Implicit Learning of a Perceptual-Motor Skill After Stroke

Background and Purpose. A motor skill can be learned implicitly, without awareness of what is being learned. The purpose of this study was to examine the ability of adults who had unilateral stroke to learn implicitly a perceptual-motor task. Subjects. Subjects were 47 people who were poststroke and 36 control subjects. Methods. Participants performed sequences of hand movements in response to target lights in 2 conditions: a patterned sequence and a random sequence. Participants were not given explicit knowledge of the presence of the 2 conditions. Those who had stroke performed with the upper-extremity ipsilateral to the lesion. Results. Subjects who had stroke performed more slowly than control subjects. For both groups, times decreased with practice of the patterned sequence, increased with introduction of the random sequence, and decreased again with reintroduction of the patterned sequence. Group differences persisted in a retention test given the next day of the patterned sequence, and both groups showed decreased times over the course of the retention test. Discussion and Conclusion. People with stroke are able to learn a perceptual-motor task even without explicit instructions regarding the patterned sequence embedded in the task. [Pohl PS, McDowd JM, Filion DL, et al. Implicit learning of a perceptual-motor skill after stroke. *Phys Ther.* 2001;81:1780–1789.]

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As a component of physical therapy interventions, motor learning is used to enhance skills. This process requires refinement of perceptual skills as well as motor skills; thus, the term “perceptual-motor skills” may be a most appropriate descriptor for this process. Cognitive processing skills are required as well.\(^1,2\) A critical part of the cognitive process for perceptual-motor learning is the ability of the learner to comprehend and utilize the instructions provided to the learner.\(^3,4\) Perhaps the most common use of instructions is to inform the learner about the goal of the task and what needs to be learned to achieve that goal. With these instructions, the learner can engage in explicit learning. In contrast, in implicit learning, the goal is not presented to the learner. The learner performs the task without awareness of what is being learned or, in some cases, without awareness that anything is being learned.\(^5\)

“Implicit learning” is a broad term used to describe the acquisition of abstract knowledge without awareness of learning.\(^5\) For example, abstract grammatical rules may be learned implicitly during the acquisition of language.\(^6\) Procedural learning may be regarded as a subset of implicit learning in that it involves the learning of a perceptual-motor skill.\(^5\)

One of the most common paradigms used to study implicit learning is serial response time tasks.\(^7\) Serial response time tasks have both perceptual and motor learning components and require the subject to respond to a stimulus, such as a light, with some motor response, such as touching it. Typically in research studies, the subject must attend to an array of 4 or more stimuli. The subject is instructed only to respond as quickly as possible to whichever stimulus lights up over a number of trials. What is not explained to the subject is that practice...
is organized in 2 ways: in 1 condition, the series of stimulus lights is presented in random order; in the other condition, a pattern for the presentation of stimulus lights is prescribed by the experimenter, and this pattern is repeated. Subjects are said to demonstrate learning of the pattern if their response time decreases during trials with the prescribed sequence and increases during subsequent trials with the random sequence. Subjects are questioned after practice is complete, and if they report not having noticed any sequence or pattern, their learning is said to be implicit. Other subjects may gain explicit knowledge of the task and report that they noticed something about the task (eg, they may have an impression that some lights follow other lights). Some subjects may have recognition or recall regarding the actual pattern of the sequence and can recognize the pattern when it is displayed or can reproduce it without cuing. Performance by these individuals reflects explicit learning.

Work by Boyd and Winstein9–12 was designed to examine the ability of people with stroke to learn by implicit and explicit means. In general, however, research that has examined motor learning in adults with stroke has focused on the instructions given to engage learners in explicit learning13–16; that is, subjects were told what they were to try to learn. Overall, the results of these studies suggest that individuals with unilateral stroke can learn motor skills when instructions are provided to give them the opportunity to function at an explicit level. It is not known whether adults with stroke can learn a motor skill implicitly.

There is now substantial evidence17–35 that implicit learning and explicit learning are controlled by different neural substrates. The functional neural network for implicit learning is thought to include the basal ganglia,17 cerebellum, and prefrontal cortex.18 The network for explicit learning is thought to include the temporal cortex, hippocampus, thalamus,19,20 and frontoparietal cortex.21 Learning differences in people with brain damage reflect, to a large extent, differences in neural substrates for implicit learning and explicit learning. For example, implicit learning, but not explicit learning, is preserved in some people with Alzheimer disease,22–25 amnesia,26 Huntington disease,27,28 and multiple sclerosis.29,30 In contrast, implicit learning is impaired in people with unilateral prefrontal cortex lesions,31 Parkinson disease,28,32,33 and cerebellar disease.32,34,35

Recently, it was shown that implicit learning is also dependent on the relationship between the side of the brain damage and the side of the effector, that is, the side of the limb performing the task. Implicit learning is preserved when adults with unilateral cerebellar lesions practice a task with the hand contralateral to the lesion, but this learning is impaired when practice is done with the hand ipsilateral to the lesion.36 In contrast, people with unilateral damage to the supplementary motor area37 or frontal area38 have impaired implicit learning involving the contralateral upper extremity (UE). Finally, people with callosal dysfunction can learn implicit tasks involving one hand, but cannot do so when both hands are required to respond to stimuli.38 Thus, it appears that the ability to learn implicitly depends on the integrity of the neuroanatomical substrates that subserve the performing UE.

Between 61% and 81% of strokes involve the anterior and middle cerebral arteries.39 The primary clinical manifestation of these strokes is hemiparesis. Even after 6 months or more, 45% of those who survive stroke are left with some degree of hemiparesis.40 Given that the primary deficits after stroke are on the side contralateral to the pathology, a unilateral stroke would leave the brain areas important for implicit learning intact if individuals performed a task with the UE ipsilateral to the lesion. Thus, it is reasonable to suggest that implicit learning would be preserved for people with unilateral stroke in the anterior circulation when performing with the UE ipsilateral to the lesion.

The primary purpose of our study was to examine the ability of adults with unilateral stroke to learn implicitly a motor skill using the UE ipsilateral to the side of brain damage compared with that of adults without stroke. If people with stroke can implicitly learn a serial response time task, performance would become faster during practice with a patterned, repeated sequence and would become slower with the introduction of a random sequence, and response time changes would be equivalent to those of people without stroke. If implicit learning is robust over time irrespective of unilateral brain damage, the speed of performance on a retention test 24 hours later should be similar between people with stroke and people without stroke.

A secondary purpose of our study was to investigate possible differences in the ability to learn implicitly relative to the severity of stroke. Given that the subjects performed the task with the UE ipsilateral to their brain damage, the severity of stroke should not affect implicit learning if implicit learning is dependent on an intact contralateral cortical substrate.

Method

Participants
We recruited 47 adults who had stroke and a comparison group of 36 adults without stroke matched for age and education (controls) (Table). To be included in the study, participants had to be: (1) at least 60 years of age,
(2) living in the community, and (3) right-hand dominant (before stroke for those in the stroke group), as assessed by a handedness questionnaire. Only subjects who were right-hand dominant were included to limit confounds in measures of performance of those with stroke related to brain laterality. In addition, those with stroke had to be at least 6 months postonset. Subjects were screened by trained research assistants to ensure that the subjects could follow 3-step commands and maintain a sitting posture independently. Exclusion criteria established by trained research assistants included having: (1) a history of any neurological disorder except for those in the stroke group, (2) impaired cognitive status (that is, a Mini-Mental Status Examination score of less than 18/30), (3) pathology of the UE that would be used to perform the task if that limitation would affect the ability to perform the movement, and (4) uncorrected visual impairment. In addition, for those with stroke, exclusion criteria included apraxia, as defined by the Florida Apraxia Screen, and stroke involving the brain stem or the posterior circulation system.

Adults with stroke were recruited from a pool of subjects who had participated in a previous study (n=27) and from local stroke support groups (n=20). The data set from the previous study included documentation made in medical charts within 14 days poststroke concerning the location of the lesion and the severity of the stroke, as defined by the Orpington Prognostic Scale. As defined by the Orpington Prognostic Scale, 18 of the 27 individuals with stroke from the previous study had mild stroke, and 9 had moderate stroke. Information about the severity of stroke was not available for the 20 participants from the stroke support groups. The presence of a unilateral lesion in the anterior circulation for those in the stroke support groups was determined from the participants’ reports. Older adults with no known pathology or impairments were recruited from the Grayhawk Panel (principal investigator: JMM), a pool of over 600 people who have agreed to participate in research.

### Task and Equipment

The equipment used was a custom-made hand movement device (Fig. 1) consisting of 16 targets of 4 types of switches. Each type of switch was easily closed but required a different hand position (modeled after that of Harrington and Haaalnd). We did not, however, specify a hand position for each type of switch. The first row (from the top) consisted of 2.54-cm-diameter knobs that were closed by turning them to the right or left. The second row consisted of switches (the size of standard light switches) that were closed by moving them to the right or left. The third row consisted of 2.54-cm-diameter buttons that were closed by pushing them in. The fourth (bottom) row consisted of switches (the size of standard light switches) that were closed by moving them up or down. A light was situated above each switch.

The hand movement device was linked to a computer that controlled the sequencing of the lights and recorded the time from the illumination of the first target light to the closure of the eighth switch (i.e., an 8-target sequence). The lights for both the patterned sequence and the random sequence, proceeded from left to right and back again for the 8 targets. The first target light was in the first column, the second target light was in the second column, and so on, with the
fourth and fifth target lights both appearing in the fourth column. The patterned sequence was randomly selected within the constraints of the order of columns. The target light remained illuminated until the correct response was made. Closure of the target switch (that is, the correct switch) caused the next light in the sequence to become illuminated. Thus, the subject was required to move from one switch to the next switch without resting.

Procedure
The rights of human subjects were protected. Participants signed a university-approved informed consent form that was part of a larger study evaluating attentional and learning capabilities of adults poststroke. The data from the motor learning task presented here are a subset of data collected. Participants with stroke used the UE ipsilateral to the side of brain damage; the UE that controls used was matched so that half used their left UE and half used their right UE. Participants practiced in 2 conditions: an 8-target patterned sequence and an 8-target random sequence. The participants were not informed that there were 2 conditions. The instructions were to close the switch corresponding to the light that became lit and to do so as quickly as possible. Practice was provided in an effort to ensure that the participant could close each switch properly.

Practice was conducted over 2 consecutive days and was organized into blocks. A block consisted of 10 repetitions of an 8-response sequence. A block was completed without interruption; that is, the closure of a target switch activated the subsequent target light to become illuminated. Subjects were given short rests of approximately 2 to 3 minutes as needed between blocks. On day 1, blocks 1 through 4 were the patterned sequence, blocks 5 and 6 were the random sequence and blocks 7 and 8 returned to the patterned sequence. The second day of practice was used as a measure of retention. Participants performed 2 blocks of the patterned sequence. Thus, participants performed a total of 100 8-response sequences; 80 of those were the patterned sequence.

A procedure commonly used to examine serial responses was used to assess explicit knowledge of the patterned sequence. In a recall test at the end of the retention measure on day 2, participants were asked whether they noticed anything about the task. Regardless of their response to this question, they were then informed that there was a patterned, repeated sequence embedded within their practice sessions. They were told to try to reconstruct that sequence by pointing to the switches (without the cuing of target lights) in the order that they thought represented the sequence. If they said they did not know, they were told to guess and to do the best they could.

Data Processing and Analysis
The sequence response time (SR) was recorded; this represented the time to complete a sequence of 8 stimuli and responses. Errors, such as moving the hand toward the incorrect switch or closing the wrong switch, were not counted individually but caused delays for the whole sequence and thus are reflected in the SR. The mean and standard error of the mean (SEM) of the SR were calculated for each 10 repetitions of an 8-response sequence to form blocks. The Statistical Package for the Social Sciences personal computer program (version 8.0)* was used for all analyses.

To examine differences between subjects with stroke and controls, 4 separate analyses of variance (ANOVAs) with a factor of group (stroke or control) and a repeated-measures factor of block were used to assess the following 4 items: learning of the patterned sequence, changes in performance with introduction of the random sequence, changes in performance with reintroduction of the patterned sequence, and retention. Effect size was calculated using an eta-square analysis ($\eta^2$). Values of $\eta^2$ of .01, .06, and .14 represent small, medium, and large effect sizes, respectively. A main effect of group would indicate a difference in SR between those with stroke and controls. If implicit learning is preserved in individuals with stroke, then there would be a main effect of block such that SR would become shorter with practice of the patterned sequence, SR would become longer when the random sequence is introduced, and SR would become shorter again when the patterned sequence is reintroduced. If implicit learning is retained in both groups, then there would be no main effect of group. For each analysis, group × block interactions would indicate differences in implicit learning between those with stroke and controls.

Explicit knowledge of the patterned sequence was assessed using a chi-square analysis. If individuals with stroke gain explicit knowledge as well as controls, then there would be no association between group and yes-no responses. The longest series of correct responses that subjects were able to generate was analyzed with a one-way ANOVA with group (stroke or control) as the factor. If individuals with stroke gain explicit knowledge as well as controls, then there would be no group effect.

To investigate whether adults with moderate stroke could learn implicitly, the data from the 27 subjects whose stroke severity had been defined as mild or moderate (ie, a subset of the large stroke group analysis) were analyzed in a 2-way ANOVA with a factor of group (mild or moderate) and a repeated-measures factor of block, with the same block comparisons as those afore-

* SPSS Inc, 444 N Michigan Ave, Chicago, IL 60611.
Results

Learning of the Patterned Sequence: Blocks 2 to 4
Means and SEMs for SR by group for the 10 blocks of practice are shown in Figure 2. Because it is likely that changes from block 1 to block 2 included improvements attributable to nonspecific learning of the task, we analyzed the block effects of blocks 2 to 4. Subjects with stroke decreased their SR over blocks 2 to 4 by 71 ± 21 milliseconds, representing a 5% improvement. Controls decreased their SR by 77 ± 12 milliseconds, representing a 7% improvement over these 3 blocks. There was a main effect of block (F = 15.795, P < .001, η² = .163), reflecting decreased SR with practice. There was also a main effect of group (F = 13.146, P < .002, η² = .140), reflecting the longer SR of those with stroke. The absence of a group × block interaction suggests that both groups improved performance at similar rates.

Means and SEMs for SR by group for the 10 blocks of practice for those with mild and moderate strokes are shown in Figure 3. From block 2 to block 4, subjects with mild stroke decreased their SR by 77 ± 27 milliseconds, and those with moderate stroke increased their SR by 40 ± 45 milliseconds. There was a main effect of group (F = 8.971, P = .006, η² = .264), and there was a group × block interaction (F = 3.358, P = .049, η² = .118). Post hoc analyses of the group × block interaction did not reveal differences between any pair of blocks for either group.

Interruption of Performance With the Random Sequence: Blocks 4 and 5
With the introduction of the random sequence, the SR of those with stroke increased 156 ± 29 milliseconds, a 12% increase over their performance at block 4. Similarly, the SR of controls increased 145 ± 35 milliseconds, a 14% increase over their performance at block 4. There was a main effect of block (F = 43.910, P = .000, η² = .352). Individuals with stroke were slower than controls, as evidenced by the main effect of group (F = 14.704, P = .000, η² = .154). There was no group × block interaction.

The SR of individuals with mild stroke increased 250 ± 49 milliseconds, and that of individuals with moderate stroke increased 95 ± 85 milliseconds. There was a main effect of group (F = 5.662, P = .025, η² = .185), and there was a main effect of block (F = 14.247, P < .001, η² = .363).

Enhancement of Performance With Reintroduction of the Patterned Sequence: Blocks 6 and 7
The reintroduction of the patterned sequence at block 7 resulted in faster SRs for those with stroke (55 ± 21 milliseconds) and controls (29 ± 12 milliseconds), representing improvements from block 6 of 4% and 3%, respectively. There was a main effect of block (F = 9.801, P = .002, η² = .108), and there was a main effect of group (F = 13.931, P = .000, η² = .147). There was no group × block interaction.

Sequence response times were 138 ± 36 milliseconds faster at block 7 for those with mild stroke and 15 ± 38 milliseconds faster for those with moderate stroke. There was a main effect of group (F = 5.797, P < .025, η² = .188), there was a main effect of block (F = 7.146, P < .014, η² = .222), and there was a group × block interaction (F = 4.610, P = .042, η² = .156). Post hoc analyses revealed that the interaction was attributable to the faster SR in block 7 than in block 6 for those in the mild-stroke group only (t = 3.885, P = .001).
Retention of the Patterned Sequence: Blocks 9 and 10
Controls and those with stroke decreased their SR over the 2 blocks of retention. There was a main effect of block (F=121.949, P=.000, \( \eta^2 = .601 \)), and there was a main effect of group (F=11.781, P=.001, \( \eta^2 = .127 \)). The analyses of blocks 9 and 10 for those with mild and moderate strokes revealed a group \( \times \) block interaction (F=6.522, \( P<.02, \eta^2 = .207 \)). Post hoc analyses revealed that the SR for block 10 was faster than that for block 9 for both those with mild stroke (t=8.643, P<.001) and those with moderate stroke (t=8.034, P<.001).

Explicit Knowledge of the Patterned Sequence
With regard to whether participants noticed anything about the task, there was no difference between the participants with stroke and the control group, with most individuals stating that they noticed something (68% of those with stroke and 75% of controls). Similarly, there was no difference between those with stroke and the controls (2.2±0.3 and 2.8±0.4, respectively) for the largest number of correct single responses in a row recalled.

There was no difference in explicit knowledge of the patterned sequence between those with mild stroke and those with moderate stroke; two thirds of those with mild stroke noticed something about the task, and just over one half of those with moderate stroke did so. Subjects with moderate stroke did recall a larger number of correct responses in a row (3.7±0.7) than did those with mild stroke (1.7±0.4), as revealed by a one-way ANOVA (F=6.818, P<.02).

Discussion
To our knowledge, this is the first study to show that implicit learning of a perceptual-motor task may be preserved in people with unilateral stroke, particularly if the stroke is mild. As we hypothesized, individuals who had stroke and used the UE ipsilateral to the side of brain damage demonstrated the ability to learn implicitly an SR task as well as older adults without impairments, although the performance of those with stroke was consistently slower than the performance of the comparison group. The SRs of both groups improved with practice of a patterned sequence, were lengthened by the onset of practice of a random sequence, and improved again with reintroduction of the patterned sequence. Adults with stroke continued to be slower than controls in the retention phase of the study. Both groups showed faster SRs in the second block than in the first block on day 2.

Although rehabilitation after stroke often has been based on the learning of motor skills, only within approximately the last 8 years has research provided some guidance regarding strategies for constructing practice for people with brain damage. Recently, the impact of instructions on rehabilitation has been discussed. Instructional strategies can provide the learner with explicit knowledge about the features of a task that are essential for performance of the task (ie, what a person needs to learn to achieve the goal associated with the task). Explicit learning is invoked when participants are searching for features, rules, or some structural property during practice and when they are able to say how they solved the problem. An alternative instructional strategy does not provide the learner with knowledge about the critical properties of the task, and the skill is learned implicitly. Implicit learning occurs when participants focus on specific items, such as searching for a target light, not rules, such as any relationship between successive target lights.

In adults without neurological damage, there is evidence that explicit instructions can lead to poorer performance than implicit instructions. What instructional set is appropriate for people with stroke? Our results demonstrate that people with stroke, particularly those with mild stroke, can learn under implicit-learning conditions, suggesting that a strategy with implicit instructions may be important in rehabilitation. Studies are needed to compare explicit and implicit strategies to determine whether there is an optimal instructional set for adults with stroke.

The differences in performance between the participants with stroke and the older adults without impairments were attributable to the slower SR of those with stroke. This finding is congruent with the findings of researchers who have demonstrated that movements with the UE ipsilateral to the side of brain damage are slower than those in controls. In general, we suggest, as others have before, that the ipsilateral UE movement slowing may be attributable to disrupted output from the damaged hemisphere influencing the control of both UEs. An alternative, but not exclusive, explanation is that both hemispheres are necessary for normal execution of unimanual movements, particularly if the movements are complex.

Implicit learning may be particularly appropriate for some people with stroke but not all. Contrary to our hypothesis, the performance of subjects with moderate stroke did not change as the practice condition changed even though the subjects performed with the UE ipsilateral to the lesion. It appears that the subjects were not able to learn the task implicitly and that the only learning that occurred was a nonspecific learning that allowed them to decrease SR and increase speed from the first block to the second block of retention. Given the small number of subjects with moderate stroke, we would need a larger sample size to reach statistical significance.
suggest that conclusions be drawn with caution. Damage
in the neostriatum impairs implicit learning,62,56 and it
may do so for both UEs. We did not have information
about precise lesion locations. People with moderate
stroke may have had greater involvement of the neostri-
atum than those with mild stroke.

Implicit learning is not a passive process,57 nor is it
unconscious.54 The learner needs to be able to attend to
the task that is practiced.7 Adults with stroke may have
deficits in attentional processing.59 In our study, numer-
ous trials were required. We chose a task that required
different hand postures rather than the single hand
posture that was required in the original serial response
time task studies.7 We did this to make the task more
interesting, although we admittedly have no measures of
whether subjects were interested or attentive.

The presence of implicit learning suggests that there is
no need to ask learners questions during practice about
what they are experiencing,3 in sharp contrast to some of
the techniques used in physical therapy. Whether there
is a dichotomy in implicit learning and explicit learning
is questionable.60 Indeed, some authors57,61 have argued
that, with all learning, some parts of learning are explicit
and some are implicit. An optimal strategy for motor
learning within the context of rehabilitation may require
some blend of explicit and implicit strategies that has yet
to be defined, but at present this notion is speculative.

Implicit learning usually is thought to occur when
changes in performance occur as the practice conditions
change, such as a change from the patterned sequence
to the random sequence in our study. The inclusion of a
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Explicit knowledge of a task learned under implicit-
learning conditions does not appear to be different
between individuals with stroke and older adults without
impairments. A large percentage of subjects answered
"yes" to the question about whether they noticed any-
thing about the task. This open-ended question did not
provide us with any information about what they noticed
but was chosen to avoid leading the respondents as
much as possible. However, the longest correct series
recalled by members of either group was only approxi-
mately 2 out of the 8 responses. Thus, although subjects
appeared, on the basis of questioning, to have some
explicit knowledge, their recall performance was limited.

The relationship between the presence of explicit knowl-
edge and the level of implicit learning in a task practiced
under implicit-learning conditions has been debated in the
literature.60,63 Explicit learning and implicit learning
may occur in parallel, as suggested by the finding that
those who train under explicit-learning conditions also
gain implicit knowledge.60 Other researchers, however,
have regarded the relationship between explicit learning
and implicit learning as "antagonistic" (see, for example,
Buchner et al63).

There are several limitations to our study. Using reports
from medical charts, personal reports, and examina-
tions, we limited our participants with stroke to those
with unilateral lesions in what appeared to be the
distribution of the anterior circulation system. We sug-
gest that the results from our study should not be
generalized to people with pathology in the brain stem
or posterior circulation system or to those with bilateral
brain damage. The diagnosis of stroke documented in
medical charts for our subjects was based on a combina-
tion of clinical signs and symptoms and radiological
information. Reports from brain imaging were not avail-
able for each subject. Without this information, it is not
possible to verify the precise lesion size and location. We
acknowledge that a branch of the middle cerebral artery
serves subcortical areas, including the basal ganglia.64 In
the absence of brain imaging reports, we cannot exclude
the possibility that some of our participants with stroke
had lesions that included the basal ganglia.

Another limitation of our study is that the participants
with stroke were at least 6 months after onset of the
stroke. We do not know whether implicit learning is
intact during the early stages after stroke, when rehabil-
itation efforts are directed. This question remains to be
answered. Our task was atypical and differed from the
reaction time task used in serial response time para-
digms. The nature of the task, that is, requiring different
hand postures for responses, may have invoked more explicit-learning strategies than a task that requires only pushing buttons for each response. Finally, the individuals with stroke performed the perceptual-motor task with the UE ipsilateral to the lesion. Recently, it was shown that the primary sensorimotor cortex contralateral to the performing UE is active during implicit learning. In this light, we would predict that people with stroke could not learn implicitly with the contralateral, more affected UE. This notion remains to be empirically tested.

**Conclusion**

Our results suggest that adults with unilateral stroke can learn implicitly, particularly if the stroke is mild. The clinician should consider the instructional set provided to people with stroke during interventions. In rehabilitation, we may often rely on verbalization to describe the goals of skills that we are teaching our clients. From our experience, we often see explicit instructions provided to clients on how to meet these goals. For example, in coming to a standing position, clients may be told to keep their head up and to lean forward so that their nose is over their knees. Although this teaching strategy may be successful, our study suggests that adults with mild stroke may learn perceptual-motor tasks through implicit-learning experiences. This may be particularly helpful for individuals who have difficulty processing extensive verbal instructions. Incorporating strategies to engage an individual in implicit learning may provide a successful avenue to the learning of motor skills during rehabilitation.

**References**


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