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The Influence of Auditory Cueing on Stroke Rate in Elite Swimmers

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Abstract
Equipment similar to a metronome provides auditory cueing to guide a person's movement pace. However, it is unknown if learning transfers to a performance setting where auditory cueing is unavailable. Though the use of tempo training is popular in swimming practice, it is prohibited in competition. The purposes of the current study were the following: (1) determine if using a tempo trainer influences swimmers' ability to maintain stroke rate in a post-test, and (2) determine if swimmers' self-efficacy in maintaining stroke rate changed based on the presence of a tempo trainer during practice. A total of 15 elite female swimmers ($\bar{x}$ *age* = 19.80, *SD* = 1.47) volunteered to participate from a Division I National Collegiate Athletic Association team in the United States of America. The study consisted of three sets of a swim workout (i.e., pre-test, intervention, post-test). Participants were randomly assigned to a control or experimental group. Both groups were instructed to maintain the same stroke rate for the entire duration of the study. The experimental group, however, was provided with a tempo trainer to use during the intervention round, and then asked to remove the tempo trainer during the post-test. Participants' average stroke rate was recorded, and volunteers responded to questions before and after each trial (four trials per set) to measure self-efficacy and subjective success in maintaining stroke rate. There were no differences observed from pre-test to post-test in either group for each measured variable (i.e., stroke rate, self-efficacy, and subjective success). This raises the question about the effectiveness of utilizing auditory cues (i.e., tempo trainer) during swim practice for the purpose of improving stroke rate during competition. Future research should consider increasing the time between the intervention and the post-test to further examine the effects of tempo training on swimming stroke rate.

Keywords
auditory cueing, instruction, transfer of learning, stroke rate

Introduction

Research, at times, has negligently assumed that training alone leads to mastery performance in competition (Piatrikova et al., 2020). On the contrary, motor skill *training* enhances performer's physiological and psychological capability to execute at task, whereas *practice* is a more accurate term to describe the acquisition of skills for future performance success. The best athletic *practice* conditions are similar to the performance setting which will be experienced during competition in terms of cognitive effort, environment, and context (Thorndike, 1914). However, some practitioners create practice environments which do not share common features with testing or competition settings. For example, recent advances in technology make it possible to provide auditory instruction or feedback concurrently during motor skills performance. Modalities such as an auditory alarm (e.g., a sound plays when a movement exceeds a pre-determined threshold), sonification of movement variables (e.g., magnitude of changes are represented by a sound), and sonification of movement error (e.g., auditory feedback about the deviation between actual performance and target performance) provide varied feedback information in an attempt to change movement execution (Sigrist et al., 2012). However, many regulatory agencies in sport (e.g., International Olympic Committee) do not allow these forms of technological aids to be used by an athlete during competition. This constraint raises a fundamental question regarding the effectiveness of using such technological aids during practice if those same aids are not allowed during competition.

Not only is it important to consider these aids from a practical point of view, there is also theoretical value in understanding how providing concurrent cues and feedback during practice affects the motor learning process. Although feedback may be used to enhance practice conditions, the use of concurrent feedback may also lead to learners developing feedback-dependency. Growing accustomed to specific feedback frequencies or modalities to optimal performance in practice may not translate well to a successful performance, specifically when feedback is unavailable (Salmoni et al., 1984). Studies using an auditory alarm found desirable changes in gait pattern measures (Eriksson & Brensin, 2010; Riskowski et al., 2009); however, these studies did not measure learning effects through retention or transfer testing where the device was removed. In a sample of expert marksmen, auditory alarms did not aid in improving performance, therefore Underwood (2009) suggested experts could benefit more from specific, kinematic feedback. In a population of expert German wheel performers, sonification of movement variables was found beneficial compared to novices (Hummel et al., 2010). Finally, research studying sonification of movement error in marksmen performance identified training benefits of this feedback modality, and its long-term retention benefits (Mononen, 2007). Based on the mixed results in the transfer of learning literature, it is not yet clear if the presence of a metronome during practice increases training effects, has no effect (e.g., zero transfer), or harmful effects (e.g., negative transfer) when later performing without the aid of the metronome.

In practice, instructions commonly precede feedback. Though there is an abundance of feedback literature supporting optimal feedback principles, the same cannot be said about literature on instruction modalities. It is known that concurrent instruction, in the form of auditory cueing, is utilized in a variety of settings (e.g., music, rehabilitation, sport) to guide movement pace. Similar to feedback literature, practicing with metronome cueing technology enhances specific training aspects of continuous skills. Researchers concluded that auditory cueing is a potentially beneficial instruction modality for maintaining pace during practice (Ghai & Ghai, 2018; Piatrikova et al., 2020). However, to our knowledge, the current literature fails to demonstrate the practice effects of auditory cueing in the facilitation of motor learning. It is less known if practicing with concurrent auditory cueing transfers to a performance setting where auditory cueing is unavailable, unsafe, or prohibited. Additionally, the guidance hypothesis (Salmoni et al., 1984) proposes that concurrent auditory cueing during practice may increase dependency, eliciting a false sense of competence. It is important to understand how providing concurrent auditory cueing during practice affects motor learning when the cueing provided during practice is removed during post-testing.

Outlined in Bandura's (1986) self-efficacy theory and motor performance, self-efficacy (i.e., belief in oneself) can either bolster or hinder performance. When high levels of self-efficacy are present, resulting in higher belief in one's capabilities to accomplish a specific performance outcome, motor performance is positively influenced (Theodorakis, 1996). Self-efficacy increases with the success of past performances, which in-turn increases his/her efficacy of repeating successful performances in the future. Related to concepts of positive transfer of learning, self-efficacy is predicted to increase when the performance expectations and actual performance are matched (Weinberg et al., 1979). Though research has studied the benefits of enhancing self-efficacy and motor performance via augmented feedback techniques (Fredenburg et al., 2001), a dearth of research exists examining how auditory guidance through instructional motor cueing influences self-efficacy and motor performance in practice and competition. Thus, removing a dependency-inducing metronome during performance may alter self-efficacy which, in turn, influences performance. Without optimal instruction principles that mirror those of feedback literature, it is less certain how to best utilize auditory cueing as an instructional modality to optimize motor learning.

In swimming, stroke rate metronomes (i.e., tempo trainers) provide auditory cues in the form of beeping via a small device placed under a swim cap, behind the ear, which theoretically guides swimmers' arm cadence (Tempo Trainer; FINIS, Tracy, CA). The use of tempo training to cue stroke rate was determined beneficial for training outcomes such as critical speed, stroke rate, and speed when used in both intervention and testing conditions (Piatrikova et al., 2020). Though the use of tempo trainers is popular in training, it is prohibited in all swimming competitions (FINIS, 2017; USA Swimming, 2022). Given that dependency is plausible from using a tempo trainer in practice, it raises the question as to how capable and confident swimmers are in maintaining a desired stroke rate if the cue is later removed. If using a tempo trainer does induce dependency, based on the fundamental principles of practice specificity (Thorndike, 1914), what is learned during training would presumably not transfer to competition when a tempo trainer is removed. Given the dependency that is plausible from consistent auditory cueing, it raises the question as to how capable and confident swimmers are in maintaining a desired stroke rate when the tempo trainer is removed. The two purposes of the current study were to (1) determine if using a tempo trainer during practice influenced swimmers' ability to maintain stroke rate during a later swimming test without a tempo trainer, and (2) to determine if swimmers' self-efficacy in maintaining stroke rate changed based on the presence of a tempo trainer. It was hypothesized that (1) swimmers using a tempo trainer in the practice condition would experience no benefit for stroke rate maintenance compared to a control group and (2) swimmers who used a tempo trainer would report lower self-efficacy for maintaining cadence in a swim test compared to a control group which did not use a tempo trainer during practice.

Methods

Participants

Participants included 15 elite female swimmers ($\bar{x}_{age}$ = 19.80, *SD* = 1. 47) who volunteered from a Division I National Collegiate Athletic Association (NCAA) team in the Southeast United States. The sample included swimmers who earned the status of All-American (*n* = 6), Conference Medalist (*n* = 4), Junior Nationals Medalist (*n* = 1), Nationals Medalist (*n* = 1), Olympic Trials (*n* = 7), Olympic Trials Medalist (*n* = 2), Olympians (*n* = 1), Junior Worlds Medalist (*n* = 1), and Worlds Medalist (*n* = 1). On average, the swimmers had 3.61 years' (*SD* = 2.66 years) experience using tempo trainers; reporting using tempo trainers as frequently as one day a week to as infrequently as two-to-three times per month.

Equipment and Measures

Tempo Trainer

FINIS tempo trainers (Tracy, CA) were set to Mode 1: Stroke Rate. In this mode, the tempo trainer beeped as an indicator for when a hand should hit the water in full extension, directly prior to the pull phase of the stroke. The experimental group used the tempo trainer during the practice phase of the experiment. Participants were instructed to set the tempo trainer to a self-selected attainable stroke rate appropriate for a 200 yd (182.88 m) freestyle swim that they could maintain throughout the experiment. The participants set the trainers between a tempo of .67 s and .75 s.

Self-Efficacy

Self-efficacy was measured with a single one-item survey prior to each swim trial. Participants responded to the question, “To what extent are you confident in your ability to maintain 200-yard race pace during this 50-yard swim?” Written responses were recorded on a 10-point Likert-scale (1 = not confident at all, to 10 = very confident) and stored for later analysis.

Subjective Success

After each swim trial, subjective success was measured with a single-item survey. Participants responded to the question, “To what extent was your performance of 200-yard race pace successful in the 50-yard swim?” Written responses were recorded on a 10-point Likert-scale (1 = not successful at all, to 10 = very successful) and stored for later analysis.

Objective Measure of Stroke Rate

The swimming trials were video recorded for use in obtaining stroke rate. Participants’ stroke rate was determined by timing hand hit speed for a total of three cycles for each length (22.86 m) swum. Using a stopwatch (Pulivia Sports Stopwatch, ShenZhen YiSheng Technology Company), the researchers collected split times for hand hit speed for the right hand after the swimmer had pushed off the wall and completed a full cycle (one hit per hand). Because individual hand hits for this sample were likely to occur as quickly as 0.6 s, recording only right-side hand hits allowed the researchers to obtain an objective split rate. To determine stroke rate per hand hit, the researchers divided the measured split by two (e.g., 1.40 s / 2 = 0.70 s hand hit per hand). A second researcher watched the videos to obtain stroke rate measures for comparison. The two researchers had an average stroke rate agreement of 99%; therefore, the two researchers stroke rate measures were averaged.

Procedures

After obtaining institutional review board approval from the university’s ethics committee, the researchers contacted all women swimmers of a NCAA Division I university to participate in the study. Participants who willingly volunteered were directed to complete an informed consent and demographics questionnaire.

The researchers scheduled a testing day with each participant on a morning she was not having swim practice in an attempt to minimize the chance of practice fatigue influencing study results. The study took approximately 45 min to complete. Due to scheduling limitations of working with a NCAA Division I swim team, one swimmer participated alone (n = 1) while the others participated with at least one other participant present (n = 14).

Set-Up

The participants were asked to wear a comfortable suit, swim goggles, and a swim cap. Upon arrival, participants checked-in with the research team and were quasi-randomly assigned to the experimental group (n = 8) or the control group (n = 7) with the constraint that there were nearly equal numbers of participants in each group. Participants were given an identification number in an attempt to protect participant anonymity. Participants were then asked for their 182.88 m freestyle stroke rate. Those assigned to the experimental group were provided with a tempo trainer and it was set to their self-indicated stroke rate. Volunteers in the control group were instructed to maintain the stroke rate they indicated, though they would not have the assistance of the tempo trainer to guide their stroke rate during the intervention.

Warm-Up

Before the experiment started, participants were informed of the general goal of the study (e.g., measure maintenance of 182.88 m freestyle stroke rate during a swim workout). Participants were then allowed 10 min to warm-up as desired. Provided the expertise of these swimmers, they were comfortable and capable of selecting an appropriate warm-up for their involvement in the experiment.

Pre-Test

At the start of the pre-test, the researchers started video recording the participants' swimming to later measure stroke rate. The pre-test was conducted to gather the swimmers initial stroke rate and self-efficacy. The participants were asked to swim a 4 x 50 yd (45.72 m) freestyle at 182.88 m race pace on a 2 min interval. This is a common training method used in swim workouts, and all swimmers were familiar with the workout instructions. The participants were able to complete each 45.72 m swim under 35 s providing ample rest between each swim. Prior to each swim, participants completed a self-efficacy question on their confidence to achieve the desired stroke rate. After each swim, participants completed a self-efficacy question on their subjective success. This process was repeated for each of the four swims. Upon completion of the pre-test, the participants were instructed to complete a 91.44 m (100 yd) active recovery in 3 min to prepare for the intervention.

Intervention

Prior to the start of the intervention, participants in the experimental condition were asked to set their tempo trainer to the desired pace, which was indicated at the initial check-in. Participants placed the tempo trainer in a comfortable position underneath their swim cap and confirmed they could hear it beeping. The control group was not provided with a tempo trainer. All volunteers were instructed to do their best to maintain the stroke rate consistent with the beeping coming from the tempo trainer (experiment group) or to maintain their stroke rate from pre-test (control group). Participants then completed another set of 4 x 45.72 m freestyle at 182.88 m race pace on a 2 min interval. Following the same protocol from the pre-test, the participants reported self-efficacy and subjective success before and after each swim, respectively. Upon completion of the intervention, the experimental group was asked to remove and turn-off their tempo trainers. All participants were instructed to complete a 91.44 m active recovery in 3 min to prepare for the post-test.

Post-Test

For the post-test, participants completed a final round of 4 x 45.72 m freestyle at 182.88 m race pace on a 2 min interval. All participants were instructed to maintain stroke rate from the intervention round. The protocol for the post-test was the same as the pre-test and the intervention. Specifically, self-efficacy and subjective success were measured before and after each swim, respectively. Upon completion of the post-test, participants were instructed to complete a 91.44 m active recovery in 3 min. Participants were then allowed to cool down further if desired.

Statistical Analysis

Data collected during the check-in process (e.g., demographics and belief of tempo training effectiveness) were analyzed using Excel. Data collected during the experiment (e.g., objective measure of stroke rate, self-efficacy, and subjective success) were analyzed using Statistical Analysis System v 9.4. A 2 (group) x 2 (time) Analysis of Variance (ANOVA) with repeated measures on the first factor which tested for time and group main effects followed by a group*time interaction. Significance was set *a priori* at $\alpha = .05$. A post-hoc power analysis was calculated, using G*Power, based on the current sample size for the main dependent variable of interest (i.e., objective stroke rate; $\eta^2 = .01$, effect size = .10, power = .11). Using this data, we determined the desired sample size needed to reach a within-between main effect of objective stroke rate to be 198 people (effect size = .10).

Results

Table 1 displays demographic means that describe the population and their experience with using tempo trainers. Participants reported using tempo trainers 1 day/week ($n = 4$), 2-3 days/week ($n = 3$), 2-3 days/month ($n = 7$), and less than 2-3 days/month ($n = 1$). The participants rated tempo trainer effectiveness for practice performance higher ($M = 7.07$, $SD = 2.22$) than effectiveness for competition performance ($M = 4.53$, $SD = 2.36$).

Table 1. Demographics and General Tempo Trainer Use Information

Variable	Experiment (n = 8)		Control (n = 7)	
	M	*SD*	*M*	*SD*
Age (years)	19.25	1.28	20.43	1.51
Tempo Trainer Experience (years)	2.79	2.20	4.43	2.99

Objective Measure of Stroke Rate

A time main effect indicated that from pre-test (*M* = 1.44, *SD* = .14) to post-test (*M* = 1.36, *SD* = .11) all participants decreased stroke rate tempo (i.e., swimmers stroke rate became faster) ($F(1, 14) = 14.92$, $p = .002$, $\eta^2 = .534$). However, there was no group*time interaction ($F(1, 14) = .132$, $p = .722$, $\eta^2 = .010$). Additionally, the change in stroke rate did not differ by group ($F(1, 14) = .468$, $p = .506$, $\eta^2 = .035$). The average measured stroke rate for the experimental group (*M* = 1.43, *SD* = .05) and control groups (*M* = 1.38, *SD* = .06) differed between .1-.3s from the indicated stroke rate set on the tempo trainer. See Table 2.

Self-Efficacy

Participants' self-efficacy slightly increased from pre-test (*M* = 7.73, *SD* = 1.78) to post-test (*M* = 8.38, *SD* = 1.26), though a main effect for time did not reach significance ($F(1, 14) = 3.04$, $p = .105$, $\eta^2 = .190$). There was no indication of a group*time interaction ($F(1, 14) = 1.54$, $p = .236$, $\eta^2 = .106$). Similarly, participants' self-efficacy did not significantly differ between groups ($F(1, 14) = 0.00$, $p = .991$, $\eta^2 = .000$). See Table 3.

Subjective Success

A time main effect indicated that from pre-test (*M* = 7.99, *SD* = 1.71) to post-test (*M* = 8.77, *SD* = 1.40) participants increased subjective success ($F(1, 14) = 6.43$, $p = .025$, $\eta^2 = .331$). However, there was no group*time interaction for subjective success ($F(1, 14) = 2.12$, $p = .169$, $\eta^2 = .140$). Additionally, the increase in subjective success did not differ by group ($F(1, 14) = 1.18$, $p = .297$, $\eta^2 = .083$). See Table 4.

Table 2. Descriptive Statistics for Stroke Rate

Group	Pre-Test			Post-Test		
	M	*SD*	95% CI	*M*	*SD*	95% CI
Experiment	1.46	.17	[1.394, 1.573]	1.40	.12	[1.312, 1.478]
Control	1.42	.09	[1.304, 1.544]	1.34	.12	[1.255, 1.433]

Table 3. Descriptive Statistics for Self-Efficacy

Group	Pre-Test			Post-Test		
	M	*SD*	95% CI	*M*	*SD*	95% CI
Experiment	7.53	2.14	[6.130, 8.932]	8.60	1.15	[7.612, 9.575]
Control	7.97	1.40	[6.467, 9.462]	8.14	1.43	[7.093, 9.192]

Table 4. Descriptive Statistics for Subjective Success

Group	Pre-Test			Post-Test		
	M	*SD*	95% CI	*M*	*SD*	95% CI
Experiment	7.42	1.81	[6.151, 8.661]	8.60	1.07	[7.500, 9.688]
Control	8.64	1.42	[7.301, 9.985]	9.00	1.76	[7.795, 10.134]

Discussion

Much motor learning research has been conducted that investigates how utilization of feedback strategies affects the motor skill learning process. Provided that instruction precedes feedback, and the methods for which each may be provided to a learner are similar (e.g., verbal, kinesthetic, visual, etc.), there is a stronger theoretical understanding for feedback principles in regard to optimizing practice and learning effects. However, the body of literature investigating the efficacy of instructional techniques lacks the same depth of investigation. This void of knowledge in the practicality of using verbal instructions, particularly within an elite athletic population, motivated the present study.

The findings of our investigation reveal no difference in an objective measure of stroke rate maintenance between elite swimmers practicing with a tempo trainer and those practicing without the cueing aid. All swimmers in the current study decreased their stroke rate (increased speed) from pre-test to post-test, irrespective of using the tempo trainer. Therefore, tempo trainers used during the intervention round of the experiment had no measurable effect on those swimmers during the post-test. This raises a fundamental question to the effectiveness of using tempo trainers to help swimmers maintain a specific stroke rate, specifically once the device is removed. This is noteworthily considering tempo trainers are not allowed during competition. Additionally, in addressing the second purpose of the study, which was to determine if swimmers' self-efficacy in maintaining stroke rate changed based on the presence of a tempo trainer, our results indicated all swimmers' self-efficacy remained the same, though their subjective success increased. Regardless of practicing with the tempo trainer or not, swimmers' efficacy and subjective success was likely not due to the presence of the tempo trainer. Bandura's (1986) work on self-efficacy suggests past mastery of performance can influence efficacy expectations. Thus, past experiences with tempo training swimming workouts could explain the expert swimmers' high rating of self-efficacy and subjective measure of success.

Since the practiced task was something familiar to the expert swimmers, it is likely they felt high levels of efficacy to complete the task and thus rated their performance high. Based on these findings, the research team concluded that using a tempo trainer did not enhance or hinder a swimmers' ability to maintain a desired stroke rate in the post-test when the tempo trainer was removed. Furthermore, removal of the tempo trainer did not negatively affect swimmers' self-efficacy for maintaining stroke rate during a later test. This latter finding suggests that the elite swimmers tested in the present study did not develop a dependency on the utilization of the tempo trainer during the intervention.

The utility of auditory cueing through modern technology provides metronome-like guidance for movement pace for various motor skills. Specifically, swimmers use tempo trainers during practice to guide stroke rate. As suggested by the FINIS Tempo Trainer Pro manual, tempo training "translates into big changes in stroke length and efficiency over time," thus "enhances your sprints and prepares you for short races" (FINIS, 2017). Well known coaches and Olympic champions endorse the use of tempo training for maintaining stroke rate, and FINIS even provides a guide for selecting an appropriate stroke rate in training that leads to optimal performance outcomes for all race distances. Despite the suggestions and endorsements of using tempo training to prepare for race conditions, little to no scientific evidence is used to support these claims in swimming. Therefore, the purpose of the current study was to test the learning effects, or lack thereof, which occur when practicing with a tempo trainer. The findings reported here indicate that practicing with a tempo trainer had no meaningful effect on later swimming performance.

Limitations and Directions for Future Research

Due to the elite level of athletes used for this study, it is unclear if similar findings to those observed here are likely in athletes who are less skilled. Additionally, there was large variability in swimmers' experience with tempo trainers (ranging from 0 to 6 years) which may have affected our results of efficacy since past experiences (both mastery and non-mastery) with using tempo trainers may influence a swimmer's current rating of efficacy. Future studies may consider comparing larger diverse samples of swimmers to test for dependency differences that could have developed over years of exposure to a tempo trainer or across of range of skill levels.

Conclusion

On the basis of the current study's results, the conclusion is that the use of tempo training for maintaining a specific stroke rate during competition may not be helpful. There is no evidence that in elite college-age swimmers the use of tempo training is beneficial for increasing self-efficacy or the ability to maintain a specified stroke rate from practice to competition. Other methods for practicing a desired race pace that do not require the use of competition-prohibited technology are encouraged to increase practice specificity. It would be best for swimmers to rely on their kinesthetic feedback, rather than auditory instruction, for maintaining a desired pace in both practice and competition. Coaches and swimmers may consider reserving the use of tempo training primarily for *training* purposes to increase physiological performance capabilities (Piatrikova et al., 2020). Further testing is needed to understand the potential enhancement or depression of physiological and biomechanical effects that may manifest as a result of using a tempo trainer during swim training.

Authors' Declarations

The authors declare that there are no personal or financial conflicts of interest regarding the research in this article.

The authors declare that the research reported in this article was conducted in accordance with the Ethical Principles of the *Journal of Expertise.*

The authors declare that the dataset is not publicly available but can be provided upon request.

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References

Bandura, A. (1986). *Social foundations of thought and action: social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Eriksson, M., & Bresin, R. (2010, April 2). *Improving running mechanics by use of interactivesonification.* [Paper presentation]. Interactive Sonification Workshop, Stockholm, Sweden.

Fédération Internationale De Natation. (2017, September 21). *Fina Swimming Rules*. https://resources.fina.org/fina/document/2021/01/12/b3885f9b-630a-4390-861d-4e7f6031f4a4/2017_2021_swimming_16032018.pdf.

FINIS (2017). Tempo trainer pro. [Apparatus]. https://www.finisswim.com/Tempo-Trainer-Pro

Fredenburg, K. B., Lee, A. M., & Solmon, M. (2001). The effects of augmented feedback on students' perceptions and performance. *Research Quarterly for Exercise and Sport*, *72*(3), 232-242. http://dx.doi.org/10.1080/02701367.2015.1093072

Ghai, S., & Ghai, I. (2018). Effects of rhythmic auditory cueing in gait rehabilitation for multiple sclerosis: A mini systematic review and meta-analysis. *Frontiers in Neurology*, *8*(1), 1-19. https://doi.org/10.3389/fneur.2018.00386

Hummel, J., Hermann, T., Frauenberger, C., & Stockman, T. (2010, April). Interactive sonification of German wheel sports movement. In *Human Interaction with Auditory Displays: Proceedings of the Interactive Sonification Workshop* (pp. 17-22).

Mononen, K. (2007). *The effect of augmented feedback on motor skill learning in shooting: A feedback training intervention among inexperienced rifle shooters* [Unpublished doctoral dissertation]. University of Jyväskylä.

Piatrikova, E., Willsmer, N. J., Sousa, A. C., Gonzalez, J. T., & Williams, S. (2020). Individualizing training in swimming: Evidence for utilizing the critical speed and critical stroke rate concepts. *International Journal of Sports Physiology and Performance*, *15*(5), 617-624. https://doi.org/10.1123/ijspp.2019-0546

Riskowski, J. L., Mikesky, A. E., Bahamonde, R. E., & Burr, D. B. (2009). Design and validation of a knee brace with feedback to reduce the rate of loading. *Journal of Biomechanical Engineering*, *131*(8). https://doi.org/10.1115/1.3148858

Rulebook 2022. (2022). USA Swimming Home. https://www.usaswimming.org/docs/defaultsource/governance/governance-lsc-website/rules_policies/2022-rulebook.pdf

Salmoni, A. W., Schmidt, R. A., & Walter, C. B. (1984). Knowledge of results and motor learning: A review and critical reappraisal. *Psychological Bulletin*, *95*(3), 355 386. https://doi.org/10.1037/0033-2909.95.3.355

Sigrist, R., Rauter, G., Riener, R., & Wolf, P. (2013). Terminal feedback outperforms concurrent visual, auditory, and haptic feedback in learning a complex rowing-type task. *Journal of Motor Behavior*, *45*(6), 455-472. https://doi.org/10.1080/00222895.2013.826169

Thorndike, E. L. (1914). General characteristics of original tendencies. *Educational psychology: Briefer course*, 1-10. https://doi.org/10.1037/10608-001

Underwood, S. M., (2009). *Effects of augmented real-time auditory feedback on top-level precision shooting performance* [Unpublished master's thesis]. University of Kentucky. https://uknowledge.uky.edu/gradschool_theses/603

Weinberg, R., Gould, D., & Jackson, A. (1979). Expectations and performance: An empirical test of Bandura's self-efficacy theory. *Journal of Sport and Exercise Psychology*, *1*(4), 320-331. https://doi.org/10.1123/jsp.1.4.320

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