CHAPTER

The Content of Augmented Feedback

Concept: Augmented feedback can be given in a variety of ways

APPLICATION

When you help a person learn or relearn a skill, do you ever think about the augmented feedback you provide? For example, when you give a person verbal feedback, how do you decide what to tell the person? If the person is making a lot of mistakes while performing the skill, how many mistakes do you tell him or her about and which do you choose? Do you ever consider that there may be more effective ways to provide augmented feedback? Can you state the advantages, disadvantages, or limitations of these various means?

Consider the following situations. Suppose that you are teaching a golf swing to a class, or working in a clinic with a patient learning to walk with an artificial limb. In each situation, the people practicing these skills can make lots of mistakes and will benefit from receiving augmented feedback. When they make mistakes, which they do in abundance when they are beginners, how do you know which mistakes to tell them to correct on subsequent attempts? If you had a video camera available, would you videotape them and then let them watch their own performances? Or would it be even more beneficial to take the videotapes and have them analyzed so that you could show them what their movements looked like kinematically? There are many alternative methods you can use to provide augmented feedback. But before you as the instructor, coach, or therapist use any one of these, you should know how to implement that method most effectively and when to use it to facilitate learning.

All of these points relate to a fundamental issue confronting every person involved in motor skill instruction, regardless of setting or type of skill. The issue is how to provide adequate information for the learner's optimal benefit. In the following discussion the goal is to increase your understanding of the variety of ways it is possible to give augmented feedback.

DISCUSSION

In this discussion, we will focus on important issues concerning the content of augmented feedback, and then examine several types of augmented feedback that professionals can use in instructional settings. Before we look at these, we will consider a characteristic of augmented feedback that has direct bearing on the choice of type and content of augmented feedback an instructor makes in any situation.

Augmented Feedback Directs Attention

When deciding the type and content of augmented feedback to give, an instructor must consider this:

A CLOSER LOOK

KP about Certain Features of a Skill Helps Correct Other Features

Participants in an experiment by den Brinker, Stabler, Whiting, and van Wieringen (1986) learned to perform on the slalom ski simulator. Their three-part goal was to move the platform from left to right as far as possible at a specific high frequency, and with a motion that was as fluid as possible. On the basis of these performance goals, each of three groups received a different type of information as KP after each trial. Researchers told participants in one group the *distance* they had moved the platform; they told another group's participants how close they were to performing at the criterion platform movement *frequency;* and they told participants in the third group how fluid their movements were (i.e., fluency). All three groups practiced for four days, performing six 1.5-min trials each day, with a test trial before and after each day's practice trials. Early in practice, the type of KP an individual received influenced only the performance measure specifically related to that feature of performing the skill. However, on the last two days of practice, KP about *distance* caused people to improve all three performance features. Thus, giving KP about one performance feature led to improvement not only of that one, but also of the two other performance features.

the feedback will influence how the learner directs his or her attention while performing a skill. Recall from our discussion of Kahneman's model of attention (chapter 8) that an influential factor in determining how attention capacity is allocated is what Kahneman called "momentary intentions." Augmented feedback can serve as a type of momentary intention, because it can direct the individual's attention to a particular feature of performing the skill.

Because of the attention-directing influence of augmented feedback, it is important to make sure that the feedback you give directs the person's attention to the particular aspect of the skill that, if improved, will improve the performance of the entire skill or the part of the skill the person is trying to improve. For example, suppose you are teaching a child to throw a ball at a target. Also suppose this child is making many errors, as is typical of beginners. The child may be looking at his or her hand, stepping with the wrong foot, releasing the ball awkwardly, or not rotating the trunk. Probably the most fundamental error is not looking at the target. This, then, is the error about which you should provide feedback, because it is the part of the skill to which you want the child to direct his or her attention. It is the part of the skill that, if corrected, will have an immediate, significant, positive influence on performance. By correcting this error, the child undoubtedly will also correct many of the other errors that characterize his or her performance.

Augmented Feedback Content Issues

We will consider here four issues related to the content of augmented feedback. Each of these concerns some of the kinds of information augmented feedback may contain.

Information about errors versus correct aspects of performance. A continuing controversy about augmented feedback content is whether the information the instructor conveys to the learner should concern the mistakes he or she has made or those aspects of the performance that are correct. The answer to this question is difficult to determine, primarily because of the different roles augmented feedback can play in the skill acquisition process. When the instructor is giving error information, augmented feedback is functioning in its informational role related to facilitating skill improvement. On the other hand, when the instructor is telling a person what he or she did correctly, augmented feedback has a more motivational role.

Research evidence consistently has shown that *error information* is more effective for encouraging skill improvement. This evidence supports an important hypothesis by Lintern and Roscoe (1980), which was an expanded version of one originally proposed many years earlier by Annett (1959). The hypothesis is that focusing on what is done correctly while learning a skill, especially in the early stage of learning, is not sufficient by itself to produce optimal learning. Rather, the experience the person has in correcting errors by operating on error-based augmented feedback is especially important for skill acquisition.

Another way of looking at this issue is to consider the different roles augmented feedback plays. Error information directs a person to change certain performance characteristics; this in turn facilitates skill acquisition. On the other hand, information indicating that the person performed certain characteristics correctly tells the person that he or she is on track in learning the skill and encourages the person to keep trying. When we consider augmented feedback from this perspective, we see that whether this feedback should be about errors or about correct aspects of performance depends on the goal of the information. Error-related information works better to facilitate skill acquisition, whereas information about correct performance serves better to motivate the person to continue.

It makes good sense to provide both error-based and correct performance information during practice. The real question of importance, then, concerns the optimal proportion of each type. Although some sport pedagogists (e.g., Docheff, 1990) have suggested that some combination of both types of information is beneficial, no research results exist on which we can base an answer to this question. A conclusion on whether there is an optimal combination to facilitate skill learning awaits experimental study. However, until such evidence is available it seems that the use of some combination is an excellent way to involve both roles of augmented feedback in a skill learning setting.

KR versus KP. Two relevant questions concerning the comparison of the use of KR and KP in skill learning situations are: Do practitioners use one of these forms of augmented feedback more than the other? Do they influence skill learning in similar or different ways?

Most of the evidence addressing the first question comes from the study of physical education teachers in actual class situations. The best example is a study by Fishman and Tobey (1978). Although their study was conducted many years ago, it is representative of more recent studies, and it involves the most extensive sampling of teachers and classes of any study that has investigated this question. Fishman and Tobey observed teachers in eighty-one classes teaching a variety of physical activities. The results showed that the teachers overwhelmingly gave KP (94 percent of the time) more than KR. The majority of the KP statements (53 percent) were appraisals of students' performance, and 41 percent of the statements involved instructions on how to improve performance on the next trial. It is also worth noting that teachers gave praise or criticism 5 percent of the time.

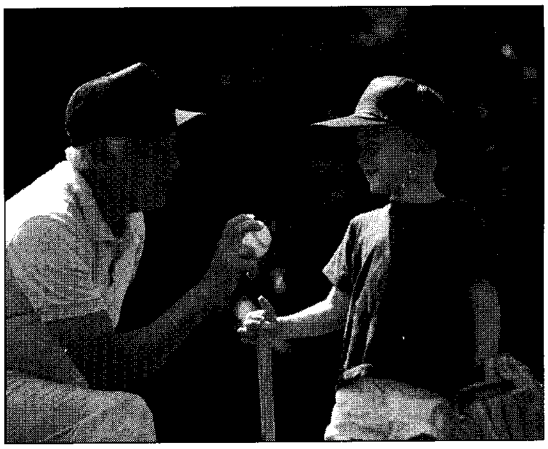
These results from physical education teachers seem to be in line with what occurs in other motor skill instructions contexts. Discussions with coaches and physical and occupational therapists would undoubtedly yield similar KP and KR percentages.

An answer to the second question, concerning the relative effectiveness of KR and KP, is more difficult to provide because of the lack of sufficient and conclusive evidence from research investigating this question. The following four examples of experiments illustrate the problem and provide some insight into a reasonable answer.

Two of the experiments indicate that KP is better than KR to facilitate motor skill learning. Kernodle and Carlton (1992) compared videotape replays and verbally presented technique statements as KP with KR in an experiment in which participants practiced throwing a soft, spongy ball as far as possible with the nondominant arm. KR was presented as the distance of the throw for each practice trial. The results showed that KP led to better throwing technique and distance than KR. Zubiaur, Oña, and Delgado (1999) reported a similar conclusion in a study in which university students with no previous volleyball experience practiced the overhead serve in volleyball. KP was specific information about the most important error to correct as it related either to action before hitting or in hitting the ball. KR referred to the outcome of the hit in terms of the ball's spatial precision, rotation, and flight. The results indicated that KP was more influential for learning the serve.

The other two experiments presented evidence that demonstrates the benefit of both KR and KP for learning a skill. Brisson and Alain (1997) reported an experiment in which the task required participants to learn a complex spatial-temporal arm movement pattern. The goal was to produce the most efficient arm movement pattern to connect four targets on the computer monitor within a criterion amount of time. One group received KP after each trial as the displacement profile for that trial. Another group received the same KP but also saw a superimposed image of the most efficient spatial pattern. A third group received KP (without the superimposed pattern) and KR, which was the total absolute timing and amplitude error for the trial. Finally, a fourth group saw the KP with the superimposed pattern and KR. Results showed that KR was an influential variable for learning the criterion pattern because both groups that received KR in addition to KP learned the pattern better than those that did not receive KP. The authors concluded that participants used KR as a reference for interpreting KP.

Finally, a study by Silverman, Woods, and Subramaniam (1999) provided additional evidence for the benefit of both KR and KP for skill learning, but in a slightly different way. Rather than evaluate the effectiveness of each form of augmented feedback on the basis of how well participants learned the skill, they compared how each related to how often students in physical education classes would engage in successful and unsuccessful practice trials during a class. The researchers observed eight middle school teachers teach two classes each, which involved skill instruction in various sport-related activities. The results indicated that teacher feedback as KR, which was teacher feedback about performance outcome, and as KP about a particular part of a skill performance, showed relatively high correlations with the frequency of students engaging in successful practice trials (0.64 and 0.67, respectively). Interestingly, KP about multiple components of a skill performance correlated notably lower at 0.49.



When giving verbal KP, it is important to provide information that is meaningful to the person to whom it is given.

Although these four studies do not provide a clear-cut answer to the question about the relative effectiveness of KR and KP, they indicate that *both forms of augmented feedback can be valuable* in skill learning sessions. But, as was discussed in the previous chapter, the importance of augmented feedback for learning skills depends on specific characteristics of the skill and the learner. The same conclusion can be made with respect to the relative importance of KR and KP. With this in mind, consider the following hypotheses about conditions in which each of these forms of augmented feedback would be beneficial. At present, these hypotheses, and undoubtedly others, await empirical investigations to determine their validity.

KR will be beneficial for skill learning for at least four reasons: (1) Learners often use KR to confirm their own assessments of the task-intrinsic feedback, even though it may be redundant with task-intrinsic feedback. (2) Learners may need KR because they cannot determine the outcome of performing a skill on the basis of the available task-intrinsic feedback. (3) Learners often use KR to motivate them to continue practicing the skill. (4) Practitioners may want to provide only KR in order to establish a discovery learning practice environment in which learners are encouraged to engage in trial and error as the primary means of learning to perform a skill.

On the other hand, KP can be especially beneficial when: (1) Skills must be performed according to specified movement characteristics, such as gymnastics stunts or springboard dives. (2) Specific movement components of skills that require complex coordination must be improved or corrected. (3) The goal of the action is a kinematic, kinetic, or specific muscle activity. (4) KR is redundant with the task-intrinsic feedback.

Qualitative versus quantitative information. Augmented feedback can be qualitative, quantitative, or both. If the augmented feedback involves a numerical value related to the magnitude of some performance characteristic, it is called **quantitative augmented feedback.** In contrast, **qualitative augmented feedback** is information referring to the quality of the performance characteristic without regard for the numerical values associated with it.

For verbal augmented feedback, it is easy to distinguish these types of information in performance situations. For example, a therapist helping a patient to increase gait speed could give that patient qualitative information about the latest attempt in statements such as these: "That was faster than the last time"; "That was much better"; or "You need to bend your knee more." A physical education teacher or coach teaching a student a tennis serve could tell the student that a particular serve was "good," or "long," or could say something like this: "You made contact with the ball too far in front of you." On the other hand, the therapist could give the patient quantitative verbal augmented feedback using these words: "That time you walked 3 sec faster than the last time," or "You need to bend your knee 5 more degrees." The coach could give quantitative feedback to the tennis student like this: "The serve was 6 cm too long," or "You made contact with the ball 10 cm too far in front of you."

Therapists and instructors also can give quantitative and qualitative information in nonverbal forms of augmented feedback. For example, the therapist could give qualitative information to the patient we have described by letting him or her hear a tone when the walking speed exceeded that of the previous attempt, or when the knee flexion achieved a target amount. The teacher or coach could give the tennis student qualitative information in the form of a computer display that used a moving stick figure to show the kinematic characteristics of his or her serving motion. Those teaching motor skills often give nonverbally presented quantitative information in combination with qualitative forms. For example, the therapist could show a patient a computer-based graphic representation of his or her leg movement while walking along, displaying numerical values of the walking speeds associated with each attempt, or the degree of knee flexion observed on each attempt. We could describe similar examples for the tennis student.

How do these two types of augmented feedback information influence skill learning? Motor learning researchers traditionally have investigated this question in experiments designed to address the *precision* of verbally presented KR. In doing so, they have assumed that quantitative KR is more precise than qualitative KR. The traditional view is that quantitative is superior to qualitative information for skill learning. However, researchers have been questioning this conclusion following a reassessment by Salmoni, Schmidt, and Walter (1984) of the research on which the conclusion is based. They showed that most of the experiments investigating the precision issue did not include retention or transfer tests.

Consider the following experiment as an example of a more appropriate conclusion about the precision effect. Each participant in an experiment by Magill and Wood (1986) learned to move his or her arm through a series of wooden barriers to produce a specific six-segment movement pattern. Each seg-

A CLOSER LOOK

Quantitative versus Qualitative Augmented Feedback and the Performance Bandwidth Technique

Cauraugh, Chen, and Radlo (1993) had subjects practice a timing task in which they had to press a sequence of three keys in 500 msec. Participants in one group received quantitative KR about their movement times (MT) when MT was *outside* a 10 percent performance bandwidth. A second group, in the reverse of that condition, received quantitative KR only when MT was *inside* the 10 percent performance bandwidth. Two additional groups had participants "yoked" to individual participants in the outside and inside bandwidth conditions. Members of these two groups received KR on the same trials their "yoked" counterparts did. This procedure provided a way to have two conditions with the same frequency of augmented feedback, while allowing a comparison between bandwidth and no-bandwidth conditions.

In terms of KR frequency, those in the outside bandwidth condition received quantitative KR on 25 percent of the sixty practice trials; those in the inside condition received KR on 65 percent of the trials. The interesting feature of this difference is that the remaining trials for both groups were implicitly qualitative KR trials, because when they received no KR, the participants knew that their performance was "good" or "not good." The retention test performance results showed that the two bandwidth conditions did not differ, but both yielded better learning than the no-bandwidth conditions. These results show that establishing performance bandwidths as the basis for providing quantitative KR yields an interplay between quantitative and qualitative KR that facilitates skill learning.

ment had its own criterion movement time, which participants had to learn. Following each of 120 practice trials, participants received either qualitative KR for each segment (i.e., "too fast," "too slow," or "correct") or quantitative KR for each segment (i.e., the number of msec too fast or too slow). Performance for the first sixty trials showed no difference between the two types of information. However, during the final sixty trials and on the twenty no-KR retention trials, quantitative-KR resulted in better performance than qualitative.

From these results we can conclude that people in the early stage of learning give attention primarily to the qualitative information, even if they have quantitative information available. The advantage of this attention focus is that the qualitative information provides an easier way to make a first approximation of the required movement. Put another way, this information allows learners to control more easily the many degrees of freedom and produce an action that is "in the ballpark" of what they need to do. After they achieve this "ballpark" action, quantitative information becomes more valuable to them, because it enables them to refine the action to make it more effective for achieving the action goal. In terms of Gentile's learning stages model, qualitative information can allow a person to "get the idea of the movement," but the learner needs quantitative information in the next stage to achieve its fixation or diversification goals.

Augmented feedback based on performance bandwidths. A question that has distinct practical appeal is, How large an error should a performer make before the instructor or therapist gives augmented

quantitative augmented feedback augmented feedback that includes a numerical value related to the magnitude of a performance characteristic (e.g., the speed of a pitched baseball).

qualitative augmented feedback augmented feedback that is descriptive in nature (e.g., using such terms as *good, long*), and indicates the quality of performance.

feedback? To many teachers and therapists, it seems reasonable to provide feedback only when errors are large enough to warrant attention. This practice suggests that in many skill learning situations, teachers or therapists develop **performance bandwidths** that establish tolerance limits specifying when they will or will not give augmented feedback. When a person performs within the tolerance limits of the bandwidth, the teacher or therapist does *not* give augmented feedback. But if the person makes an error that is out side that limit, the person instructing does give feedback.

Research supports the effectiveness of the performance bandwidth approach. For example, in the first reported experiment investigating this procedure, Sherwood (1988) had subjects practice a rapid elbow-flexion task with a movement-time goal of 200 msec. Participants in one group received KR about their movement-time error after every trial, regardless of the amount of error (i.e., 0 percent bandwidth). Participants in two other groups received KR only when their error exceeded bandwidths of 5 percent and 10 percent of the goal movement time. The results of a no-KR retention test showed that the 10 percent bandwidth condition resulted in the least amount of movement time variability (i.e., variable error), whereas the 0 percent condition resulted in the most variable error. Other researchers have replicated these results (see, e.g., Lee, White, & Carnahan, 1990; Cauraugh, Chen, & Radlo, 1993).

An important question related to implementing the performance-bandwidth technique in skill learning situations concerns its relationship with the learner's stage of learning. It might seem reasonable, for example, to reduce the size of the error bandwidth as the learner advances from an early to a later stage of learning. However, at least two experiments have demonstrated that this type of reduction is not necessary. Goodwin and Meeuwsen (1995) compared a 0 percent and a 10 percent bandwidth for all practice trials with expanding (0-5-10-15-20 percent) and contracting (20-15-10-5-0 percent) bandwidths for learning a golf putting task. Their results, which can be seen in figure 17.1, indicated that changing the bandwidth size during practice did not provide any additional learning benefit. In fact, both the expanding and constant 10 percent bandwidth conditions produced similar performance on a 48-hour retention test, and were superior to the contracting and 0 percent bandwidth conditions. Others have reported similar evidence that the changing of bandwidth sizes during practice does not improve learning beyond the level achieved with a constant bandwidth during practice (e.g., Lai & Shea, 1999a).

Another practical issue concerning the use of the bandwidth technique relates to the instructions learners receive about the bandwidth procedure. This issue is relevant because when the learners receive no augmented feedback about their performance, the implicit message is that it was "correct." The instruction-related question here is: Is it important that the learner explicitly be told this information, or will the learner implicitly learn this information during practice? Butler, Reeve, and Fischman (1996) investigated this question by telling one group of participants that when they received no KR after a trial, their performance was "essentially correct." A second group was not told this information. The task required a two-segment arm movement to a target in a criterion movement time. The results showed that the bandwidth technique led to better learning when the participants knew in advance that not receiving KR meant they were essentially correct.

Erroneous augmented feedback. In the Discussion section in chapter 16, one of the ways that was described that could result in augmented feedback hindering learning was to provide people with erroneous information. While this statement may seem unnecessary because it seems to make such common sense, the statement gains importance when it is considered in the context of practicing a skill that can be learned *without* augmented feedback. In this skill learning situation, augmented feedback is redundant with the information available from task-intrinsic feedback. As a result, most people would expect that to provide augmented feedback would be a waste of time because it would not influence the learner. But, research evidence shows that this is not the case because even when augmented feedback is redundant information, learners, especially beginners, will use it rather than ignore it.

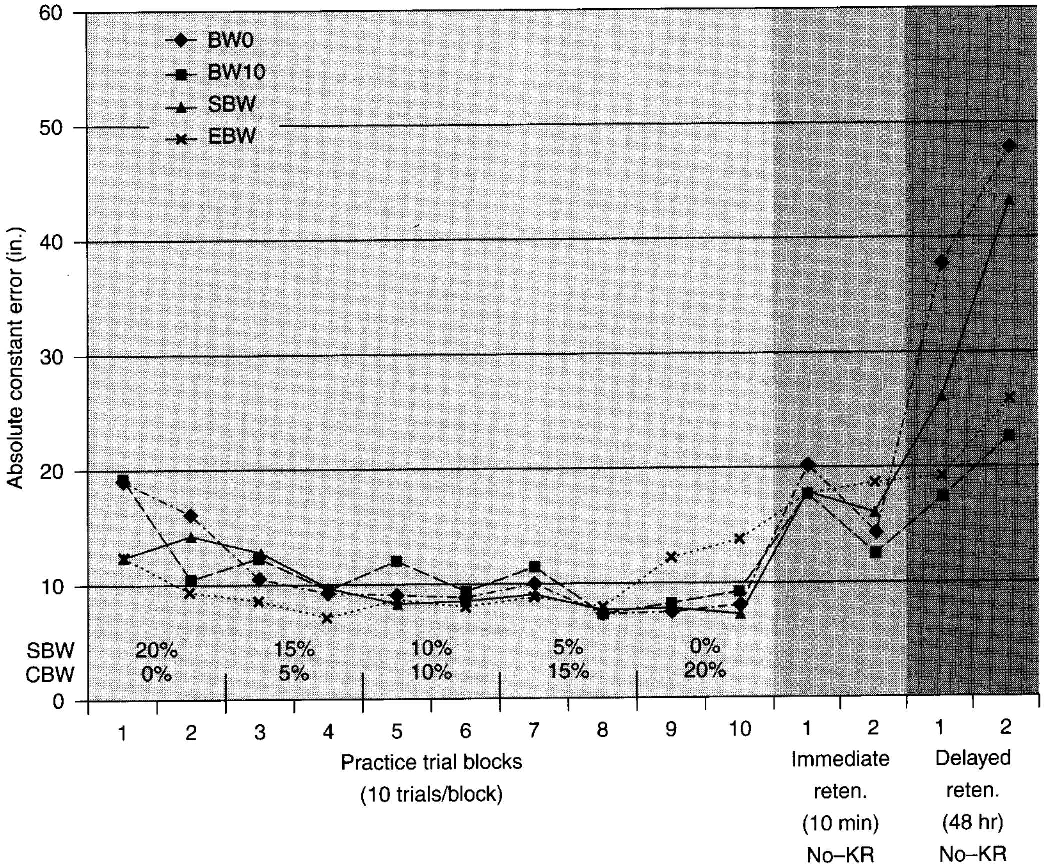


FIGURE 17.1 The results of the experiment by Goodwin and Meeuwsen, which compared four different performance-based bandwidth (BW) conditions for KR during the practice of a golf putting task. The BW0 is a 0 percent bandwidth, BW10 is a 10 percent bandwidth, SBW is a shrinking bandwidth, and EBW is an expanding bandwidth. Practice trial blocks show the mean of ten trials for each. The actual bandwidth for the SBW and EBW conditions are shown for each set of twenty trials. [Adapted from data in Goodwin, J. E., & Meeuwsen, H. J. (1995). Using bandwidth knowledge for results to alter relative frequencies during motor skill acquisition. *Research Quarterly for Exercise and Sport, 66,* 99–104.

One way to demonstrate this effect is to consider the influence of erroneous (i.e., incorrect) augmented feedback. The hypothesis is that if the learner ignores augmented feedback when it is redundant with task-intrinsic feedback, then the erroneous information should have no effect on learning the skill. But, if the learner uses the augmented feedback, then the erroneous information should influence learning in such a way that will bias the learner to perform according to the erroneous information.

The first test of this hypothesis was reported by Buekers, Magill, and Hall (1992). Participants practiced an anticipation timing task similar to the one

performance bandwidth in the context of providing augmented feedback, a range of acceptable performance error; augmented feedback is given only when the amount of error is greater than this tolerance limit.

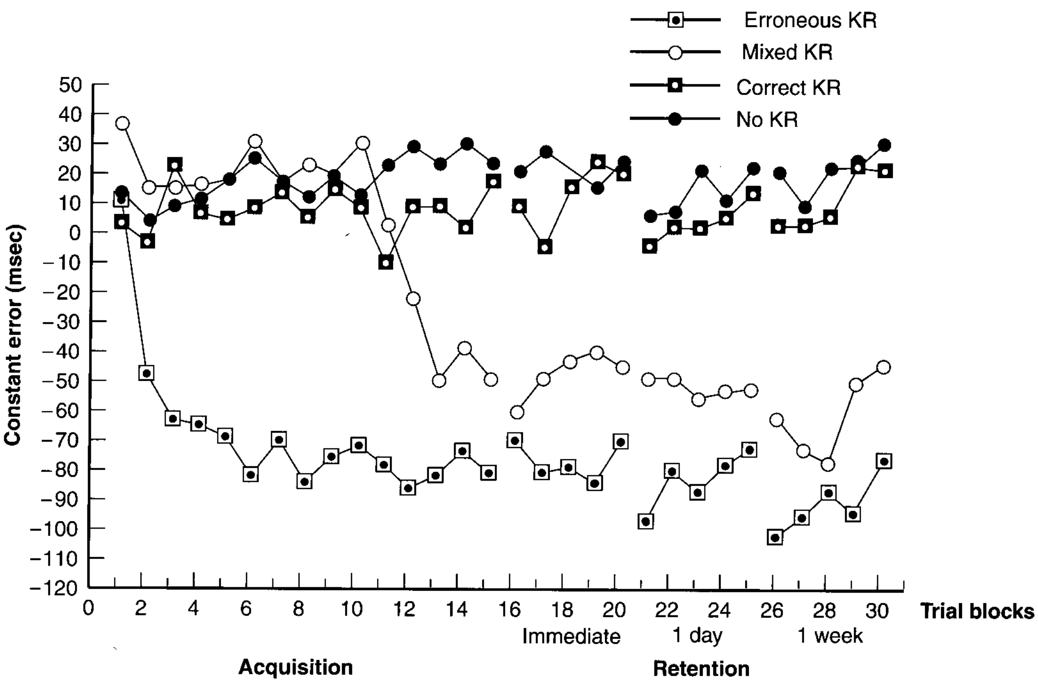


FIGURE 17.2 Results of the experiment by Buekers et al., showing the effects of erroneous KR compared to no KR and correct KR for learning an anticipation timing skill. Note that members of the mixed-KR group received correct KR for their first fifty trials and then received erroneous KR for their last twenty-five practice trials. [From Buekers, M. J., Magill, R. A., & Hall, K. G. (1992). The effect of erroneous knowledge of results on skill acquisition when augmented information is redundant. *Quarterly Journal of Experimental Psychology. 44* (A), 105–117. Reprinted by permission of The Experimental Psychology Society.]

used by Magill, Chamberlin, and Hall (1991), which was described in chapter 16 as a task for which KR about movement time error is not needed to learn the task. In the Buekers et al. (1992) experiment, three of four groups received KR after every trial. The KR was displayed on a computer monitor and indicated to the participants the direction and amount of their timing error. For one of these groups, KR was always correct. But for another group, KR was always erroneous by indicating that performance on a trial was 100 msec later than it actually was. The third KR group received correct KR for the first fifty trails, but then received the erroneous KR for the last twenty-five trials. A fourth group did not receive KR during practice. All four groups performed twenty-five trials without KR one day later, and then twenty-five more no-KR trials one week later. The results (Figure 17.2) showed two important findings. First, the correct- and the no-KR groups did not differ during the practice or the retention trials, which confirmed the KR redundancy results of the Magill et al. (1991) experiments. Second, the erroneous KR information led participants to perform according to the KR rather than according to the task-intrinsic feedback. This latter result suggested that the participants used KR, even though it was erroneous information. Even more impressive was that the erroneous KR influenced the group that had received correct KR for fifty trials and then was switched to the erroneous KR. After the switch, this group began to perform similarly to the group that had received the incorrect KR for all the practice trials. And the erroneous information not only influenced performance when it was available, it also influenced retention performance one day and one week later when no KR was provided. A subsequent experiment (McNevin, Magill, & Buekers, 1994) demonstrated that the erroneous KR also influenced performance on a no-KR transfer test in which participants were required to respond to a faster or slower speed than they practiced.

More recent investigations have focused on why erroneous KR affects learning a skill for which KR is redundant information. The most likely reason appears to be that beginners rely on augmented feedback to help them deal with their *uncertainty* about what the task-intrinsic feedback is telling them. For the anticipation timing task the uncertainty may exist because the visual task-intrinsic feedback is difficult to consciously observe, interpret, and use. Evidence for an uncertainty-based explanation has been demonstrated in experiments by Buekers, Magill, and Sneyers (1994), and Buekers and Magill (1995).

While practicing the anticipation timing task, beginners use the erroneous KR to adjust the timing of the initiation of their movement, rather than the movement component of the task (Van Loon, Buekers, Helsen, & Magill, 1998). This evidence further supports the view that even when augmented feedback is redundant with task-intrinsic feedback, beginners use augmented feedback. And it also tells us something about how beginners actually use the erroneous information. For the anticipation timing task, they use it to interpret, or calibrate, the visual task-intrinsic feedback, which means they use the augmented feedback to confirm their visual task-intrinsic feedback. When there is a conflict between these two sources of feedback, beginners resolve the conflict in favor of augmented feedback.

The important message for practitioners here is that people who are in the early stage of skill learning will use augmented feedback when it is available, whether it is correct or not. This is especially the case for skills for which the task-intrinsic feedback is difficult for beginners to interpret and use to improve performance. Because of their uncertainty about how to use or interpret task-intrinsic feedback, beginners rely on augmented feedback as a critical source of information on which to base movement corrections on future trials. As a result, instructors need to be certain that they provide correct augmented feedback, and establish a means for beginners to learn to use task-intrinsic feedback in a way that will enable them to eventually perform without augmented feedback. Beginning learners are of particular concern here because they will ignore their own sensory feedback sources, and adjust future performance attempts on the basis of the information the instructor provides to them, even though it may be incorrect.

From a learning theory perspective, this reliance on augmented feedback by learners in the early stage of learning suggests that cognitive information can override the perception-action link, which suggests that the perceptual motor control system does not "automatically" use task-intrinsic feedback appropriately. The perceptual component of this system appears to require some calibration. If augmented feedback is available, the learner uses this information to carry out this calibration process. However, if augmented feedback is not available, and if the task is one where augmented information is not necessary for learning the skill, then this calibration process appears to occur by means of trial-and-error experience occurring during practice.

Different Types of Knowledge of Performance

Most of the research on which we base our knowledge of augmented feedback and skill learning comes from laboratory experiments in which researchers gave KR to participants. Although most of the conclusions from that research also apply to KP, it is useful to look at some of the research that has investigated different types of KP. As discussed earlier teacher performance research indicates that most people engaging in motor skill instruction give KP more than they give KR. But, as movement analysis technology becomes more available, nonverbal forms of KP are becoming more prominent in skill acquisition settings. As a

A CLOSER LOOK

An Example of Basing Verbal KP on a Skill Analysis

In an experiment by Weeks and Kordus (1998), twelve-year-old boys who had no previous experience in soccer practiced a soccer throw-in. The participants' goal was to perform throw-ins as accurately as possible to a target on the floor. The distance to the target was 75 percent of each participant's maximum throwing distance. They received verbal KP on one of eight aspects of technique, which the researchers referred to as "form." Which aspect of form each participant received was based on the primary form problem identified for a throw-in. The researchers constructed a list of eight "form cues" on the basis of a skill analysis of the throw-in, and used this list to give verbal KP. The eight form cues were:

1. The feet, hips, knees, and shoulders should be aimed at the target, feet shoulder width apart.
2. The back should be arched at the beginning of the throw.
3. The grip should look like a "W" with the thumbs together on the back of the ball.
4. The ball should start behind the head at the beginning of the throw.
5. The arms should go over the head during the throw and finish by being aimed at the target.
6. There should be no spin on the ball during its flight.
7. The ball should be released in front of the head.
8. Feet should remain on the ground.

result, it is important to understand the influences on skill learning of various types of KP.

Verbal KP. One of the reasons practitioners give verbal KP more than verbal KR is that KP gives people more information to help them improve the movement aspects of skill performance. One of the problems that arises with the use of verbal KP is determining the appropriate content of what to tell the person practicing the skill. This problem occurs because skills are typically complex and KP usually relates to a specific feature of skill performance. The challenge for the instructor or therapist, then, is selecting the appropriate features of the performance on which to base KP.

To solve this problem, the first thing a teacher, coach, or therapist must do is perform a *skill analysis* of the skill being practiced. This means identifying the various component parts of the skill. Then, he or she should prioritize each part in terms of how critical it is for performing the skill correctly. Prioritize by listing the most critical part first, then the second most critical, and so on. To determine which part is most critical, decide which part of the skill absolutely must be done properly for the entire skill to be performed correctly. For example, in the relatively simple task of throwing a dart at a target, the most critical component is looking at the target. This part of the skill is the most critical because even if the beginning learner did all other parts of the skill correctly (which would be unlikely), there is a very low chance that he or she would perform the skill correctly without looking at the target. In this case, then, looking at the target would be first on the skill analysis priority list, and would be the first part of the skill assessed in determining what to give KP about.

After determining which aspect of the skill to give KP, the practitioner needs to decide the content of the statement to make to the learner. There are *two types of verbal KP statements.* A **descriptive KP** statement simply describes the error the performer has made. The other type, **prescriptive KP,** not only identifies the error, but also tells the person what to do to correct it. For example, if you tell a person, "You moved your right foot too soon," you describe only the problem. However, if you say, "You need to move your right foot at the same time you move your right arm," you also give prescriptive information about what the person needs to do to correct the problem.

Which type of KP better facilitates learning? Although there is no empirical evidence, common sense dictates that the answer varies with the stage of learning of the person practicing the skill. The statement, "You moved your right foot too soon," would be helpful to a beginner only if he or she knew that the right foot was supposed to move at the same time as the right arm. Thus, descriptive KP statements are useful to help people improve performance only once they have learned what they need to do to make a correction. This suggests that prescriptive KP statements are more helpful for beginners. For the more advanced person, a descriptive KP statement often will suffice.

Videotape as augmented feedback. The increasing use of videotape as augmented feedback argues for the need for instructors and therapists to know more about how to use it effectively.

It is common to find articles in professional journals that offer guidelines and suggestions for the use of videotape replays as feedback (e.g, Franks & Maile, 1991; Jambor & Weekes, 1995; Trinity & Annesi, 1996). However, very little empirical research exists that establishes the effectiveness of videotape replays as an aid for skill acquisition. In fact, the most recent extensive review of the research literature related to the use of videotape replay as a source of augmented feedback in skill learning situations was published many years ago by Rothstein and Arnold (1976). Their review included over fifty studies that involved eighteen different sport activities, including archery, badminton, bowling, gymnastics, skiing, swimming, and volleyball, among others. In most of these studies, the students were beginners, although some included intermediate- and advanced-level performers.

Despite the age of the review, current research and practice related to the use of videotape as augmented feedback tends to follow or is based on its general conclusions. Overall, Rothstein and Arnold reported that the results of the studies they reviewed were mixed with regard to the effectiveness of videotape as a means of providing augmented feedback. However, an important conclusion from that review was that the critical factor for determining the effectiveness of videotape as an instructional aid was the skill level of the student rather than the type of activity. For beginners to benefit from videotape replay, they required the assistance of an instructor to point out critical information. Advanced performers did not appear to need instructor aid as frequently, although discussions with skilled athletes suggests they receive greater benefit from observing replays when some form of attention-directing instructions are presented, such as verbal cues and checklists.

Kernodle and Carlton (1992) provided evidence that demonstrated the benefit of having an instructor point out what the observer of the videotape replay should look for. Participants practiced throwing a soft, spongy ball as far as possible with the nondominant arm. One group of participants received specific technique–related cues about what to look for on the videotape replays of each trial. Participants in a second group received this same information plus a verbal prescriptive KP statement that told them how to correct the technique problem. A third group watched only the video and received no cues or verbal KP. And a fourth group received verbal KR about the distance of each throw. The results showed that the participants in the two groups who received the specific technique

descriptive KP a verbal knowledge of performance (KP) statement that describes only the error a person has made during the performance of a skill.

prescriptive KP a verbal statement of knowledge of performance (KP) that describes errors made during the performance of a skill and states (i.e., prescribes) what needs to be done to correct them.

cues to look for while watching the videotape replays learned to throw the ball farther and with better technique than the other two groups.

Another conclusion about the use of videotape replay comes from research since the time of the Rothstein and Arnold review. Videotape replays *transmit certain types of performance-related information to the learner more effectively than other types.* One of the best examples of research evidence that supports this conclusion was an experiment conducted many years ago by Selder and Del Rolan (1979). They compared videotape replays and verbal augmented feedback (in the form of KP) in a study in which twelve-to-thirteen-year-old girls were learning to perform a balance beam routine. All the girls used a checklist to critically analyze their own performance after each trial. The verbal augmented feedback group used verbal KP to complete the checklist; the videotape feedback group completed the checklist after viewing videotape replays of each trial. Two results are especially noteworthy. After four weeks of practice, performance scores for the routine did not differ between the two groups. But at the end of six weeks of practice the videotape group scored significantly higher on the routine than the verbal feedback group. Second, when each factor of the total routine score was evaluated, the videotape group scored significantly higher on only four of the eight factors: precision, execution, amplitude, and orientation and direction. The two groups did not differ on the other four: rhythm, elegance, coordination, and lightness of jumping and tumbling. The importance of these results is that they demonstrate that although videotape replay can be effective, it does not facilitate the learning of all aspects of a complex motor skill.

The results of the Selder and Del Rolan study suggest that videotape replay facilitates the learning of those performance features that the performer can readily observe and determine how to correct on the basis of the videotape replay. However, for performance features that are not as readily discernible, videotape replay is not as effective as verbal KP.

A more recent study by Hebert, Landin, and Menickelli (1998) provided further evidence concerning the effectiveness of videotape replay but, more important, identified steps skilled athletes go through to use this information. Skilled college female tennis players who needed to improve their attacking stroke, either observed or did not observe videotape replays of their practice sessions. The performance results demonstrated that the players who observed the videotape replays improved more than the players who did not. And evidence from recordings of players' comments during videotape observation sessions and the researchers' field notes indicated that the players progressed through four stages in their use of the videotape replay information. During the first stage, players familiarized themselves with observing themselves on videotape and made general observations about how they personally looked on videotape as well as their technique. In the second stage, players began to recognize specific technical errors. The third stage was more analytical as the players made connections between technique and outcome. In the fourth stage, players began to show evidence of the use of their previous observations of replays by correcting their technique errors. As a result of this final stage, the players acknowledged what they considered to be the important key points related to successfully hitting the attack shot.

An alternative use of videotape replays as augmented feedback was demonstrated in an interesting study by Starek and McCullagh (1999). They showed adult beginning swimmers three-minute videotape replays of their swimming performance during the lesson of the previous day. The replay showed four swimming behaviors they had performed correctly, and four they had trouble performing. Then, some of the students saw only their own successfully performed skills from the previous day, whereas other students saw a skilled swimmer successfully perform these skills. The results showed that swimmers who saw their own videotaped performance performed better than those who saw the same skills performed by someone else. This use of videotape replay in which people see themselves performing a skill correctly is referred to as *self-modeling,* which combines modeling as a form of instruction with modeling as also a form of augmented feedback.

Movement kinematics as augmented feedback. With the widespread availability of computer software capable of providing sophisticated kinematic analysis of movement, it has become increasingly common to find sport skill instruction situations in which students can view graphically presented kinematic representations of their performances as a form of feedback. Unfortunately, as was the case with the use of videotape replays, there is very little empirical evidence that provides definitive answers to questions concerning the effectiveness of this means of providing augmented feedback. However, the few studies that have been reported provide some insight into the use of this form of augmented feedback.

One of the first studies to investigate the use of movement kinematics as augmented feedback did not involve a computer, and was carried out many years ago. However, this study is important because it illustrates the historical interest in this type of feedback, it involved a real-world training situation, and it exemplifies the positive effect that kinematic information can have on skill learning when it is used as augmented feedback. Lindahl (1945) investigated the methods used to train industrial machine operator trainees to precisely and quickly cut thin disks of tungsten with a machine that required fast, accurate, and rhythmic coordination of the hands and feet. The traditional approach to training for this job was a trial-and-error method. To assess an alternative method, Lindahl created a mechanism that would make a paper tracing of the machine operator's foot movement pattern during the cutting of each disk. During training, the trainers showed the trainees charts illustrating the correct foot action (see the top portion of figure 17.3), and periodically showed them tracings of their own foot action. The results (see the bottom portion of figure 17.3) indicated that this training method based on movement

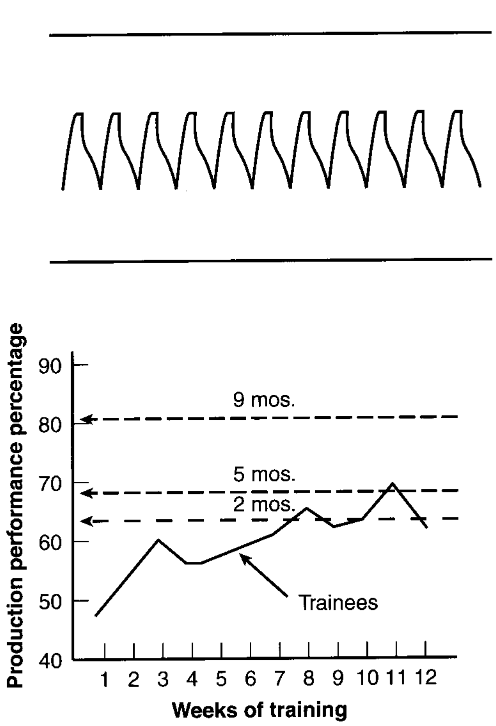


FIGURE 17.3 The upper panel illustrates the foot action required by the machine operator to produce an acceptable disk cut in the experiment by Lindahl. The graph at the bottom indicates the production performance achieved by the trainees using graphic information during twelve weeks of training. The dashed lines indicate the levels of performance achieved by other workers after two, five, and nine months of experience. [From Lindahl, L. G. (1945) Movement analysis as an industrial training method. *Journal of Applied Psychology, 29,* 420–436, American Psychological Association.]

kinematic information as augmented feedback enabled the trainees to achieve production performance levels in eleven weeks compared to the five months required by trainees who used the traditional trial-and-error method. In addition, the trainees reduced their percentage of broken cutting wheels to almost zero in twelve weeks, a level not achieved by those trained with the traditional method in less than nine months.

Most of the research evidence we have about the use of movement kinematics as augmented feedback comes from laboratory-based experiments (e.g., Hatze, 1976; Newell, Quinn, Sparrow, &

Walter, 1983). A comprehensive series of experiments reported by Swinnen and his colleagues serve as good examples of this research (Swinnen et al., 1990; Swinnen, Walter, Lee, & Serrien, 1993). Participants in these experiments practiced a bimanual coordination task that required them to move two levers at the same time, but with each lever requiring a different spatial-temporal movement pattern. Kinematic information was presented as augmented feedback in the form of the angular displacement characteristics for each arm superimposed over the criterion displacements. In several experiments, the kinematic augmented feedback was compared with various other forms of augmented feedback. The results consistently demonstrated the effectiveness of the displacement information as augmented feedback.

These laboratory-based experiments generalize very well to real-world skill learning contexts. For example, Wood, Gallagher, Martino, and Ross (1992) provided a good example of the use of graphically displayed movement kinematics for learning a sport skill. Participants practiced a full-swing golf shot with a five iron from a platform into a backstop net. A commercially marketed golf computer monitored the kinematics of the golf swing as the head of the club passed over light sensors on the platform. The computer assessed the velocity, displacement, and trajectory path of each swing and displayed this information on a monitor for learners in two groups. One group saw a template of an optimum pattern along with the kinematics; the other group did not see this template. A third group received kinematic information verbally in the form of numbers referring to kinematic outcomes of the swing. A fourth group received no augmented feedback. On a retention test given one week later without augmented feedback, the group that had observed the graphic presentation of the swing kinematics along with the optimum pattern template performed best.

Finally, it is important to point out that when teachers, coaches, and therapists use graphic displays of movement kinematics as augmented feedback, they should take the stage of learning into account. Beginners benefit from kinematic information only when they can interpret and use it to improve their own performance. Thus, it is useful to show a template of the kinematic goal to beginners. More skilled people can take advantage of more complex kinematic information.

Biofeedback as augmented feedback. The term **biofeedback** refers to an augmented form of task-intrinsic feedback related to the activity of physiological processes, such as heart rate, blood pressure, muscle activity, etc. Several forms of biofeedback have been used in motor skill learning situations. The most common is *electromyographic (EMG) biofeedback,* which provides information about muscle activity. Most of the research concerning the use EMG as biofeedback has been undertaken in physical rehabilitation settings, and has shown positive results as an effective therapy intervention. The following two examples illustrate different types of intervention purposes for the use of this form of augmented feedback.

Brucker and Bulaeva (1996) used EMG biofeedback with long-term cervical spinal cord–injured people to determine if it would help them increase their voluntary EMG responses from the triceps during elbow extension. Some of the 100 participants received only one forty-five-minute treatment session, whereas the others received an average of three additional sessions. Results of a posttreatment test indicated that participants who experienced only one session significantly increased their triceps EMG activity, and those who experienced the additional treatment sessions demonstrated even further increases.

The purpose of a study by Intiso and colleagues (1994) was to determine the effectiveness of EMG biofeedback to help poststroke patients overcome foot drop of the paretic limb during the swing phase of walking. Some patients received EMG biofeedback during their physical therapy, whereas others did not. A unique characteristic of this study was the use of gait analysis to assess foot drop during the gait cycle. Results of this analysis demonstrated that the EMG biofeedback intervention led to better recovery than physical therapy without the biofeedback.

A CLOSER LOOK

A Case Study of the Use of Biofeedback for Balance Training for Stroke Patients

A form of biofeedback that has been used for balance training in physical therapy contexts is the visual presentation on a computer monitor of a person's center of gravity. A case study reported by Simmons and associates (1998) is an interesting example of the effectiveness of this type of biofeedback in a clinical setting. The patient was a seventy-four-year-old post-stroke, hemiparetic male with whom therapists were working to help him regain balance control while standing. Following a pretest, the patient engaged in three balance training therapy sessions a week for four weeks. During each therapy session the patient stood on two force plates while looking at a computer monitor placed at eye level. On the monitor, he could see a small white dot superimposed on a white cross, which indicated an appropriate center of gravity while standing. During each therapy session, a clear plastic template marked with a circular pattern of eight alphabetic letters was placed on the monitor. A verbal command to the patient indicated that he should initiate a weight shift that would cause the white dot to move from the center and hit the target letter and then return the dot back to the center cross. The patient did this for six 1-min intervals with a 45-sec rest between intervals. A posttest followed at the end of the four-week training period, and a retention test was given two weeks later. One of the tests simulated a sudden loss of balance, which involved a quick (400-msec) 5.7-cm forward and backward movement of the force plates on which the patient was standing. The patient's performance on this motor control test during the two-week retention test showed a 60 percent improvement for response strength of the affected leg, and a marked shift in balance onto the affected leg in the patient's attempts to regain balance.

Chollet, Micallef, and Rabischong (1988) used another type of biofeedback with skilled swimmers to help them improve and maintain their high level of performance. The authors developed swimming paddles that would provide information to enable highly skilled swimmers to maintain their optimal velocity and number of arm cycles in a training session. The swimming paddles contained force sensors and sound generators that transmitted an audible signal to transmitters in a swimmer's cap. The sensors were set at a desired water-propulsion-force threshold; when the swimmer reached this threshold, the paddles produced a sound audible to the swimmer. The authors found this device helped swimmers maintain their stroke count and swimming speed when they otherwise would have found it decreasing through the course of a long-distance practice session.

Finally, a rather unique type of biofeedback in motor skill learning contexts has been applied in the training of competitive rifle shooters (Daniels & Landers, 1981). Heartbeat biofeedback was presented auditorally to help these athletes learn to squeeze the rifle trigger between heartbeats, which is a characteristic of elite shooters.

In general, research evidence has supported the effectiveness of biofeedback as a means of facilitating motor skill learning. However, debate continues concerning the specific situations in which the use of biofeedback is an effective and preferred form of augmented feedback (Moreland & Thomson, 1994). In addition, biofeedback is usually presented as concurrent augmented feedback, which leads to concerns related to the development of a dependency on the availability of the augmented feedback to maintain an acquired level of

biofeedback a type of augmented feedback that provides information about physiological processes through the use of instrumentation (e.g., EMG feedback).