

Can Two-Dimensional Technology Measure Changes in the Swing of Elite Croquet Players Following a Self-Talk Intervention?

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Abstract To assess the influence of self-talk on an athlete's performance techniques are required to measure changes in skill execution but there are limitations to these techniques. Analysis of movement is often done in laboratory settings using three-dimensional motion-capture technology. The limitations of this approach make it impractical for most people to use and therefore we investigated if a high-speed video camera and two-dimensional software could measure changes in the swing of elite croquet players across different self-talk conditions. Significant differences were found for the timing of the backswing and downswing with mallet angle at follow-through approaching significance. These results are promising in relation to detecting changes in performance with two-dimensional techniques but there are limitations that must be considered regarding conclusions drawn from such findings.

Keywords: sport psychology, self-talk, mental skills, croquet

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1. Introduction

The enhancement of athletic performance receives a lot of attention from many disciplines (e.g. Sport Psychologists, mental skills professionals, coaches, trainers). While the approaches and techniques used to help an athlete perform better may vary across disciplines, the common goal for any input or intervention is to change/improve the athlete's performance.

The success of an athlete's performance, and the influence of interventions to help their performance, is often measured by the outcome of the performance rather than the many factors that contributed to the result. To better understand the effectiveness of an intervention on an athlete's performance it is important to be able to assess how it has influenced their performance (i.e. not just the outcome) and therefore developing an easy and cost-effective way to assess athletic performance in real-world settings would be of considerable benefit.

1.1. Evaluating the Effectiveness of an Intervention

Analysis of movement is often done in laboratory settings using techniques such as three-dimensional motion-capture technology which analyses a person's movement by estimating anatomical landmarks and three-

dimensional co-ordinate data from a series of markers attached to the person [2,20]. This data enables the calculation of variables such as body segment angles, displacements, velocities and accelerations which can provide detailed information regarding the person's movement and performance. While this technology can provide very useful data, it has several limitations that can make it impractical for people to use (e.g. data collection errors, costs, space, expertise, etc.). For example, while three-dimensional motion-capture is regarded as the 'gold standard' of biomechanical analysis errors can occur due to such things as soft tissue artifacts [14], instrumental errors [3] and anatomical landmark misplacement [4]. Other limitations of three-dimensional motion-capture are the considerable financial and spatial costs [17] as these systems require laboratory space and trained technicians to collect and analyse the data. The need to be housed within a laboratory setting also raises the issue of validity of three-dimensional data as the artificial nature of the environment may influence how an athlete performs. As stated by McGinnis [18], whenever an athlete is taken from their natural performance environment the chance of recording a natural/uninhibited performance diminishes. Some caution is therefore required when interpreting three-dimensional laboratory data in terms of its relevance to a real-world performance.

Two-dimensional techniques offer an alternative to three-dimensional motion-capture systems. These techniques

involve recording the athlete with a video camera and using computer software to analyse motion in one plane [18]. While this type of analysis can be less precise, unless the movement in question is occurring entirely in the plane of progression (i.e. the plane the camera is recording) [26], its benefits are cost, user-friendliness and the ability to record athletes in their usual performance settings.

Software packages that aid two-dimensional analyses are becoming more common and are characterised by their ease of use, affordability, accessibility and adaptability [15]. It should be noted however that while software packages are marketed to provide athletes, coaches and other sports providers with tools to measure and analyse sporting technique and performance, the accuracy of analysing real-time athletic movement is not well established and therefore caution is required with considering the data from such technology.

More studies are needed in this area to determine the accuracy and hence usefulness of this approach to movement analysis. As stated by Glazier [6], the increasing use of coach-friendly biomechanical analysis packages for applications beyond their design has resulted in oversimplification of biomechanical analyses. This is an important point to consider as this technology is used to not only assess overall performance, but changes in performance due to interventions such as the use of mental skills (e.g. self-talk). More information is therefore required to understand if the data obtained from two-dimensional techniques accurately measures the parameters of an athlete's movement that are being assessed so that those using these techniques can confidently interpret their results and draw conclusions from their findings.

1.2. Self-Talk

An athlete's performance can be affected by many intrinsic and extrinsic factors and therefore mental skills to help them manage these influential factors are needed in order to increase the likelihood of the athlete competing successfully. As a driving force of an athlete's performance is what they're thinking, techniques that can help them control what and how they're thinking are very beneficial. A commonly used strategy to help athletes take control of their thought processes is self-talk.

Self-talk is a multidimensional phenomenon that refers to what a person is saying to themselves [7,8,23] which may relate to how they are thinking or feeling and/or it may relate specifically to what task they are engaged in. As a technique to improve performance, self-talk is intended to help the person be more aware of, and in control of, what they're thinking by using specific words or phrases to control and focus their thoughts. Within a sporting context self-talk can be used by athletes to improve emotional and cognitive states (e.g. calming nerves and improving focus) as well as the acquisition and execution of sport-specific skills or techniques.

While much of the research on self-talk with athletes has looked at the influence of this technique on mental and emotional states [7] and the execution of specific skills [13,16], there has been less investigation into the effect that personalising self-talk words has on the effectiveness of this mental skill. For example, it is not clear if tailoring (i.e. personalising) self-talk words is more beneficial than

using self-talk words typically used by coaches and trainers (i.e. 'prescribed' words).

While the benefits of using techniques such as self-talk can be assessed in relation to the outcome of an athlete's performance, understanding how this technique influences an athlete's performance is essential in order to determine its effectiveness. For those who work with athletes on ways to enhance their performance through such means as adjusting the execution of a specific skill or implementing mental skills techniques, a means of identifying and measuring relevant movements is required in order to assess the effectiveness of their interventions.

The purpose of the present study was therefore to determine if a high-speed video camera and two-dimensional software programme could be used to measure changes in the swing of elite croquet players as mediated by the use of different types of self-talk.

2. Materials and Methods

2.1. Participants

Ten elite croquet players (eight men and two women; age 36.9 ± 20.5 years; playing experience 18 ± 15 years) participated in the study. Elite players were defined as having competitive experience at an international croquet event and were competing at a national or international level at the time of the study. The recruitment of players and all study procedures were approved by the University's Human Participants Ethics Committee.

2.2. Establishing Personalised Cue Words

On the day of testing, participants undertook a pre-testing interview in which they were asked to provide words to describe how they felt and/or what they were focusing on when they executed what they considered to be an ideal croquet swing. From these descriptions two 'personalised' cue-words were identified and confirmed with participants as representing their ideal swing. These words were used during the 'personalized' self-talk condition.

2.3. Measuring the Influence of Self-Talk

The influence of self-talk on performance was determined by measuring changes in several aspects of the croquet swing as well as from participant feedback.

Testing occurred on a standard croquet lawn with participants positioned 6.4m from a standard croquet hoop (i.e. the distance from the side-line to the hoop). Croquet swings were recorded with a high-speed video camera (Casio Exilim EX-F1) at 300fps in the sagittal plane. In a warm-up condition, participants struck three croquet balls, attempting to run each ball through the hoop.

Participants began the testing session by hitting the balls, attempting to run them through the hoop, without the use of self-talk (baseline/'no' self-talk condition). In the next two self-talk conditions participants again attempted to run the balls through the hoop while using either 'prescribed' or 'personalised' self-talk. The 'prescribed' self-talk condition involved participants saying to themselves two words commonly used by croquet coaches (i.e. "relax" and "concentrate"). In the 'personalised'

condition, participants repeated to themselves the cue words that had been identified in the interview prior to testing as representing how their optimal swing felt and/or what they are focusing on when executing their shot (e.g. “smooth”, “through”). The order of the ‘prescribed’ and ‘personalised’ self-talk conditions were carried out in a randomized order to prevent a practice effect.

Prior to carrying out the ‘prescribed’ and ‘personalized’ self-talk conditions participants were briefed on how to internally recite their cue-words immediately prior to each swing. Prompting of cue-words was done before every second or third swing in order to prevent distracting participants. Prompting was delivered in the form of repeating cue-words for the participant followed by the prompt to take their shot/swing.

2.3.1. Analysis of the Croquet Swing

For each participant, three video recordings of their croquet swing were made (i.e. one for each self-talk condition) and analysed using Siliconcoach Pro version 7.0 [22]. We analysed the croquet swing because as with golf, the execution of the swing influences the outcome of the shot. For example like golfers, croquet players can tend to rush the transition between the backswing and the downswing when in a pressure situation. Golf self-help books frequently emphasise not rushing the backswing [19] and similarly, croquet coaches can often be heard telling players not to rush or “snatch” their backswing.

As there is little documented about the parameters of the ideal croquet swing we based the phases of the croquet swing on previous work with golfers [1]. For the present study the croquet swing was defined as: 1) backswing (the start of the swing backwards to the point when the mallet reached its greatest vertical distance from the ground); 2) downward swing (the end of the backswing to impact/first point of discernable ball movement); and 3) follow-through (from the point of ball impact to the highest point of the follow-through).

To assess changes in players’ croquet swings in relation to different self-talk conditions the timing and height/angle of swings were measured using the Siliconcoach Pro ‘stopwatch’, ‘discrete line’ and ‘angle’ tools. It should be noted that when undertaking motion capture analysis, a system of markers is commonly used to define body segments however, croquet is generally played with loose fitting clothing and therefore asking participants to wear tight-fitting clothing in order to permit the application of markers would make the situation artificial and introduce confounding variables. We therefore used the ‘zoom in’ and ‘free line’ tools within Siliconcoach Pro to locate easily identifiable and ‘constant’ points on the participant to serve as ‘markers’ from which measurements were made. As the analyses of players’ movements were done in a frame-by-frame manner these points were easily and clearly identifiable.

2.3.2. Participant Feedback

To assess the influence of self-talk on the execution of the croquet swing, following each self-talk condition, participants were asked to provide a rating of how their croquet swing felt on a five point Likert scale (‘extremely poor’ to ‘excellent’).

Upon completion of the three self-talk conditions participants were asked to indicate if they noticed any

change in their swing across the different self-conditions, if their swing felt different between the three self-talk conditions, and indicate which type of self-talk they preferred. Participants then completed the Self-Talk Use Questionnaire (STUQ) [8] which assesses the multidimensionality of self-talk across three dimensions (valence, structure and overtness) as well as how/why self-talk is used.

3. Results

3.1. Two-Dimensional Measurement of Changes in the Croquet Swing

A significant difference between self-talk conditions was found for the timing of the backswing ($F(1.23, 35.67) = 5.88, p < 0.05$) with mean swing times being slower when participants used ‘prescribed’ self-talk (0.50 ± 0.19 seconds) compared to the ‘personalised’ self-talk (0.48 ± 0.17 seconds) or ‘no’ self-talk (0.45 ± 0.16 seconds) conditions. Significant differences were also found between self-talk conditions for the down wards wing ($F(1.045, 30.30) = 4.23, p < 0.05$) with mean swing times being slower when participants used ‘prescribed’ self-talk (0.32 ± 0.04 seconds) compared to ‘personalised’ self-talk (0.31 ± 0.04 seconds) or ‘no’ self-talk (0.30 ± 0.05 seconds). As might be expected, the slower timing of the backswing and downward swing for the ‘prescribed’ self-talk condition affected the croquet swing at follow-through. It was found that differences between the self-talk groups for the angle of the mallet at the end of the follow-through approached significance ($F(2, 58) = 3.068, p = 0.056$) with mean angles being lowest for the ‘prescribed’ self-talk condition ($51.5^\circ \pm 16.1^\circ$) compared to the ‘no’ self-talk ($59.8^\circ \pm 28.5^\circ$) or ‘personalised’ self-talk ($59.0^\circ \pm 27.3^\circ$) conditions.

3.2. Measuring the Perceived Influence of Self-Talk and Self-Talk Use

When asked to rate their performance following each self-talk condition, it was found that participants’ perceptions of their swing were significantly influenced by self-talk ($F(2, 18) = 3.94, p < 0.05$) in that mean swing rating was significantly higher when using ‘prescribed’ self-talk than when using no self-talk (baseline). A trend was found for mean swing rating between baseline and personalised with participants preferring to use ‘personalised’ self-talk rather than no self-talk however this was not statistically significant (see Table 1).

Table 1. Mean scores for participants’ ratings of their swing in relation to self-talk type

Self-talk Condition	Mean Swing Rating (SD)
Baseline (no self-talk)	2.9 (0.74)
Prescribed self-talk	3.8 (0.79)
Personalised self-talk	3.6 (0.84)

When comparing their performance across the different self-talk conditions, all participants ($n=10$) reported that their swing felt different between the self-talk conditions and 9 out of 10 reported noticing a change in their swing between conditions. With regard to self-talk preference,

more participants reported that their swing was better when they used self-talk compared to no self-talk. Five participants preferred 'prescribed' self-talk, four preferred 'personalised' self-talk and one preferred no self-talk (i.e. 'baseline').

To understand how/why/when the participants used self-talk we asked them to complete the STUQ [8]. The participants' responses (see Table 2) indicated that they used self-talk more in competitions than in training ($F(1, 9) = 11.29, p < 0.01$) and more during practice/competition than before or after practice/competition ($F(2, 18) = 3.97, p < 0.05$). Scores for the valence, structure and overtness dimensions of the STUQ indicated that the mean proportion of participants' self-talk that was positive was significantly higher than the mean proportion that was neutral or negative ($F(1.24, 11.16) = 9.21, p < 0.01$) and tended to be in phrases rather than as single words or sentences ($F(2, 18) = 5.38, p < 0.05$). It was also found that the mean proportion of participants' self-talk that was covert was significantly larger than the mean proportion that was spoken or muttered aloud ($F(1.08, 9.69) = 9.35, p < 0.05$).

Table 2. Mean scores for STUQ variables.

STUQ Variable		Mean Scores (SD)
Setting	Training	4.77 (2.64)
	Competition	6.23 (2.42)
Time	During practice/competition	6.40 (2.37)
	Before practice/competition	5.10 (2.55)
	After practice/competition	5.00 (2.79)
Valence	Positive	0.67 (0.33)
	Negative	0.16 (0.18)
	Neutral	0.17 (0.21)
Structure	Single words	0.18 (0.24)
	Phrases	0.60 (0.30)
	Sentences	0.23 (0.21)
Overtness	Covert	0.67 (0.31)
	Overt	0.07 (0.07)
	Overt (muttered)	0.27 (0.32)

4. Discussion

For those working with athletes on ways to improve their performance (e.g. Sport Psychologists, mental skills professionals, coaches, trainers) it is important that they have ways to analyse not just the effectiveness of their interventions in terms of the outcome achieved but also how their interventions have influenced the athlete's performance. To do this techniques are required that will enable those working with the athlete to assess how their intervention influences the athlete's movement and execution of sport-specific skills.

Analysis of movement is traditionally done in a laboratory setting using three-dimensional high-speed motion-capture technology, however there are several limitations to this type of analysis including factors such as costs (e.g. laboratory space and technicians), the influence of the artificial environment on athletic performance, and the inability to assess some sports within a laboratory environment due to practical issues (e.g. space, safety). Due to such limitations alternative, easy-to-use and cost-effective techniques are needed in

order to practically assess athletic performance and the influence of interventions such as self-talk.

In the present study we used a high-speed video camera to capture the sporting performance of elite croquet players and analysed this data with the two-dimensional software programme Siliconcoach Pro.

4.1. Measuring the Influence of Self-Talk

Using high speed video and two-dimensional analysis software to measure a number of characteristics of the croquet swing as well as changes in the execution of swings following the use of a self-talk intervention, we found that different self-talk words influenced the execution of the croquet swing of elite players with the most significant effects being found when participants used 'prescribed' self-talk words.

Of those characteristics measured, we found significant differences between the 'no', 'personalised' and 'prescribed' self-talk conditions for the timing of the backswing and downward swing with swing times being slowest when participants used 'prescribed' self-talk and fastest when using 'no' self-talk. Differences between the self-talk conditions were also found for the angle of the swing at follow-through however these were not significant.

With regard to the influence of 'personalised' and 'prescribed' self-talk on a sporting performance, our findings are similar to those of Edwards, Tod and McGuian [5] and Tod, Thatcher, McGuigan, and Thatcher [25] who found differences in lower limb kinematics between self-talk conditions ('no' self-talk, 'prescribed' self-talk and 'personalised' self-talk) during vertical jump tests. As the movements within croquet are not as dynamic as those of a vertical jump and hence are not prone to considerable variation, the fact that we were able to detect changes in the croquet swing across the different self-talk conditions indicates that with the use of a high-speed video camera that allows for accurate frame-by-frame playback, it is possible to use two-dimensional technology to measure an athlete's performance and changes in that performance. As this technique can assess changes in skill execution in relation to a mental skills intervention (i.e. self-talk) future studies are required that can expand on this work in order to assess how these changes influence skill execution and sport-specific outcomes (e.g. shot accuracy).

4.1.1. Detrimental Influence of Prescribed Self-Talk

Golf self-help books frequently emphasise not rushing the backswing [19] and like golfers, croquet players can tend to rush the backswing and/or the downswing, especially when distracted or out of their comfort zone (e.g. when in a pressure situation). To have an optimal performance it is important for the croquet player to find the right balance between a swing being too fast and too slow in that while a player doesn't want to rush their swing they also don't want to over-think their swing as this can negatively influence its, timing, fluidity and effectiveness.

The finding that the use of 'prescribed' self-talk slowed the timing of the backswing and downward swing, and reduced the angle of the mallet at follow-through, could indicate that this type of self-talk resulted in players hesitating in their swing and then cutting short their

follow-through. This type of swing would be considered problematic as it was not executed in a fluid and continuous manner (i.e. it was “snatched”) which could be detrimental to executing a croquet shot.

It is possible that the potentially detrimental effect of ‘prescribed’ self-talk found in the present study occurred because participants found the ‘prescribed’ self-talk words distracting resulting in this type of self-talk interfering with their ability to concentrate and execute their swing in an optimal fashion (i.e. slowing the timing of their swing and shortening their follow-through). In contrast to the ‘personalised’ words selected by participants, because the ‘prescribed’ words were not chosen by participants they may not have been meaningful or relevant to them and therefore they could have distracted them and/or caused them to think about the words too much thus negatively affecting their swing. This is consistent with the findings of Thornton and Peters [24] who found that self-talk has the potential to interfere with motor activity by overloading the mental resources of an individual and removing them from present-focused attention.

Self-talk is a cognitive process that facilitates many aspects of an athlete’s ability to execute a performance including concentration, focus, attentional control and information processing [10,12]. To successfully execute a sporting performance the athlete needs to concentrate on the appropriate aspects of the task [21] and therefore, if the self-talk words they use are not familiar or relevant to them they could be detrimental to their performance by interfering with their motivation, focus, concentration and task execution. To increase the likelihood of self-talk being effective and not detrimental to an athlete’s performance it would therefore be beneficial for those working with athletes to help them personalise their self-talk so that the words or phrases they use have meaning and relevance for them.

4.1.2. The Influence of Previous Self-talk

In the present study we wanted to compare the influence of different types of self-talk on the performance of croquet swings of elite players and therefore we asked participants to undertake croquet swings under three conditions: baseline (i.e. ‘no’ self-talk), ‘personalised’ self-talk and ‘prescribed’ self-talk. Although we found differences in performances across the three self-talk conditions, it should be noted that while it was clear what words were used in the ‘personalised’ and ‘prescribed’ conditions as participants were prompted to use specific words, we cannot be certain that no self-talk was used in the baseline (i.e. ‘no’ self-talk) condition as no prompting was done and therefore athletes may have used words or phrases that they have used in the past.

Self-talk has been promoted as an essential component of successful sporting performance and is therefore often an integral part of psychological skills training programmes [9,11]. It is therefore likely that as the participants in the present study were elite croquet players they have used self-talk at some time in their sporting careers. This possibility is supported by the results of the STUQ which indicated that participants have used self-talk and when they used this technique it was used more during competitions than in practice settings and consisted of positive phrases said covertly.

If participants have used self-talk previously it is therefore possible that it was used in the baseline (i.e. ‘no’ self-talk condition) and this may have occurred without participants’ awareness as the finding that 9/10 participants preferred using self-talk (five preferred ‘prescribed’ self-talk and four preferred ‘personalised’ self-talk) compared to no self-talk indicates that they were not aware of using self-talk in the baseline (i.e. ‘no’ self-talk) condition.

If participants did use self-talk in the ‘no’ self-talk condition this possibility does not interfere with the intention of the present study as we were able to show that ‘personalised’ and ‘prescribed’ self-talk influenced the execution of the croquet swing differently. To better understand how different types of self-talk (e.g. ‘personalised’ and ‘prescribed’) influence a croquet player’s performance more studies are needed. For example, in addition to using the analysis techniques of the present study (i.e. high-speed video camera and two-dimensional software programme) to measure changes in the croquet swing, it would be beneficial to assess the effect of different types of self-talk on the outcome of the croquet swing (i.e. shot accuracy).

4.1.3. The Influence of Self-Talk on a Croquet Performance

The results of the present study indicate that different types of self-talk (i.e. ‘personalised’ and ‘prescribed’) can influence the execution of a croquet swing in different ways and therefore players need to be aware of their self-talk and what types of self-talk are beneficial or detrimental to their performance.

With regard to how self-talk influenced the performance of croquet players, determining the relationship between the influence of different types of self-talk on a croquet swing and how that affects the outcome of the croquet shot are beyond the scope of the current study as we did not assess the influence of different self-talk words on performance measures such as shot accuracy.

It would be expected that as different types of self-talk (i.e. ‘personalised’ and ‘prescribed’) influence the execution of the croquet swing differently they would similarly influence the outcome of the croquet shot and therefore in addition to further investigating the use of two-dimensional technology to assess the influence of interventions on an athlete’s performance, future studies are needed to determine how the influence of different types of self-talk affect croquet performance in relation to specific outcomes (e.g. shot accuracy).

The results of the present study indicate that self-talk can influence the execution of the croquet swing of elite croquet players and it is possible to measure these changes with two-dimensional technology, however, some caution is required when using this technology and interpreting the results obtained.

4.2. Caution Needed when Using Two-Dimensional Technology to Assess Athlete Performance

While the results of the present study are promising in terms of demonstrating that the techniques used (i.e. high-speed video and two-dimensional software) provide an

easy-to-use and cost-effective way to evaluate an athlete's performance, and changes in that performance in relation to an intervention, one must be cautious when drawing conclusions from these results as this technique is limited by factors that could influence how the data looks and hence is interpreted. For example, two-dimensional technology does not allow for the detection of rotation or lateral movement as this occurs in the same plane the camera is recording.

Unlike three-dimensional technology, two-dimensional techniques do not have a third referential point from which measurements are made and data is extrapolated meaning that while results can indicate movement, and changes in movement, the accuracy of these conclusions are limited. As reported by Yeardon and Challis [26], when using two-dimensional techniques movements are analysed by projecting points onto the sagittal plane or plane of progression. While this enables recording and measurements of movement within that plane it ignores the fact that subjects are moving in three dimensions and thus the data does not completely represent the movement in question. Caution must therefore be taken when recording movement in two-dimensions and surmising the implications of that movement as many sporting movements may appear to be two-dimensional in nature but in fact are three-dimensional and therefore require three-dimensional data collection techniques to determine their full effect [26]. For example, in the current study we measured a change in mallet height/angle which can relate to a change in hand height/angle, but as we cannot see if the person moved to their left or right or rotated our ability to draw conclusions about the measurements obtained is limited and therefore our results must be interpreted with caution. Further research is needed to more directly compare two-dimensional and three-dimensional systems to better understand the ability of two-dimensional techniques to provide accurate and hence meaningful data.

5. Conclusions

When athletes use techniques such as self-talk it is important that they use words or phrases that enhance the effectiveness of this technique and minimize the likelihood of it being detrimental to their sporting performance. As demonstrated by the results of the present study, different types of self-talk (i.e. 'personalised' and 'prescribed') can influence the execution of a croquet swing in different ways and therefore players need to be aware of their self-talk and what types of self-talk are beneficial or detrimental to their performance.

For those working with athletes on ways to improve their performance (e.g. coaches, instructors, Sport Psychologists, Mental Skills Trainers) having easy-to-use and cost-effective ways to assess performance is necessary in order to determine the influence of interventions such as self-talk. As shown by the results of the present study, it is possible to use two-dimensional technology to assess the influence of interventions such as self-talk, however caution is required when interpreting these results due to the limitations inherent with two-dimensional recording/analysis techniques.

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