. 1).

The rhythm trainer had three functions. One function was to set a pattern for the green light illuminations. The green lights were illuminated sequentially for 0.5 second. The interval between the activation of the green lights was set at either 0.5 second or 1 second. These intervals were chosen because 1) preliminary testing indicated that both intervals were not extremely divergent from the heel-down gait pattern subjects preferred in walking and 2) the longer interval was twice the length of the shorter interval so that if a difference was caused by training, it would be found. When the top green light was illuminated, the subject was instructed to apply pressure on the heel switch. When the bottom green light was lighted, the subject was instructed to release pressure from the heel switch.

A second function of the rhythm trainer was to allow us to assess a subject's ability to reproduce the set pattern we established for the learning task. During the period when either green light was activated, the subject was instructed to change the pressure on the heel switch, either by removing pressure from the heel switch or by applying pressure through the heel to the switch. If the subject did not respond correctly, a buzzer would sound until the subject was again in compliance with the sequence set by the device.

The third function of the rhythm trainer was to signal when learning had been completed. Learning the task was defined as the ability to perform the task error free for one minute. A red light turned off when learning was complete.

Procedure

Day 1. Subjects were divided sequentially into three groups. 1) a Control Group (n = 10), 2) a Short-Rhythm Group (n = 10), and 3) a Long-Rhythm Group (n = 11). The heel switch was placed inside the subject's right shoe, and the subject was asked to walk until the switch felt comfortable. The gait analyzer was attached around the subject's waist with a belt, and the heel switch was connected to the gait analyzer. A pretest was conducted in which each subject was asked to walk a straight line at a normal pace for about 30 steps.

After the pretest, the subjects were asked to sit in a straight-backed chair and perform one of three different tasks. Subjects in the Control Group were asked to sit quietly for 15 minutes. The operation of the rhythm trainer was demonstrated to each subject in the Short- and Long-Rhythm Groups, and questions about the use of the device were answered. Subjects in the Short-Rhythm Group placed their right heel on the heel switch attached to the rhythm trainer. The device was set with a 0.5-second interval between the green light activations. The subjects were instructed to learn the synchronous heel-up–heel-down rhythm that the rhythm trainer produced as cued by the green lights. They also were informed that the

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* Model No. 196 00N, Medtronic, Inc, 7000 Central Ave, NE, PO Box 1250, Minneapolis, MN 55440.
buzzer indicated an error. They were asked to continue with the task until they were able to perform the task for one minute without an error. Before learning the task, subjects in the Short- and Long-Rhythm Groups were told they would be asked to walk on three different occasions over a three-day period reproducing the rhythm learned in the sitting position. They then were asked to start the task. The experimenter noted the times when the subject started and completed the task. Subjects in the Long-Rhythm Group followed the same procedure as the Short-Rhythm Group except that the training device was set for a one-second interval between green light activations.

At the completion of the task, posttests were conducted recording each subject’s gait pattern in the same manner as in the pretest. The Control Group subjects were asked to walk at their normal pace, and the Short- and Long-Rhythm Groups were asked to walk reproducing the rhythm learned in the sitting position. Each subject was asked to return each of the following two days so the ability to maintain what they had learned could be assessed.

Days 2 and 3. A heel switch was placed in the subject’s right shoe and attached to the gait analyzer. The subjects were asked to walk 30 steps reproducing the rhythm learned on Day 1 or at their normal pace.

Data Analysis

For the 10 analyzed (timed) steps, timer one of the gait analyzer recorded cumulative times for the amount of time the heel switch was closed (heel-down). For the same 10 steps, timer two recorded the amount of time from when the heel switch was contacted on step 10 to the time of contact on step 20. Thus, timer two gave the total time that the subject required to take 10 steps with the right leg and included both heel-down time and heel-off time. Heel-down time (timer one) was subtracted from total time (timer two) to give the heel-off time. All statistical analysis was based on these cumulative times for heel-down and heel-off during the 10 steps.

An analysis of variance (ANOVA) for repeated measures of the heel-down times and an ANOVA for heel-off times were conducted to ascertain the subjects' ability to reproduce and maintain the heel-down and heel-off sequence learned in the sitting position or the subjects' ability to maintain their preferred rhythm after the inactivity of sitting quietly.

The rhythm a subject learned in the sitting position and then attempted to reproduce in walking consisted of two components: 1) an equal ratio of heel-off to heel-down positions and 2) a specific length of time for heel-off and heel-down. The specific length of time for the Long-Rhythm Group was 1 second heel-off and 1 second heel-down. The time for the Short-Rhythm Group was 0.5 second for heel-off and 0.5 second for heel-down. We used a two-tailed $t$ test to compare the subjects' gait pattern of heel-off and heel-down with the exact settings of the training device.

The time the subject started learning the task was subtracted from the ending time to give the amount of time a subject needed to learn the task. A two-tailed $t$ test was performed comparing the amount of time required by the Short-Rhythm Group and the Long-Rhythm Group to learn their respective tasks in the sitting position. This comparison was done to ascertain whether the two tasks required the same amount of effort to learn.

RESULTS

The mean cumulative times for heel-down and heel-off for the three groups are presented in Figures 2 and 3, respectively. An ANOVA for repeated measures was conducted to ascertain the apparent differences in heel-down and heel-off times among the three groups over the three days of testing. The results indicated that a difference in a subject's times was based on which type of training he received (heel-down times, $p < .05$; heel-off times, $p < .01$). The subject's times also varied with repetition of gait testing (gait repetition of heel-down $\times$ testing, $p < .01$; gait repetition of heel-off $\times$ testing,
p < .01. A subject's performance, however, was not based solely either on the group to which he was assigned or on which repetition of testing occurred. A subject's performance was based on an interaction between the type of training received and the repetition of the gait test (training x repetition interaction for heel-down times, p < .01; training x repetition interaction for heel-off times, p < .01). Table 1 summarizes the ANOVA for the heel-down times; Table 2 summarizes the ANOVA for the heel-off times.

To identify the specific relationship between the type of training and the four repetitions of gait testing, we used Newman-Keuls post hoc analyses. Each group's heel-down times and heel-off times were analyzed. The post hoc tests indicated that the Long- and Short-Rhythm Groups' heel-down times changed significantly from the pretest to the first posttest (p < .05). The second and third posttests did not differ significantly from the first posttest. The tests on the heel-off times for the Long- and Short-Rhythm Groups indicated a significant change from the pretest to the first posttest (p < .01). The second and third posttests did not vary from the first posttest in the Short-Rhythm Group. In the Long-Rhythm Group, the second posttest did not differ from the first posttest. The third posttest, however, differed significantly from the second posttest (p < .05), but it did not differ from the first posttest. The Control Group's heel-down times did not differ significantly from the second posttest (p < .05), but it did not differ from the first posttest. The Control Group's heel-down times did not differ significantly from each other on any of the four tests. A similar lack of difference between tests occurred for the Control Group's heel-off times.

The differences between the groups in heel-down and heel-off times for the four gait tests also were analyzed with Newman-Keuls tests. We found no significant difference between the groups on the pretest in either their heel-down times or their heel-off times. On the first posttest, we found no significant difference between the Long- and Short-Rhythm Groups in the heel-down times or the heel-off times. We, however, did find a significant difference between Long- and Short-Rhythm Groups and the Control Group in the heel-down times (p < .05) and the heel-off times (p < .01) on all tests except the pretest.

A similar result was found on the second posttest of gait times. The Long- and Short-Rhythm Groups did not differ from one another in their heel-down or their heel-off times. The Control Group's heel-down times differed significantly from those of the Long- and Short-Rhythm Groups (p < .05). Furthermore, the Control Group's heel-off times differed from the Long- and Short-Rhythm Groups' heel-off times (p < .01).

On the third posttest, the heel-down times exhibited a pattern similar to the first and second posttests. The subjects in the Long- and Short-Rhythm Groups were significantly different from the Control Group (p < .05), but they were not different from one another. The heel-off times of the Long-Rhythm Group, however, were significantly different from those of the Short-Rhythm Group (p < .05). The Long- and Short-Rhythm Groups' heel-off times also differed from those of the Control Group (p < .01).

To determine whether the subjects were able to reproduce specifically the rhythm learned in a sitting position, the pretest and first posttest results were compared. The subjects' performances were evaluated in terms of the requirements set by the rhythm trainer: 1) an equal ratio of heel-down to heel-off motions and 2) a duration of heel-off and heel-down times of either 0.5 or 1 second. A two-tailed t test with our stated requirements demonstrated a pattern of performance among the three groups. The Control Group exhibited the same ratio of equal heel-down to heel-off motions in the pretest and first posttest. In both of these tests, the heel-off and heel-down times did not differ significantly from an acceptable population standard of 0.5 second. The Long- and Short-Rhythm Groups also demonstrated the same ratio of equal heel-down to heel-off motions in the pretest and first posttest. In the Long- and Short-Rhythm Groups, however, the duration of heel-off and heel-down times changed from not differing from 0.5 second (p > .05) to not differing from 1 second (p > .05). These changes were not significant.

The t test comparing the speed of learning of the short-rhythm task and the long-rhythm task indicated that the subjects required a significantly longer period of time to learn the short-rhythm task (average 15.9 minutes) than the long-rhythm task (average 5.8 minutes) (t = 2.42, df = 19, p < .05).

**DISCUSSION**

We first asked ourselves whether healthy people could learn a task in a sitting position and, in turn, transfer that learning to walking. If a learning transfer does occur, we wished to know whether it would be nonspecific or whether it would reflect specific components of the learning accomplished in the sitting position. The finding that subjects modified their gait pattern, as indicated by changes in their heel-off and heel-down times, after the learning task demonstrates that subjects were capable of using learning accomplished in a sitting position to modify their ambulation. The transfer influence appears to be nonspecific because the posttest times between the Long- and Short-Rhythm Groups in their heel-off times and in their heel-down times were not significantly different. If their training had had a specific influence, the two groups would have performed significantly different from one another based on their training, and they did not do so. Also, these groups did not differ before and after training in the ratio of heel-off to heel-down times. The transfer influence noted in the first posttest was a general slowing of gait. This

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**TABLE 1**

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<td>647.74</td>
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* Significant at p < .05.

**TABLE 2**

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* Significant at p < .01.
training is task specific. 

Because the Short- and Long-Rhythm Groups did not differ in their first posttests, we asked ourselves whether the training had any influence besides causing a general slowing of gait. The Long-Rhythm Group exhibited a different pattern of heel-off time retention than the Short-Rhythm Group. The Short-Rhythm Group exhibited a steady performance of heel-off time in the three walking tests following the learning they accomplished in the sitting position. The Long-Rhythm Group exhibited a slight decline in heel-off time on the second posttest and a significant increase on the third posttest. The type of training, therefore, did not dictate a specific rhythm of gait, but influenced the retention of the gait pattern learned during the training. In addition, the interval between light flashes during the training session had a significant influence on the subject's acquisition of the skill in the sitting position. The Short-Rhythm Group took significantly longer to learn the task than the Long-Rhythm Group.

Several explanations exist for the differences in learning acquisition and retention between Long- and Short-Rhythm Groups. In this study, regardless of the type of training, the subjects assumed a heel-off time of about 1 second. We infer from this finding that, regardless of the type of training, the subjects preferred a 1-second heel-up rhythm. The concept that healthy subjects have preferred rhythms for activities has been confirmed by several studies. 

In this study, an extrapolation of Underwood's findings would lead us to believe that if a preferred 1-second heel-up rhythm was acquired by training, the group that was trained with a similar sequence (Long-Rhythm Group) would be expected to learn faster. The similarity between the heel-up training rhythm and the preferred heel-up rhythm developed during the training also would lead to competition between the two rhythms and hasten a rapid disintegration of performance in the Long-Rhythm Group. The 0.5-second heel-off task (Short-Rhythm Group) would be dissimilar to the preferred 1-second heel-off rhythm, and learning it would be difficult for subjects in the Short-Rhythm Group. After the task is learned, however, better retention would occur because competition between the 0.5-second training and the 1-second preferred pattern would be less.

Because our results indicate that proactive interference influences the acquisition of a new motor skill whereas other studies in motor learning do not support indications for proactive interference, some explanation is necessary for the difference in findings. In an earlier study in verbal learning, Underwood found the greater the degree of learning of the first of two lists of words, the greater the proactive inhibition. In our experiment, the preferred rhythm interfering with the acquisition of the skill in sitting and later interfering with the retention of the new gait pattern was either an innate preference or a preference that has been established for at least 20 years and practiced extensively everyday (ie, preferred walking pattern). In motor learning experiments finding no proactive inhibition, the amount of practice in the first task was considerably different. In this experiment, the preference for a one-second heel-off time or the extended practice of the first task of walking in this experiment may have been responsible for the proactive interference.

An additional source of interference in retention of the task may have occurred because subjects assumed their normal walking pattern between retests. Studies in verbal learning demonstrate that retention of lists of nonsense syllables is worse if subjects are required to learn similar lists of nonsense syllables between learning the initial list and tests for recall. In our study, the subjects' normal heel-off–heel-down gait patterns between posttests could be considered practice of a similar gait pattern to the one learned in a sitting position. Normal gait, therefore, would interfere with the retention of the gait pattern learned in the sitting position.

Another possible explanation exists for the difficulty in retention of the one-second heel-on–heel-off pattern used by the Long-Rhythm Group. Purdy and Lockhart found that the amount of original learning influenced the ability to retain a motor task. Increased learning time correlated with increased retention. Because the Long-Rhythm Group learned the task faster than the Short-Rhythm Group, they may have experienced greater difficulty in retaining the task. We cannot account, however, for this group's initial ability to learn the rhythm more rapidly.

Finally, we asked ourselves whether the transfer of learning occurring from sitting to gait has an equal influence on the heel-down and heel-off motions of gait. Two findings in this study indicate that heel-down times are influenced differently than are heel-off times. First, in comparing the Long- and Short-Rhythm Groups' performances with the Control Group, we found that the heel-off times exhibited the most significant increase 

Specific aspects of motor learning do not transfer between sitting and gait. Attempts to modify gait are limited to a general influence of speed. If the desire is to modify an exact component of gait, such as the duration of stance, sitting activities are ineffective.

If a person learns a task that requires minor changes in performance, the learning will occur rapidly with reduced retention. Major changes take longer to acquire so that increased retention can be exhibited. The extent of attempted modifications, therefore, in a person's performance should be based on the duration of the training program and the desired longevity of the performance change.

The new learned behavior is in competition with preexisting behaviors. This competition will lead to the eventual deterioration of the new learning. A person, therefore, should develop a technique to monitor compliance with behaviors established in training so that the benefit of training can be maintained. Further research should be conducted with patients to determine whether these conclusions should be considered in the treatment of clients.
REFERENCES

Rehab Med 11:95–103, 1979
3. Brunnstrom S: Movement Therapy in Hemiplegia: A Neurophysiological
128
4. Bobath B: Adult Hemiplegia: Evaluation and Treatment, ed 2. London,
5. Smith LE: Specificity versus generality of relationships between individual
Quarterly 28:364–373, 1957
ance under physical fatigue and the specificity principle. Can J Appl Sport
Sci 4:302–308, 1979
10. Hicks RE, Cohn DM: Lack of proactive inhibition in a psychomotor task at
11. Montague WE, Hillix WA: Intertrial interval and proactive interference in
1969, pp 449, 451
14. Purdy BJ, Lockhart A: Retention and relearning of gross motor skills after
46:283–300, 1951
19. Safranek MG, Koshland GF, Raymond G: Effect of auditory rhythm on
20. Underwood BJ: Proactive inhibition as a function of time and degree of