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SPECIAL SECTION

Optimizing Motor Reeducation Using Surface Electromyography: Grandma, Feedback, and Self-Regulation

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Procedures used on a daily basis often become routine. This human tendency toward automatic functioning is adaptive in the sense of increased efficiency. However, treatment programs using the various forms of biofeedback are often deceptively simple and can easily mask quite complex interactions between an action (be it a change in muscle recruitment, temperature, brainwave, etc.) and an outcome (video game progress, good job from the clinician). This article highlights some of the hidden obstacles to good treatment protocol development.

Introduction

Grandma knew exactly how to handle her grandchildren. If they came in from playing at the first call, they got an extra helping of dessert. If they did not apologize for hitting their younger sister, they got spanked until they said they were sorry. If they did not put their toys away, they were sent to their room. If they began to fight while watching television, the television was turned off. But seemingly mundane choices become a puzzle. Does one reward coming in on time with dessert or punish late arrivals? If no apology is forthcoming for hitting a sibling, should a favorite toy be removed, or a spanking delivered, or should the child miss out on storytelling time? Clinicians designing biofeedback treatment sessions also must wrestle with these issues.

In every biofeedback session, behavior is modified in an if-then sequence. If the patient reduces body tension below a set microvolt level, the stormy ocean on the screen calms. If the patient dorsiflexes the foot above a set threshold, a favorite song begins to play. If a patient modulates brain activity in a set frequency band in the desired way, points are earned as a figure moves on the screen. All of these examples have proved to be effective strategies; however, there are times when success is elusive for no obvious reason.

Some evidence as to the reason for this lack of success may be found in an examination of the typical write-up of a biofeedback outcome study. It is common for the author to briefly sketch out how the reward contingency is set up or for the reader to be referred to another published work for the details, giving the impression that much of the operant procedure is obvious. After all, what more could there be? Actually, the simple appearance of stimulus and response belies a much more complicated program. Although this article focuses on surface electromyography (sEMG) as a tool to aid in motor reeducation, the general principles are applicable to other forms of biofeedback.

Using Applied Behavioral Analysis to Tease out Hidden Strengths and Weakness of the Plan

From a learning theory perspective, Grandma's interventions can be broken down into four possibilities. They are first listed in everyday language followed by a more technically accurate description:

1. Serving an extra helping of dessert to reward coming in on the first call.
2. Getting spanked until we say we are sorry.
3. Being sent to our room for not putting away our toys.
4. Turning the television set off if a fight erupts while watching television.

These possibilities have technical terms, corresponding to the numbers above. These if-then paradigms are also known as syllogisms.

1. Positive reinforcer: increases a behavior by pairing an action with a reward. (*If* we come in on the first call, *then* we are rewarded with an extra helping of dessert.)
2. Negative reinforcer: increases a behavior by stopping something obnoxious as soon as a subject does an action. (*If* we do not say we are sorry, *then* we will be spanked until we say we are sorry.)
3. Positive punisher: decreases behavior by having the action followed by something obnoxious. (*If* we do not put away our toys, *then* we are sent to our room.)
4. Negative punisher: decreases behavior by having a reward end as a result of an action. (*If* a fight erupts while watching television, *then* the set is turned off.)

A major difference among the conditioning protocols listed above is that only the reinforcement protocols teach about the temporal sequence of an action followed by an outcome. The trainees learn (in the case of a negative reinforcer) that an action is followed by the cessation of something obnoxious. They also learn (in the case of a positive reinforcer) that an action is followed by something rewarding. In each case, if the subject repeats the behavior, something desirable happens. In the punishment protocols, behavior is followed by something unpleasant; there is no to-do behavior that is being taught. The subject does not learn what to do but rather what not to do.

Let us consider this procedure as Study A: Feedback consists of a video clip that activates with increased muscle recruitment (anterior tibialis).

In the present form, Study A uses a positive reinforcer. With increased muscle recruitment of the anterior tibialis, a positive reinforcer (the video clip) comes on. As the recruitment level waxes and wanes, by default a negative punisher is part of the procedure. The video stops because of a decreased recruitment level in the anterior tibialis (a motor action paired with the termination of a reward).

In Study B, we add a tone to the mix that sounds whenever the recruitment level drops below a certain value. The tone serves as a positive punisher (a positive punisher decreases behavior by pairing a motor action with an aversive event) and also a negative reinforcer (increases behavior by pairing the termination of an aversive event with a motor action). Recall that both a positive reinforcer and a negative reinforcer reinforce or give the subject information on what to do. By including both a positive and negative reinforcer, we have doubled the amount of information as to what to do.

In Case A, the subject is either increasing the level of motor recruitment (causing the reward to activate) or he or she is continuing to try to do so, is daydreaming or resting, or is bored, and so forth. In Case B, the subject is constantly cued one way or the other as to his or her performance on the task. One could even modify the existing program in another way: have the clip play backward whenever the recruitment level falls below a set threshold. It would be constructed as follows:

1. Positive reinforcer: activation of the video clip.
2. Negative reinforcer: termination of the backward playing of the video clip.
3. Positive punisher: activation of backward playing of the clip due to lowered recruitment level.
4. Negative punisher: termination of the video clip once activated due to deficient recruitment level.

One consistent finding from behavioral analysis work comes from research done in substance abuse programs. Typically, the programs are set up to reward compliance with a drug-free state with a monetary reward. For example, for every day a blood test is clean, the patient earns $3. In one scenario, if the patient has a clean blood test, he earns $3 per day. If he has a clean blood test for 3 consecutive days, the daily reward increases by $1 to a maximum of $10 per day. if the patient fails a day, he does not earn the $3 for that day, but success on the next day allows him to pick up where he left off on the reward continuum. In another scenario, if he fails, not only does he not earn the $3, but the reward also gets reset back to the original amount he started at. The most effective intervention was the reset intervention, in which the patient not only did not earn the day's reward but also lost out by having the reward set back to an earlier (less money) level.

Another example is the study by Roll and Higgins (2000) on the effects of reinforcing cigarette smoking abstinence in humans. In one group, increasing amounts of money could be earned with each successful abstinence. If the subjects relapsed, they could pick up where they left off on the earning continuum by resuming abstinence. In the second group, relapses resulted in a decrease in the money earned for abstinence back to the initial value (an example of negative punishment). There was a significant difference in favor of the second group in the amount of time the smokers remained abstinent. In the earlier video clip example, still another option to fine-tune the contingency could be made. Recall that the program could be modified to include additional behavioral information by having the clip play forward or backward depending on the subject's response. If the clip were merely paused whenever the recruitment dropped below threshold, the program would consist of both a positive reinforcer and negative punisher. However, if the clip was allowed to continue to run unseen, the program would now also include a positive punisher and negative reinforcer (the former being the loss of ongoing scenes from the video clip, the latter ending the loss of scenes from the video clip).

Maximizing the Patient's Skill at Self-Regulation

In past years, the official journal of the Association for Applied Psychophysiology and Biofeedback was called *Biofeedback and Self Regulation*. It is fascinating that the term *self-regulation* appeared in an article in *Psychological Bulletin* by Deci, Koestner, and Ryan in 1999. The article reviewed experiments examining the effect of external rewards on behavior. The authors found that "although rewards can control people's

behavior, the primary negative effect is that *they tend to forestall self-regulation*" (p. 659, italics added). In other words, reward contingencies can undermine people's taking responsibility for motivating or regulating themselves! The implication for biofeedback clinicians is that how a program is constructed and presented is just as important as what is presented. Early in treatment, a detailed applied behavioral analysis may be needed to train and motivate the learning of a new skill, especially with children. But that same approach later on may hinder the development of self-regulation by too much focus on reward contingencies. For example, the instructions to a patient using sEMG in muscle reeducation may change from "every time the line reaches or exceeds the red mark you will hear a tone, and the longer you keep the tone on the more points you will earn" to "I'd like you to experiment a little and see how thinking about your toe coming up off the floor changes the position of the lines . . . then see if your leg feels different when the line dips."

Lots of Decisions, But Well Worth the Effort

How these various contingencies are incorporated into a treatment plan depends on the overall structure of the plan including patient age, motivation, behavior to be changed, and the risk that the behavior, if not treated, has for the subject. Although the negative consequences of punishment have been well documented, it is the fastest way to alter a behavior, and there may be some instances in which it is proper to use it. Milder forms of punishment such as the termination of a reward along with positive reinforcers provide additional information to the subject by giving information on both what to do and what not to do.

The canned programs that came with your equipment may or may not fit the bill for the intervention you have in mind. It might be valuable to sketch out the type of rewards being used and the details as to how they are attained. If the threshold point is "lost," what is the consequence and how quickly does it occur? Do you want to give the patients information that they are about to lose an earned reward (tone begins to decrease), or will that be information overload? How does the loss of the reward occur? For example, if it is a video clip, does it just stop playing (negative punisher) and resume when the threshold is reached, or does it continue to play unseen (negative punisher with positive punisher)? How does the patient react? Does he or she see the missing of the video (having it continue to play unseen) as an added challenge, or does it up the frustration level to the intolerable range? Is the patient so engrossed in the task that it becomes less a biofeedback session and more a video game? If it is the latter, would more information (in the form of both positive and negative reinforcement) about what is causing the Pacman to move up or down be valuable? Recall that reinforcement protocols teach the subject something about the behavior they are doing. How critical is the program? Is the patient in treatment to see if a last-gasp electroencephalography intervention would work to reduce seizures before surgery is scheduled to perform a hemispherectomy? In that case, a more aggressive intervention employing all four forms of reinforcement/punishment might need to be used.

Punishment does not need to be shock or anything close to that level of discomfort. Recall the added effectiveness in the smoking cessation study of adding response cost to the mix. Not only did the trainees not get money for having failed the abstinence, but the amount of money subsequently earned for compliance was less. Would adding response cost to the behavioral protocol enhance or hinder behavioral change?

Deluca once described sEMG as a seductive muse in that the numbers generated by the equipment appeared to be straightforward and easy to interpret. The same can be said of setting up a biofeedback intervention program. In an article on the foundation and practice of neurofeedback in the treatment of epilepsy, Sterman and Egner (2006, p. 30) observed that the details of a treatment program may not be attended to by the producers of biofeedback programs and deserve close scrutiny by the potential customer. It takes considerable thought to tease out the details of a seemingly simple response-reward program. Remember, you are the expert in your chosen biofeedback field. It is likely that the software programs that came with your unit will have to be tweaked for maximum benefit of your patient.

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