CME Objectives:
Upon completion of this article, the reader should be able to (1) recognize the influence of age on the ability to learn muscle relaxation, (2) identify the effect of different timing conditions of myofeedback on leaning muscle relaxation, and (3) differentiate the effect of myofeedback on the more permanent changes in the relaxation task from the transient changes in performance.

Level: Advanced.

Accreditation: The Association of Academic Physiatrists is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.
The Association of Academic Physiatrists designates this continuing medical education activity for a maximum of 1.5 credits in Category 1 of Physician's Recognition Award of the American Medical Association. Each physician should claim only those credits that he or she actually spent in the education activity.

Disclosure: Disclosure statements have been obtained regarding the authors' relationships with financial supporters of this activity. There is no apparent conflict of interests related to the context of participation of the authors of this article.

Supported, in part, by the National Institute on Disability and Rehabilitation Research, grant H133A010403. The opinions contained in this article are those of the grantee and do not necessarily reflect those of the NIDRR and the U.S. Department of Education.

0894-9115/06/8502-0148/0
American Journal of Physical Medicine & Rehabilitation

DOI: 10.1097/01.phm.0000197959.17247.5b

CME ARTICLE ● 2006 SERIES ● NUMBER 1

Effects of Age and Timing of Augmented Feedback on Learning Muscle Relaxation While Performing a Gross Motor Task

ABSTRACT

van Dijk H, Hermens HJ: Effects of age and timing of augmented feedback on learning muscle relaxation while performing a gross motor task. Am J Phys Med Rehabil 2006;85:148–155.

Objective: To examine the combined effect of age and timing of augmented feedback on learning muscle relaxation. Performing a gross motor task, subjects had to lower their trapezius muscle activity using the electromyographic signal as visual myofeedback.

Design: Healthy subjects (16 young adults: 20–35 yrs; and 16 older adults: 55–70 yrs) were randomly assigned to one of two timing conditions of myofeedback: concurrent (feedback was provided immediately during the trial) and terminal (feedback was provided delayed after the trial) condition.

Results: The results indicated that young adults had a higher level of motor performance (i.e., lower muscle activity) compared with older adults when myofeedback was provided. These effects persisted during short- (after 10 mins) and long-term retention (after 1 wk) when no myofeedback was provided. In contrast to young adults, older adults did not improve their performance throughout the experiment. There were no interactions of age with the timing conditions of myofeedback during acquisition and retention.

Conclusions: Either timing condition of augmented feedback was equally helpful to young adults, whereas neither was helpful for older adults in learning muscle relaxation.

Key Words: Rehabilitation, Learning, Motor Skills, Biofeedback, Aging

Authors:
Henk van Dijk, MD
Hermie J. Hermens, MD

Affiliations:
From Roessingh Research and Development, Enschede, the Netherlands (HVD, HJH); and Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, Enschede, the Netherlands (HJH)

Correspondence:
All correspondence and requests for reprints should be addressed to H. van Dijk, Roessingh Research and Development, PO Box 310, 7500 AH Enschede, the Netherlands.

Learning new motor skills is essential across the lifespan for our everyday adaptation to the environment. With aging, the ability to learn new skills continues to be crucial for maximizing function and quality of life. For example, older adults may need to learn new skills such as a leisure activity or an adaptation task such as propelling a wheelchair. Although there is an abundance of research on how young adults learn motor skills, little is known about whether older adults learn skills in the same manner as young adults do.

One general conclusion from motor learning research using young adults is that the learning of motor skills is a problem-solving process that requires cognitive intervention between perception and action, particularly in the early stages of skill acquisition.[1,2] Aging may influence how older adults use information in this early, highly cognitive stage. Research findings suggest that there are changes in cognitive processing associated with aging.[3] In addition to these cognitive changes, there is evidence that there are changes in how older adults perform movements.[4] The changes in cognition combined with the age-related changes in motor control may affect how older adults use information to learn new motor skills.

Motor learning research on young adults has identified many variables such as augmented feedback that enhance learning processes.[1,2,5–8] Although there are a limited number of studies on older adults, the available results suggest that despite the changes associated with aging, older adults benefit from augmented feedback similarly to young adults.[9–12]

Wishart et al.[13] conducted a study investigating the effects of age and the role of visual augmented feedback in the acquisition of a new bimanual coordination pattern. Young and older subjects were randomly assigned to receive either concurrent or terminal timing of feedback. The concurrent timing of feedback refers to augmented feedback that is given while the movement is in progress; the terminal timing to augmented feedback that is given after the skill has been performed. Both young and older adults benefited from the concurrent condition, but older adults gained more than young adults did, relative to the terminal condition. The results suggest that when learning bimanual coordination patterns, older adults are more sensitive to the availability of concurrent visual information (i.e., older adults did not benefit from augmented feedback similarly to young adults).

The study by Wishart et al.[13] raised the question of whether their deviating findings were specific for the acquisition of a new bimanual coordination pattern. The above-mentioned previous studies[9–12] all involved the learning of motor tasks using only the dominant hand, not a bimanual coordination task.

Augmented feedback is usually implemented as concurrent augmented feedback, which might result in the development of a dependency on the availability of feedback as indicated by the guidance hypothesis. This hypothesis indicates that the role of augmented feedback in learning is to guide performance to be correct during practice.[14] However, if it is provided too frequently, it causes the learner to develop a dependency on its availability, and therefore to perform poorly when it is not available. So, practice with concurrent augmented feedback is beneficial for the immediate performance, but might not be for the learning of motor skills. Terminal augmented feedback can be effective in most skill learning situations.[15]

In the present study, we compared young and older subjects regarding their ability to use visual augmented feedback to learn a new unilateral motor task. The task selected for the present study was to lower muscle activity as measured by surface electromyography (sEMG) while performing a gross motor task. This task was based on a treatment program used on groups of patients with work-related musculoskeletal pain.[16,17] Subjects were provided with a visual EMG signal, which varied in proportion to the electrical activity recorded from a target muscle. Subjects could then monitor the target muscle while attempting, through trial and error, to decrease muscle activity. Lowering muscle activity while actually using the same muscle to perform a gross motor task is physiologically possible, but difficult to perform for many subjects, leaving room for improvement with muscle reeducation procedures. Research by Voerman et al.[18] has indicated that subjects performing this muscle relaxation task profited from a sensory feedback (myofeedback) training procedure.

Hermens and Hutten,[16] Vollenbroek-Hutten et al.,[17] and Faucett et al.[19] found similar results in groups of patients with work-related musculoskeletal pain receiving myofeedback training. The results indicated that the use of myofeedback can result in a change of muscle activation pattern, so apparently it assists in making subjects aware of their muscle activation.

The first purpose of the present study was to examine whether concurrent or terminal timing of augmented feedback is most effective in facilitating motor skill learning. Based on the understanding of the detrimental guiding role of augmented feedback on learning, it was expected that by providing terminal instead of concurrent augmented feedback, the dependence on augmented feedback would decrease, and the learning of motor skills would improve (i.e., lower muscle activity while performing gross motor task).

The second purpose of this study was to examine the combined effect of age and timing of augmented feedback on motor skill learning. Separate groups of the feedback timing conditions were formed for both young and older adults to examine age-related effects on motor learning. We hypothesized that both age categories would learn the new motor task. However, given the cognitive and performance changes associated with aging, the young adults were expected to achieve a better level of performance than the older adults (i.e., lower muscle activity). In addition, based on previous findings suggesting that older adults benefit from the learning variables similarly to young adults, it was expected that the guidance hypothesis is also valid for older adults. In other words, the timing of augmented feedback has similar learning effects on both young and older adults.

METHODS

Design and Subjects

Healthy, able-bodied subjects within two age categories (young adults: 20–35 yrs; and older adults: 55–70 yrs) were selected by means of a checklist concerning the health status of the subjects. To be included in the study, subjects had to be free of any history of upper-extremity pathology. Subjects were excluded if they suffered from blindness or cognitive impairments (e.g., dementia). Recruitment of the young adults was performed under the employee-population (also graduate students) of Roessingh Research and Development and the University of Twente in Enschede, the Netherlands. Older adults were recruited among the wide circle of acquaintances of the researchers. The study was approved by the Roessingh ethics committee. All subjects signed an informed consent.

In total, 32 subjects (16 young and 16 older adults) were recruited for the study. The subjects of both age categories were randomly assigned to two groups (A or B) with the restriction that the groups were balanced for gender. Eight subjects were assigned to each group (three males and five females per group). The two groups were differentiated in terms of timing of augmented feedback that provided subjects with information related to the muscle activity. Subjects had no prior experience with the experimental task and were not aware of the specific purposes of the study. Demographic characteristics of the subject population for both age categories are listed in Table 1.

TABLE 1 Demographic characteristics of the subject population

Characteristics	Young Adults	Older Adults
n	16	16
Sex (male/female)	6/10	6/10
Age,[a] yrs	27.1 (4.5)	64.3 (8.8)
Weight,[a] kg	68.7 (6.3)	80.1 (15.5)
Length,[a] cm	177.1 (8.7)	173.2 (9.5)
Body mass index,[a] kg/m^2	21.9 (1.8)	26.5 (3.6)
Dominant hand (right/left)	13/3	14/2

[a] Mean (standard deviation).

Surface Electromyographic (sEMG) Detection

sEMG was recorded from the upper trapezius muscle of the dominant side. Its superficial location makes the trapezius muscle highly suitable for sEMG recording and feedback applications.[20] Before electrode placement, the skin was prepared by cleaning it with alcohol. Adhesive surface electrodes (interelectrode distance 2.5 cm) were placed 2 cm laterally to the midpoint between cervical 7 and the lateral end of the acromion.[21] The position of the electrodes was marked with a permanent marker to ensure identical placement of the electrodes during measurements on different days.

The sEMG signal was amplified (15×), digitized (22 bits ADC), and smooth rectified with removal of the low frequency components. Sample frequency was 512 Hz and the signal was band pass filtered between 30 and 250 Hz. Embedded software provided the root mean square (RMS). The system was connected with a computer, and data were stored for offline analysis.

Task and Procedure

Subjects were seated behind a table in a chair without arm support. The height of the table and the chair were then adjusted so that elbow flexion of the dominant arm was within a range of 90–95 degrees when the upper arm was held along the body with the forearm placed on the table. An angle

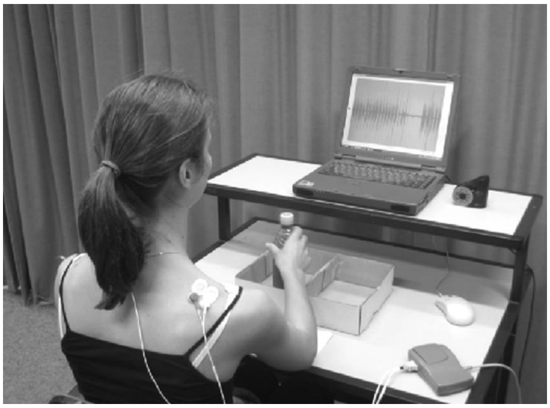


FIGURE 1 *"Bottle-in-a-case" task.*

<90 degrees would cause undesired trapezius activation due to elevation of the shoulder when moving the forearm and hand above the table. A computer monitor was positioned approximately 50 cm directly in front of the subjects.

Subjects performed a unilateral gross motor task in which they had to move their dominant arm/hand continuously by performing a "bottles-in-a-case" task. Herewith, a bottle (with a weight of 160 g) must be replaced inside a case (Fig. 1). The hand starts on the table, then grabs the bottle in the case and moves the bottle to the other side of the case. After this, the hand returns to the table and again replaces the bottle. The pace of the arm/hand movement (88 marks per minute) was kept constant with the use of a metronome.[22] The goal of the task is to try and keep the trapezius muscle activity as low as possible during the motor task. Subjects were provided with visual myofeedback (raw EMG signal on the computer monitor) about their trapezius muscle activity. Besides a postural and supporting function, the trapezius muscle is important for the adjustment of the scapula during elevation of the upper arm, and it prevents from downward dislocation of the humerus.[23]

The 32 selected subjects were randomly assigned to two feedback timing conditions (A or B). The conditions were differentiated in terms of concurrent and terminal timing of augmented feedback:

A. Concurrent augmented feedback—visual myofeedback was provided immediately during the trial by means of displaying the raw EMG signal;
B. Terminal augmented feedback—visual myofeedback was provided after a delay (10 secs) after the trial by means of displaying the recorded EMG signal from the prior trial.

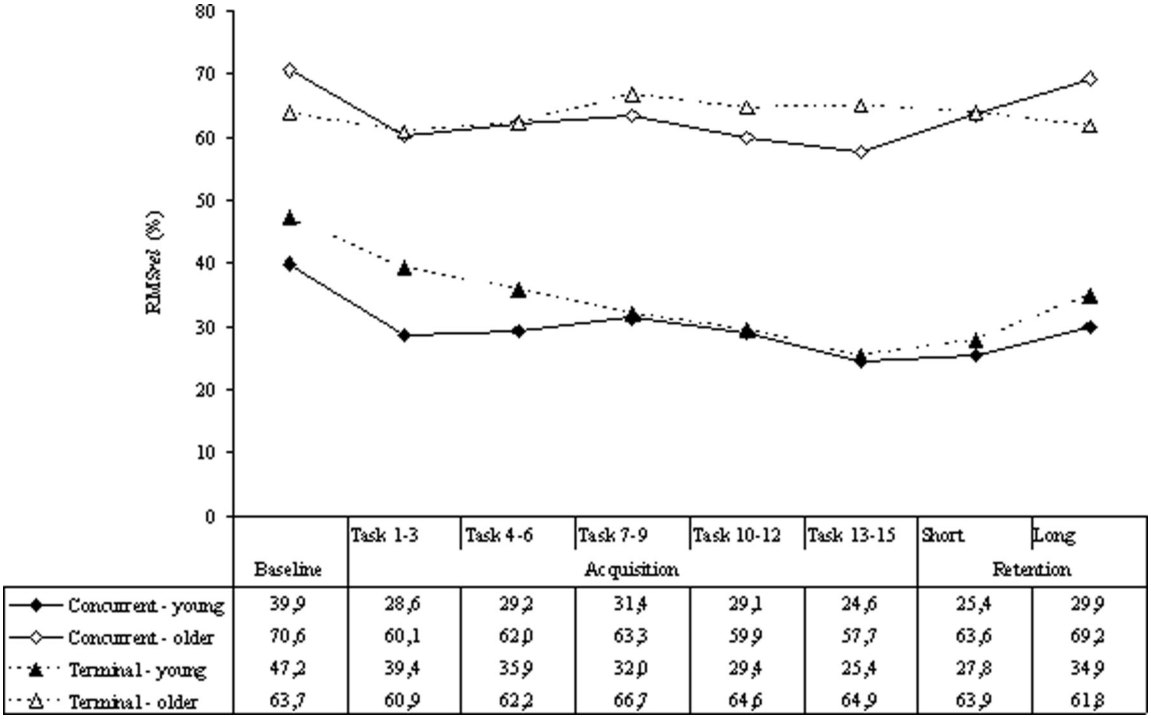
sEMG recordings started with four *reference* contractions of the upper trapezius muscle performed according to the guidelines of Mathiassen et al.[24] These reference contractions were followed by three tasks of 1 min without myofeedback to determine *baseline* activity. Subjects were instructed that they had to perform the task with the upper extremity (especially the dominant shoulder) as relaxed as possible with the nondominant arm resting on the table. Subsequently, subjects performed the 1-min task 15 times with myofeedback. In between each measurement, there was a rest period of 1 min to prevent subjects from muscle overload. Subjects were instructed that they had to discover a manner of performing the task that would result in the lowest muscle activity (shown on the computer monitor). Again, the nondominant arm was resting on the table. These 15 tasks are considered the *acquisition* phase. Three 1-min tasks without myofeedback were performed twice to study retention: after 10 mins (*short-term retention*) and after 1 wk (*long-term retention*). Instructions were identical as those given during baseline measurement. The retention trials after 1 wk (again preceded by a reference measurement) were measured on the same part of the day (morning or midday) as the acquisition trials. The retention trials were implemented to differentiate the effect augmented feedback may have on the more permanent changes in a motor skill from the transient changes in performance that may be observed during the acquisition phase of the study.

The myofeedback training procedure had a comparable amount of practice (and subsequent myofeedback exposure) to the study by Voerman et al.[18] in which subjects actually learned to lower their muscle activation level while performing a gross motor task.

Data Analysis

Learning muscle relaxation was defined as a decrease in trapezius muscle activity expressed in sEMG outcome parameter root mean square (RMS, in μV). sEMG was continuously recorded during baseline, acquisition, and retention trials, and after the removal of artifacts, the RMS values were calculated over a period of 40 secs within the 1-min trials (first and last 10 secs were neglected because of possible starting and ending effects). This resulted in three baseline values, 15 acquisition values, and 2 × 3 retention values of RMS. These values were subsequently averaged resulting in one value for baseline, one per three acquisition trials, and one for each retention measurement per subject.

The RMS values during the reference contractions were computed for the middle 10 secs of each



	Baseline	Task 1-3	Task 4-6	Task 7-9	Task 10-12	Task 13-15	Short	Long
		Acquisition					Retention	
—◆— Concurrent - young	39,9	28,6	29,2	31,4	29,1	24,6	25,4	29,9
—◇— Concurrent - older	70,6	60,1	62,0	63,3	59,9	57,7	63,6	69,2
··▲·· Terminal - young	47,2	39,4	35,9	32,0	29,4	25,4	27,8	34,9
··△·· Terminal - older	63,7	60,9	62,2	66,7	64,6	64,9	63,9	61,8

FIGURE 2 *RMS*rel *as a function of blocks for baseline, acquisition, and retention.*

reference contraction,[24] and the mean value was used for normalization. This means that RMS values during baseline, acquisition, and retention trials were expressed as percentages of this mean reference value (RMS *relative* = RMS trial/RMS reference * 100%). After this normalization procedure, individual values were averaged to obtain group results.

Statistical Analysis

The dependent measure RMS*rel* was analyzed in a two-sample *t* test for baseline measurements comparing the two feedback timing conditions separately for the age categories. This was done to check the randomization procedure for both young and older adults.

With regard to the first purpose of the present study, the acquisition data were analyzed using a 2 (feedback conditions) × 6 (baseline and acquisition blocks) analyses of variance (ANOVA) with repeated measures on the last factor. Retention data were analyzed with a similar design, except that there were only two trial blocks (short- and long-term retention). These analyses were done separately for the age categories young and older adults. With regard to the second purpose of this study, the acquisition and retention data were analyzed using a 2 (age categories) × 6 (baseline and acquisition blocks) ANOVA with repeated measures on the last factor. These analyses were done separately for the feedback timing conditions concurrent and terminal. The Greenhouse-Geisser correction factor for *df* was used in all ANOVAs. Alpha was set at 0.05 for all statistical tests.

RESULTS

Baseline Phase

The initial performance level on the relaxation task was compared between the two feedback timing conditions separately for the age categories by conducting a two-sample *t* test for the baseline phase. This analysis did not result in a statistical significant difference for young adults: 95% confidence interval (CI) from −0.26 to 0.11, $P = 0.41$; and for older adults: 95% CI from −0.17 to 0.31, $P = 0.55$. Therefore, randomization was accepted as satisfactory for both age categories.

Acquisition Phase

The dependent measure RMS*rel* is plotted as a function of feedback timing conditions and blocks in Figure 2.

The first part of the analysis concerned the two-way ANOVA (feedback condition × block) for repeated measures on the second factor. This was done separately for the age categories young and older adults. Concerning the young adults, a statistical significant main effect for block was found, $F = 7.82$, $P = 0.00$. No statistical significant main effect for feedback condition, $F = 0.24$, $P = 0.63$, and no interaction effect (feedback condition × block) was found, $F = 1.00$, $P = 0.39$. Concerning the older adults, no statistical significant effects were found on main effect for block, $F = 1.19$, $P = 0.33$, main effect for feedback condition, $F = 0.02$, $P = 0.90$, and interaction effect, $F = 1.11$, $P = 0.35$.

The second part of the analysis consisted of the two-way ANOVA (age category × block) for repeated measures on the second factor, performed separately for the feedback timing conditions concurrent and terminal. The concurrent condition showed a statistical significant main effect for block, $F = 3.24$, $P = 0.04$, and for age category, $F = 9.53$, $P = 0.01$. No statistical significant interaction effect (age category × block) was found, $F = 0.03$, $P = 0.98$. The terminal condition only showed a statistical significant main effect for age category, $F = 6.40$, $P = 0.02$. No statistical significant effects were found on main effect for block, $F = 2.01$, $P = 0.16$, and interaction effect, $F = 3.15$, $P = 0.06$.

Retention Phase

Again, two parts of analysis were performed. The first part that was performed separately for both age categories concerned the two-way ANOVA (feedback condition × block) for repeated measures on the second factor. For young adults, no statistical significant effects were found on main effect for block, $F = 2.20$, $P = 0.16$, main effect for feedback condition, $F = 0.31$, $P = 0.56$, and interaction effect, $F = 0.10$, $P = 0.75$; and for older adults on main effect for block, $F = 0.24$, $P = 0.63$, main effect for feedback condition, $F = 0.09$, $P = 0.77$, and interaction effect, $F = 1.17$, $P = 0.30$.

The second part of the analysis consisted of the two-way ANOVA (age category × block) for repeated measures on the second factor, performed separately for the feedback timing conditions. The feedback timing conditions only showed a statistical significant main effect for age category; concurrent condition, $F = 21.38$, $P = 0.00$, and terminal condition, $F = 8.00$, $P = 0.01$. For concurrent condition, no statistical significant effects were found on main effect for block, $F = 1.44$, $P = 0.25$, and interaction effect, $F = 0.02$, $P = 0.91$; and for terminal condition on main effect for block, $F = 0.62$, $P = 0.45$, and interaction effect, $F = 2.06$, $P = 0.17$.

DISCUSSION

The present study compared the effects of timing of myofeedback on learning muscle relaxation in two age categories (young and older adults). Due to the small simple size used in this study, we must be cautious when interpreting the data. This is especially the case in the group of older adults because aging is a highly personal process, with individuals possiblly being different from each other.[4]

As expected and indicated by the significant main effect for block during baseline and acquisition, young adults succeeded to lower their muscle activity while performing the gross motor task; that is, they improved their performance. In contrast, older adults did not improve their performance of the relaxation task. No statistical significant main effect for block was found. The latter result is in contrast to the findings of Hermens and Hutten.[16] Their study indicated that the use of myofeedback can result in a change of trapezius muscle activation pattern in patients with work-related musculoskeletal pain. Palmerud et al.[25] showed that a redistribution of activity takes place as the subject endeavors to minimize the signal level from the trapezius muscle. We expected that healthy subjects were also able to change this muscle activation pattern in the completion of a given task as was reflected in the study by Voerman et al.[18] Apparently, this was just the case for young adults and not older.

To explain this lack of improvement in older adults, it can be argued that the provided information about the muscle activity (myofeedback) used in the present study was too complicated for older adults to interpret. The age-related changes in cognitive processing[3] possibly hindered them to comprehend this specific information and use it to improve their performance. In addition to this argument, Swinnen et al.[26] argued that learning new motor skills in older adults is more susceptible to the influence of previous learning than it is for younger adults. Old habits, over learned tasks, and naturally preferred or automated processes seem particularly difficult for older adults to inhibit when trying to perform tasks in which these processes must be suppressed.

The first purpose of the present study was to examine whether concurrent or terminal timing of augmented feedback is most effective in facilitating motor skill learning. Regardless of age, no significant interaction effects were found between the two feedback timing conditions on both acquisition and retention phase. These results do not support the predictions based on the guidance hypothesis, according to which the dependence on augmented feedback can be decreased by reducing the availability of the feedback.[14,15]

In accordance with the present results, Wishart and Lee[12] encountered a similar failure to replicate previous findings based on the guidance hypothesis. They found for both young and older adults that relative frequency conditions of augmented feedback do not have a differential influence on learning a motor skill during any phase of the experiment. Also, Mulder and Hulstijn[27] showed no difference between the effect of concurrent and terminal myofeedback in learning voluntary abduction of the big toe. They suggested that the timing of feedback is not the main factor in myofeedback, but rather the specificity of the information.

In the present study, the lack of differences between the two feedback timing conditions could be caused by the response complexity of the task. The relaxation task used in this study is very different from the tasks that were typically used in motor learning research.[1,2] Motor learning research usually concerns simple, one-dimensional tasks that generally require little response complexity. The task in this study requires an interaction between more influential factors like actual performance factors (posture, placement of the bottle, and pace of the movement according to the metronome) and physiologic factors (stress, muscle fatigue, and energy level). In accordance with this, Swinnen[8] challenged in a review the current understanding of the detrimental guiding role of augmented feedback on motor learning in that the role of feedback may be quite task (and subject) specific.

The second purpose of the present study was to examine the combined effect of age and timing of augmented feedback on motor skill learning. Regardless of the timing condition of myofeedback, young subjects performed the task with lower muscle activity than older adults did both during the acquisition trials (when myofeedback was provided) and during the retention trials (when myofeedback was withheld) as illustrated in Figure 2 and by the significant main effects for age category. In accordance with the present results, Laursen et al.[28] found in their study higher levels of EMG activity in older adults compared with young adults. Their explanation was that the changed motor control in older adults necessitates an increased muscle activity. The higher levels of EMG activity indicate a relatively higher effort of the older adults. Considering that the absolute mechanical load was very similar for both age categories, a decrease in mechanical output of the muscles might contribute to this finding.

Based on previous results of studies examining the combined effect of age and learning variables on motor skill learning,[9–12] we expected no differences in the manner motor learning was facilitated by the variable timing of augmented feedback for both age categories. The absence of any interactions of age with the timing conditions supports the contention that older subjects used the concurrent and terminal timing conditions in a similar manner as young adults did. However, because older adults did not improve their performance throughout the experiment, this finding should be interpreted with caution. The chosen task did not illustrate the effects of timing of augmented feedback for the older adults, that is, either timing condition was equally helpful to young adults, while neither was helpful for older adults.

From motor learning research, there is evidence that as task complexity increases, the differences in motor performance between young and older adults increase.[29] It is possible that a more complex motor task (like the specific tasks used in the present study and in the study by Wishart et al.[13]) would elucidate the age-related changes in the use of learning variables. Further research is needed to examine the role of augmented feedback on the learning of motor skills in older adults, particularly as it relates to the complexity of the specific motor tasks. Perhaps using another less complicated type of feedback, older adults are able to improve the relaxation task as presented in this study. The impact of the present study on the use of myofeedback systems (e.g., as used by Hermens and Hutten[16]) is that the treatment program should be carefully evaluated (and possibly adjusted) when treating older patients to increase their level of muscle rest.

ACKNOWLEDGMENTS

This study was supported by a grant from the department of Economical affairs provided to the ExO-Zorg project.

REFERENCES

1. Magill RA: *Motor Learning: Concepts and Applications*, 6th ed. New York, McGraw-Hill, 2001
2. Schmidt RA, Lee TD: *Motor Control and Learning: A Behavioral Emphasis*, 4th ed. Champaign, Human Kinetics, 2005
3. Salthouse TA: *Theoretical Perspectives on Cognitive Aging*. Hillsdale: Lawrence Erlbaum Associates; 1991
4. Spirduso WW: *Physical Dimensions of Aging*. 2nd ed. Champaign: Human Kinetics; 2005
5. Mulder T, Hulstijn W: Sensory feedback therapy and theoretical knowledge of motor control and learning. *Am J Phys Med* 1984;63:226–44
6. Newell KM: Motor skill acquisition. *Annu Rev Psychol* 1991; 42:213–37
7. Salmoni AW, Schmidt RA, Walter CB: Knowledge of results and motor learning: a review and critical reappraisal. *Psychol Bull* 1984;95:355–86
8. Swinnen SP: Information feedback for motor skill learning: a review, in Zelaznik HN, (ed): *Advances in Motor Learning and Control*. Champaign, Human Kinetics, 1996, pp. 36–66
9. Carnahan H, Vandervoort AA, Swanson LR: The influence of summary knowledge of results and aging on motor learning. *Res Q Exerc Sport* 1996;67:280–7
10. Swanson LR, Lee TD: Effects of aging and schedules of knowledge of results on motor learning. *J Gerontol* 1992; 47:406–11
11. Wiegand RL, Ramella R: The effect of practice and temporal location of knowledge of results on the motor performance of older adults. *J Gerontol* 1983;38:701–6
12. Wishart LR, Lee TD: Effects of aging and reduced relative frequency of knowledge of results on learning a motor skill. *Percept Mot Skills* 1997;84(3Pt1):1107–22
13. Wishart LR, Lee TD, Cunningham SJ, Murdoch JE: Age-related differences and the role of augmented visual feed-

back in learning a bimanual coordination pattern. *Acta Psychol (Amst)* 2002;110:247–63

14. Park JH, Shea CH, Wright DL: Reduced-frequency concurrent and terminal feedback: a test of the guidance hypothesis. *J Mot Behav* 2000;32:287–96
15. Winstein CJ, Pohl PS, Cardinale C, Green A, Scholtz L, Waters CS: Learning a partial-weight-bearing skill: effectiveness of two forms of feedback. *Phys Ther* 1996;76:985–93
16. Hermens HJ, Hutten MM: Muscle activation in chronic pain: its treatment using a new approach of myofeedback. *Int J Ind Ergon* 2002;30:325–36
17. Vollenbroek-Hutten MM, Hermens HJ, Voerman GE, Sandsjo L, Kadefors R: Are changes in pain induced by myofeedback training related to changes in muscle activation patterns in patients with work-related myalgia? *Eur J Appl Physiol* 2004;8
18. Voerman GE, Sandsjo L, Vollenbroek-Hutten MM, Groothuis-Oudshoorn CG, Hermens HJ: The influence of different intermittent myofeedback training schedules on learning relaxation of the trapezius muscle while performing a gross-motor task. *Eur J Appl Physiol* 2004;93:57–64
19. Faucett J, Garry M, Nadler D, Ettare D: A test of two training interventions to prevent work-related musculoskeletal disorders of the upper extremity. *Appl Ergon* 2002;33:337–47
20. Wærsted M, Westgaard RH: An experimental study of shoulder muscle activity and posture in a paper version versus a VDU version of a monotonous work task. *Int J Ind Ergon* 1997;19:175–85
21. Hermens HJ, Freriks B, Merletti R, et al: European Recommendations for Surface ElectroMyography, Results of the SENIAM Project. Enschede: Roessingh Research and Development, 1999
22. Nederhand MJ, IJzerman MJ, Hermens HJ, Baten CT, Zilvold G: Cervical muscle dysfunction in the chronic whiplash disorder grade II (WAD-II). *Spine* 2000;25:1938–43
23. Basmaijan JV, De Luca CJ: *Muscles Alive. Their Functions Revealed by Electromyography.* 5th ed. Baltimore, Williams & Wilkins, 1985
24. Mathiassen SE, Winkel J, Hägg GM: Normalization of surface EMG amplitude from the upper trapezius muscle in ergonomic studies: a review. *J Electromyogr Kinesiol* 1995;4:197–226
25. Palmerud G, Sporrong H, Herberts P, Kadefors R: Consequences of trapezius relaxation on the distribution of shoulder muscle forces: an electromyographic study. *J Electromyogr Kinesiol* 1998;8:185–93
26. Swinnen SP, Verschueren SM, Bogaerts H, et al: Age-related deficits in motor learning and differences in feedback processing during the production of a bimanual coordination pattern. *Cogn Neuropsychol* 1998;15:439–66
27. Mulder T, Hulstijn W: Delayed sensory feedback in the learning of a novel motor task. *Psychol Res* 1985;47:203–9
28. Laursen B, Jensen BR, Ratkevicius A: Performance and muscle activity during computer mouse tasks in young and elderly adults. *Eur J Appl Physiol* 2001;84:329–36
29. Light KE, Spirduso WW: Effects of adult aging on the movement complexity factor of response programming. *J Gerontol* 1990;45:107–9

How to Obtain CME Category 1 Credits

To obtain CME Category 1 credit, this educational activity must be completed and postmarked by December 31, 2007. Participants may read the article and take the exam issue by issue or wait to study several issues together. After reading the CME Article in this issue, participants may complete the Self-Assessment Exam by answering the questions on the CME Answering Sheet and the Evaluation pages, which appear later in this section. Send the completed forms to: Bradley R. Johns, Managing Editor, CME Department-AAP, *American Journal of Physical Medicine & Rehabilitation*, 7240 Fishback Hill Lane, Indianapolis, IN 46278. Documentation can be received at the AAP National Office at any time throughout the year, and accurate records will be maintained for each participant. CME certificates are issued only once a year in January for the total number of credits earned during the prior year.