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A Review of Feedback Techniques Used to Improve Athletic Performance

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A Review of Feedback Techniques Used to Improve Athletic Performance

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
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Dedication

There's no way I would have been able to make it this far in my life, educationally or otherwise, without those who've played a role every step of the way. To my family, my friends, mentors, supervisors, coworkers, clients, all of those who've I've grown close to and grown apart from, it's because of their support that I was able to keep myself from giving up. To everything in my life that served as a delay or an obstacle to get to this moment, those complications were just the road that needed to be taken to get here. The only way towards progress is forward, and while it everyone's path may not be the same way, there are no mistakes, regrets, or failures if you eventually move towards your destination. I'm grateful for everything I've experienced throughout my life and hope to continue to move forward.

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Abstract

Feedback is an important component to successful behavioral interventions. Regarding interventions to improve athletic performance, several studies have used different forms of feedback across multiple sports. This area paper examined the different types of feedback across studies on athletics, describing the forms of feedback and directions for future research highlighted among them. In particular, this paper described video feedback, verbal feedback, auditory feedback, and public posting.

Introduction

Numerous studies have investigated athletic performance as a target of behavioral intervention (Luiselli & Woods, 2011). Of these studies, interventions have been formed to affect both the acquisition of skills (e.g., Downs et al., 2015) and the improvement of skills in participants of varying experience levels (e.g., Giambrone & Miltenberger, 2020). These studies have also been conducted on a variety of sports, including but not limited to: horseback riding (Kelley & Miltenberger, 2016), discus and hammer throwing (Maryam et al., 2009), tennis (Scott et al., 1998), soccer (Brobst & Ward, 2002), dance (Quinn et al., 2015), swimming (McKenzie & Rushall, 1974), gymnastics (Wolko et al., 1993), pole vaulting (Scott et al., 1997), and football (Smith & Ward, 2006). As such, components of these different interventions should be investigated to evaluate which would be the most effective in improving the acquisition or enhancement of performance when developing treatment packages for athletes.

An important aspect of any effective intervention is the incorporation of feedback. Komaki and Barnett (1977) determined that providing feedback contingent on players' performances was more effective than coaching as usual in improving the play of a youth football team. However, studies differ in how feedback is given to participants. Whereas Komaki and Barnett used verbal feedback, other studies have used different methods. These other methods include using video feedback (Kelley & Miltenberger, 2016), auditory feedback (Fogel et al., 2010), public posting (Brobst & Ward, 2002), and behavioral skills training (BST, Tai & Miltenberger, 2017) The purpose of this review paper is to investigate the various forms of feedback used in interventions to improve athletic performance. The paper aimed to both define

and describe the various forms of feedback used in the mentioned sources. The focus was to discuss the efficacy of each feedback method and describe various future directions that these studies identify. Doing so, the following also intends to assist with guiding research in improving athletic performance.

Video Feedback

Video feedback involves video recording an athlete's performance and then reviewing the performance with the athlete while providing positive comments for correct performance and instruction for improving incorrect performance. Access to a video of past performance allows coaches and researchers to more accurately identify and deliver positive and corrective feedback on the performance (Prieto et al., 2016). This can be done in the form of either stopping recordings to comment on specific components of a performance trial (Kelley & Miltenberger, 2016); or comparisons of participants to footage of expert performers (Boyer et al., 2009). The following describes several different forms in which video feedback has been utilized in various studies.

Video Feedback Alone

Some studies have shown that the use of video feedback alone can serve as an effective intervention for improving athletic performance. Kelley and Miltenberger (2016) used video feedback as an intervention to increase the performance of three horseback riding skills. The intervention itself consisted of video recording a participant performing the skill and then showing the participant the performance and delivering specific feedback on correct and incorrect aspects of the performance. The results showed improvements in the performance across all participants. BenitezSantiago and Miltenberger (2016) also used video feedback alone to improve skills associated with Capoeira, a form of martial arts. In this study, they targeted three specific skills and developed a task analysis of each skill. Intervention sessions consisted of the researcher video recording attempts of target skills during regular practice times, viewing the

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video with the participant immediately after the performance, and providing praise for correct steps and corrective feedback on steps that were not correct. In each training session, this process was repeated three times and then the skill was assessed. The results of this study showed that video feedback increased performance. However, performances increased even further when participants engaged in extra practice after each video feedback trial. In addition to these two studies, several other studies also demonstrate the effectiveness of video feedback for improving sports skills. For example, Guadagnoli et al. (2002) compared self-guided, verbal feedback, and video feedback groups in how effectively they would improve an individual's accuracy and distance of their golf swing. While each group had the same 90 min time for training sessions, the three groups differed in how participants received feedback and how many performance trials they performed. The self-guided group received the instruction to practice as they would on a driving range, a professional instructor gave feedback on performance to the verbal feedback group, and the video feedback group had the same instructor, but the instructor gave specific feedback using video recordings of performance trials. Immediately following the training period, Guadagnoli et al. found no significant improvements in accuracy and distance scores for any group, nor did they differ much from each other. However, they attributed this as an effect inherent to golf, that even with corrective changes to form, it can take time for players to become comfortable with altered techniques. The study supported the long-term benefits of the feedback groups; both conditions showing improvement after a two-week post-test, with the video feedback group showing the greatest benefits.

Hazen et al. (1990) conducted two experiments on the benefits of video feedback for improving various swimming skills for young competitors. The first compared an intervention package in which the initial sessions used coach-modeling and role-play, but subsequent sessions

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used feedback on videos of participant performance to coaching as usual in the form of non-systematic verbal feedback. The second experiment aimed to compare individualized video feedback to video feedback procedures attributed to group "video-sessions" that some sports teams use. In this experiment, participants in the group video sessions watched recorded performance trials of each participant together, while the experimenter gave corrective feedback. The individualized feedback sessions were similar to those in the first experiment, with the first sessions incorporating modeling and rehearsal, but all subsequent sessions only using video feedback on performance. Both studies showed that individualized video feedback was more effective in improving swimming performance in all participants, although for both experiments, there was a participant whose improvements did not maintain during maintenance phases.

Video Feedback with Modeling

In video modeling, the athlete views recordings of someone proficient in the target behavior showing accurate performance. In some studies, video modeling has been used in conjunction with video feedback. Boyer et al. (2009) used a combined procedure of these two interventions to improve gymnastics skills. During review periods, participants watched the expert video and a clip of their own performance together, pausing the videos at different points while the researcher delivered feedback. The results of this study showed that performance improved more quickly than during normal practice conditions. Baudry et al. (2006) also compared a teaching-as-usual group to a combined video modeling and video feedback group in how they benefited gymnasts performing a double leg circle movement on a pommel horse. In their intervention, participants watched simultaneous footage of their performance with that of a national champion performing the same motion. Using the video, participants received direction to attend to relevant parts of the skills demonstrated by both models. Baudry et al. concluded that

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immediately following the training period, participants improved in all components of the double leg circle, and in periods where they did not receive feedback, such as across the post-test and retention phases for the feedback group, subjects did not improve.

Barzouka et al. (2007) also combined video feedback with modeling but compared using either just an expert model with verbal instruction to presenting both the expert model and participant performance together. Their study looked to determine each method's effectiveness in improving volleyball players' abilities to receive and return the ball from different positions and on the court. Unlike Boyer et al. (2009) or Baudry et al. (2006), Barzouka et al. found no significant difference between the simultaneous presentation, video modeling and verbal instruction, or verbal instruction alone groups. They concluded that all three methods achieved similar improvements in the participants. Rikli and Smith (1980) also had conflicting conclusions regarding how effective video modeling and feedback are. Their study compared changes in components to tennis serves across a no-video feedback group and three groups having different deliveries of video feedback. Rikli and Smith based these deliveries as either all video feedback being given during the first day of instruction, the third day of instruction, or at both days during the instruction phase. During feedback sessions, instructors simultaneously presented videos of the participants' current performance and video of the instructor displaying correct form, with instructors then guiding the participants to attend to specific parts of the model. Similar to Barzouka et al. (2007), Rikli and Smith concluded that video feedback procedures are not as effective as they initially thought. Their study resulted in only some components of serves having significant differences from the control, with the temporal component of when feedback was delivered not having a significant effect. Quinn et al. (2019) conducted a comparison of video modeling and video modeling plus video feedback on their

effectiveness in increasing performance in competitive dancers. The results showed that video modeling alone was associated with modest increases in correct performance, but the combined procedure led to greater, more substantial improvement. Thus, Quinn et al. (2019) suggested that modeling alone was a weak intervention, with feedback being a crucial component for significant improvement.

Todorov et al. (1997) used a virtual environment to provide feedback to teach different table tennis shots to their participants. During intervention, subjects saw a 3D model of a teacher executing the desired movements, which were specific hits of the ball that landed on different targets on the table. The model also included a simulated ball and relevant sound effects. Participants attempted to mimic the movements of the teacher as it played, with the model recording initially playing slowed down and gradually being increased to full speed. After every attempt, the participant saw a score reflecting the similarity between their movement and that of the model. These training sessions continued for 10 min before participants conducted actual trials of attempting the different hits. This study conducted two experiments, with the first experimental group having a baseline phase of attempts at the target behavior, and the second study's experimental group not having this phase. In both experiments, Todorov et al. concluded that feedback in the virtual environment resulted in better performance than their control groups without the intervention. In the case of the second experiment, the benefits of the virtual environment feedback were shown even with the control group receiving more practice opportunities than the experimental group.

Video Self-Evaluation

Scott et al. (1998) described that one benefit of utilizing video in interventions is that feedback can be more easily delivered at the participants' pace. Studies showing that being able

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to stop the videos while delivering feedback (Kelley & Miltenberger, 2016) also support that feedback at the learner's pace may optimize improvement. Video feedback can utilize participant involvement in the form of self-evaluation and delivering of consequences. Downs et al. (2015) applied this video self-evaluation intervention to teaching yoga poses to participants with no prior experience. During the intervention, after two sessions of the researcher providing instruction on how to observe their performance on video and score their performance, in future sessions the participants conducted the procedure independently. This study concluded that for five of the six poses introduced to the participants, video self-evaluation alone resulted in increases in performance. However, booster sessions were needed due to low treatment integrity. In addition, the researchers also used video feedback procedures if levels of performance showed only minor improvements. Giambrone and Miltenberger (2020) used video self-evaluation to benefit performance in competitive dance. Participants were trained to score own data and watched and evaluated their performance with recordings of themselves attempting various dance movements. Participants initially evaluated their final baseline performance and following self-evaluation, performed the skill again and evaluated this performance. Each session consisted of three self-evaluation trials. This study resulted in improvements in all of the target movements for each participant. In addition, the researchers found that not all participants improved at the same rate, supporting claims that video interventions can be optimized to fit the participant's pace of learning (Scott et al., 1998).

Future Directions of Video Feedback Procedures

The studies identified as using different methods of video feedback describe several difficulties and directions for future research. Giambrone and Miltenberger (2020) identified a lack of studies using video self-evaluation, suggesting that this method would need further

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investigation for determining it as an effective intervention. In addition, regarding video self-evaluation, treatment integrity of participants for this and Downs et al. (2015) showed difficulties. Researchers conducted retraining sessions, and Downs' and colleagues' study suggested that the necessary amount of training needed for participants to be ab le to accurately score themselves was something worthy of future studies.

Other studies have described complications that can come from the technology of the videos themselves. Quinn et al. (2019) recorded both model and participant videos with the camera facing either the front or back of the one being recorded. Their study suggested that the perspective of the videos can affect the intervention. Boyer et al. (2009) reported technical difficulties as well, as freeze-frames and pauses could blur the screen, making it more difficult to accurately identify components of accurate performance. This study also pointed out that recordings of both the model and participant cannot always be correctly synched together, complicating comparisons between the two.

The amount of time used for sessions in video feedback interventions is also worth further investigation. BenitezSantiago and Miltenberger (2016) reported that sessions for video feedback took 45 min, which is the same length of time used in the initial sessions of Downs et al. (2015). Both studies suggest that the immediacy of feedback, regardless of procedure, can influence its efficacy, with Downs et al. (2015) being able to decrease the duration of sessions to 15 min. Kelley's and Miltenberger (2016) had even shorter feedback sessions, only requiring up to 2 min. However, based on the findings of the mentioned studies, the different video feedback interventions led to increases in performance despite differing session lengths. Thus, future studies may wish to compare session and training lengths to see if there is an optimal amount of time to achieve the best results.

Verbal Feedback

Verbal feedback describes the delivery of comments about performance following the performance to reinforce desired behavior or to reduce undesired behavior. Regarding athletics, it could be said that many "coaching as usual" procedures incorporate some form of verbal feedback (Shapiro & Shapiro, 1985). However, traditional coaching often does not deliver feedback in a systematic way, and often incorporates other consequences such as punishment. The following will describe research with procedures that primarily use verbal feedback.

Kladopoulus and McComas (2001) used verbal instruction and reinforcement, in the form of praise for correct performance, to affect foul-shooting for women collegiate basketball players. During intervention, the researchers gave instruction on proper form, and there was no corrective feedback on form in the case of a missed shot. If the participants' shots had correct form, regardless of the shot being made, they received praise. Incorrect shooting only resulted in a description of the proper form. The study concluded that there were immediate improvements in form for all participants and that correct form was related to accuracy.

Verbal Feedback in Package Interventions

Studies by Ziegler (1994) and Luyben et al. (1986) implemented verbal feedback in package interventions. Luyben et al. created a procedure in which most-to-least prompting was used to teach their three developmentally disabled participants to perform a side-of-the-foot soccer pass. Feedback came in the form of providing praise for correct performance on steps, and descriptive feedback (instructions for improvement) in the case of errors. Additionally, the researchers used levels of prompting beginning at full physical prompts from the implementer,

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transitioning to lesser physical prompts, then to imitative and gestural prompts, and finally to verbal instruction. They did this to improve and promote independent performance. Luyben et al. (1986) concluded that this procedure was useful in teaching the pass to their participants, with the results both maintaining post-intervention, and generalizing to a different location. The study suggested that for some interventions, going from most-to-least prompting can be the optimal strategy in order to have novice performers quickly contact reinforcement for correct performance, but it depends on the skill complexity and performer.

Ziegler (1994) used an attentional shift training procedure to improve practice skills for four collegiate soccer players. The intervention included: exercises on shifting attention given both on and off the field, concentration drills to attend to one task as the researcher gradually added distractors, watching videos of team performance and only switching attention when prompted, tactical decision making drills in which the researcher showed diagrams of different decisions with the participant needing to choose the correct one, and application of the drills to an indoor area. The study then scored performance on practice drills in which the participant received a pass from the experimenter, then one-touch-passes it to a specific target. Subsequent drills then added to the complexity of the task by adding to components like the number of possible targets. This study concluded that attentional shift training could benefit athletic performance, as the intervention resulted in increases in participants' practice scores. However, the researcher did not record game performance data.

Behavioral Coaching/Behavioral Skills Training

Often, verbal feedback procedures are implemented with other behavioral interventions in combinations similar to behavioral skills training (e.g., Komaki & Barnett, 1977). While verbal instruction and contingent praise can be an effective intervention (Kladopoulus &

McComas, 2001), corrective feedback (instructions for improvement) and modeling are common additional components used by researchers and sometimes referred to as behavioral coaching. Komaki and Barnett (1977) modified practice procedures for five youths across different positions on a football team in order to increase the percentage of steps required to successfully complete a play. In their procedure, the coach modeled desirable behavior, and gave explanations in the event the participants performed incorrectly. The study concluded that this procedure, which only added to normal coaching procedures, improved play execution for all of the participants.

Allison and Ayllon (1980) developed a "behavioral coaching" package combining differential reinforcement, modeling, and verbal feedback to benefit participants across football, gymnastics, and tennis. Their package began with the coach giving instructions of the specific target behavior as well as setting expectations for the consequence, in the form of praise for correct behavior or saying "stop" or "freeze" when an error occurs. In the event of a "stop," the coach then described the error that occurred, modeled the correct response, then had the participant imitate that response correctly before returning to attempting the target behavior. This study concluded that behavioral coaching was effective for teaching blocking in football, several different movements for gymnastics, and essential components for tennis.

Future studies would expand on the procedure from Allison and Ayllon (1980). Fitterling and Ayllon (1983) applied this procedure to beginning ballet students. They used a similar procedure of instruction, stopping and providing corrective feedback in the case of errors, modeling, and rehearsal. The study concluded that the intervention was more effective than standard instruction for its four participants to both acquire and improve upon four dance movements. Koop and Martin (1983) further expanded on this procedure, using it to improve

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performance on different swimming strokes for beginning swimmers. The behavioral coaching package was similar, however due to the sport, instructors would tap the participants instead of vocalizing for them to stop. Their conclusion was that errors in performing the swimming strokes decreased with the intervention, with three of the four participants maintaining their performance when transitioning back to normal practices. However, Koop and Martin did not investigate whether correct form would translate to faster swimming times. Shapiro and Shapiro (1985) used this method to work on essential skills for three inexperienced members of a high school track team. Unlike Koop and Martin, Shapiro and Shapiro found the procedure both was effective in helping the participants to acquire track skills, and in reducing participants' running times.

One other form of verbal feedback similar to behavioral coaching is behavioral skills training (BST). BST combines instruction, modeling, rehearsal, and feedback to assist learners in acquiring and improving on skills. Tai and Miltenberger (2017) used BST to teach safe tackling to Pop Warner football players. The principle researcher provided the instructions and served as the model for correct tackling. During participant rehearsal, the researcher provided feedback and further instructions on how to improve tackling form before the participant would try again. This continued until participants executed two to three consecutive successful tackles, before then executing the trials for recording in a traditional practice scenario. The study concluded that the percentage of correct steps of proper tackling increased for all six of its participants, with participants being able to achieve perfect scores multiple times, and two participants showing generalization to games. In addition, the researchers noted a decrease in dangerous tackles in which the tackler led with his helmet. O'Neill and Miltenberger (2020) reported similar successful results using BST to improve three field hockey shots for three teenage participants.

Future Directions in Verbal Feedback

Due to the similarity that verbal feedback can have to coaching as usual, many studies do not look at its effectiveness in isolation. While Kladopoulus and McComas (2001) could be considered evidence for systematic verbal feedback being effective, most studies combine systematic feedback with other procedures such as modeling (Allison & Ayllon, 1980), gradual fading of physical prompts (Luyben et al., 1986), or combinations of multiple procedures such as with BST (Tai & Miltenberger, 2017). Shapiro and Shapiro (1985) suggested that verbal feedback itself is not enough, with the behavioral coaching method (aka, BST) being a preferable intervention. Thus, future studies may wish to investigate the effectiveness of systematic delivery of verbal feedback on its own.

Additionally, the studies utilizing and modifying the procedure from Allison and Ayllon (1980) point out other directions to guide future research. Both Koop and Martin (1983) and Fitterling and Ayllon (1983) noted that while their procedure did improve performance on the targeted skills, there was no generalization in novel or untrained skills. Kladopoulus and McComas (2001) also concluded that improvements to form from their verbal feedback procedure might not lead to in-game results, but this conflicts with the shorter running times reported by the participants of Shapiro and Shapiro (1985). Future studies should look into the generality of improvements made using verbal feedback-based procedures, as well as look at which components of these combined procedures are the most essential for effective intervention (Komaki & Barnett, 1977).

Auditory Feedback

Auditory feedback describes the use of an audible stimulus to serve as a consequence for target behavior. For example, Quinn et al. (2015) used a clicker to indicate successful performance of a step in a task analysis of a dance movement with young dancers. This is done with the intention that the stimulus will serve as a conditioned reinforcer for accurate performance in athletic skills. Benefits of auditory feedback over other methods include it not requiring the participant to pivot away from performance when receiving feedback (Krukauskas et al., 2019) and feedback being deliverable close to immediately following performance trials (Broker et al., 1993). This speed of auditory feedback delivery can be used to customize procedures in various ways, such as consequences being automatically delivered when a target criterion is reached by technology (Scott et al., 1997) or using a trained implementer to deliver feedback during practices (Harrison & Pyles, 2013). The following will describe various methods in which auditory feedback is used, as well as highlight components of those procedures that could be targeted in future studies.

Teaching with Acoustical Guidance (TAGteach)

TAGteach is a standardized forward-chaining procedure, used to assist practitioners in delivering contingent auditory feedback, in the form of clicker clicks referred to as "tags," to shape progressive approximations to the target behavior. Fogel et al. (2010) described the procedure in detail in their study to teach a golfer with no experience how to successfully swing the club. The procedure, implemented by someone certified in performing the procedure, begins with breaking down the behavior into its components with a task analysis. During TAGteach,

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each component, or tagpoint, is attempted, with tags being delivered when tagpoints are performed accurately, and subjects continue through the task analysis. However, upon three unsuccessful attempts, the procedure suggests that a new, easier to perform, tagpoint be created and targeted in the hopes of increasing the likelihood of success when returning to the previous tagpoint. TAGteach also emphasizes that during intervention, the practitioner and learner have debriefing meetings to determine whether the learner is ready to advance in the task analysis, and to ensure that the learner has knowledge of the current target component. Fogel et al. used this procedure, concluding that the participant improved in four of five identified skills considered essential to a proper golf swing, with those skills showing maintenance during follow up, and generalization when using a different club than the one during training. However, in this study, the participant was unable to continue sessions before achieving proficiency in the final skill.

Quinn et al. (2015) also made use of TAGteach to improve performance of dance skills, with the participants' dance instructors being the trained implementers of the procedure. This study added to the potential benefits of using TAGteach in that it not only resulted in increases in performance for its participants but proved that modifications to the procedure could be made while still being effective. These modifications included training teachers to deliver the intervention while still benefitting learners and combining TAGteach with a token economy when one participant did not show increases in target behavior upon intervention. This token economy, in which points could be exchanged for tangibles such as candy or stickers, helped to establish the tag as a conditioned reinforcer.

Auditory Feedback

The literature shows that auditory feedback can be an effective procedure with and

without the inclusion of additional TAGteach procedures. Scott et al. (1997) used an auditory stimulus, in the form of an audible beep, to reinforce gradually increasing heights of the jumps from a university-level pole vaulter. They also delivered a prompt ("reach") immediately before the behavior occurred. The target behavior was raising the pole high in the air just before planting the pole for the vault. The criterion was indicated with a photoelectric beam that would need to be broken for the beep to sound at increasing criterion heights. The procedure resulted in improvements in the maximum height that the participant could make and increasing the participant's arm extension when making jumps.

A number of studies using auditory feedback modified a procedure used in Quinn et al. (2015), in which TAGteach, was used to benefit participants' dance performance. These studies, consistent with the TAGteach procedure, used auditory feedback in the form of a clicks from a clicker in a forward chaining procedure to reinforce improvements in each studies' target behavior (Carrion et al., 2019; Krukauskas et al., 2019; Quinn, Miltenberger, & James, 2017). Krukauskas et al. (2019) used this procedure to increase the percentage of steps completed for amateur mixed martial arts practitioners' right cross, while also using a coach as the one to deliver feedback. Following intervention, the researchers concluded that feedback improved participants' performance, with all participants being able to execute the right cross at near 100 percent of the criterion. In addition, they concluded that the procedure can be considered efficient as well, with each participant only spending up to a maximum of 1hr in the intervention phase.

The other studies to modify the procedure of Quinn et al. (2015) expanded both on how the procedure can be implemented, and on the populations it can be effective for. Carrion et al. (2019) found their auditory feedback procedure effective in improving the dance performance for

three children who were diagnosed with either cerebral palsy, autism spectrum disorder, or spina bifida. Also, this study was novel in that it followed an ABAB design, showing experimental control in that performance worsened upon removal of the intervention. Quinn, Miltenberger, and James (2017) looked into whether dance skills could be improved when peers used auditory feedback and looked into whether being the deliverer of feedback could improve performance as well. Their study trained three of their six participants to deliver feedback, with the researcher and dance instructor supervising to ensure treatment integrity, and recording their attempts to perform the same target behaviors as those receiving the feedback. For the participants who received feedback, their performance increased to a greater degree, but those who implemented the procedure did improve in the target movements as well. This provides more support for the versatility of auditory feedback procedures in affecting athletic performance, as students are capable of both implementing the procedure to benefit others, and simultaneously benefit themselves.

Auditory Feedback Combined with Other Procedures

Similar to how Quinn et al. (2015) modified TAGteach by adding tokens for one participant, other studies have combined auditory feedback procedures with other techniques in order to benefit athletes. Harrison and Pyles (2013) combined auditory feedback with verbal instruction to improve the quality of tackles by high school football players. During intervention, at the introduction of each of the four component target skills for tackling, players were provided with verbal instruction before receiving the auditory feedback procedure. Unlike the other described studies using auditory feedback, Harrison and Pyles used a megaphone beep in order to ensure that feedback was audible to players across the football field. This study concluded that their procedure did increase performance for all participants, while also being able to use a

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relatively simple task analysis, with only four target skills. Stokes et al. (2010) used a bullhorn to provide auditory feedback with football players while evaluating a combination of descriptive feedback, video feedback, and TAGteach to enhance offensive line pass-blocking. Even though the researchers concluded that descriptive feedback and video feedback phases were effective in improving performance, they showed TAGteach improved performance even further, with participants exceeding criterion or consistently performing at criterion levels.

Future Directions of Auditory Feedback Procedures

With the promise for improving sports performance that auditory feedback shows, future studies should explore aspects that these studies highlight to further improve on its implementation. While many of the auditory feedback studies utilized a handheld clicker, both Harrison and Pyles (2013) and Stokes et al. (2010) highlighted that for some sports, using a clicker may not be possible, as it can be inaudible in some environments. While it is possible to use other devices to deliver auditory feedback instead of a clicker, Harrison and Pyles also reported that there was difficulty in timing the sound of the megaphone to accurately deliver feedback contingent on correct performance. Thus, future studies should include other sources of auditory stimuli, and which types of auditory stimuli can be optimal in different practice environments. This study also highlighted that future researchers should explore its use in training multiple participants at the same time.

Another aspect future research could highlight is whether the skills taught with auditory feedback generalize to in-game scenarios. Stokes et al. (2010) reported that when recording game performance, participants maintained improvements from training. However, Krukauskas et al. (2019) only conducted simulated MMA sparring sessions with the coach and questioned whether subjects' improvements in performing a right cross would generalize to more traditional

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MMA training and sparring. Furthermore, Quinn et al., (2015, 2017) assessed performance in practice but not in actual dance competitions.

While studies showed that coaches (Krukauskas et al., 2019; Quinn et al., 2015) and learners (Quinn, Miltenberger, & James, 2017) can be efficiently trained to implement auditory feedback procedures, the training of non-certified practitioners in implementing these methods may require further exploration. Throughout intervention Quinn, Miltenberger, and James (2017) used the investigators and coach to supervise and provide feedback on implementation, which may suggest that without supervision, treatment integrity may not remain high. In addition, this study reported social validity scores lower than expected, with some participants claiming that the practices in intervention were more difficult than a regular class. Accordingly, ways to achieve high values of social validity as well as the optimal ways to train implementors should be included in future studies investigating auditory feedback.

Public Posting

Public posting refers to interventions involving the presentation of participants'

performance data during their implementation. In these procedures, performance data can be

visible to only the participant (Wolko et al., 1993) or to other individuals in the vicinity (Ward et

al., 1997). Ward et al. (1997) noted that public display of data as a consequence can both be a

positive reinforcer for increases in successful responding, or negative reinforcement when

successful responding allows individuals to avoid aversive consequences such as scrutiny from a

coach or other players. Quinn, Miltenberger, Abreu, and Narozanick (2017) described that

posting could serve as an establishing operation, increasing the value of improvement as a

reinforcer. However, they also noted that posting data could also be aversive to participants. The

following will describe multiple ways in which public posting procedures have been used to

benefit athletic performance.

Public Posting Alone

Various studies suggest that public posting procedures, whether progress data are visible

to others or only to the participant, can be used to improve athletic performance without

combining it with other feedback techniques. Studies in which participants record and display

their own data named these procedures self-recording or self-monitoring (e.g., McKenzie &

Rushall, 1974; Poloha et al., 2004). In these studies, displaying progress data allows for athletes

to serve as the deliverer of their own consequences, similar to that of video self-evaluation.

However, in these self-recording and self-monitoring procedures, subjects are not able to revisit

aspects of individual performance trials with a video. Instead, the aspect of performance

recorded and displayed is the source of feedback.

      McKenzie and Rushall (1974) introduced self-recording for two experiments aimed at either increasing attendance or increasing the completed laps and performance of target skills for youths on a

competitive swimming team. For both experiments, participants recorded their own target behavior by marking check marks on a board displayed for the entire team to see. During the first experiment, the subjects had to meet the criterion for attendance before being able to add a check mark. The criterion began as the swimmer had to both attend and swim in practice, then had to be on the pool deck at the beginning of practice, and finally being present from the beginning to the end of practice. In the second experiment, the swimmers would be able to mark the board for both laps completed, and accurately performing specific target skills, named "work units," during the practice. The results of the study showed that the intervention increased both attendance and work rates for the participants, but there was variability among the lap and work unit completion data. The researchers also noted that, especially in the case of attendance, self-recording allowed for coaches to prioritize instruction more, allowing for more productive practices overall. Along with easing the burden of coaches, McKenzie and Rushall reported that the swimmers were enthusiastic and self-motivated to perform with the intervention. Polaha et al. (2004) also used a self-monitoring procedure to improve swimming skills. During the intervention, their participants, eight adults and three collegiate level swimmers, reported the average number of swimming strokes per 25-yard distance on a board at the end of the pool. Stroke counting was described as something that all of these swimmers already had in their repertoire. They concluded that while the procedure was effective in decreasing stroke counts in participants, the results of self-monitoring may be dependent on the baseline skill levels of the

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athlete.

Galvan and Ward (1998) used public posting, with progress data being reported by the researchers and coach, to decrease different inappropriate on-court behaviors in collegiate tennis players. During the intervention, trained observers watched videos of the participants' scrimmages during practices, counting the average number of instances of inappropriate behaviors across the number of sets in the practice match. These behaviors were inappropriate use of the racquet such as throwing it, negative verbal comments, using the ball for any purpose other than play, and inappropriate physical actions such as the player pulling their hair. Participants were told that on the next practice day, a graph of their data would be posted including the previous practice. Galvan and Ward also prompted alternative or incompatible behaviors but did not publicly display data on their occurrence. They concluded that the intervention reduced the target behavior among the participants but did not completely remove the inappropriate actions from the players' repertoires.

Public Posting Combined with Other Procedures

Public posting is often combined with multiple other feedback procedures when its used to improve on athletic performance. Wolko et al. (1993) compared two procedures, public posting combined with goal setting, or self-recording combined with goal setting, on their effectiveness in improving performance for gymnasts. During the intervention, public posting sessions had the participants put a program board up on the wall and displayed their percentage of successful attempts at balance beam skills individualized to their skill level. If the players met coach-set goals during practices in this condition, they were awarded with a fun activity. In the private, self-recording, condition, the researchers taught participants how to set their own goals and asked them to keep the recordings and the display to themselves but could still receive the

reward for reaching the goal. Their study concluded that while both conditions of the intervention were effective, self-recording combined with goal setting was the more effective alternative. Ward and Carnes (2002) used a combined public posting and self-set goal setting intervention to improve several defensive skills for five collegiate football linebackers. Their method involved the player setting practice goals for each session, and the performance chart displayed in public showed if they made or did not make their goal. Even though the performance chart only displayed progress in the form of yes or no for the goal being met, Ward and Carnes' procedure improved performance on all of the target behavior, with players both meeting and exceeding 90% correct performance on their first 10 attempts. Quinn, Miltenberger, Abreu, and Narozanick (2017) used a public posting procedure to improve performance for several dance movements for inexperienced dancers. During the intervention, session data for all of the participants were displayed on a board visible to others in the studio. The procedure also incorporated goal setting, in which participants also earned gold stars to display along with the data if the participant either performed at their highest percentage yet or maintained a score of 90% or higher. The researchers concluded that all participants improved upon intervention, with the stars serving as a way to reinforce meeting individualized goals.

Brost and Ward (2002) and Smith and Ward (2006) added a verbal feedback component along with goal setting to their public posting procedures. Brobst and Ward evaluated their combined procedure to improve upon ball-handling skills for three high school soccer players. During their intervention, the participants' coach told them that practice data would be posted on a daily performance chart with a criterion goal of 90% performance across the three target skills. Additionally, at the start of sessions, the researcher met with participants individually, providing praise for meeting goals, or words of encouragement if the goals were not met. The study

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resulted in increases in performance for all of the target behaviors for each of the participants. Smith and Ward (2006) compared three procedures of public posting with verbal feedback, goal setting with verbal feedback, and a procedure of all three in how effectively they improved target skills for collegiate football wide receivers. The verbal feedback component described contingent verbal feedback and error correction from the coach. During the public posting and verbal feedback condition, a daily performance chart in the locker room displayed players' practice data. In the goal setting and verbal feedback condition, players received either praise or words of encouragement at the end of sessions for meeting a 90% correct performance, but no data were displayed. The third condition combined both of the previously mentioned procedures. While Smith and Ward were unable to give a conclusion about the relative efficacy of the components to the intervention, they did determine that performance during the goal setting and verbal feedback condition improved better than in the public posting and verbal feedback condition.

Future Directions in Public Posting

The current research in public posting highlights several common topics worthy of future research. Several studies have conflicting results when it comes to generalization of improvements from the intervention to game scenarios. Procedures combining public posting with other procedures such as the ones in Smith and Ward (2006) suggest that in the future, researchers should determine the relative efficacy of each component. Brobst and Ward (2002) claimed that because of the lack of similarity between practices and games, as well as the degree of coach interaction between them, that generalization of their results was limited. But, Ward and Carnes (2002) and Ward et al. (1997) found that their results were maintained during games. Thus, future research should look into how well results from public posting procedures generalize to games, while taking into account difficulties that could arise from each individual

sport. Ward and Carnes suggested that future studies should look at the difference in outcomes if the implementer of the procedure is the coach or researcher. As such, research can try to compare those forms of implementation of public posting and compare them to self-recording (e.g., Wolko et al., 1993). New studies in public posting should also look into its effectiveness across multiple skill levels. Galvan and Ward (1998) suggested that their procedure to reduce inappropriate behavior during play would be more effective with less experienced athletes, due to their shorter history of engaging in those actions. Poloha et al. (2004) had a similar conclusion, saying that swimmers with the highest stroke counts, a behavior targeted for decreasing, during baseline saw the greatest amount of reduction upon intervention. They suggested that when working with more experienced athletes, who may not have the same degree of improvement with simpler self-monitoring procedures, implementers may need added complexity to discriminate improvements in performance.

Discussion

The different forms of feedback described in these studies have all had varying degrees of success in improving athletic performance. While many studies demonstrated the efficacy of using one of these procedures alone (e.g., Scott et al., 1997; Kelley & Miltenberger, 2016), many studies use a combination of these feedback procedures to benefit participants. This is evident when considering that effective use of video feedback often uses the video as a means of directing verbal feedback to specific aspects of the target behavior for correction (Baudry et al., 2006; Guadagnoli et al., 2002). Thus, it is important to emphasize that when developing interventions for athletic performance, it is necessary to determine what factors specific to the performers or skill would most benefit from a particular method of feedback. Some studies' show that TAGteach can be successful at working with novel skill acquisition (Fogel et al., 2010), while public posting may not benefit novices as well as those with more experience (Poloha et al., 2014). Thus, future implementers should find the relative advantages and disadvantages inherent to each form of feedback, to develop packages that can both achieve improvement in athletics, but also maintain those results over time for subjects.

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