University of Nevada, Reno

Elbow's Up! Using Acoustic Feedback to Shape High-Elbow Catch Sequences in Swimming Stroke Technique

A thesis submitted in partial fulfillment

of the requirements for the degree of

Master of Arts in Psychology

By

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May 2020

THE GRADUATE SCHOOL

We recommend that the thesis
prepared under our supervision by

Michelle Katherine Forman

entitled

Elbow's Up! Using Acoustic Feedback to Shape High-Elbow Catch Sequences in Swimming Stroke Technique

be accepted in partial fulfillment of the
requirements for the degree of

MASTER OF ARTS

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ABSTRACT

A review of behavior analysis within the area of sport psychology supports a respectable foothold in past and current-day research. Whereas behavior-based sport psychology research is on the rise in certain sports, there remains a necessity to bring more current behavioral practices to the more neglected areas, such as competitive swimming. Additionally, there remains a need to incorporate a more immediate feedback system into training in swimming. The purpose of this study is to evaluate the effects of acoustic feedback on competition-level swimmers' high-elbow catch sequences over stroke topography. High-elbow catch sequences in three of the four competition strokes (butterfly, breaststroke, and freestyle) were targeted for intervention in a multiple-baseline design. Results indicate that acoustic feedback can be used to initiate behavior change in high-elbow catch sequences with competition-level swimmers who had not improved under standard coaching practices. All except one participant, who was unable to hear the feedback beep, showed improvement in their high-elbow catches in at least one stroke with varying degrees of improvement. Carry-over effects were only seen in one participant and no sequence effects were observed.

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to my faculty advisor, Dr. Larry Williams. His unceasing support and encouragement helped drive me to succeed and without whom this thesis would have remained just an idea. Words can never express how grateful I am for all his guidance over the years. I would also like to thank my committee members, Dr. Patrick Ghezzi and Dr. Maryann Demchak, for their feedback on this project. An additional thanks to Dr. Ghezzi who’s Research Methods class first fueled the idea for this thesis.

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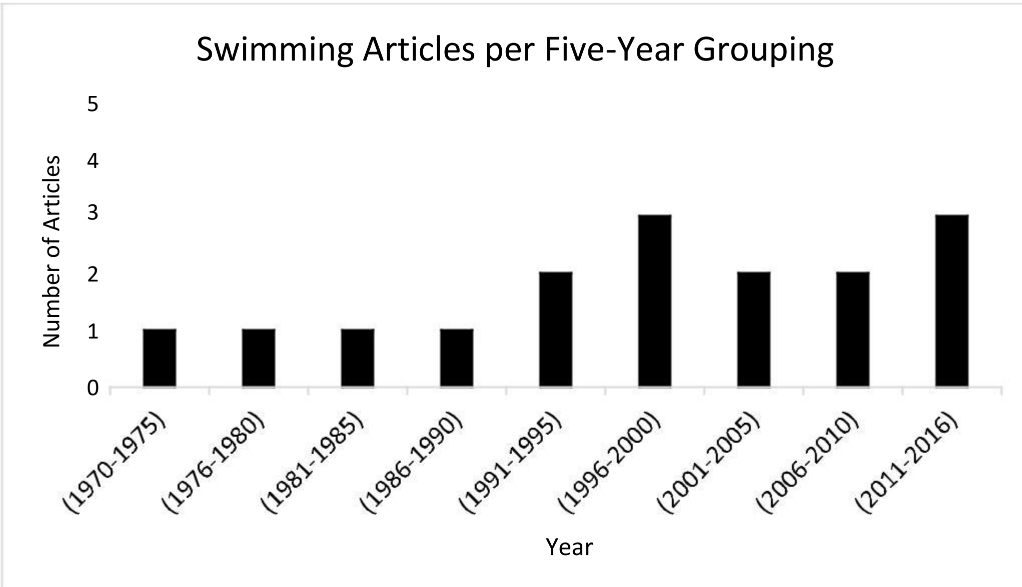

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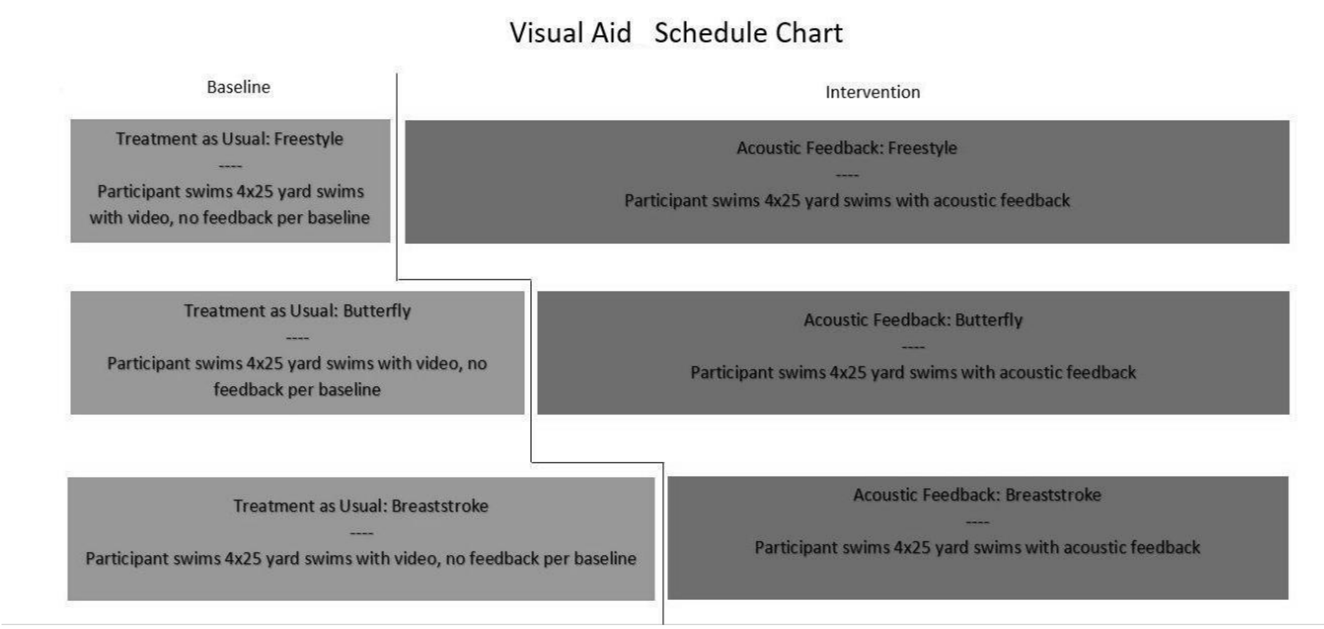


Behavior Analysis in Athletics

Behavior analysis made its debut into sports with the 1974 issue of the *Journal of Applied Behavior Analysis* (JABA) (McKenzie & Rushall, 1974). However, the first study into behavioral applications for athletic improvement was in a study by Rushall and Siedentop in *Development and Control of Behavior in Sport and Physical Education* (1972). McKenzie and Rushall (1974) later published an article which combined behavior analytic principles and then-current sport research, with an emphasis on single-subject designs, as was recommended by Bear, Wolf, and Risley (1968). Bear et al. expressed a need for single-subject designs for demonstrating experimental control over the target behavior in question. Since then, behavioral interventions in sport practice have been used, albeit not at the consistency of other research, but have been seen in continued usage over time (Martin, Thompson, & Regehr, 2004). According to Martin et al. (2004) “during the past 30 years, research in sports that used single-subject designs has steadily increased [and] averaged 0.6, 1.2, and 2.2 published articles per year during [the] past three decades, respectively” (p.263). Whereas research in sports is increasing, there remains a necessity to bring more current behavioral practices to the field.

Much of the research utilizing behavioral science in athletics is focused on behavioral coaching. This involves a feedback system of the coach to the athlete (Boyer, Miltenberger, Batsche, & Fogel, 2009; Kladopoulos & McComas, 2001; Smith & Ward, 2006). Coaching practices have been investigated within the scope of behavioral science in numerous areas, such as golf (Fogel, Weil, & Burris, 2010), volleyball (Grgantov, Katić, & Marelić, 2005; Barnes, Schilling, Falvo, Weiss, Creasy, & Fry, 2007), track and field (Scott, Scott, & Goldwater, 1997), football (Harrison & Pyles, 2013; Smith & Ward, 2006; Stokes, Luiselli, Reed, & Fleming, 2010), swimming (Koop & Martin, 1983) and many more. There have been numerous studies which have demonstrated the effectiveness of behavioral coaching on the improvement of athletic skills development, retention, and/or acquisition. This research has been limited in some instances, however the newer procedure of acoustic feedback has a demonstrated effectiveness at producing positive behavioral changes in athletic skills (Gonzalez, 2014).

Behavioral coaching is a set of techniques for promoting changes in a skill or set of skills and then maintaining and generalizing learning over time (Martin & Hrycaiko, 1983a; Martin & Hrycaiko, 1983b). Behavioral coaching has been referred to as a scientific model based on validated and measurable goals (Skiffington & Zeus, 2003) and can include such components as reinforcement, feedback, and goal setting (Stokes et al., 2010).

Research on Swimming

One sport which has not seen as much research as others, such as football, is swimming. Research in swimming spans from the 70's to the present. Figure 1 illustrates the dates of publication for behavioral-based swimming-focused research, not taking into account the type of study reported, only that swimming was involved in some way. Not only is swimming a relatively neglected field of study in sports, but the research into swimming took years after its initial studies until intervention with swimmers returned to the water rather than targeting behaviors while on land, and more time still before effects of immediacy of feedback were demonstrated.

At its peak, the most behavioral-based research on swimming in a five-year period was in the mid-70's to early 80's (McPherson, Marteniuk, Tihanyi, Rushall, & Clark, 1980). This began with McKenzie & Rushall (1974) article published in the Journal of Applied Behavior Analysis. While McKenzie & Rushall (1974) may have looked at swimming in relation to self-recording, they implemented their research during a "dry land" activity. This is the term used in swimming for when a swimmer works on skills outside of the water. The following year, Rushall & Smith (1979) reported in the Journal of Sport Psychology. This research, while focused on swimming, did not target the swimmer, but the coach. This article was influential in establishing a backing for the ineffectiveness of standard coaching practices. However, despite this realization, research into coaching practices did not increase insofar as swimming was involved. The next area of research to arise in swimming was Dowrick & Dove (1980) in the Journal of Applied Behavior Analysis. This was a unique approach to swimming skills, but not the population in question. Though influenced by the methodology of McKenzie & Rushall's (1974) research, this study represents a move towards placing the swimmer in the water for the intervention whereas the research to-date had focused on dry land activities. However, swimmers were self-monitoring (which involved a score board outside the water) on which they had to report.

These research articles represent the burst of investigation in the area of swimming and Behavior Analysis for a number of years. Other research studies were published, such as that by Martin, LePage, & Koop (1983) and Koop & Martin (1983), but these chose to focus on the coach over the swimmer. However, it was Koop & Martin's (1983) research which isolated swimming stroke errors as the area for focused research, whereas the research to-date had not. This marked a change towards imperative area to competitive swimming that had been lacking up to that point.

Despite putting swimmers back in the water, there was still a key element missing in the research to date—immediacy of feedback. Hazen, Johnstone, Martin, & Srikameswaran, (1990) demonstrated a way in which feedback could be enriched over the standard verbal feedback given by coaching staff. This experiment moved research closer towards the simple complexity so thoroughly researched and supported in other areas of Behavior Analysis. However, it still required a swimmer to swim for a minimum of a lap before the video feedback could be offered.

While swimming research was taking a step in the right direction, the next published article was not an advancement on Hazen et al.'s (1990) study, but a more focused and broadened approach to McKenzie & Rushall's (1974) original swimming study as well as taking into account the current literature on ineffective coaching practices. Critchfield & Vargas (1991) focused on self-recording procedures, instruction type, and self-graphing in a public area to see the effects of this type of intervention on age-group swimmers. A novel addition to their study was to take the coach out of the picture by having the swimmers be their own monitors. Despite the advancements in swimming research to this point, there remained another understudied area in competitive swimming. This had to do with reinforcers and feedback types.

As though with this in mind, Hume & Crossman (1992) brought a new variation to swimming feedback in the form of musical reinforcement. With the water barrier, delivering feedback immediately to swimmers when they perform a correct stroke is a challenge. The article by Hume & Crossman makes a significant advance towards alleviating that barrier by introducing the idea of acoustics. The next published article on swimming, published seven years later, was an evaluation of the effect of self-monitoring on swimmers. Critchfield (1999) in his study found that attendance at swim practice increased when the recording schedule was the "least frequent" (p. 389). It seems then, based on the evolution of swimming research, the next step for behavioral-based swimming interventions should target stroke efficiency and entail feedback with minimal to no delay.

An overview of the research in swimming to this point has isolated an area for further analysis: research targeting individual stroke components with athletes. For example, of the nine common errors in freestyle stroke, the high-elbow catch (HEC) is one of the most influential in establishing efficiency and speed in the water (Counsilman et al., 1979). It is also a component that is ranked among the top five most common mistakes in all four swimming strokes (Counsilman et al., 1979). High-elbow being described as the arm initiating the pull sequence of the stroke while between a 110 and 90-degree angle in the front quadrant of the stroke. Should the angle be more obtuse or more acute, or if the elbows fail to come up to the desired degree while the arm is still in the front quadrant of the stroke, the catch (stroke) would no longer be classified as high-elbow and would instead be an error stroke (Counsilman et al., 1979). This definition excludes straight-arm freestyle, which is more common with the "sprinter" (50 or 100 yards/meters events) stroke style.

Current coaching strategies involve waiting for the athlete to error in their catch before providing feedback (Van Rossum, 2004), or providing stroke correction and practice while the swimmer is out of the water (dryland). Within swimming coaching, the option of quantity over quality is popular despite evidence to the contrary (Rushall and Smith, 1979). Errors are expected to fade over time and muscle memory relied upon to keep the stroke within correct parameters once "perfected". Swimmers have swum thousands of yards a day for years, slowly molding their strokes into the perfect all-around stroke complete with HEC. However, taking the time to correct a stroke first could result in faster acquisition of the desired stroke and subsequent speed resulting in repeated movement for muscle memory of the correct form rather than incorrect. Targeting specific components within the stroke, such as a correct HEC, would be beneficial.

Whereas there are a variety of studies which look at improving swimming stroke proficiency, such as Martin, LePage, and Koop's (1983) study with age-group swimmers, few target collegiate-level swimmers and even fewer still offer immediacy of feedback when the swimmer demonstrates correct form while in the water (Martin, Thompson, & Regehr, 2004). The immediacy of feedback is paramount in shaping behavior. However, with competitive swimming, athletes are required to swim, at minimum, one lap (25 yards) before stroke feedback is given while they are in the water. This is due to the dulling of sound from the athlete being submerged in water. Specific verbal feedback cannot be understood from within the water when such feedback does not also contain a visual presentation. For example, a coach yelling "hold your core" at a swimmer while they are swimming is unlikely to produce the desired response. Consequently, coaches might yell that same phrase, but while also patting their stomach when the swimmer turns their head to breath (allows a goggle to clear the water for limited visibility of the coach). The swimmer can then associate the distorted sound of the verbal with the model and assume an issue in the area visualized. This is common feedback for higher-level swimmers granted they have a previously established history with that coach and his or her ways of representing movement correction. This form of feedback is used across coaching staff and athletes as common stroke correction procedure. However, this is not always feasible and also does not account for the coach's limited visual range of what is occurring under the water. Other than a coach swimming alongside the swimmer as they complete laps, there has not been a demonstrated effective method for delivering feedback for an underwater component of swimmer stroke technique while a swimmer completes stroke training laps.

Acoustic feedback, a form of operant conditioning with use of a small sound emitter, a "clicker", is a form of training which initially made its debut in dog training and referred to as "clicker training," (Pryor, 1999) could provide an alternative method for providing immediate feedback in many sports (LaMarca, 2013).

Overview of the Literature of Acoustic Feedback

Acoustic feedback (AF) has been described as the use of an audible stimulus produced by a clicker, or similar sound device, which serves as a conditioned reinforcer to produce immediate feedback following a specified behavior (Pryor, 1999). AF has been most commonly applied to settings in which animal behaviors were the targeted topographies. Bringing in this conditioned immediate reinforcer to animals has seen success. AF has since moved into a variety of other areas, including sport sciences.

Several journals were reviewed for content specific to acoustic guidance, or any of its other titles excluding articles where the participants were nonhumans, regardless of the topic of the journal. In addition, Master's theses and dissertations where AF was used were also added to this review. These journals were the following: Journal of Applied Behavior Analysis, the Journal of Strength and Conditioning Research, Behavior Modification, Journal of Behavioral

Health and Medicine, Collegium Antropologicum, Sport Psychologist, Journal of Sport Sciences, Journal of Applied Sport Psychology, Journal of Sport Psychology, the Behavior Analyst, Behavior Modification and Coaching, Canadian Journal of Applied Sport Sciences, Journal for the Education of the Gifted, and ProQuest Dissertations and Theses Global. The following is a review of reported articles which used acoustic feedback, whether by that name or alternative names such as acoustic guidance or TAGTeach.

Acoustic feedback within athletics began with Scott, Scott and Goldwater (1997). While not explicitly stated as such, and in addition to a prompt, the authors used a “beep” as a form of feedback for when a vaulter engaged in a correct behavior known as “when the photoelectric beam” is broken. This means the individual successfully chained together appropriate behaviors to achieve a desired height. This included fully extending the arm, which was where the participant self-reported as being inadequate and what the authors designed their intervention around. The study procedure was “proven effective” (p.574). This meaning the participant improved his extension at the plant of the pole (p.575).

Thirteen years later, a second article reported acoustic feedback. This was Diokno and Pyles’ study which is an unpublished manuscript of the Chicago School of Professional Psychology in 2010. However, as this study was unpublished, there remains a barrier to obtaining a copy for review. Given the title, using clicker training to improve volleyball passing Form (2010), there is strong suggestion that it utilizes AF principles, and which is why it remains within this review.

Within the same year, another study by Fogel, Weil, and Burris (2010) was published in the Journal of Behavioral Health and Medicine. This study offers the surname TAGteach (teaching with acoustical guidance) to what had previously been untitled (afore mentioned unpublished study excluded). The purpose of their study was as an evaluative tool. The authors used the methodology of TAGTeach as an intervention for teaching golf swings. Their participant was a novice golfer who participated in seven sessions. Results showed the participant acquired, shown across a multiple-baseline deign, four of five targeted skill areas (2010). In addition, the effects achieved were observed to generalize to use of an additional golf club. Golf requires the use of several different types of clubs, most commonly used for fairway or Tee shots (Davies, Davies & Davies 1962).

Evaluation of coaching procedures also came in to play in 2010 with Stokes, Luiselli, Reed, and Flemming's (2010) study. This article looked at behavioral coaching procedures with the intention of improving offensive pass-blocking skills. The targeted population were high school varsity football players. A multiple baseline design was utilized to evaluate the components. The results showed that video feedback and AF were the most effective procedures. However, the players did require additional intervention to maintain their levels of pass-blocking.

Jump forward three years and the use of AF remains within the realm of football. Harrison and Pyles (2013) look at verbal instruction and AF in shaping high school football players' tackling proficiency. Their results show what had been observed to-date, increased proficiency in the desired behavior. The authors did note a difficulty with using AF. This being providing the beep at the right time. As participants were often sprinting, additional training would be required of coaches to implement AF in daily coaching practices.

The Chicago School of Professional Psychology produced another unpublished Master's thesis concerning the use of AF within the area of sport psychology. Gonzalez (2014) looked in to volleyball players in her thesis. She noted that the athletes in the study showed "immediate improvement" from their starting skill level. The skills maintained after the conclusion of the study, as well. The author did note, however, that it was uncertain if it was the TAGTeach which shaped the skills. "[Because] it was a treatment package, it is unclear which element(s) of the treatment package were responsible for behavior change". This is a common theme in the studies published up to this time. Replication considering the individual components would be needed before it could be said that TAGTeach alone attributed to the desired skill acquisition.

Quinn and Miltenberger (2015) bridged this gap of using TAGTeach within a package and conducted a study in which the acoustic feedback was the sole intervention tool. The authors looked at the effectiveness of TAGTeach when implemented by dance teachers to teach three behaviors in dance students. These were a turn, kick, and leap. The results showed little movement towards criterion while in baseline. However, once the TAGTeach was implemented all participants improved. Whereas additional studies will be required, the authors' results support TAGTeach as a stand-alone intervention for shaping desired athletic skills.

In addition to the afore mentioned studies, another study was published in 2015 looking at the effects of acoustic guidance on a para-rowing national team. The authors, Schaffert and Mattes (2015a), reported, via a within-participant ANOVA, the effectiveness of AF as evidenced by an increase in boat speed over baseline. However, it is in question by a second author, who published a letter to the author of whether the original study actually measured what they intended to measure (Hill, 2015). The original authors wrote a reply in which they defended their original position concerning their results (Schaffert & Mattes, 2015b). While the results are contestable, the study itself demonstrates a use of AF within the area of athletics.

Current Study

Focusing on the swimmer, within the water, and on the technique of each stroke could help with two issues. The first being how to produce faster swimmers in the future. "Faster" meaning the product of reduced errors per stroke cycle and a more efficient distance-per-stroke (a more equalized forward movement to energy output ratio). Secondly, it could potentially reduce the amount of shoulder-related injuries swimmers sustain as a result of improper form. Injuries, such as rotator cuff impingement, tendonitis, tears, or even damage to the ligaments and cartilage, are considered typical for swimmers at the collegiate-level or beyond, rather than the exception. Whereas these injuries will most likely not be completely alleviated due to competitive swimmers also being at increased likelihood of overuse injuries, injuries resulting from improper use could be narrowed. For example, a catch that crosses over the swimmer's head (the right arm, instead of reaching straight forward, reaches Cross and over the head and towards the left-hand side) puts additional strain on the tendon groups within the shoulder. As swimmers have incredible flexibility in their shoulders, and are often accused of overuse due to continued repetition of the stroke cycle during practice and competition, the chance of eliminating inflammation of the tendons altogether is not feasible given the nature of a study into proper HEC. However, it would be useful to see if quickened acquisition to proper form resulted in a reduction of injuries that had previously been caused by improper form.

Given the results of studies targeting motor movement and technique were effective, Behavior Analysis could have a significant impact on the world of competitive and elite-level swimming. The question remains, how? This is where the Acoustic Feedback comes in.

Research has shown the potential promise of AF as a teaching procedure, but more research is needed not only on the effectiveness of the current areas of involvement, but an evaluation of future avenues as well (Quinn, Miltenberger, & Fogel, 2015). For example, while research has documented effects of immediate versus delayed feedback in sport psychology research, there is a paucity of research in utilizing AF as a feedback measure against other measures (Quinn et al, 2015). Currently, Fogel et al's., (2010) evaluation of the effectiveness of AF as a stand-alone procedure is the only known article to evaluate the practice in this manner. AF could also be used in additional areas of less known athletic fields, such as competitive swimming. Luiselli, Woods, & Reed (2011) said of AF that the method "appear[ed] to be promising but require[d] further evaluation" (p. 1001). Consequently, AF should be studied in more populations, in particular within the area of sport behavior.

The current study seeks to determine if acoustic feedback can be used to decrease errors in high-elbow catches, and if there would be carryover effects of the intervention from one stroke type to another. Given the relationship of a high-elbow catch in three of the four swimming strokes, that being a very similar body motion of moving the elbow and arm to the desired angle in freestyle, breaststroke, and butterfly, it is anticipated there would be some carryover with the successful reduction in catch errors in freestyle after the addition of the intervention. Breaststroke and butterfly might see this carryover effect the most, given their close relationship in how the catch and body are oriented. That being both arms moving in sync while the torso pivots on the short axis. However, as freestyle requires the swimmer to pivot on their long axis and the arms move do not move in sync, it is anticipated there will be minimal to no carry-over effect for this stroke. Since backstroke requires a swimmer to be on their back with the high elbow out to the side rather than in front of or below the body, in addition to the researcher being unable to reach criterion for correctly identifying high-elbow catch sequences during video training, this stroke was excluded from the study. The null hypothesis assumes no effect of the intervention on high-elbow catch sequences. The alternative hypothesis assumes there will be an effect of the intervention and is a directional hypothesis in that there will be a positive result (behavior will improve rather than decrease). A secondary hypothesis is there will be carryover effects of the intervention.

H_0: Baseline = Intervention.

H_1: Baseline $\neq$ Intervention.

The dependent variable is the high-elbow catch. The independent variable is the acoustic feedback. A supplementary dependent variable will be decreased distance per stroke (energy output to forward propulsion ratio), meaning the athlete will take more strokes per lap. This is due to a switch in muscle groups from the arms and shoulders to the lats and shoulders. It is unlikely the underutilized latissimus dorsi muscle (lats) will be able to generate as much power in the moment as the dominant muscle the swimmer is currently using to generate stroke power (typically the arms and shoulder muscles). However, once the lats are trained to the same level as the arms previously were, the swimmer will generate better forward movement with reduced energy output, which would lead to increased endurance during races and faster overall swimming times. Also termed as "efficiency of stroke" in swimmer culture. This is the reason a correct high-elbow catch is considered one of the best tools in a swimmer's repertoire. This study is not long enough to change the physiology of muscle groups. Therefore, it is anticipated there will be decreased "efficiency" in the form of an increase in stroke count per 25-yard segments.

METHOD

Participants

Five athletes with a background as competitive-level swimmers participated in the study. All lived in the local area, were between the ages of 21 and 40, and had been swimming competitively for at least a year. "Competitively" was defined as having had a coach in the past and had competed in at least one USA-sanctioned or unsanctioned event in Age-Group Swimming, Masters Swimming, Triathlon, or Open Water Swimming event(s). The swimmers were identified by their current coach, or self-reported, as requiring additional assistance establishing a consistent high-elbow catch. They either did not perform a correct catch or had persistent intermittent errors in the catches of the three competitive strokes: freestyle, breaststroke, and butterfly. In addition, all participants were required to be able to swim at least 25 yards without rest of the three strokes. Potential participants were given a questionnaire (see appendix B: Inclusion Criterion) which excluded any swimmer who identified as having significant body-line errors ("significant" being a body position which generates a slope from the upper to lower body where the swimmers' upper body parallels the water while the lower body is six inches or greater distance below the surface of the water) in any of the strokes, as this would make engaging in a high-elbow catch more difficult or possibly impossible, or those with health issues which would lead to unnecessary increased health risk through participating in water sports.

Setting

The University of Nevada Lombardi Recreation Center pool, a 25-yard, eight lane, competition pool was the setting for the study. The Lombardi pool varies between 3 ½ feet deep along the perimeter, descending to 6 feet deep at the center. Average temperature of the pool was 28 degrees Celsius. The pool contained eight lanes which were divided by standard racing lane lines of a blue-grey and white striped pattern with similar university-themed backstroke flags at either end. Because the study required a wall for the researcher to follow beside the swimmer while viewing underwater footage, only lane one was used during the study (lane eight was unavailable since the lifeguard stand was positioned on that side). The lead researcher was also a certified American Red Cross Lifeguard and then a CPR instructor during the duration of the study. Additionally, Lombardi had a minimum of one other Lifeguard on duty.

Materials

The main materials for the study included a wireless Blue Tooth speaker, a wireless camera (GoPro Hero® 4), an Android® tablet, an Android® Galaxy S9 smartphone, an RG 174 coaxial antenna cable to boost the WiFi frequency from the GoPro to the tablet, and an apparatus built of pvc piping and a skateboard to hold all the components (see Appendix E). The speaker was a Bluetooth underwater speaker which had a waterproof rating of IPX7 out of the IPX0 (not waterproof) to IPX8 (full waterproofing up to four feet) scale. This device synced with the researcher's phone and delivered a brief, loud beep contingent on the researcher turning it on. The GoPro Hero is a high definition camera containing the required properties to sync with the researcher's tablet via Bluetooth. The hand-made apparatus moves all the materials along the pool side. It has a stabilized set of piping with attachments for the Android tablet and phone. The apparatus was designed to run along the edge of a pool deck, pushed by the researcher/coach at the speed of the swimmer, to record the technique which takes place under the surface of the water. A data sheet was used for IOA purposes. The videos were recorded for measuring procedural integrity of the lead researcher's discriminations of a correct high-elbow catch sequence and for collecting inter-observer agreement.

Personnel

Behavioral observations were taken by the researcher and an assistant, whom the researcher trained. Training for the assistant was conducted in two phases, modeled after the study by Koop and Martin (1983). Phase one consisted of an orientation run by the researcher on the data collection procedure and on how to use the technical gear during the study. In the second phase, the assistant practiced collecting data on a nonexperimental swimmer until the minimum interobserver agreement of 90 % agreement for three consecutive trials were met. The acoustic feedback procedure was implemented by the researcher only.

Procedure and Design

The primary researcher swam with the underwater sound system to adjust the pitch and volume until the beep omitted upon a correct HEC could be clearly heard. The participant swimmers were also instructed to swim warmup while the apparatus was set up. Each of the five participants were recorded swimming one length, 25 yards, of the pool at a time. This way their right arm faced the camera on the way down the pool, and their left on the way back. During the baseline conditions, they swam without any acoustic feedback, but with the lead researcher and assistant researcher following and taking IOA data of the swimmers' strokes. This also gave the lead researcher time to acclimate to each swimmers' individuality between strokes. If the lead researcher was not able to reach criterion of accurately discriminating HEC for each stroke by the time that stroke was set to switch from baseline to the AF condition, the AF condition was not implemented. However, this did not occur during the study. This was to protect the swimmer from receiving inconsistent feedback and potentially shaping incorrect form. Swimmers completed four laps (for a total of 100 yards) of freestyle, butterfly, and breaststroke. This constituted as a round. In round one, all strokes were in baseline. In round two, the first stroke (i.e. Freestyle) received the AF while the other two strokes remained in baseline. In round three, both strokes one and two (i.e. freestyle and butterfly) were added to the intervention while the last stroke remained in baseline. Round four, all three strokes (i.e. freestyle, butterfly, and breaststroke) received the AF intervention. This concluded the study procedure for one individual. Participants were instructed to not use underwater dolphin kicks or the breaststroke pulldown so as to avoid decreasing the available total stroke count (15 yards of the available 25 yards of each length can be utilized for underwaters versus the approximately 5 yards used when simply pushing off the wall).

Swimmers were run through all four rounds one at a time. As in, each session contained only one participant. The swimmers also only swam a single 25-yard segment at a time before pausing on the wall. This way, the camera and equipment could be properly adjusted and started before each participant lap as needed. The live-streamed video was recorded for later data collection purposes. Once downloaded, the researcher reviewed the baseline footage for treatment integrity checks and the assistants reviewed the footage for IOA, pausing or slowing at each catch to establish whether a 110 or 90-degree angle (correct HEC criterion) has occurred within the front quadrant of the stroke. Should the arm angle lie within those parameters, it was logged as correct. The count of correct and incorrect strokes was recorded per 25-yards.

During the intervention, the researcher followed from the deck alongside the participant swimmer as they completed the four laps of the pool per each stroke. When the participant completed a correct HEC, the researcher pressed the “on” button for the acoustic feedback which delivered a high-pitched sound the lead researcher previously tested as being easily heard from within the water. There was no programmed consequence for an incorrect HEC. No additional incentive, outside the potentiality for improved stroke and a detailed stroke analysis video review with the lead researcher upon conclusion of the study, were used for increasing the instances of correct HEC. For data collection purposes, the researcher also said “yes” when they identified a correct high-elbow catch (this was quiet enough to be unheard by the swimmer) or “no” for the incorrect catches. The research assistant coded each stroke catch report on a data sheet according to what the lead researcher said (yes or No). This was used for research integrity later. *Experimental Design*

A multiple baseline design across stroke types and replicated over subjects was used. The protocol represents a repeated measures design, though the data is not substantial enough to run a statistical analysis. Feedback was delivered at a FR 1 schedule with no consequence for incorrect behavior. Each participant was assigned a stroke condition order at random to account for sequence effects.

RESULTS

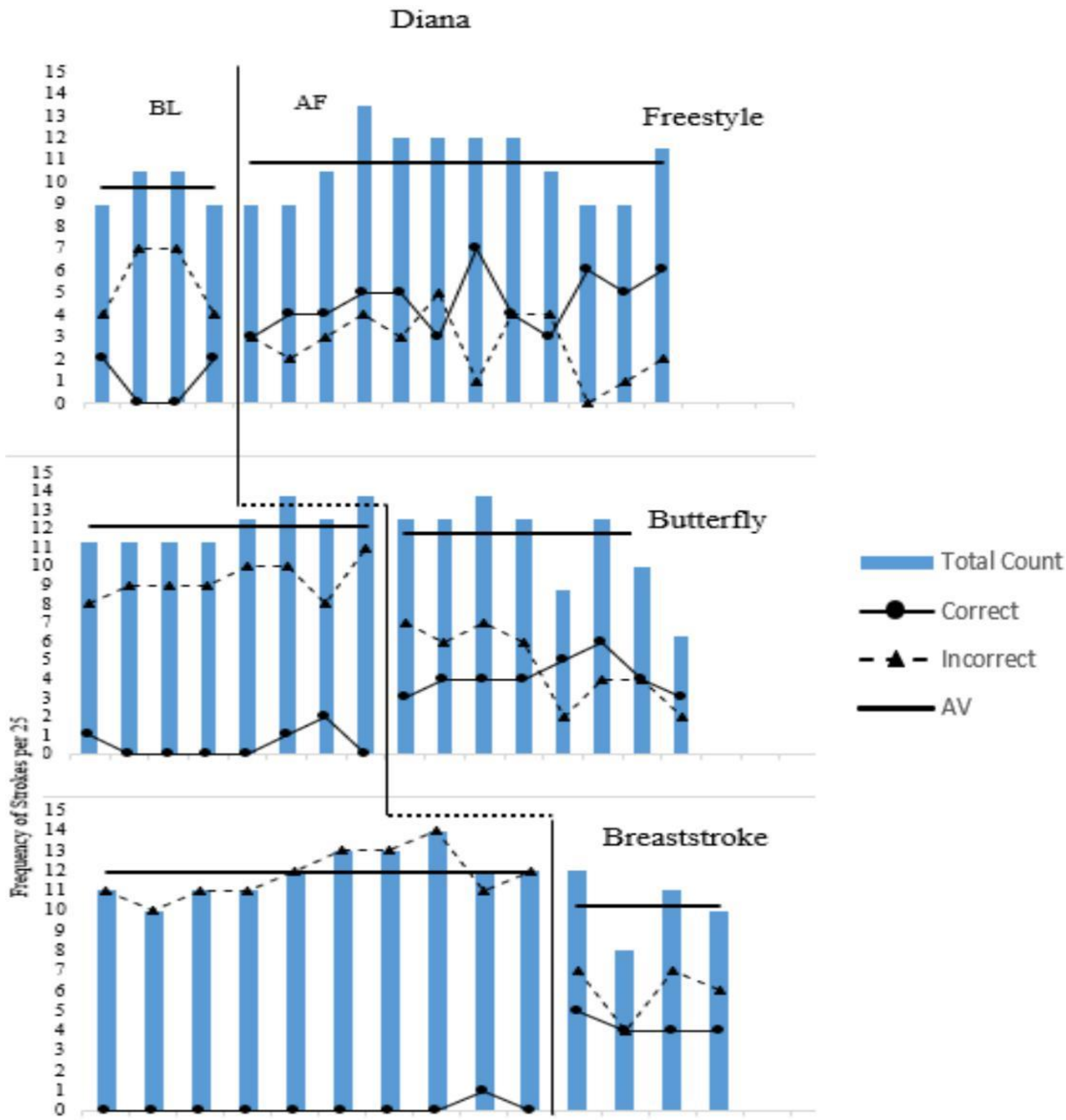
Interobserver agreement using exact count per interval was completed on 100% of all data. The videos were slowed down to half-speed when reviewing and could be paused when needed. The mean agreement was 96.7%. The means per stroke type were, for Butterfly, 98%, breaststroke, 95%, and freestyle, 97%. The accuracy with breaststroke was at 97% until participant five, who swam a unique form of breaststroke where his head did not breach the water on every stroke. This provided a bit of disagreement concerning whether or not the catch occurred at the front-quadrant due to the head being either completely within the quadrant or only halfway depending on whether the participant swam a head down or head up stroke. Similar numbers were seen in regard to research integrity with butterfly at 99%, freestyle at 97%, and breaststroke dropping to 93%. The turnover rate of breaststroke for two participants provided increased difficulty, as compared to the other participants, for the lead researcher to accurately discriminate a correct from an incorrect high-elbow catch. Turnover rate refers to the speed in which the participant's arms are moving through the water. The faster the arm movement the higher the turnover rate. Butterfly had the slowest turnover rate across all participants.

Following the conclusion of the study, a social validity questionnaire was distributed to the participants. The feedback was used to determine the participant's self-report with the effectiveness of the feedback type and their opinion of whether they would like to receive similar feedback in the future. Four of the five participants reported liking the feedback and would like to use it more in the future. The one participant who did not report similarly as the others was participant Reed who reported at the conclusion of the study that he could not hear the acoustic feedback.

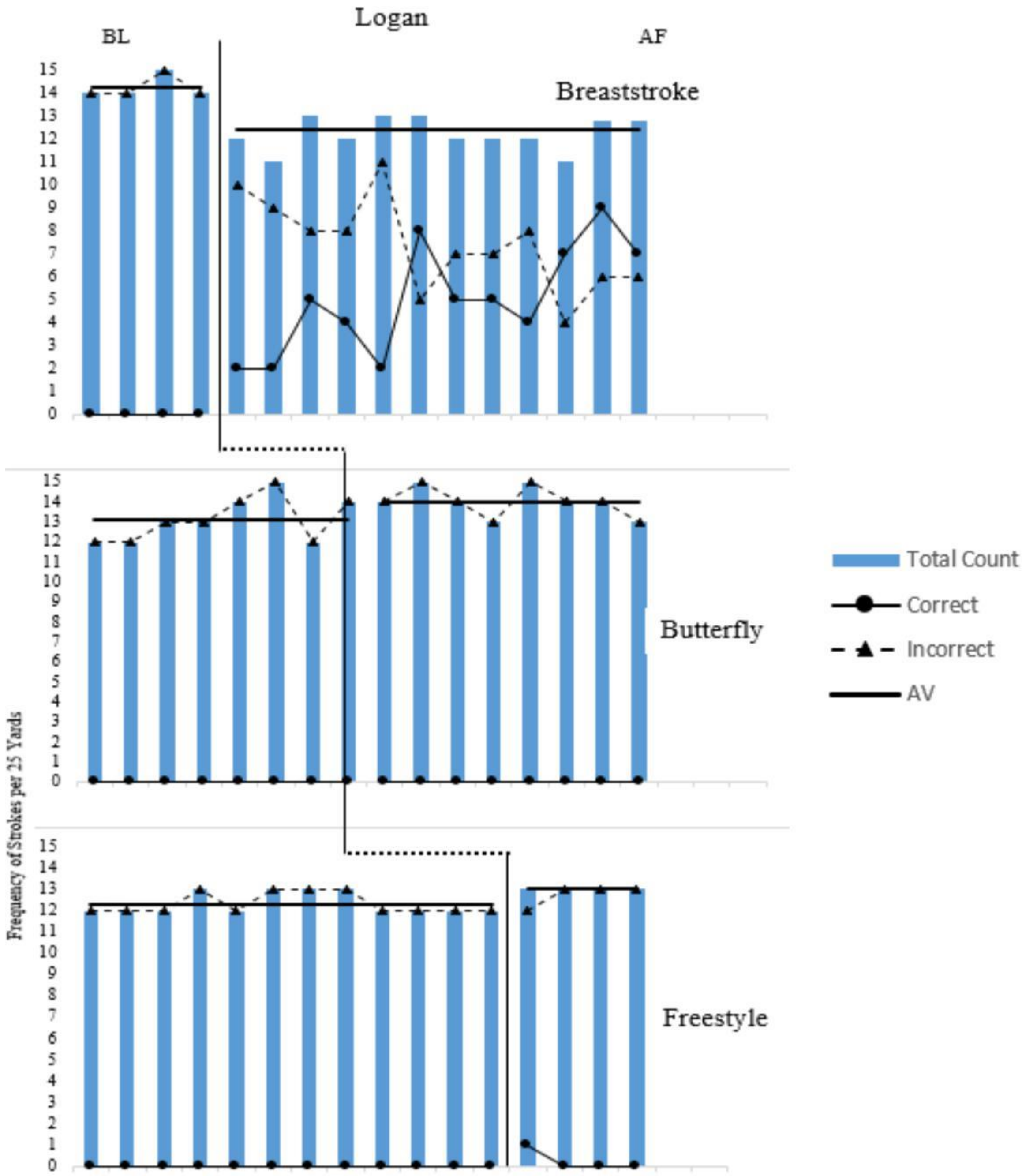
The acoustic feedback was effective in decreasing swimming stroke HEC errors, as shown in the figures below, for at least one stroke for all except one participant. The participant who failed to improve self-reported at the conclusion of the study that he could not hear the acoustic feedback while he was swimming. His data showed no improvement and no changes in average number of stroke count. He requested he still be able to review his underwater footage with the researcher. Despite the relationship of the high-elbow catch in the swimming strokes, only one participant demonstrated carryover effects. No sequence effects were observed. With this data it can be suggested that the use of acoustic feedback can be used to successfully initiate positive change in high-elbow catch sequences trending towards a decrease in HEC stroke errors, but is unlikely to encourage carryover effects. The increased stroke count anticipated was also variable between participants and strokes, with the long-axis stroke (freestyle) being more likely to increase while the short-axis strokes (breaststroke and butterfly) being more likely to decrease in the total number of strokes per 25-yards as the number of correct strokes increased. The data is promising for rejecting the null. That being, there was a change in behavior of HEC from baseline to intervention in a positive direction (an increase in correct HEC and a decrease in HEC errors).

The below graphs depict the data. The left of the phase change line, marked BL, shows data in baseline and the right, marked AF, is the data after implementation of the acoustic feedback. The horizontal axis represents each 25-yard segment while the vertical axis represents a frequency count of stroke catch by 25-yards. The dotted lines are incorrect strokes with the solid lines being the correct. The blue bars represent the total stroke count by 20-yards and the horizontal lines across the bars being the average stroke count for that condition. All swimmers started with feedback on their right side. Consequently, each data point reads right arm, then left arm, then right, then left, etc. Always starting with the right arm and ending with the left.

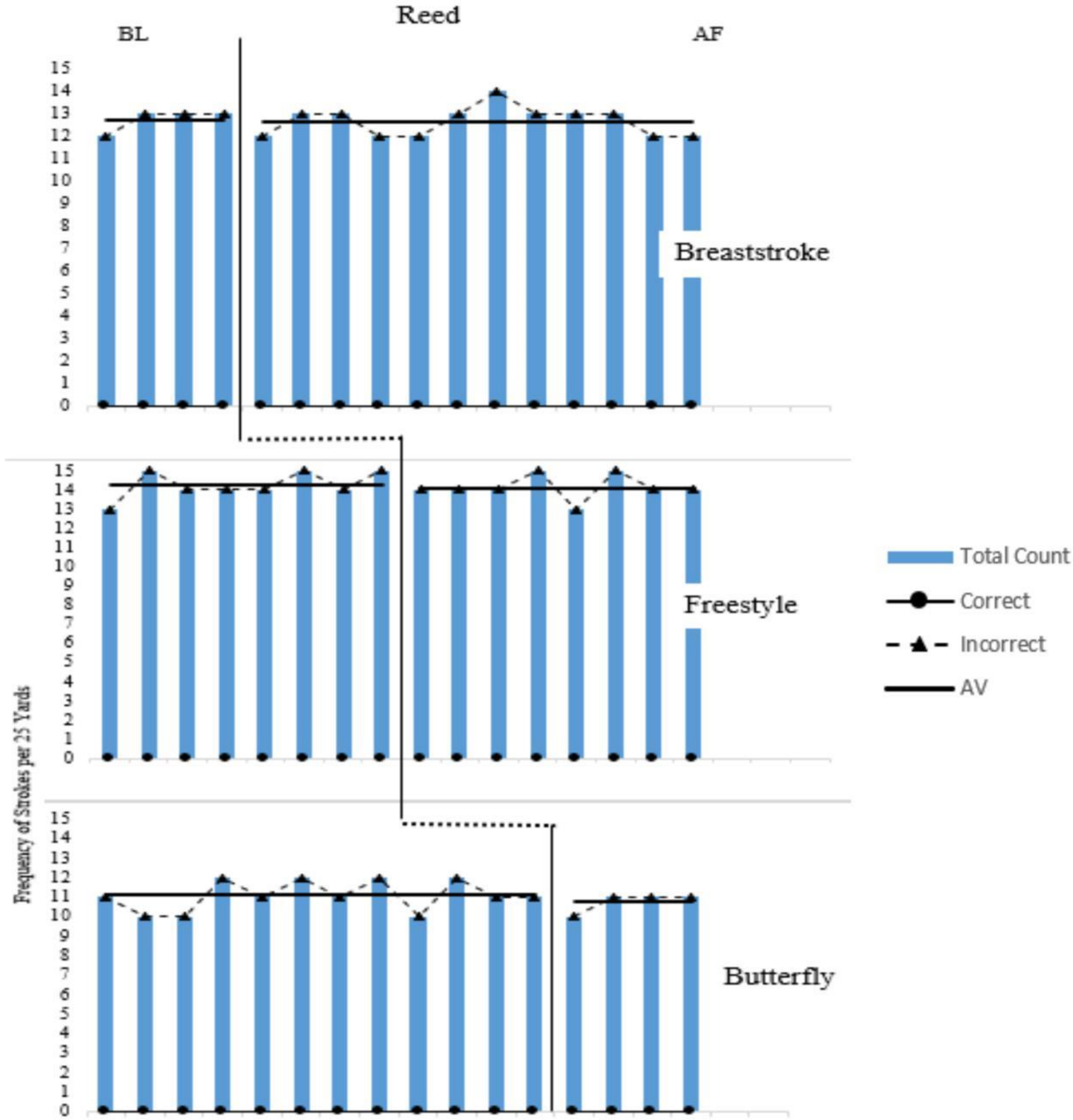
Diana was a female college student at UNR with a history of USA Swimming and USA Triathlon competitions. She worked with multiple coaches in the past and self-reported as having done extensive technique and drill work. Her stroke order was freestyle, butterfly, and then breaststroke.



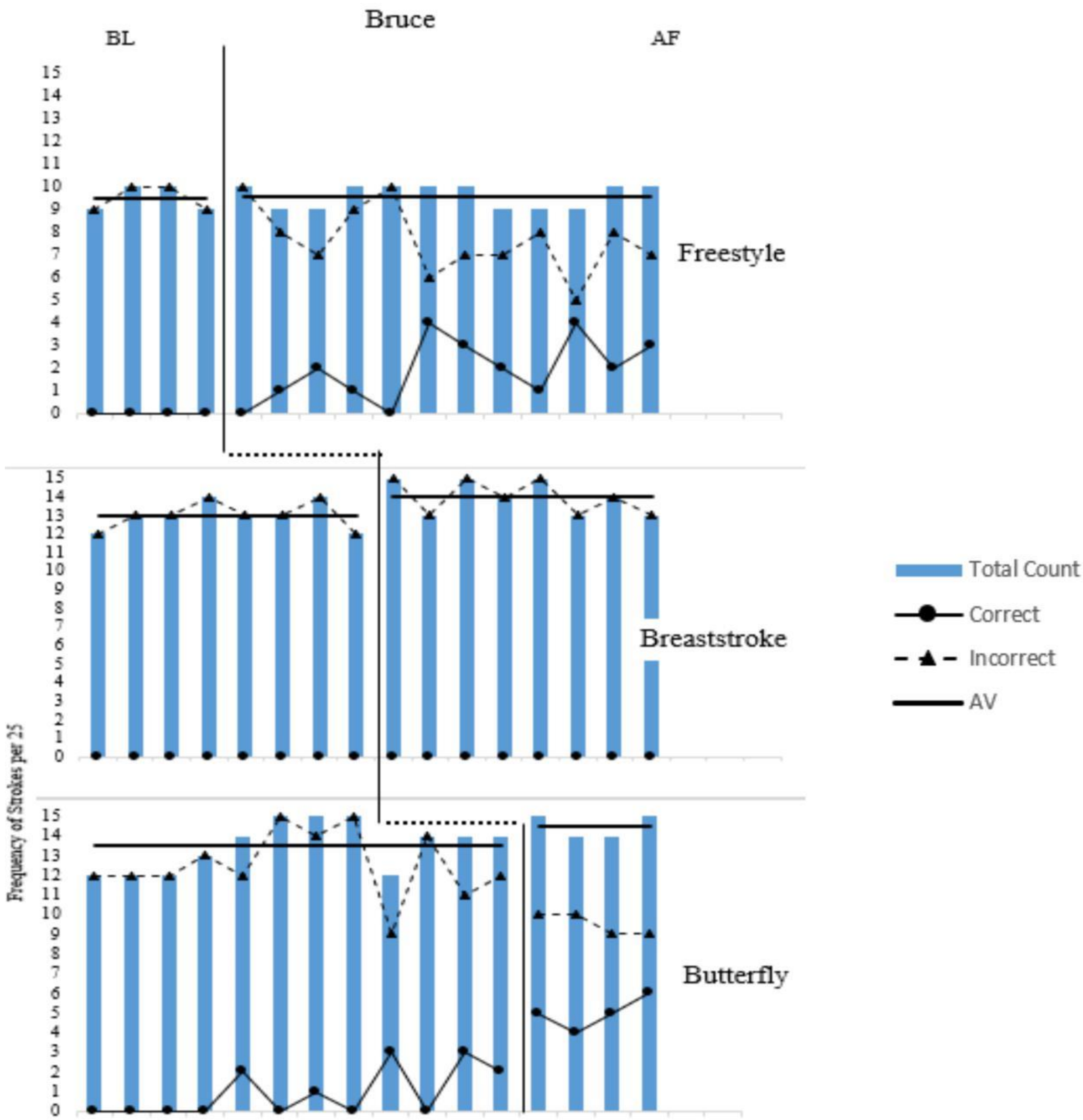
Logan was a male UNR alum with a history of USA Triathlon competitions. He self-reported as being new to anything more than freestyle swimming (the only stroke used in triathlon). He has worked with coaches in the past and currently trains for triathlon. Logan’s stroke order was breaststroke, butterfly, and then freestyle.



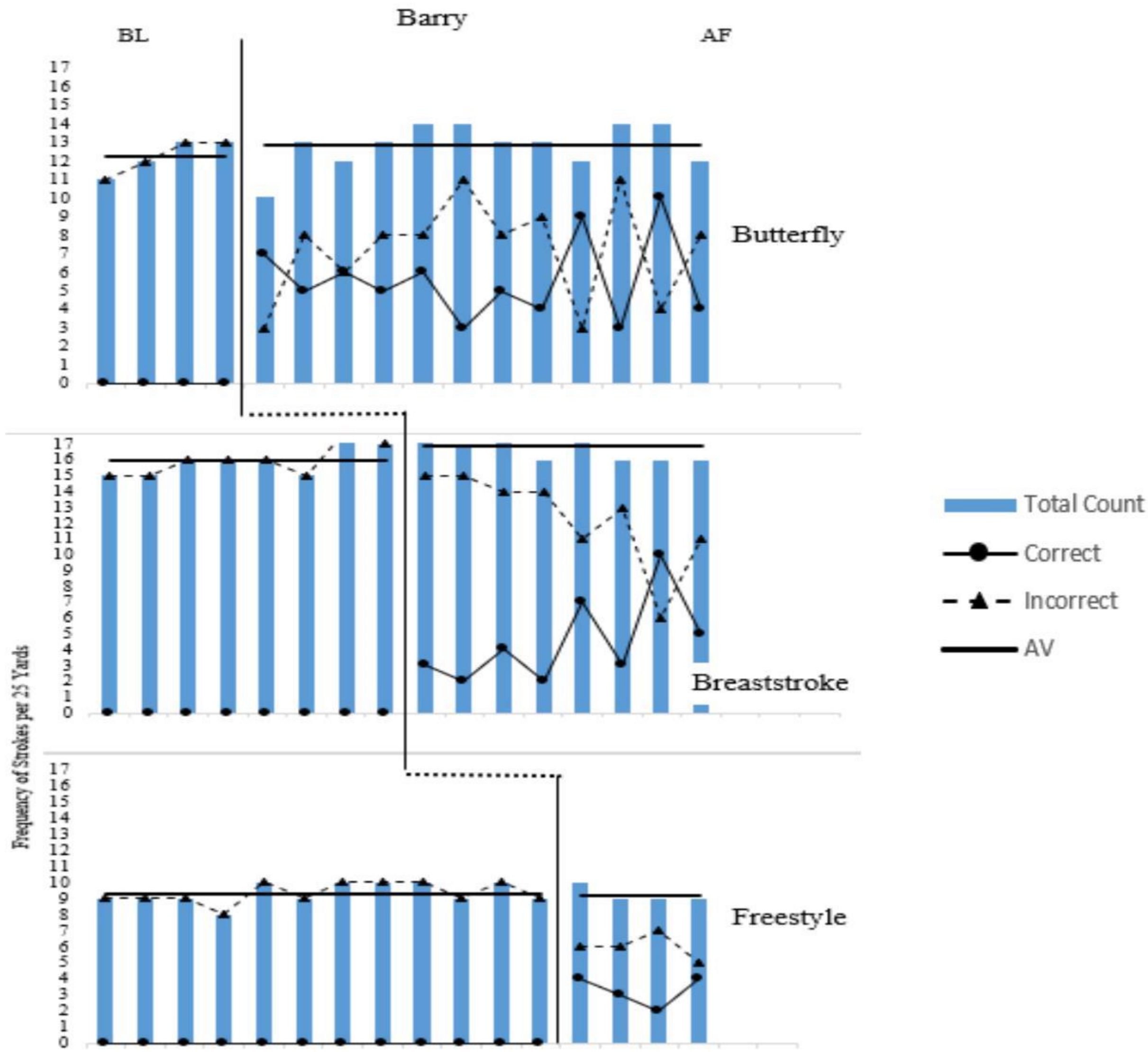
Reed was the third participant and a master's-level swimmer. He both worked with a coach currently as well as in the past. His stroke order was breaststroke, freestyle, and then butterfly.



Bruce was a male athlete who trained in open-water and triathlon events. He was referred to the study by his coach. Bruce swam competitively in the past as well. His stroke order was freestyle, breaststroke, and then butterfly.



The last participant was Barry, a triathlete with a history of stroke technique although he never competed in events other than freestyle. This participant is also a coach working with a variety of athletes including swimmers. His stroke order was butterfly, breaststroke, and freestyle.



DISCUSSION

All participants except one demonstrated improvement in their HEC sequences in at least one stroke. However, only one participant demonstrated a carry-over effect. Participant Reed was the only participant to fail to increase his HECs during the AF condition. Reed could not hear the feedback and served as a control participant. He declined a second attempt at the study and self-expressed appreciation for being able to see his strokes from under the water. During baseline, participant Diana's correct HECs occurred less than twice per 25-yards, with the average number of strokes being 12 per 25-yards. After intervention with the acoustic feedback, the number of incorrect strokes decreased to below the number of correct strokes in both the freestyle and butterfly conditions. Breaststroke also improved in that the number of corrects increased while the number of error strokes decreased. The stroke count for freestyle increased as was anticipated, however the number of strokes per 25-yards decreased in both the butterfly and breaststroke conditions.

For participant Logan, he did not demonstrate a correct high-elbow catch in any of his baseline conditions. After the acoustic feedback was introduced, only breaststroke improved with the number of correct catches exceeding the errors by the end of the study. Breaststroke also showed a decrease in the number of strokes taken per 25-yards (from 14 strokes to 12). Butterfly did not improve, although the number of strokes taken per length increased by one. Changes in the stroke occurred but failed to meet HEC criterion. Freestyle went from no correct strokes to one correct stroke with an increase in total stroke count by one. Changes seen in freestyle involved the participant switching from dropped elbow (the error) to a straight-arm freestyle catch (not incorrect, but also not a high-elbow catch. This is typically a sprint-event style of catch). As this was the last condition to receive AF, it is believed had the trials been able to continue longer the participant would have continued to correct until he achieved a more consistent HEC.

Bruce was the only participant to demonstrate a potential carryover effect. He had no correct high-elbow catches in baseline of any of the three strokes. However, once the first stroke received acoustic feedback, butterfly also increased the number of correct strokes per 25-yards. A sharper rate of increase was noticed in butterfly after that stroke also received the AF. Breaststroke did not improve although the stroke rate quickened which resulted in an additional stroke per 25-yards on average. The total stroke count increased by one in the butterfly condition while the stroke count for freestyle remained the same. In both freestyle and butterfly, the participant showed an increase in correct strokes and a decrease in errors after the implementation of the AF, although there is also the carryover in butterfly.

The final participant was Barry. This athlete did not correctly demonstrate a correct high-elbow catch during any baseline condition. In both the butterfly and breaststroke conditions, his HECs increased while errors decreased. Barry also demonstrates a potential side bias as evidenced in both the butterfly and breaststroke conditions left-side right-side variability. It is also possible the participant was overexaggerating the HEC then backing off during the following 25-yard length until the feedback stopped in which case he would return to the catch previously completed to contact the contingency. The athlete believes the former, as he self-reported difficulty with his left arm (that being the same arm seen in the data as having lower rates of correct catches) which he reported as being his non-dominant arm. He expressed having difficulty with his left arm being as competent in physical activity as his right arm. This athlete's freestyle was his most efficient stroke, in that he averaged 9 strokes per 25-yards. It is also the lowest of all the participants. The average total stroke count decreased marginally as correct HEC sequences increased for freestyle, however there was an increase in stroke count for the other two conditions. Also, of note, this participant decreased his total reach as he increased his correct stroke catches. Reduced arm reach is disadvantageous, although less so than a dropped elbow catches, and the researcher took care to provide feedback on this during the video review with the participant. Despite reducing his reach, the participant reported their total time per 25-yards decreased from an average of 21 seconds to 19 seconds as the high-elbow catches increased, indicating an increase in power output per stroke by the last 25 yards swum with the acoustic feedback. These times were reported by the participant through data taken by his smart watch after which he analyzed using his Training Peaks software comparing turnover rate increases with total time per 25-yards. While the data form the Training Peaks program did align with the researcher's data, the researcher has not worked with Training Peaks before to understand any known limitations in the program.

Overall, the use of acoustic feedback in this research study demonstrates an effective way to develop swimming form regarding the high-elbow catch across three competition strokes. “Effective” meaning the successful shaping of appropriate swim skill technique associated with the high-elbow catch. Given the results of the study follow the anticipated results of the primary research question, this study would support the hypothesis that acoustic feedback training, delivered via an underwater Bluetooth apparatus, is an effective way to shape appropriate high-elbow catch in freestyle, butterfly and breaststroke. There may be a possibility of a carryover effect, however as this occurred in only one participant it is too minimal to support the secondary hypothesis that carryover effects occurred. Whether the average number of strokes per 25-yards increased or decreased was variable across both participants and strokes. The author believes this may be due to muscle inclusion. Meaning, the muscles included in the change from dropped elbow and high-elbow were not always substantially different which might result in the variation in stroke counts either increasing or decreasing. If the lats were previously excluded, suddenly including them could result in faster fatigue and increased stroke count. Alternately, if the athlete cross-trained or included lats despite also having a dropped elbow stroke, the sudden inclusion would not affect their stroke count and could even account for the decrease in stroke count seen in some participants.

All participants self-reported liking the study and expressed interest in using it again to target different skills. Only one participant showed a potential disadvantageous effect of participating in the study. That being a reduced range-of-motion as the number of high-elbow catches increased. This being in the butterfly condition. Reduction in range-of-motion is not uncommon as swimmers change muscle groups or change a component of their stroke. The participant would have to be monitored to see if he corrected for the error or if his range of motion increased again once the HEC moved from novel to muscle memory.

Limitations and Future Research

A notable limitation of this study is the requirements on the part of the experimenter to successfully differentiate between a high-elbow catch and an error stroke while the participant is swimming. While the data demonstrates an improvement to stroke HEC errors in some participants, in others there was no improvement in one or more strokes. Additionally, this research does not target the longitudinal effects of improvement of the HEC. Future research would be to replicate this study, but instead of looking at carryover across strokes, look for catch errors associated with a high-elbow catch. For example, breaking the wrist in freestyle during the initiation of the stroke cycle and throughout the completion of that cycle, is a common error listed in Counsilman's (1979) most common swimming errors. It refers to the wrist flattening out to an angle rather than staying in-line with the forearm either when first starting the catch or anywhere throughout the rest of the pull cycle before the recovery cycle which occurs out of the water. Would a HEC intervention in a swimmer who also breaks their wrist during the pull correct both problems? This study demonstrates a way to shape HEC, but more research is needed to conclude if it results in faster swim times. Longitudinal research is also needed to look at the long-term effects of shoulder-related injuries swimmers sustain as a result of improper form. As swimmers have incredible flexibility in their shoulders, the chance of eliminating inflammation of the tendons altogether is not feasible given the nature of this study. However, it would be useful to see if quicker acquisition of stroke form, and consequent less time with error strokes resulted in a reduction of injuries that were caused by improper form rather than overuse.

For future directions, incorporating Training Peaks data into the study could be a useful addition. Changing the feedback type from audible to visual (such as a light displayed upon successful high-elbow catch) would help alleviate difficulties in hearing the sound, and also looking at using this type of feedback in other stroke errors, such as kick, head position, body-line, or others would be beneficial. The material apparatus design used in this study could be mass marketed as a kit available for consumers to purchase and use in developing their stroke training plan. Applied Sport Psychologists and/or coaches could also be brought in, or those already staffed, could also duplicate this study with their swim teams. This type of intervention, applied at the beginning of the season with each new incoming class, then moved to maintenance [random scheduling of underwater footage throughout the season to be reviewed by the athlete and coach at a later date (this is something most swim programs already do)] with the sole purpose of making sure the behaviors shaped are retained, has the potential to drastically change the life of the competition-level swimmer.

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Appendices

Appendix A: IRB Approval

University of Nevada, Reno

Research Integrity Office
218 Ross Hall / 331,
Reno, Nevada 89557
775.327.2368 / 775.327.2369 fax
www.unr.edu/research-integrity

DATE:	May 15, 2017
TO:	Wilfred Williams, Ph.D
FROM:	University of Nevada, Reno Institutional Review Board (IRB)
PROJECT TITLE:	[945368-1] Elbows Up: Using Acoustic Feedback in Shaping High-Elbow Catch Sequences in Freestyle Swimming Strokes, Looking at Carry-Over Effects
REFERENCE #:	Social Behavioral
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	May 15, 2017
REVIEW CATEGORY:	Exemption Category # Flex-Exempt

The Research Integrity Office, or the IRB reviewed this project and has determined it is EXEMPT FROM IRB REVIEW according to federal regulations. Please note, the federal government has identified certain categories of research involving human subjects that qualify for exemption from federal regulations.

Only the Research Integrity Office and the IRB have been given authority by the University to make a determination that a study is exempt from federal regulations. The above-referenced protocol was reviewed and the research deemed eligible to proceed in accordance with the requirements of the Code of Federal Regulations on the Protection of Human Subjects (45 CFR 46.101 paragraph [b]).

Reviewed Documents

- Abstract/Summary - TAG Teach Paper- Forman.doc (UPDATED: 02/24/2017)
- Abstract/Summary - Research Paper Swim Studies.docx (UPDATED: 04/11/2017)
- Application Form - Exempt IRBFlex Min Risk No Federal Support 122215.docx (UPDATED: 02/24/2017)
- Confidentiality/Non-Disclosure - Appendix 5 Data Protection.docx (UPDATED: 04/21/2017)
- Consent Form - Consent Video-Photo Release Template Forman.doc (UPDATED: 02/24/2017)
- Consent Form - Consent Short Form Template English Forman Thesis.doc (UPDATED: 02/24/2017)
- Consent Form - Consent Information Script Forman Thesis.docx (UPDATED: 02/24/2017)
- Cover Sheet - Part I, Cover Sheet (UPDATED: 02/24/2017)
- CV/Resume - CURRICULUM_VITAE_PDF_Version_12.10.2016.pdf (UPDATED: 02/24/2017)
- Data Collection - Thesis Data Sheet.xls (UPDATED: 04/11/2017)
- Other - Appendix 4 Underwater Instruction.docx (UPDATED: 04/11/2017)
- Other - thesis-microfilm-agreement.pdf (UPDATED: 02/24/2017)
- Other - Appendix 3 High Elbow Catch Instructions.docx (UPDATED: 02/24/2017)
- Other - Appendix 2 Study Materials List.docx (UPDATED: 02/24/2017)
- Publication Materials - References Thesis (1).docx (UPDATED: 04/21/2017)
- Questionnaire/Survey - par-q.pdf (UPDATED: 04/21/2017)
- Questionnaire/Survey - Appendix 6 Inclusion Criterion.docx (UPDATED: 04/21/2017)
- Questionnaire/Survey - Appendix 7 Social Validity Questionnaire.docx (UPDATED: 04/21/2017)

- 1 -

Generated on IRBNet

- Study Plan - Appendix 1 Participant Agenda for Study (1).docx (UPDATED: 04/21/2017)
- Training/Certification - citiCompletionReport4416682FORMAN.pdf (UPDATED: 04/11/2017)
- Training/Certification - RBT Certificate Forman.pdf (UPDATED: 04/11/2017)
- Training/Certification - Lifeguard Certificate 2016.PNG (UPDATED: 04/11/2017)

If you have any questions, please contact Raymond Avansino at (775) 327-2372 or at ravansino@unr.edu.

NOTE for VA Researchers: You are not approved to begin this research until you receive an approval letter from the VASNHCS Associate Chief of Staff for Research stating that your research has been approved by the Research and Development Committee.

Sincerely,

Richard Bjur, PhD
Co-Chair, UNR IRB
University of Nevada Reno

Janet Usinger, PhD
Co-Chair, UNR IRB
University of Nevada Reno

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Nevada, Reno IRB's record.

Appendix B: Inclusion Criterion

The following survey will be completed by the participant before participation in the study. Only check the boxes with a phrase you would answer "yes" or "correct". For the last two phrases, an "unsure" option is available. NOTE: a preliminary assessment will be required should one or both end phrases be selected as "unsure".

I am in good physical health (PAR-Q)

I am at no/low risk for health problems or injuries (PAR-Q)

I have not been diagnosed as having tendonitis in my shoulders or elbows that would prevent me from completing proper high-elbow movement.

I do not have restricted range of motion in my shoulders (I can raise my arms straight over head with my thumbs touching)

I have never passed out during exercise

I am motivated to improve my swimming form

I can swim at least 25 yards at once of all four competition strokes I have

plans to participate in a minimum of 1 workout per week I have been

swimming for ______________ years/months

I am a ☐ beginning ☐ intermediate ☐ advanced swimmer

I do not currently perform a high-elbow catch correctly at least 50% of the time. ☐ Unsure.

I do not have issues with maintaining correct body line (I can float in prone position with my face in the water). ☐ Unsure.

Appendix C: Data Sheet (Example Freestyle)

Date:		**Experimenter:**	
Time:		**Participant**	
Condition:	PILOT (Freestyle)	**Data Collector (RA):**	

Target Behavior: High-Elbow Catch

Total 'Yes' Intervals: /

#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	
			1			1			1			1				Right Arm
			2			2			2			2				
			3			3			3			3				
			4			4			4			4				
			5			5			5			5				
#	E	IOA	#	E	IOA	#	E	IOA	#	E	IOA	#	E	IOA	#	50 Yards
			1			1			1			1				Left Arm
			2			2			2			2				
			3			3			3			3				
			4			4			4			4				
			5			5			5			5				

#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	
			1			1			1			1				Right Arm
			2			2			2			2				
			3			3			3			3				
			4			4			4			4				
			5			5			5			5				
#	E	IOA	#	E	IOA	#	E	IOA	#	E	IOA	#	E	IOA	#	50 Yards
			1			1			1			1				Left Arm
			2			2			2			2				
			3			3			3			3				
			4			4			4			4				
			5			5			5			5				

#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	
			1			1			1			1				Right Arm
			2			2			2			2				
			3			3			3			3				
			4			4			4			4				
			5			5			5			5				
#	E	IOA	#	E	IOA	#	E	IOA	#	E	IOA	#	E	IOA	#	50 Yards
			1			1			1			1				Left Arm
			2			2			2			2				
			3			3			3			3				
			4			4			4			4				
			5			5			5			5				

#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	Occurred? E	IOA	#	
			1			1			1			1				Right Arm
			2			2			2			2				
			3			3			3			3				
			4			4			4			4				
			5			5			5			5				
#	E	IOA	#	E	IOA	#	E	IOA	#	E	IOA	#	E	IOA	#	50 Yards
			1			1			1			1				Left Arm
			2			2			2			2				
			3			3			3			3				
			4			4			4			4				
			5			5			5			5				

(PILOT) Freestyle

Appropriate setup of room:	Participant is prepared with swimming attire (suit, goggles, cap if needed), pool use has been established for the timeline required for study.
Appropriate data collection:	Data will be collected by the primary trainer assigned to participant. Data is to be collected in 10 sec partial intervals on the above table. If the screaming occurs at *any* point within the 10 sec interval, shade in the cell corresponding to the correct time and YES column. If the screaming does *not* occur within the 10 sec interval, shade in the cell corresponding to the correct time and NO column.
Appropriate consequence for behavior:	Participant will hear the audible "click" (the TAG) when a high-elbow catch is performed at the select FR schedule. Data will be taken on all HEC (high-elbow catch sequences) as well as which ones resulted in reinforcement (TAG). IOA will be conducted at a later time to check whether the TAG was delivered appropriately.
When to start session:	Participant is allowed warm-up to the extent they perceive to be sufficient. No little than 100 yards and no more than 500 yards. Instruction according to the written protocols will be delivered. Participant is then instructed to begin.
During session:	Experimenter is watching for catch sequences and delivering the TAG. RA is taking data.
When to terminate session:	The session will be terminated immediately if participant and/or staff safety is at potential risk. Otherwise, the session should be terminated following the data collection for the last interval (competition of laps by target area) of the session.
After session:	Refer to written session conclusion protocol.

Appendix D: Bubble Buddy Live-Stream Apparatus