Effect of Attentional Focus on the Performance of Motor Skills. A Meta-Analysis and Survey.

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Impact of COVID-19

Due to the Covid-19 outbreak the original research plans of my study have been disrupted which led to changes. With no face-to-face research and contact allowed for a long period of time, the original plan which consisted off a meta-analysis along with a study testing the findings of the meta-analysis had to be cancelled. Covid-19 led to an inability to go to and perform research at the chosen location of a rugby academy as well as the backup option of at the Human Performance Unit. Instead, a longer meta-analysis had to be performed which not only looked at the main effects of external vs internal cues on performance outcomes, but also delved into the impact of specific moderator variables on the effects of different coaching cues. This was to consolidate the literature already produced and to be able to help inform coaching practice. Following from this we then decided to produce a survey to look at coaches and athletes understanding and use of internal and external cues to see what individual factors influenced their understanding. We decided to do this to get an insight into what types of cues the sample of coaches used most frequently as well as their level of understanding. Within the survey coaches and athletes will be asked what cues they were more likely to use to get an understanding of what they typically focused on and whether this supported the findings of the meta-analysis performed prior to this. This was supported by previous research finding a lack of understanding amongst track and field coaches, yet no further populations had been asked within this previous survey.

Abstract

Focus of attention is the direction of cognitive resources towards a particular focus. Focusing externally on the outcome of the movement has been found to be beneficial in the performance of skills such as sprinting, jumping, throwing, balancing and even in rowing, as well as helping create a more automatic process. The purpose of this thesis was to compare the effects of different cues on sprint and jump performance in acute studies and to determine the influence of moderator variables using a meta-analysis. A survey was later conducted following the findings of the meta-analysis to determine the level of understanding both coaches and athletes have and if there's a discrepancy based on their individual differences. For a study to be included in the meta-analysis it must have compared internal and external cues, utilised a cross-sectional study design and measured either jumping or sprinting tasks. The meta-analysis used an inverse-variance random-effects model. Effect sizes were represented by the standardized mean difference and presented alongside 95% confidence intervals. Twenty-two studies were included in the meta-analysis. There was a small main effect size [0.30(95% CI 0.19, 0.40, $Z=5.46(p<0.00001)$] favouring the use of external coaching cues compared to internal coaching cues for enhancing performance with no moderator variables performing better under an internal focus compared to an external one. To take part in the survey an individual had to be either an active athlete or coach. The results of the survey found coaches to have a greater understanding of attentional focus than athletes with experience along with strength and conditioning qualifications

being an indicator of increased use of external cues. Overall, an external focus of attention has been shown to be superior to an internal focus and coaches and athletes could be educated more in this field to attempt to aid future athletic development.

Keywords: Attentional Focus, jumping, sprinting, meta-analysis, survey

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Chapter 1: Introduction

The specific training conditions an athlete endures along with genetic factors can influence their ability to learn motor skills and affect their long term development and performance (1). There are many small and simple alterations that can be implemented to an athlete's programme to enhance an athletes overall development (2). Of interest to coaches in this regards is the manipulation of an athlete's focus through the use of different cues to direct their attention to a specific focus (3). The manipulations made to verbal cues by a coach have been found to enhance athletic performance of movements such as jumps and sprints.

Attentional focus is the process by which athletes consciously distribute mental resources to cues, stimuli or states (4). From a coaching perspective, instructions and cues allow a coach, prior to the skills execution, to alter an athletes focus of attention towards what they deem to be an important feature of the motor skill (5). Coaching cues have been classified within two dimensions, task-relevance (association or dissociation) and direction (internal and external) (6). Attentional focus has been investigated mostly from a standpoint of either being focused internally or externally (4). Wulf (3) defined an external focus as directing attention to the movements intended effect whilst an internal focus causes the athlete to focus on the body's movement. Coaches can draw an athlete's attentional focus internally or externally by varying the language they use. When an athlete is executing a skill, a coach who directs their athletes to focus on the movement of a specific body part (internal focus) will create different kinematic responses to that of a coach who uses an external cue and instructs the athlete to focus on the outcome of the movement. The use of verbal instructions and feedback gives athletes valuable information on how they can perform a sporting action or skill. Augmented feedback is information provided during or after a skills execution specific to an athletes performance(7). Unlike sensory information which is obtained naturally by an athlete via their own sensory mechanisms (i.e., vison, touch, proprioception etc.), augmented feedback can only be provided via an outside source such as a coach (8). A coach can word their feedback either externally or internally, which will inherently affect an athlete's attentional focus. For example, whilst an athlete performs a broad jump, the coach can either get the athlete to focus internally by saying "extend your knees as

rapidly as possible" or externally by specifying a goal or outcome of their movement such as "focus on jumping as close to the cone as possible (the cone is 3m away)" (9).

In a review done in 2013 by Wulf et al.(3), comparing the effects of external and internal cues, there were eighty experiments finding a significant advantage of external foci relative to an internal one. A couple of the studies saw no difference in effect between the two cueing types (10-12) yet in no case did any study find an internal focus as more favourable. The benefits of an external cue have been shown for a variety of skills, expertise levels and ages (3) yet Wulf published this review eight years ago and in the intervening period, there have been numerous research papers produced since. The study by Wulf was just a literature review and did not take an extensive look into the statistics of each paper instead opting to just state their findings unlike a meta-analysis. A meta-analysis was eventually performed in 2020 (13) in which the authors looked at the effect of attentional focus manipulation on jump performance. Unfortunately, this paper only analysed studies that included healthy over 18-year-olds and measured jump performance only. In terms of athletic development and testing, both jump height and distance are key indicators of athleticisms and power output, yet an individual's sprint time is another key measure of their ability to produce force. Previous studies have looked at the association between various jump tests and sprint times with Hennessy and Kilty (14) finding the countermovement jump (CMJ) to be related to 30-, 100- and 300-m sprint times. Moreover, the meta-analysis mentioned also did not include a moderator analysis. This is important in order to assess the effect that moderating variables, such as age, can have on the main effect, an outcome measure, and is a common and integral feature of numerous meta-analyses(15-17). This would allow for a more definitive statement to be made on how specific factors, such as age and experience, influence the effects seen by manipulating the focus of attention.

Based on the above, it was determined that the first study of this investigation was to be an updated, and more statistically sound, meta-analysis that examined the effects of external and internal attentional focus' on sprinting and jumping alongside a much-needed moderator analysis which could show how the demographics and study design features of each study affected results. This is to try and attempt to find potential influences on the effects of an external focus and see if any valuable practical coaching applications and advice could be obtained for use in the field. It was envisioned that this could allow for more specific findings and allows us to determine which cue type was most effective along with whether moderating variables could help inform coaching practice by informing coaches on how factors such as age or experience influence the effects of attentional focusing strategies.

The use of attentional focus as a means of improving performance has been researched as far back as the 1960s (18). Despite the large amount of research, it is common for coaches to rely on the use of internally directed cues for motor skill teaching. This was most notable in Porter et als. (7) study in which they surveyed 13 track and field athletes from a USA Track and Field Outdoor National Championship. The survey found that 84.6% reported that their coach used internal focus

cues during practice and 69% reported that they focused internally during competition. This finding is backed up by Benz' (19) survey that asked 111 sprint and hurdle coaches about what type of verbal instructions they provide to the athletes they coach. He found that the coaches provided more internal cues (54%) than external cues (42%) whilst in practice but provided more neutral focus instructions (46%) than external focus instructions (35%) during competition.

The overall goal of this research is to get a better understanding of how the use of different attentional foci affects an individual's performance in sprinting and jumping and whether this is altered by certain moderating factors such as age and training experience.

Chapter 2: Literrature Review

Research into the effects of attentional focus and cueing first came about when Wulf et al. (20) looked into balancing during windsurfing. The researcher found that focusing on the position and pressure of their feet led to them failing and falling into the water during practice. The author decided to start to focus on the tilt of the board which led to a subsequent improvement in the quality and fluidity of movement. Focusing on the tilt of the board is an example of an external focus, when the individual's attention is drawn to the outcome of their movement. This is instead of an internal focus which is when the individuals attention is drawn to the exact movement of their body part such as their feet whilst balancing (3). Often studies use verbal coaching cues to create the desired focus of attention in the individual. An internal cue, such as "extend the forearm rapidly" creates an internal focus by directing the individual's attention to a certain area or component of their body which is required to move to produce the desired movement. Whilst, an external cue, such as "jump towards that cone", directs their attention to the effects their movement will have on the environment (21, 22), creating an external focus. Since then, Wulf found in a 15 year review (3), 21 studies investigated the effects of attentional focus on balance, 20 of those (11, 23-34) found an external focus to be better than an internal focus and just one (35) study, looking at stick balancing, found the two attentional focus' to be equal. These tests measured the individual's ability to balance under different attentional foci using several methods such as using a stabilometer, an isokinetic dynamometer as well as a ski-simulator. Many studies have also looked at the effect of attentional focus on movement efficiency which is defined by Wulf (3) as a movement pattern that is more efficient or economical by producing the same movement outcome with less energy expenditure. Of the 23 (36-51) studies summarised by Wulf (3) looking at movement efficiency all 23 studies saw an external focus to be superior to an internal focus of attention. Many different outcomes were measured such as isometric force production, standing long jump, and running. Only seven studies included in Wulfs' review looked at jumping performance and just one investigated sprint performance. Since then, 17 more jump-based studies and six more sprint-based studies have been published. Across these studies a range of outcomes were measured using participants of all ages and experience levels. An external focus of attention has been shown to be superior for different outcome measures in a range of populations making these findings highly generalizable. For instance, the superior effects of an external focus of attention have been shown for a range of ages from children(52-64), young adults, who were used in the majority of the studies, as well as older individuals(11, 28, 65). An external focus of attention benefits not just healthy individuals, it has been shown to benefit participants with Parkinson's(32, 66), injuries(34, 67-69) and children with motor learning disabilities(52). Across varying levels of expertise, an external cue has been shown to be superior at improving performance compared to an internal cue such as for elite athletes(7, 70-73), as well as intermediate athletes (74) and the novice

athletes used in most other studies. Several studies have actively compared the use of external and internal attentional focuses on groups of differing ability. One investigation by Ille et al. (75) looked at 10m sprint times for elite and novice sprinters. The authors showed that an external cue led to an improved sprint time no matter the ability of the participants in the study. Interestingly, the authors also found expert sprinters typically adopted an internal focus of attention when given no cue. The experienced high-skilled sprinters who participated in Ille et als study would spontaneously adopt a focus of attention that is non-optimal. Their focus during the experiment may have been influenced by the instructions their coaches usually gave to them during training (7). This may highlight the negative effects of some types of instructions given by coaches during training on subsequent performance, which have been shown by numerous authors(23, 76).

Early work by Prinz(77) on the common-coding theory of perception and action(23, 78) stated that actions are more effective if they are planned in terms of their intended outcome (or remote effects), rather than in terms of the specific movement patterns. Therefore, with recent studies finding that movements were more effective having been planned in relation to the outcome effect (externally focused) as opposed to the specific movement pattern (internally focused) helps support Prinz's' common coding theory. Following on from this, Wulf et al.(25) proposed the constrained action hypothesis (CAH). The belief was that an internal focus causes a conscious control of an individual's actions, constraining their motor system by interfering with the automatic control processes of movement. An external focus of attention was said to promote automaticity of the motor system control using more unconscious, fast, and reflexive control processes(3). In support of this theory studies have shown an association between an external focus of attention and lower attentional capacity demands(25), higher frequency movement adjustments(21) and more efficient motor planning(48). The hypothesis that an internal focus of attention leads to a constraining effect has also been shown by Wulf and Dufek(41) who studied jump and reach kinematics and kinetics. They found the external condition produced greater impulses and higher jump and reach heights. There was a higher correlation between hip, knee, and ankle moments under an internal focus of attention yet under the external cue the joint moments were less correlated. This means that under an external focus each joint or segment was able to move freely to a greater degree as needed whilst under an internal focus certain joints range of motion was hindered. Wulf and Dufek(41) then hypothesized that the internal cue was restricting coordination within the lower extremities, thus resulting in less movement variability. Conversely, the limited correlation between joint moments under an external cue allowed unconstrained coordination which led to greater movement variability and better outcome metrics(79). This phenomenon has been mentioned before by Wulf (3) who called it "a 'freezing' of degrees of freedom". The internal focus seemed to have the effect of linking semi-independent body segments thereby constraining the motor system(80). Vidal et al. (79) believed that the

methodological approach researchers were using to measure the effects of focus of attention on movement production and coordination were limited. The previously mentioned study by Wulf and Dufek(41) measured joint coordination using a series of cross correlations between joint moments. Mullineax et al. (81) stated that not enough information is provided by the correlations between two joint angles or moments on the intralimb coordination patterns, neither can it help inform us on the coordination variability within a movement itself.

To allow for a more descriptive movement pattern examination a dynamical systems approach would need to be used. This approach to analysing coordination looks at the relationship between the movement of limb segments(intralimb coordination), or the movement of two different limb segments(interlimb coordination)(82). Vector coding is commonly used to quantify coordination using angular time series plots of two joints(83). Chang et al (84) used a modified vector coding method, initially used to quantify rearfoot-forefoot coordination in walking allows for the description of coordination patterns based on joint and segment movement and can classify them based on for categories: antiphase, in-phase, proximal phase, and distal phase coordination. When looking at joint coordination using this superior vector coding method Vidal(79) replicated findings of increased jump performance when adopting an external focus(49, 85). They also found support for the CAH that when participants were told to extend their knee rapidly their coordination dynamics were dominated by movement of the knee when lowering their centre of mass yet there was minimal movement of the hip and ankle joints. This helps illustrate how the internal focus led to a freezing of the degree of freedom. Yet, under an external focus, the knee and ankle worked together in flexion to lower their centre of mass.

The way an external cue is composed has been shown to influence its effectiveness. For example, external cues be altered by manipulating the direction, distance, and description of the required movement. Whilst the effects of altering the stated direction and description are under researched, the effect the distance of the focus point has on an athlete's performance has been thoroughly investigated. In general the further a focus is from an individual's body the greater the effect the cue has on the athletes performance(21, 22, 57, 73, 74, 86-90). Flores et al.(57) investigated the benefits of external cues for children of varying ages whilst learning a balancing task. The authors found that children who focused on the effects of their movement, especially at greater distances, can have improved learning of the pedalo balancing task. No matter the age of the children, they seemed to learn better under a distal external cue compared to under an internal focus. The older, 10-year-old, children saw a greater learning effect under an external focus compared to the other age groups however that was said to be down to them being in a more advanced stage of their development. Several studies have looked at the distance of a cue on individuals golfing ability(73, 86, 87, 90) all of which found a distal external cue to be superior for golfing accuracy during tasks

such as putting. This was found for both simple and complex tasks as well as across a range of expertise levels. This effect was also found by Porter et al.(22), when looking at distance jumped. For example, participants jumped further when asked to focus on jumping as close as possible to a target as opposed to when they were asked to jump as far past the start line. McNevin et al.(21) were able to show an increased automaticity in movement control under a distal external focus of attention. They did this by analysing the mean power frequency of a balance platforms movements. This measure can detect small frequency differences between groups which may provide important information on one's ability to maintain balance between the different conditions. In this study they also used a retention test in which they had 28 female and 12 male university students come back in two days later to re-perform the task under no instructions. The participants all had no prior experience with the task used within the experiment. All external groups performed better in the retention test compared to the internal group with the distal group doing the best. This is similar to the results of Flores et als.(57) who found children aged between six and ten performed a pedalo balance task faster during a retention (transfer) test using a distal external cue compared to both proximal and internal ones. The authors followed this up by asking participants to perform the same task as fast as possible whilst also having their hands placed on their head to determine the transference effect. This still led to the distal external group performing significantly better than the internal groups $F(3,100) = 4.84$, ($p<0.01$). Porter et al.(9, 22) performed a study looking at proximal and distal external cues. However, the proximal cue used was directed away "when you jump, jump as far past the start line" and the distal cue was directed towards "when you jump, jump as close to the cone as possible". The result of the study found the distal or "away" external focus was superior to the proximal or "towards" focus. The third factor is description, the two most common descriptions are push and punch, with punch creating a focus with more intensity and speed when compared to push which is associated with a longer, slower action(5). Analogies are often used within cues as a way of describing the movement the individual should produce. Analogies have been shown to improve motor skill learning to a greater extent compared to explicit instruction(91-93). An example of an analogy for improving acceleration from a 2-point stand is "Focus on driving off the start line like a jet taking off". It helps the athlete visualise an angled body position with continuous rise whilst going very fast like a jet(5).

Whilst there have been numerous studies finding a positive effect to using an external focus of attention, it seems apparent that this finding isn't necessary being utilised in the field. Two surveys have looked into this, one by Porter et al. (7) which surveyed 13 track and field athletes competing at the USA track and field outdoor national championships. The athletes were highly skilled or elite since the higher ranked athletes would go on to represent the USA at the summer Olympics. The survey also assumed that their coaches too were highly skilled or elite. In the survey athletes were asked a series of questions relating to what their coaches tell them to focus on and what they focus on whilst performing. Interestingly, 84.6% of athletes stated their coaches' instructions were to focus

internally, whilst the remaining athletes stated they were instructed to focus both internally and externally, not a single person stated they were told to exclusively focus externally. Also, 69.2% of track and field athletes reported they adopt an internal focus of attention when participating in competitions. Unfortunately, this study did not ask coaches what cues they used, instead it only asked the athlete meaning the reports may not be entirely accurate to actual practice in the field. This therefore means that there's a chance the athlete may have forgotten the kinds of cues they had been asked and makes it difficult to form an insight into the knowledge of coaches. A second survey was performed by Benz (19) as part of a doctorate thesis which questioned the coaches as opposed to the athlete. The survey questioned 111 sprint and hurdle coaches asking questions relating to what cues they provide to athletes. In summary they found whilst in practice, coaches utilised more internal cues (54%) than external cues (42%) yet whilst the athlete was competing, coaches provided more external (35%) or internal (20%) cues. The issue with the overuse of internal cues during practice is the fact that it limits the athlete's ability to learn (23), limits movement automaticity(94) and hinders movement quality and coordination patterns (95) forming less than optimal movement patterns.

Whilst some studies were characterized by within-subject study designs to look at the acute practice performance, others have directly assessed the effects of focus of attention on motor skill learning using delayed retention and transfer tests or even with the addition of dual task assessments. There is a distinct difference between performance and learning. Performance "refers to the temporary fluctuations in motor skill behaviour that can be observed and measured during or immediately after the skill acquisition phase" yet learning "refers to the relatively permanent changes in motor skill behaviour that supports long term retention and transfer"(96). During a study(97) looking at the effect of focus of attention on performance and retention of standing long jump the authors found that there was a significant difference in their performance during the post-test and retention phase favouring the use of an external cue(97). This finding is consistent with the results of other studies (60, 61, 65, 66, 96, 98-100) and is supported by the apparent processing hypothesis which suggests that whilst under an external attentional focus, the individual processes only one source of information, yet when focusing internally, they process both the internal and the external information. This causes a limited processing capacity, which causes a poorer performance under an internal focus (97). The reduced demands on one's attentional capacity and processing appears to be a well-supported theory when it comes to explaining why an external cue is beneficial for motor skill learning(25). A dual task procedure is a method to assess the attentional demands of both an external and internal focus. Wulf et al.(25) got participants to perform a stabilometer task whilst being asked to respond to a random stimulus as fast as possible via a finger response. The assumption was that the performance of the secondary probe reaction time (RT) task would be related to the size of the participant attentional demand whilst performing the primary stabilometer tasks. The slower their probe RT tasks

performance would infer a larger attentional demand during the primary task(101). The results of this study supported this statement finding that probe RT was lower throughout the practice and retention phases for the external cue. Further to this, Wulf et al.(27) looked at attentional focus performance changes whilst performing a supra-postural (i.e., holding an object still) and balancing task, simultaneously. Along with improved balance during a suprapostural task under an external attentional focus, balance was still enhanced even with the removal of the secondary task. Research by Song and Bédard (102) looked at visuomotor adaptation tasks either with or without a secondary task present. When participants were tested during a recall phase, if the motor skill was learnt as part of a dual task, it was only remembered whilst a similar secondary task was being performed. Without the second task their performance of the motor skill was at an untrained level. This helps show a benefit to learning and recall taking place within consistent environments, hinting to the specificity of motor skill learning(103-105). A coach using a consistent attentional focus induced by a specific trained instructional cue, may help battle the external environment cue (aka the secondary task). This is important as, if the attentional cue used during the formation of motor memory is consistent, learned motor skills may be performed even whilst in an altered external environment(102, 106, 107).

Within the literature, two meta-analysis produced both by Grgic et al. (108, 109) that looked at the effects of attentional focus strategies on muscular strength and endurance producing an effect size as a quantitative measure. In study for an acute effect on muscular endurance, an external focus of attention was found to be superior to an internal focus (SMD: 0.34; 95% CI: 0.22, 0.46;p< 0.001;I2= 40%). For the meta-analysis for the long-term effects, there was no significant difference between training using an internal focus over an external focus on gains in muscular strength (SMD: 0.32; 95% CI: –0.08, 0.73;p= 0.113;I2= 0%). When Grgic et al. investigated the effects of focus of attention on muscular strength they found an external focus to also be beneficial compared to an internal focus (Cohen's d: 0.58; 95%CI: 0.34 to 0.82). Makurak et al.(13), produced a meta-analysis to attempt to compare the difference in effect size between an external and internal focus of attention on jump performance. This study found a significant beneficial effect to directing participants' attention externally as opposed to internally (SMD = 0.33, 95% CI 0.14 to 0.51, Z = 3.50, p < 0.001). The authors of this study restricted their analysis to investigations that measured jump performance in those older than 18 years old and there was no subsequent subgroup analysis performed to determine potential moderators of the main effect. This is important as moderator variables such as age, training experience and cue complexity could impact the effectiveness of attentional focus manipulation strategies. The results of Makaruk et als. (13) investigation originally found 380 records which was narrowed down to 14 studies included in the meta-analysis. Of the 14 studies, 12 of them included a comparison between external and internal focuses. Having looked at the studies included in the meta-analysis further, three of 12 studies appeared to have incorrect data inputted. In the table of studies,

the first study by Abdollahipour et al. (110) stated that for vertical jump height the external and internal group achieved an average height of 30.93±41.01cm and 30.09±42.43cm, respectively. However, the actual figured published in the paper for both external; and internal attentional focuses was 30.93±8.37cm and 30.09±8.66cm, respectively. Similar mistakes were made for the following studies: Wulf and Dufek (41), Wulf et al. (44), Asadi et al. (111) and Becker et al.(112) as seen in Table

Table 1: Incorrectly reported statistics from meta-analysis

Study	Task	Reported by Makaruk et al.(13)		Actual Result	
		External	Internal	External	Internal
Wulf and Dufek (41)	VJ (cm)	31.9±10.2*	30.4±9.6*	31.9±3.23	30.4±3.04
Wulf et al. (44)	VJ (cm)	32.4±8.6*	31.0±8.99*	32.4±3.05	31.0±3.18
Asadi et al. Study 1 (111)	SLJ (mm)	208.86±21.61*	196.26±23.94*	206.9±21.61	196.27±23.94
Asadi et al. Study 2 (111)	SLJ (mm)	247.24±14.67	235.48±15.04*	247.24±14.67	235.49±15.04
Becker et al. (112)	SLJ (mm)	177.55±38.65*	169.50±39.96*	183.69±38.66	172.69±40.25

** Incorrect statistic 1, VJ = Vertical Jump & SLJ = Single Leg Jump*

A major key performance indicator for athletic performance is the ability for an athlete to produce force fast. Both jumping and sprinting are key movements in sport along as a major indicator of an athlete's ability to produce force often used as a tool to evaluate athletic performance(113-116). The acceleration phase whilst sprinting is heavily dependent on the stretch shortening cycle (SSC)(117) which relates to the muscle action when active muscles lengthen and immediately shorten. SSC is characterised, based on the ground contact time (ms), as either long (>250ms), or short (<250ms)(117). The acceleration phase whilst sprinting utilises the long SSC yet as maximum speed is reached the GCT decreases and the SSC is utilised(118). The SSC is utilised whilst jumping to help achieve greater jump heights and distances. Athletes performing the CMJ, which utilises the SSC to a better degree than the squat jump, have been found to achieve jump heights 2-4cm greater than when preforming the squat jump(119). Increasing the speed- or size- of the loading force during the eccentric phase will result in greater jump heights or distance (120, 121). Both jumping and sprinting utilise the SSC which may explain why researchers have often found a correlation between the two. When investigating the relationship between CMJ height and 30 m sprint time a very strong negative correlation(($r=-0.93$, $p<0.01$) was found by Bosco et al. (122). A similar result was found by Hori et al. (123) ($r = -0.69$, $p<0.01$) along with Lopez-Sigovia et al.(124) ($r = -0.54$, $p<0.05$). Being

able to produce high levels of muscular power output is critical for an athlete to have a successful performance in many sports(125). The implementation of external cues, drawing an athlete's attention to the outcome of their movement, and the subsequent improvement in their jumping and sprinting performance may provide further long-term benefits which aids the athlete in their sport. Due to the lack of an in-depth meta-analysis assessing the effects of moderator variables the literature fails to provide a statement on the size of the effect of attentional focus on both sprinting and jumping as well as to what degree these findings are generalizable. That's why this meta-analysis is being performed, to help consolidate the findings of the literature as well as to provide coaches with a clear answer to how they should structure their feedback to athletes.

Chapter 3: Effects of External vs. Internal Cues on force dependant performance outcomes: A Meta-Analytical Comparison.

3.1 Abstract

External coaching cues have been suggested as a better alternative to internal coaching cues due to their ability to allow the body to move more efficiently. A cue serves as verbal feedback to an individual being either external, and focusing on the movement outcome or internal, the movement itself. Multiple studies have found focusing on the outcome of the movement leads to greater force expression and as a result a greater performance measure outcome. The objectives of this meta-analysis were to compare the effects of external vs. internal cues on sprint and jump performance and to determine variables which play a role in determining their effectiveness. The data sources utilised were Googler Scholar, PubMed and Microsoft Academics. For a study to be eligible for inclusion it must have compared internal and external cues, utilised a cross-sectional study design and measured either jumping or sprinting tasks. The meta-analysis used an inverse-variance random-effects model as it allocates a proportionate weight to trials based on the size of both their individual standard errors and facilitates analysis whilst also accounting for heterogeneity across studies. Effect sizes were represented by the standardized mean difference and presented alongside 95% confidence intervals. Twenty-two studies were included in the meta-analysis. There was a small main effect size [0.30(95% CI 0.19, 0.40, Z=5.46(p<0.00001)] favouring the use of external coaching cues compared to internal coaching cues for enhancing performance. Subgroup analyses showed between-group heterogeneity ranging from very low to high and demonstrated statistical significance in numerous cases. Effect sizes were small to moderate between each type of cue across all the moderator variables. Studies which used simpler external cues created a slightly greater benefit to performance (0.32[0.20, 0.45]) in comparison to more complex external cues (0.20[-0.01, 0.42]). Participants whose age was less than or equal to the median split (21) benefited from the use of external cues more (0.39 [0.22, 0.56]) than those below the age of 21(0.22 [0.08, 0.36]). Individuals who were more experienced saw a greater benefit from the use of external cues (0.33[0.13, 0.52]) compared to less experienced individuals (0.28[0.15, 0.41]). External coaching cues are slightly more beneficial for enhancing acute jump and sprint performance when compared to internal cues. This is important for coaches as it provides a guideline for how they should verbally interact with their athletes to allow them to perform to the best of their capabilities. The benefits of external coaching cues have been shown to be highly generalizable and provide benefits to performance in many tasks and with individuals of different levels of expertise and characteristics. The use of an external focus of attentions helps individuals both perform better whilst also aiding motor pattern learning in skill-based tasks.

3.2 Introduction

An athlete's limited capacity to focus on tasks either in training or in competition combined with the large number of decisions that must be made at high speed, is often a limiting factor in their performance(126). Hick's law(127) describes the time taken for a person to make a decision as a function of the number of options available when making that particular decision. This is due to a limitation in one's attentional capacity leading to a sub-optimal performance when their focus drifts towards disruptive factors. However, this can be explicitly manipulated by coaches using verbal cues helping to direct one's focus, or implicitly through task design and connecting successful outcomes to a specific focus(5). Verbal cues can be used to elicit either an external, internal, or neutral focus of attention for an athlete performing a task. An external cue is defined as a cue that directs an individual to focus their attention on the effects or outcome of a given movement and the environment, whereas an internal cue is one which directs their focus of attention on the body movements associated with successful performance of a skill(5). The performance benefits of external cues have been shown in a variety of tasks such as balance and suprapostural tasks (21, 23, 24, 27, 28) and neuromuscular force expression(36, 38, 128, 129), along with a variety of different skills(37, 40-43, 47, 49, 71, 74, 75, 88, 130).

The reasoning behind the aforementioned performance benefit is best explained by the constrained action hypothesis (CAH). In movements such as balancing on a stabilometer, a participant's attempt to actively control their movements may disrupt relatively automatic processes that normally control that movement. McNevin et al.(21) argued that when using an external cue, the further away the focus of attention is from the individual's body (to a limit), the greater the benefit the cue has on their performance. When a participant's focus is on the effects of their movement on something close to their body, they might be more likely to actively interfere with basic control processes than participants focusing on a more distant focus. The results of McNevins' study went on to agree with this statement with two groups focusing on distant markers clearly making smaller corrections in maintaining their balance compared to the group focusing on markers closer to their feet.

Given that balance on an unstable surface must be maintained using small, very rapid (reflexive) patterns of activation (21), it appears reasonable to assume that active intervention in these, relatively automatic, processes may reduce one's coordination as distractive elements impact upon movement stability. An external focus of attention seems to allow the body to automatically control movements needed to balance, thus allowing for faster adjustments and generally enhanced performance and learning during task execution (21). This belief can be traced back as far as the 19th century when Lotze(131) and James(132) stated that attention should be directed to the intended

outcome of an action rather than the body movements associated with it (kinaesthetic feedback). This interference that results from the conscious control of the motor control system results in decreased accuracy, slower movements and overall depressed motor performance (3). Vance et al. (36) and Marchant et al. (38) used EMG to show that an external focus of attention during the bicep curl (elbow flexion) led to a more efficient contraction of the biceps and a more highly organized motor program. This has been further evidenced by Lohse (133) and Sherwood(133, 134) who found that the use of internal cues led to inefficient or elevated muscle activity during a simple seated force production test.

The generalizability of these findings in relation to complex motor patterns such as jumping or sprinting has been investigated, in single study designs, in detail (135). Investigations by Wulf et al. (37) and Porter et al. (43) examined vertical and standing long jump, respectively. The authors found that even during more complex skills, an external focus of attention led to improved performance in the form of a greater jump height and distance. The size of a positive effect due to an external cue, in comparison to an internal cue, may vary dependant on many factors such as the task being performed, the participants age and experience level. Both verbal and visual cues are an important coaching tool and coaches need to have a good understanding of when it is best to utilise an external cue and when it may be best to implement an internal coaching cue. Wulf et al. (3) wrote about the high generalizability of an external focus of attention with different measures of movement efficiency including force production and EMG activity. The verbal external coaching cue led to greater improvements in performance in force related measures than when using an internal cue(3). This review by Wulf did not directly compare the findings of the studies to give an effect size and significance of the effect of external cues when compared to internal cues. A study by Makaruk et al. (13) investigated the effects of external vs internal attentional focuses on jump performance through the use of a meta-analysis. They found a small positive effect size of 0.33 [0.14, 0.51] favouring the use of an external over an internal focus of attention when looking to improve jump performance. However, as previously mentioned there were a few studies which were used within the meta-analysis that had miss reported statistics. As well as this, the meta-analysis lacked a subgroup analysis to assess the potential effects moderator variables have on the main effect. Therefore, the main purpose of this systematic review and meta-analysis is to compare the effects of external and internal verbal and visual cues on both sprinting and jumping as indirect measures of force expression. A secondary aim was to determine how the effects of internal and external cueing on athletes' performance could be influenced by moderating factors such as age, experience, number of attempts, cue complexity and movement types etc. Wulf (3) wrote in a review how future research has the challenge to "disentangle these potential influences". They were referring to the structure of an external focus and the effect the athletes' specific demographics has on the impact on performance. The hypothesize put forward in

this review is that, in the studies analysed, external cues will be found to be beneficial in improving sprinting and jumping performance compared to an internal cue.

3.3 Methods

Literature search

A systematic search of PubMed, Google scholar and Microsoft Academic was undertaken, and the results were compiled in a spreadsheet in Microsoft Excel. Articles must have been published had to be in the English language to be included. The initial searches were undertaken in February 2021 were updated in February 2022. Using Boolean logic, the following terms were searched: ('Internal' AND 'External') AND 'Cue' AND 'Coaching' AND ('Attention OR Attentional') AND 'Focus' AND' Verbal' ('Instruction' OR 'Directions' OR 'Feedback') AND ('Performance' OR 'Motor Skills') AND ('Sport' OR 'Athletic' OR 'Plyometrics' OR 'Speed'). In selecting studies for inclusion, a review of all relevant article titles was conducted before an examination of article abstracts and then, full published articles. Following the formal systematic searches, additional hand searches were conducted. The search process is outlined in Figure. 2. A second search was performed in February 2022 with the aim of finding any new papers, that search used the following search terms: "external cue" OR "internal cue" OR "attentional focus" AND (Plyometrics OR Speed OR Jump OR Sprint). The record found were assessed in the same way as the first search and can be seen in Figure. 3. New search terms were used because, originally, when the first search was conducted the papers that were being searched for were not exclusively limited to just those that measured jump and sprint performance. However, by the time of updating the study the study's inclusion criteria had been altered.

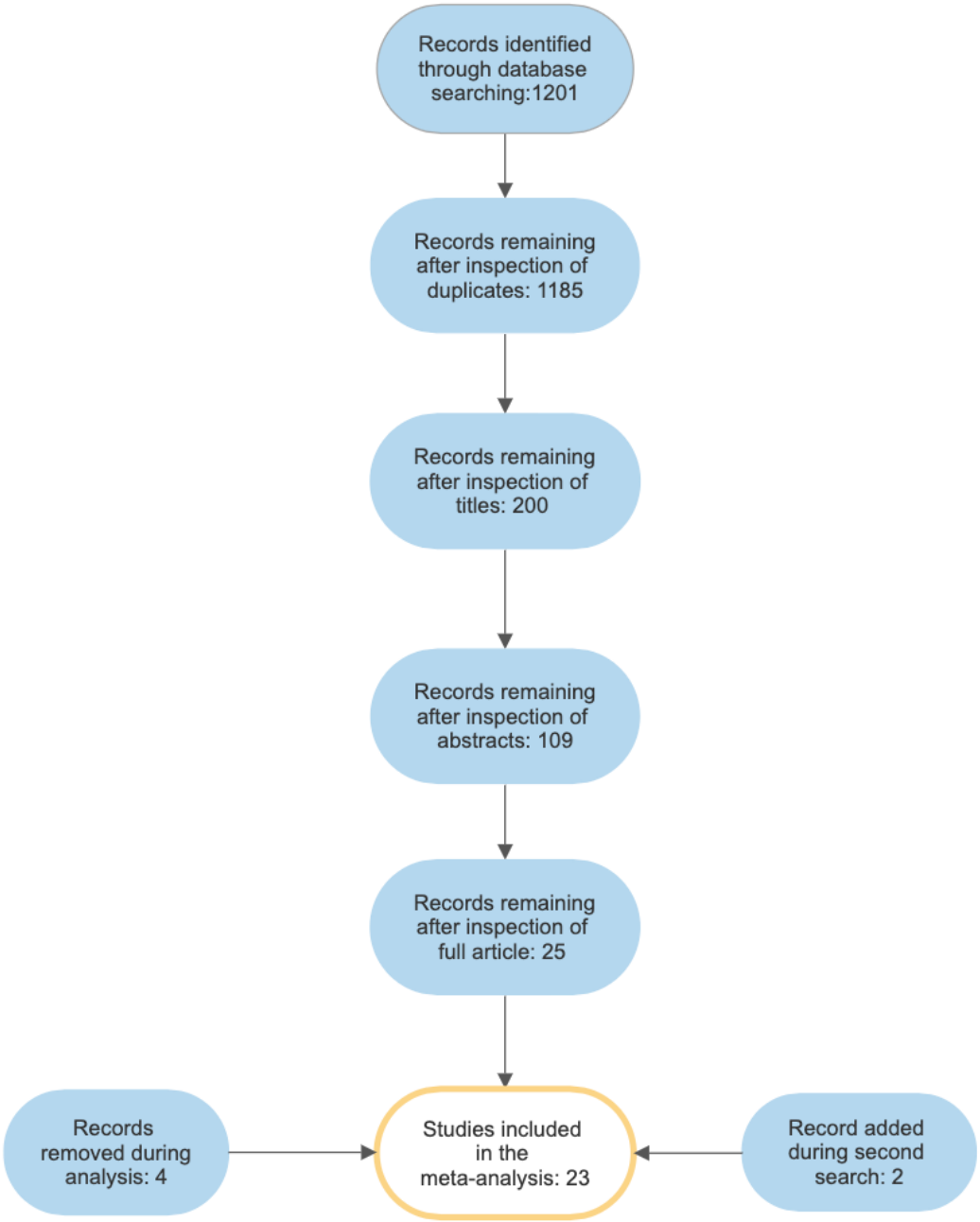

Figure 1: Flow chart of inclusion and exclusion procedure for studies

Inclusion and Exclusion Criteria

Data was extracted from the gathered articles using a spreadsheet created in Microsoft Excel. The following criteria were used to determine whether a study was to be included in the review: Studies comparing external and internal cues in a cross-sectional research design including outcome measures that were related to jump height or distance, or sprint time. Whilst most studies stated they utilised a counterbalanced study design, others did not state this. To maximise included data this was not used as an inclusion criterion. An internal cue was defined as one which directs the participant's

attention to the movement of the body executing the skill and an external cue as one which directed their attention to the outcome of the motion executed (23).

Study duration was used as an exclusion criterion so that only papers using a short-term cross-sectional study design were to be analysed to prevent learning effects altering the effect sizes. Both male and female participants were included. The standardised mean difference was used as a measure of effect size to account for the varied nature of these measures and so that the extracted data could be validly pooled. Studies lacking a detailed description of the cues used were excluded as a further comparison of cue complexity (length) was to be performed. Accordingly, this meant that researchers must have included an exact, word-for-word, description of the coaching cue used for each variable. Studies must have included this information as without it, it would have been difficult to determine the complexity of each cue based on its length.

Table 2 Participant Characteristics

Study	Participants, n	Sex	Age, y(SD)	Body mass, kg (SD)
Abdollahipour et al. 2016(110)	24	Mixed	25±3.3	
Asadi et al. (Low-Skill)(111)	15	Male	23	74
Asadi et al. (High-Skill)(111)	15	Male	23	71
Becker et al. 2018 (79)	29	Male	24	
Becker and Smith (136)	68	Mixed	20.84±2.72	72.29±13.44
Bezodis (137)	18	Male	22	78.2
Coker(138)	21	Female	19.33±1.49	
Comyns et al.(139)	17	Mixed	24.4	81
Ducharme(85)	21	Mixed	21.3±1.74	67.4
Hebert and Williams (140)	27	Mixed	21.78	
Ille et al. (Expert) (21)	8	Male	20-30	
Ille et al. (Novice) (21)	8	Male	20-30	
Imtair et al. (141)	65	Mixed		
Keller et al.(142)	19	Mixed	27.5	69.1
Kershner et al. (143)	43	Male	20±1.5	88.9±8.8
Makaruk et al. (144)	15	Male	22.3	76.9
Marchant et al. (2018) (63)	44	Mixed	7.35±1.7	28.01±9.24
Porter and Sims (2013) (70)	9	Male	21.11±1.22	93.24±36.23
Porter et al.(2013) (9)	38	Male	20.7±2.2	89.7±21.7
Porter et al.(2015)(51)	84	Both	20.5±1.69	71.41±12.04
Winkelman(145) Novice	17	Both	28±4.32	73.3±7.94
Winkelman (145) Experienced	13	Both	19.41±1.06	73.76±10.7
Wu et al. (49)	21	Both	21.3±1.74	67.4±10.5
Wulf and Dufek (41)	10	Mixed	25	
Wulf et al. 2010 (44)	8	Mixed	22.6	
Yamada et al. Male (146)	20	Male	22±2.19	77.7±13.04
Yamada et al. Female (146)	20	Female	22±3.87	71.48±20.66

SD = Standard Deviation

Table 3 Study Characteristics

Study	Experience	Cue Complexity	Outcome measure	Attempts
Abdollahipour et al. 2016(110)	Novice	Simple	CMJ height (cm)	3
Asadi et al. (Low-Skill)(111)	Novice	Simple	Standing Long Jump (cm)	3
Asadi et al. (High-Skill)(111)	Experienced	Simple	Standing Long Jump (cm)	3
Becker et al. 2018 (79)	Novice	Simple	Standing Long Jump (cm)	2
Becker and Smith (136)	Novice	Simple	Long Jump (cm)	5
Bezodis (137)	Experienced	Simple	10m Sprint(s)	3
Coker(138)	Experienced	Simple	Single Leg Jump (cm)	2
Comyns et al.(139)	Experienced	Simple	Drop Jump (cm)	2
Ducharme (85)	Novice	Complex	Standing long jump (cm)	2
Hebert and Williams (140)	Novice	Simple	Standing long jump (cm)	3
Ille et al. (Expert) (75)	Experienced	Simple	10 m sprint time (s)	5
Ille et al. (Novice) (75)	Novice	Simple	10 m sprint time (s)	5
Imtair et al. (141)	Novice	Simple	Vertical Jump (cm)	3
Keller et al.(142)	Experienced	Simple	CMJ height (cm)	5
Kershner et al. (143)	Experienced	Simple	CMJ height (cm)	4
Makaruk et al. (144)	Experienced	Simple	Standing Long Jump (cm)	3
Marchant et al. (2018) (63)	Novice	Simple	Standing long jump (cm)	6
Porter and Sims (2013) (70)	Experienced	Complex	18.28 m sprint test (s)	3
Porter et al.(2013) (9)	Experienced	Simple	Long Jump (cm)	2
Porter et al.(2015)(51)	Novice	Complex	20-m Sprint(s)	3
Winkelman(145) Novice	Novice	Simple	10-m Sprint	2
Winkelman (145) Experienced	Experienced	Simple	10-m Sprint	2
Wu et al. (49)	Novice	Simple	Standing Long Jump (cm)	2
Wulf and Dufek (41)	Novice	Simple	Counter-movement Jump	10
Wulf et al. 2010 (44)	Novice	Simple	Counter-movement Jump	3
Yamada et al. Male (146)	Novice	Complex	DJ height (cm)	2
Yamada et al. Female (146)	Novice	Complex	DJ height (cm)	2

SD = Standard Deviation

Analysis and Interpretation of Results

The Cochrane Software Review Manager (Revman) 5.3 was used to calculate the meta-analytical comparison in this study. Within-subject comparisons were made using means and standard deviations used to calculate an effect size (ES), the standardised mean difference. The model used for the meta-analyses was the inverse-variance random effects model as trials it weights proportionally based on their standard error and accounts for heterogeneity across studies. The standardised mean difference was used to alongside 95% confidence intervals (CI). Effect sizes were interpreted using the terminology used by Hopkins et al.(147) for a standardised mean difference (< 0.2 = trivial; 0.2–0.59 = small, 0.6–1.19 = moderate, 1.2–1.99 = large, 2.0–3.99 = very large, > 4.0 = extremely large).

Assessment of Risk of Bias

To assess the risk of bias the Physiotherapy Evidence Database (PEDro) scale was used. This allows for an assessment of studies' methodological quality to be assessed on a scale of 0 (high risk of bias) to 10 (low risk of bias). The threshold score for studies with a low risk of bias is ≥ 6 (147).

All studies were assessed by AG with the said ratings displayed in Table 3.

Table 4 Physiotherapy Evidence Database (PEDro) scale ratings.

Study	1[a]	2	3	4	5	6	7	8	9	10	11	Total
Abdollahipour et al. 2016(110)	1	1	1	1	1	0	0	1	1	1	1	8
Asadi et al. (Low-Skill) (111)	1	1	1	1	1	0	0	1	1	1	1	8
Asadi et al. (High-Skill) (111)	1	1	1	1	1	0	0	1	1	1	1	8
Becker et al. 2018 (79)	1	1	1	1	1	0	0	1	1	1	1	8
Becker and Smith (136)	1	1	1	1	1	0	0	1	1	1	1	8
Bezodis (137)	1	1	1	1	1	0	0	1	1	1	1	8
Coker(138)	1	1	1	1	1	0	0	1	1	1	1	8
Comyns et al.(139)	1	1	1	1	1	0	0	1	1	1	1	8
Ducharme (85)	1	1	1	1	1	0	0	1	1	1	1	8
Hebert and Williams (140)	1	1	1	1	1	0	0	1	1	1	1	8
Ille et al. (Expert) (21)	1	1	1	1	1	0	0	1	1	1	1	8
Ille et al. (Novice) (21)	1	1	1	1	1	0	0	1	1	1	1	8
Imtair et al. (141)	1	1	1	1	1	0	0	1	1	1	1	8
Keller et al.(142)	1	1	1	1	1	0	0	1	1	1	1	8
Kershner et al. (143)	1	1	1	1	1	0	0	1	1	1	1	8
Makaruk et al. (144)	1	1	1	1	1	0	0	1	1	1	1	8
Marchant et al. (2018) (63)	1	1	1	1	1	0	0	1	1	1	1	8
Porter and Sims (2013) (70)	1	1	1	1	1	0	0	1	1	1	1	8
Porter et al.(2013) (9)	1	1	1	1	1	0	0	1	1	1	1	8
Porter et al.(2015)(51)	1	1	1	1	1	0	0	1	1	1	1	8
Winkelman(145) Novice	1	1	1	1	1	0	0	1	1	1	1	8
Winkelman (145) Experienced	1	1	1	1	1	0	0	1	1	1	1	8
Wu et al. (49)	1	1	1	1	1	0	0	1	1	1	1	8
Wulf and Dufek (41)	1	1	1	1	1	0	0	1	1	1	1	8
Wulf et al. 2010 (44)	1	1	1	1	1	0	0	1	1	1	1	8
Yamada et al. Male (146)	1	1	1	1	1	0	0	1	1	1	1	8
Yamada et al. Female (146)	1	1	1	1	1	0	0	1	1	1	1	8

[a] *Item 1 is not included in score calculation*.

Analysis of Moderator Variables

The potential effects of other moderator variables were assessed using a subgroup analyses. Moderator variables were chosen based on how they might impact upon the main effect. These variables included age, sex, training (S&C) experience, cue complexity, outcome measure type, jump type, number of attempts per cue and participants' body mass. Age was chosen as a moderator variable based on the notion that older participants may be able to understand what is being asked of them by the cue to a better extent than younger participants. The age groups were divided using a median split of 21. This left two groups of participants one group who were above and equal to 21 years and one below 21 years old. External cues have been shown to work across multiple ages (3), however, whether one age group sees a greater benefit to performance under an external or internal cue than another has not yet been determined. Studies were split by the number of attempts given for the task per cue, also by median split (Median equalled 3). This was done because it has been shown that external cues improve the learning of a skill, compared to an internal cue, in areas such as golf

pitching or basketball shooting (3), therefore, it was believed that the more attempts a participant has under an external cue the greater motor pattern development and subsequent performance will be. Cue complexity was determined by looking at the number of points which the participant was asked to focus on in each cue. This was used as a moderator variable due to the notion that the more complex the cue the more attentional focus it would take up, this potentially hindering performance. Citing Ille et als, study (75), Winkelman (145) stated that the internal cue used within Ille et als. study possessed four different instructional elements or focus points, whereas the external cue they used only had three. Therefore, this required more conscious processing when using the internal cue compared to the external cue, effecting the performance of the required skill due to the reduced number of attentional resources available for the task(145). Even though this was seen between an external and internal cue the use of shorter less complex cues in general may lead to a greater performance even when both using an external cue due to lower attentional demands being placed on the individual. Wulf(3) stated that the benefits of using an external cue compared to an internal one have been found for a range of expertise levels from the novices in most studies to intermediate(74) and experienced performers(73). In this analysis, participants were categorised as being experienced if they received previous coaching in the specified performance measure, a point of interest that was commonly reported in the gathered studies. It was believed that experienced participants would possess a greater capacity to understand and apply the external cue to their movement allowing for a greater performance in comparison to when using an internal cue. This is further aided by the reduced attentional and cognitive demands of a tasks execution as practice of said tasks is increased, as stated by theories of motor learning (148-150). Studies were split by the type of movement they tested, either jumping or sprinting. Previously this hasn't been compared however it is being investigated to see whether, one may benefit more from an external focus of attention. Similarly, all jumps were categorised and split up based on whether they were vertical or horizontal jump, along with whether they used a drop jump or a CMJ type movement. This was to determine if the technique or plane of movement played a factor in whether it is beneficial to implement an external or internal cue.

3.4 Results

Main Effect

Twenty-three studies were included in the main effect analysis with 3 studies providing effect sizes for multiple groups (such as novice vs expert or male vs female). There was a small, significant($p<0.05$), between-mode effect size [0.30(95% CI 0.19, 0.40, $Z=5.46(p<0.00001)$] in performance measures that favoured the use of an external coaching cue when compared to an internal coaching cue when looking to elicit greater force production outcomes. There was an insignificant, low, level of between study heterogeneity [$I^2 = 0\%$ ($P = 0.82$)]. The main effect is below in a forest plot (Figure.4.)

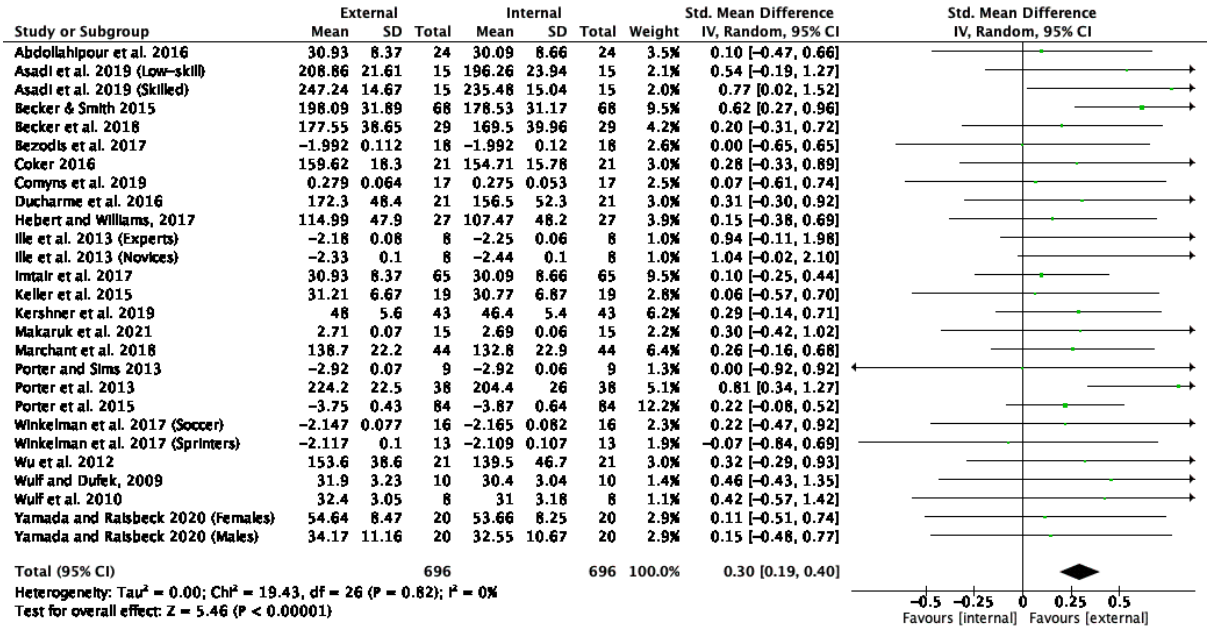

Figure 2: Forrest Plot to show the main effects results

Effect of Moderator Variables

A subgroup analysis was performed (Table 4) and it showed between-group heterogeneity ranged from very low to high, demonstrating statistical significance in numerous cases. Effect sizes were small to large between each type of cue across all the moderator variables. Studies which used simpler cues reported a greater benefit in performance from external cues (0.32 [0.17, 0.46]) in comparison to more complex cues (0.20 [-0.01, 0.42]). Participants whose age was more than or equal to the median split benefited slightly from the use of external cues (0.39 [0.22, 0.56]) compared to those below the age of 21 (0.22 [0.08, 0.36]). Individuals who were more experienced saw a very similar benefit from the use of external cues ([0.33[0.13, 0.52]) compared to less experienced individuals 0.28[0.15, 0.41].

Table 5 Moderator Analysis

Sub-group	Studies, n	Participants, n	Estimated effect size, means (95% CI)
Age			
>21	19	634	0.22 [0.08, 0.36]
≤21	6	492	0.39 [0.22, 0.56]
Cue Complexity			
Simple	19	788	0.32[0.20, 0.45]
Complex	6	338	0.20[-0.01, 0.42]
Outcome Measure Type			
Jumps	18	814	0.31[0.19, 0.44]
Sprints	7	312	0.22[0.00, 0.45]
Jump Type			
Drop Jump (DJ)	3	114	0.11[-0.26, 0.48]
Countermovement Jump (CMJ)	5	208	0.23[-0.04, 0.50]
Vertical Jumps	8	322	0.16[-0.02, 0.35]
Horizontal Jumps	10	492	0.43[0.27, 0.59]
Attempts per cue			
>3	7	280	0.42[0.23, 0.62]
≤3	18	846	0.24[0.11, 0.37]
Experience			
Novice	14	694	0.28[0.15, 0.41]
Experienced	11	432	0.33[0.13, 0.52]

Positive effect size favours external cues, CI confidence interval

3.5 Discussion

Main Effect

This meta-analysis aimed to determine whether the use of external or internal coaching cues were favourable when it comes to eliciting increased performance during movement tasks which require the study participant to exert force such as sprinting and jumping. The main findings of this meta-analysis indicate that the use of external cues helps improve an individual's jump and sprint performance when compared to internal cues. This is important for coaches to know as it helps to improve the quality of the coaching they are providing whilst also allowing for a simple and immediate improvement in performance from their athletes both jumping (20, 37, 38, 43, 49, 51, 94, 110, 143, 151, 152) and sprinting(51, 70, 75, 145) . These results seem to indicate that external cues may be favourable to internal cues and one of the ways in which they might do this is by drawing the participant's focus of attention away from their own body as explained by the CAH(3). The CAH states that by using an external coaching cue, the automatization of a given movement is enhanced and this can help to facilitate enhanced motor performance. This is due to more efficient motor

planning allowing for an individual to overcome the issue of degrees of freedom. Degrees of freedom (153) relates to the vast number of movement options available for the body to carry out one movement. This makes it difficult for the nervous system to produce an optimal movement strategy (154) yet is made easier under an external attentional. In contrast, when using an internal cue, an internal focus of attention is adopted by an athlete and this can cause them to increase their deliberate and conscious control of a movement which constrains the individual's 'normal' automatic control processes (94). Kal et al. (94) assessed the effect on an individual's ability to perform skills automatically by measuring dual task cost under both internal and external foci of attentions. Due to limited attentional resources(155) and tasks competing for the same pool of cognitive resources (156) the simultaneous performance of two tasks will lead to a reduction in performance, this is known as the dual task cost. Kal et al. found that not only did an external focus of attention result the participants achieving superior performance compared to an internal focus, but that directing one's attention externally also resulted in enhanced movement automatization, which seemed to support the underpinning rationale of the CAH.

From the studies included in this meta-analysis, the largest effect size found was 1.04 in the investigation by Ille et al(75) . This effect size was found when a novice group of 8 individuals, with an average age of 25, were asked to run a 10m sprint test. The study found an external cue to have a moderate effect on an individual's 10m sprint time when compared to when internal cues were used. The study's findings are supported by previous research which explained that an external focus of attention resulted in increased force production and decreased muscular activity, demonstrating a more efficient muscle recruitment and coordination (38). Marchant et al. (38) suggested that under an external focus of attention, agonist and antagonist muscle group coordination was more effective and efficient. This led to the increased force production and decreased bicep activity during an isokinetic elbow flexion task due to more efficient activation of the triceps (antagonist) muscle group (36). Contrastingly, an internal focus of attention seemed to produce more "noise" in an individual's motor system, which was shown quantifiably through increased muscular activity(37, 133). Not only is the increased muscular activity not transferred to the movement desired, but it also interferes with movement control(38) . This is vital for coaches to know, especially for those training high level sprinters who are aiming to produce large amounts of force in a short period of time whilst also maintaining their sprinting form throughout execution.

Of the twenty-five studies included in this meta-analysis, just one (145)study reported a negative effect size favouring an internal cue. This study was by Winkelman (145) who found a trivial negative effect sizes of -0.07, which favoured neither the internal or the external cues used in the study. In that investigation, the researchers were looking at the effect of an external or internal attentional focus, on 10m sprint performance, with respect to athletes' level of experience. It was the "experienced" group of sprinters which demonstrated a trivial negative effect size, achieving an

average 10m sprint time of 2.109s ± 0.107 and 2.117s ± 0.1 under an internal and external attentional focus, respectively. In this investigation, the "novice" group of soccer players achieved an average 10m sprint time of 2.147s ± 0.077 and 2.165s ± 0.082 with a small effect size of 0.22 [-0.47, 0.92]. It was hypothesised by Winkelman et al. that both novice and expert sprinters would perform better under an external attentional focus as opposed to an internal focus. The researchers noted their finding for the expert sprinters as surprising and contradictory to other investigations findings. Winkelman et al. went on to examine theories of learning within their study to get a better understanding of their finding. With experience and long durations of learning, goal-relevant dimensions of the skill (sprinting) end up becoming consolidated (157) and the athlete no longer attends to the skill consciously whilst performing (76). Therefore, highly experienced sprinters may focus on their 'normal focus' or whatever was coached to them unconsciously leading to superior performance. No matter the cue provided (145). Contradictory to Winkelman et als. finding, Ille et al.(75) also looked at attentional focus' effect on 10m sprint performance as a function of skill level. They found a significant positive effect size, for their experienced group of sprinters, of 0.94. Both studies involved a similar age of participants with Winkelman et al. having an average age of 28 ± 4.32 years and Ille et als. Participants were between the ages of 20-30 years old. Ille at als. Participants were made up of 6 females and 7 males who had ⩾ 8 years of high school and collegiate track and field experience (competing recreationally or professionally). Winkelman et als. participants were made up of 8 male sprinters all of which were involved in regional to international level competitions. One of the main discrepancies between the two papers are the cues they used and how the coaches communicated these cues. The cues used by both papers are shown below in Table 6.

Table 6: Cues used by Winkelman et al(145). and Ille et al.(75)

Study	External Cue		Internal Cue	
	Initial Cue	Reminder	Initial Cue	Reminder
Winkelman et al.	"Focus on driving the ground back as explosively as you can"	"Drive the ground back explosively"	"Focus on driving your legs back as explosively as you can"	"Drive your legs back explosively"
Ille et al.	"Get off the starting blocks as quickly as possible, head towards the finish line rapidly and cross it as soon as possible"	None	"Push quickly on your legs and keep going as fast as possible while swinging both arms back and forth and raising rapidly your knees"	None

The coaching cues used by Ille et al. are notably longer than those used by Winkelman et al. especially the internal cues. Under an external attentional focus, the sprinters in Winkelman et als. and Ille et als. studies both got times of 2.117s ± 0.077 and 2.18s ± 0.08, respectively, whereas under an internal focus they achieved times of 2.109s ± 0.107 and 2.25s ± 0.06, respectively. The difference in effect sizes seen between the two studies appears to be because of athletes achieving a much slower time under the internal focus during Ille et als study. Internal cues have been shown to result in a n increased attentional demand relative to external cues (25). The greater internal cue length used by Ille et al. causes a greater stimulus, more cognitive load (158) and decreased movement effectiveness (159), the internal cue in Ille et als. study created a greater hinderance on motor performance compared to in Winkelman et als. study. Along with this, Winkelman et als. study used shorter coaching cues as reminders during the sprinting task potentially further improving the positive effects of the external coaching cues by reminding them what to focus on.

As previously mentioned, a similar meta-analysis by Makaruk et al. (13) was performed. Whilst these authors also compared the effects of external versus internal attentional foci, they only examined studies that measured the participants' jump performance. Conversely, we included studies using both jump and sprint outcome measures, th e reason for this is because they both act as useful and easy field tests for force production and output. As well as this, jump and sprint tests relationships have been investigated a significant negative correlation between the two (122-124), this means they can be viably pooled for analysis which increases statistical power. Makaruk et al. also reported a significant, small effect size of 0.33[0.14, 0.51], favouring the use of an external focus of attention, which is very similar to the results of the current meta-analysis (0.30 [0.19, 0.40]). The addition of sprint studies and newer jump studies led to an additional 13 studies, thus increasing the statistical power of the analysis.

The findings of this study are important for coaches due to the practical benefits they reveal. The study shows that overall, it is better to use an external cue than an internal one when trying to improve an athlete's performance during force dependant motor skills such as jumping and sprinting. However, the current evidence does suggest that this is just a small effect and so the potential benefits may be overstated in the current literature. External cues can reduce the attentional cost of an athlete's skill execution, therefore allowing for the participant to focus on important external factors in games such as the opposition. They therefore should be used not only during performance testing, but also during training to ingrain better movement automaticity which can, in the long run, lead to improved motor learning and skill retention, which can be beneficial for performance during competition (23).

Subgroup Analysis

Unlike the previous meta-analysis by Makurak et al.(13), a subgroup analysis of moderator variables was performed looking into age, cue complexity, outcome measure type, jump type, number of attempts and experience. The first moderator was age where participants were split using a median

split into equal to or less than 21 years and more than 21 years. The sub-group analysis found those younger than or equal to 21 years old had a greater effect size of 0.39 [0.22, 0.56] favouring an external over internal cue when compared to an effect size of 0.22 [0.08, 0.36] for the group over the age of 21 years. The difference in effect sizes is not too substantial with Becker and Smith(136) finding the effects of attentional focus to be similar in both children and adults. In a review on attentional focus, Wulf (3) stated how researchers only found an effect of age and focus during a learning test, but not a retention test (160). The difference in the effects of external cues between age groups may be small, but studies still show that an external cue is more beneficial than an internal cue for both adults and children(3), which agrees with the findings of this sub group analysis. Therefore, from a practical standpoint, implementing external cues may see a greater jump and sprint performance, compared to an internal cue, no matter the age of the participant but an external focus should be slightly more beneficial for individuals below 21 years old compared to those above 21 years. External cues have also been shown to benefit motor skill learning (23), so their use with youth athletes may see a greater rate of skill acquisition and aid in the eventual mastery of skills.

The second moderator analysed was participants' reported experience level. Studies using 'experienced' participants saw a greater improvement in performance from an external cue than an internal cue when compared to 'novice' participants with effects sizes of 0.33[0.13, 0.40] and 0.28 [0.15, 0.41], respectively. The CAH can be used to help understand why the use of external cues helps improve performance more in experienced athletes. Kershner et al.(143) who looked at countermovement jump (CMJ) height in experienced athletes found an effect size of 0.29. In their paper they discussed how the CAH explains that elite performers should be more successful whilst not consciously thinking about their body and its movements due to the fact that the goal-relevant dimensions of the skill have been consolidated and the skill should be more autonomous due to the increased practice time(145). If the individual actively attempts to concentrate on the movement of their body and not the outcome of their movement, they may interfere with the motor patterns developed thus leading to sub-optimal performance in comparison to an external focus of attention. A participant's level of experience is most often a by-product of having had more time being coached, with a greater level of exposure to cueing of movements leading to a greater understanding of what the coach is asking. This could potentially explain the increase in performance in this group. Contrary to these results, Kershner et al.(143) also found that in a novice population, any form of instruction, no matter the attentional focus, would lead to disruption and manipulation of their movement yet the sub-group analysis here shows that even novices saw an increase in performance with the use of the external cues. Ille et al. (75) looked at both novice and experienced participant's separately in their study testing sprint times and found novice participants to benefit more from an external cue than experienced ones. Both groups were aged between 20-30 years old, and both had large effect sizes of 1.15(novice) and 0.94 (experienced). When verbal reports were later taken in Ille et als(75) study they

found that experienced athletes were spontaneously adopting a suboptimal internal focus of attention when positioned in the starting blocks. This may be due to the instructions coaches normally gave them were influencing their focus(7). Singer et al.(161) found that trained participants were more successful whilst adopting "nonawareness" strategies, similar to external cues, attempting to not focus on the skill execution, rather focusing on the result and their surroundings. Elite athletes, whilst competing, appear to not think about the skill they are doing, and therefore are able to focus on environmental factors of success such as the position of the opposition or their own teammates. Singer, however, believed that to make a novice think the same way as an expert is wrong as they simply lacked the automatic mastery of necessary skills. A Five-Step Approach(162) was developed to help learning and performing self-paced motor skills. This strategy follows a pathway from "learning to prepare for the act, to image, to focus on meaningful cue, to execute with a quiet mind, and to evaluate the act". Implementing this strategy is directed at helping a novice individual work from awareness (internal focus of attention) to nonawareness (external focus of attention) components. The results of Singer et als. (161) study found the use of nonawareness strategies alone to be as useful as this Five-Step Approach in improving ball-throwing accuracy in novices. Overall, the experience level of an athlete seems to play a significant role in determining the amount of benefit an individual sees from an external cue, but regardless of experience, an external cue seems to be more beneficial than an internal one. Therefore, from a practical standpoint, coaches with a novice group of athletes may see further benefits from the implementation of external cues to further aid in the nonawareness of their skill execution, whilst needing to ensure simple skills are mastered, potentially through the initial use of internal cues, to allow for more autonomous use during competition. Coaches of elite athletes should also use external cues, ensuring they continue to perform what should already be a well-developed motor pattern.

Porter et al(51). found less experienced athletes to benefit best from an external focus of attention and Porter and Sims(70) found high skilled athletes performance benefited most from no assigned focus. A later study by Winkelman et al.(145) in 2016 looked at both highly and moderately skilled sprinters in two separate experiments and emphasised the importance of expertise level in determining the influence of attentional focus on a skill like sprinting. The first experiment by Winkelman et al. investigated the 10m sprint times of collegiate athletes under an external focus, internal focus, and control condition. Whilst the participants in their first experiment were not expert level sprinters they were collegiate level athletes and therefore Winkelman saw them as moderately experienced in sprinting(145). They went on to state that whilst an external cue might not improve performance in moderately skilled individuals when compared to no coaching cue, both are still preferable over an internal coaching cue. This aligns with the CAH(3) as the use of internal cues creates an internal focus of attention in athletes leading to an interference in their automatic body

control patterns, potentially hindering force output performance. However, the findings of Winkelman's second experiment did not agree with their original hypothesis that an external focus of attention would result in faster 10-meter sprint times than an internal focus of attention in expert level sprinters. The second experiment showed no difference in 10m sprint time between the external, internal or control conditions. Winkelman et al(145). wrote that experience level plays a role in the abstraction of information from attentional focus cues and those theories of learning would help to explain this. Stage models of motor learning suggest that as skills are consolidated, normally because of experience, they are no longer consciously attended to during performance as they have progressed from a goal-relevant dimension of the skill to an autonomous or procedural stage(76). Therefore, highly experienced individuals should possess an understanding of the goal-relevant dimensions leading to success and no longer focus on every stage of movement execution(41). Research(163) has recently suggested that experienced individuals extract generalised and subjective meaning from instructional information, whilst inexperienced individuals are more likely to take the information literally. People with limited experience are unable to select the optimal goal relevant features due to their action concepts and perceptual representations surrounding the skill being underdeveloped(164). In the second experiment by Winkelman et al. (145) the participants had had at least eight years of competitive track and field experience, therefore, all having an understanding of how to perform the skill as well as knowing how it should feel to execute(164). In summation, Winkelman et al.(145) hypothesized that participants who are highly experienced were able to abstract similar subjective meaning from all three kinds of cueing types used whereas the collegiate athletes from experiment one lacked this ability and were dependant on the cue provided to inform their technique, which is why the internal cue led to the previously seen reduction in performance compared to the external cue as explained by the CAH(3). Ille et al.(75) stated that one of the limitations of their study was how the internal cues may have been more complex than the external ones, this may have resulted in the longer sprint times seen under the internal condition compared to the external condition. The more complex internal cue would have caused more cognitive load on the working memory. This helps to inform coaching practices as it shows that the instructions used with an athlete at a lower to moderate level of expertise should direct their attention to the effects of their movement (external). As the individual gains a better understanding of action concepts and their motor plans are more developed, the benefits of an external cue may become reduced, leading to no benefit of one specific type of cue in a training session alone.

The next moderator variable looked at was cue complexity with studies split by the number of attentional focus points of each cue used in the studies. In a verbal coaching cue, an attentional focus point is the part of the cue which draws the attention of the participant, for example, telling an athlete to "push off from the ground". The studies using shorter, simpler cues had only a slightly greater effect size of 0.32 [0.20, 0.45] compared to 0.20[-0.01, 0.42] for multiple or longer cues. This trend is

largely reflected in a study by Marchant et al(152) who reported that both the external and control cue, which were not significantly different to one another, were both superior to the internal cue. The authors, therefore, finding that an internal cue was inferior at improving performance when compared to their control group of no cue. They believed the relative complexity of their cues led to this outcome with previous research such as that by Wulf(3) using singular, short cues. The CAH states that as cognitive load during performance increases, the effectiveness of the movement will decline(158). Cognitive load refers to the amount of information that can be held in the working memory at one time and this has a limited capacity. On this basis, the longer the verbalised stimulus, the more cognitive load is seemingly produced (158) thus decreasing the efficiency of the movement(159). Accordingly, focusing on internal cues can produce extra cognitive load due to forcing the participant to focus on the smaller elements of a skill, resulting in decreased movement efficiency and automaticity and affecting the individual's performance. Despite this result, Polsgrove et al.(159) found that no matter the cue being used, external or internal, poor quality of instructions led to poor performance. They stated that providing a precise direction as opposed to a vague instruction on where to move would lead to more effective motor outputs. This is because with a limited attentional capacity, we can only focus on a small portion of the stimulus provided (I.e. the cue) (165). This therefore suggests that coaches should keep their cues as simple and precise as possible to aid athletes' ability to understand the cue as well as benefit from it. As the coach - athlete relationships develops and a greater sense of understanding is formed, the coach may be able to get cues down to as little as one word to reduce cognitive load even further. This is only if the athlete fully understands what is being asked of them by that one word, thus an implicit level of trust in the coach is required.

When split by movement type it was found that jumping had a slightly greater effect size (0.31 [0.19, 0.44]) over sprinting (0.22[0.00, 0.45]) performance measures yet both are classed as a small effect size. The reason for this slightly greater effect may be that during studies looking at the effects of coaching cues on jumping, the cues are often directed to points further away such "I want you to think about jumping as close to the green target as possible."(85) compared to in sprinting studies which use cues directed closer to the individuals body such as "focus on powerfully driving forward while clawing the floor as quickly as possible"(70). Importantly for this point, it has been found that the further away the external focus is from the body, the greater the improvement in performance that is seen(3). McNevin et al.(21) argued that an internal, or even a more proximal external, focus may cause the participant to intervene in their movement pattern, which in this studies case was postural control. Therefore, the fact that the external cues used within studies measuring jump distance or height tend to focus on going towards a point may allow for greater motor planning and force production compared to the proximal external cues often used in sprinting studies.

Studies looking at attentional focus' effect on sprint performance have generally been quite varied. Current research seems to suggest that experience level is a large component in determining the optimal focus of attention whilst sprinting. Both sprinting and jumping are very technical and complex skills, with many components to them(3). For example, during the CMJ, six key phases (weighing, unweighing, braking, propulsion, flight and landing) have been found via analysis of force-time characteristics (166). As the CAH explains internal cues interfere with a performer's automatic movement efficiency and can inhibit power output. It has been demonstrated that focusing externally results in more effective movement patterns by increasing muscle fibre recruitment efficiency thus allowing for a greater level of force production(38). Wu (49) stated that the discrepancy in jump performance between an internal and external focus of attention may be due to the jumper's projection angle. The external cue may have produced a more beneficial angle of projection compared to the internal cue group. For example, when performing a long jump, the external focus may have produced an optimal movement plan that combined both vertical and horizontal force components as efficiently as possible(49). Wulf and Dufek(41) believed that an internal cue led to a 'freezing' of the body's degrees of freedom, where joint moments around multiple joints (i.e., ankle, knee, hip) all correlated with each other. So, an internal focus of attention seems to lead to the linking of semi-independent body segments, causing the constraining of the motor system, whereas an external focus had the opposite effects(3). This could have an impact on participants' technique and form leading to slower sprint times and shorter jump heights. From a practical point of view, if a coach is looking to induce not only a greater force production but also technical proficiency, the use of external cues might help them with this.

As well as looking into the difference between different movement types, different jump techniques were used as a sub-group to be analysed to see if an external or internal focus was more beneficial for jump performance depending on the type of jump measured. The subgroup analyses included both drop jumps (DJ) and countermovement jumps (CMJ) and also compared vertical jumps and horizontal (long) jumps. Interestingly, all four jump types had positive effect sizes favouring the use of an external focus compared to an internal focus. Horizontal jumps had the greater effect size (0.43 [0.27, 0.59]) compared to Vertical jumps (0.16 [-0.02, 0.35]) and CMJ had a slightly larger effect size (0.23[-0.04, 0.50]) compared to DJs (0.11[-0.26, 0.48]) which seemed to be unaffected either way, with a trivial effect size. No research has directly compared the impact of external cues on vertical vs horizontal jumps. As previously mentioned, Wulf(3) believed the increased jump height and distance came from the 'freeing' of the body's degrees of freedom which contributed to the larger force output found with an external cue. Findings suggest that an external focus on the intended movement allows for 'functional variability'(3) allowing the motor system to adjust to the various degrees of freedom autonomously to achieve the greatest effect(23). Overall, an external focus of

attention is beneficial in comparison to an internal cue when looking at jumping movements, and therefore should be implemented by coaches during training and testing to produce greater results from their athletes. It should also be noted that the greater the distance from the participant to the focus point, within a cue, the greater the benefit an external cue has on performance(3). This means that whilst being utilised in a practical setting the cues focus point should be further away from the participant's body. For example, during the long jump instead of focusing on pushing away from the starting line, the participant should focus on aiming to jump towards a target landing point(22).

An analysis was performed looking into how the number of attempts a participant has could affect the effect size seen using different attentional foci. A median split was used for the sub-group analysis producing two groups of below or equal to three and above three. The group which had more than three attempts had a slightly greater effect size of 0.42 [0.23, 0.62] compared to 0.24 [0.11, 0.37] for the group which had less than or equal to three attempts. Originally it was believed that the more attempts a participant had the greater their learning and understanding of both the cue and the task, which may have led to a larger impact on performance. For example, two studies both looking at sprinting, one by Ille et al looking at 10m sprint times (75) and the other by porter et al. looking at 20m sprint times (51) had effect sizes of 1.15 and 0.22, respectively. Both were testing novices, and apart from the distance difference the only other notable difference was the fact that Ille et al(75) gave their participants more than three attempts with each cue whilst porter et al. (51) gave theirs less.

Limitations of this meta-analysis include the large number of moderator variables which can inflate the chances of finding positive results (167) due to multiple comparisons being made. Regardless of this, the chosen moderators were selected due to their relevance to the analyses performed. Statistical power may also be reduced and there may also be residual confounding of results due to the median split method of creating subgroups being applied to continuous data in the moderator analysis (167, 168).

Future research

There is a great deal of potential research routes that can be explored from this meta-analysis that could help develop coaching practices with a guidance on how these cues should be used in the field. External cues are made up of a distance, direction and description (5). The distance relates to the distance from the participants body of the focus point of the cue and are normally referred to as being "distal" and "proximal". One of the main issues surrounding the assessment of the effects of distance of external cue on performance outcomes is that often the exact distance of the cue is not noted and therefore makes it difficult to compare two separate studies cues. Whilst a great deal of research has looked into the effects of the distance of an external cue (21, 22, 57, 73, 74, 86-90) it seems that little to no research as of yet has directly looked into the effects of varying description and

direction has on performance under external cueing. Description is often split into two categories action verbs (i.e., push, punch) or analogies (i.e. propel like a jet engine). Whilst description hasn't been directly researched multiple studies have found analogies to be effective for learning(91-93) . During a study looking at skill learning within table tennis(91), the authors concluded that learners having analogies spoken to them seemed to have less conscious control over their movements than explicit learners, favoring a more automatic mode of control which is beneficial in skill performance(91). When talking about the direction of the cue it refers to whether the cue gestures to move "towards" or "away" from the focus point. One study by Porter et al.(22) indirectly looked into the effects of altering coaching cue direction. They found an increase in jump distance when giving a "towards" cue when compared to using an "away" cue. The study didn't originally set out to investigate this hypothesis of whether the direction of a coaching cue influenced performance outcomes, instead they had been looking at the effect the distance of the cue had. The cues used by Porter et al. were "jump as far past the start line as possible" and "jump as close to the cone as possible" (the cone was 3m away). The first cue used by Porter, whilst being a proximal (near) external cue was also in fact a cue with an "away" direction and the second cue was a distal (far) external cue yet was also a "towards" cue. The effect on jump distance seen when the direction of a cue is altered could simply be down to the change in the distance of the cue too. As "towards" cues tend to have a focal point at a greater distance in comparison to "away" cues, with the effect of distance having been a greatly researched factor. Future studies may be able to look at how changes in the description and direction of cues impact performance outcomes to further develop the way coaches interact with their athletes. The one previously mentioned study by Porter et al. (22) that indirectly looked at the effect of a cues direction on performance measures only investigated its effect on jump performance. Therefore, it would be necessary for research to see whether this effect was also seen with other movements such as sprinting.

Another route research may take in the future is looking at the impact of vertical vs. horizontal jumping when under external cues and investigating the difference external cues make on form and technique. A more in depth look at the movement kinematics and how these changes depending on the cue being used and the type of jump being performed. To further the knowledge of how movement types, including jump types, affects the effect of external cues, a testing battery could be performed on participants to see how changes may be on an individual-to-individual basis or if there is a more consistent pattern between movements.

Another interesting research route may be to look at how both coaches and athletes use and understand internal and external cues and whether there may be a lack of coaching education when it comes to how coaches' structure what they say and how this is perceived by athletes. A survey by Porter et al. (7) validated the need for further research in the area of coaches' use of attentional focus by finding that 84.6% of the athletes they surveyed reported that their coaches used internal cues and

instructions during practice. This value may be inflated though due to the respondents of the survey being the athletes as opposed to the coaches themselves.

3.6 Conclusion

Based on the result of this meta-analysis, the data suggests that external coaching cues are overall more beneficial than internal coaching cues for performance outcomes and have been shown to be generally usable across many different motor skills, levels of expertise and populations. The use of an external focus of attentions can helps individuals to perform better and, possibly, to aid motor pattern learning in skilled tasks. This effect has been explained best by the CAH (3) which proposes that the use of an external cue and/or focus of attention can lead to an improved automaticity of body control, resulting in less interference in execution of a movement which can be seen whilst using an internal focus of attention. When performing a sub-group analysis to look at the impact of multiple variables on the benefit of an external cue over an internal cue, it was found that an individual's level of experience and age both had an impact, along with the type of movement being performed and how many attempts they received with each. The more experienced an individual was the greater the benefit they saw from receiving an external cue over an internal one. This may be because of a more experienced performers ability to understand the cue having performed it many times over a long period of time this resulting in greater mastery of the specific skill and allowing for better unconscious performance (145). In terms of age, the results of this meta-analysis showed older participants to benefit more from an external cue, yet what is most important from a practical standpoint is the fact that participants of all ages benefited from the use of an external cue compared to an internal one. When looking at the effects of different movement types, the use of an external cue when jumping lead to a slightly greater effect size compared to sprinting, yet an external cue saw the greatest effect size when specifically performing horizontal jumps but all jump related measures benefited from using an external cue more than an internal cue.

When using an external cue it is important to give the individual ample time to accustom themselves to the cue as well as ensure they are understanding what is being asked of them by keeping the cue short and simple, potentially also using an analogy which may resonate more with them (91-93). When coaching novices, it may be beneficial to use a learning model such as the 5-step approach (162) to firstly improve their skill mastery to the point of being able to perform the skill more automatically and then to help them develop the ability to focus on external factors when performing the skill. These findings have practical implications for all settings involving motor performance and learning from elite sports training to classroom PE lessons. Whilst this study only included jumping and sprinting measures, it shows that when looking improve an athlete's performance of the two motor skills an external cue is more beneficial than an internal one.

Chapter 4: A survey to evaluate both athletes and coaches understanding of internal and external cues.

4.1 Abstract

External coaching cues have been shown, consistently, to be more beneficial than internal cues when it comes to enhancing performance in a variety of tasks and measures ranging from accuracy during basketball shooting drills to max vertical jump tests. It therefore makes sense for them to be the standard for coaches to use to drive performance for athletes through communication in training and in competition. It has been shown by researchers that track and field coaches seem to not be implementing these coaching cues yet whether this is consistent amongst other sports is unknown. Thus, the purpose of this study was to determine coaches' and athletes' understanding of internal and external coaching cues and to appreciate if there are specific groups which lack an understanding of their use. Participants comprised of both male and female athletes and coaches from various sports, ages, and sporting success. These participants were emailed a survey which asked for basic sporting information and provided them with four separate scenarios asking which coaching cue they would use along with a final question asking for a brief definition of an external cue. The results of the study showed coaches to be more likely to choose external coaching cues compared to athletes as well as showing some interesting trends in the coach's background and whether they chose the external cue. Overall, it seems that education on attentional focus manipulation using coaching cues is lacking especially from an athlete's perspective. The education of athletes may prevent them from switching attentional focus' during performance allowing for an improved performance. Further coaching

education may help elicit improved performance within jumping and sprinting tests along with previously found improvements in motor skill learning,

4.2 Introduction

The use of coaching cues that are not necessarily aligned with the type of task they are being used to enhance execution of can lead to unfavoured outcomes in athletes' performance. This problem can be worsened if a coach repeatedly uses a coaching cue that is ill-suited for the task at hand. 'Practice doesn't make perfect, perfect practice makes perfect' is a phrase used in a range of sporting contexts implying that proper practice aids motor skill acquisition in turn enhancing motor skill performance(7). The specific training conditions imposed on an individual have an influence on their motor skill learning; therefore, many factors must be taken into consideration when coaching an athlete to help develop their performance and prepare him or her for competition(169).The focus of attention an athlete uses during the performance of skills such as jumping, or sprinting may be advantageous or dis-advantageous to their performance (3, 37, 78). A coach can explicitly influence an athlete's focus of attention by using verbal coaching cues before or during the execution of a skill or after in the form of feedback. A cue can help to direct an athlete's attention to a specific premeditated area or object. Verbal cues act as augmented feedback as they are pieces of information provided during or after a skill is executed specific to the task being performed. Augmented feedback can only be obtained from an outside source such as a coach(8), unlike sensory feedback which is information obtained through an athlete's sensory inputs (i.e., vision, touch, proprioception, etc.). The augmented feedback enhances or supplements the sensory feedback naturally obtained through interaction with one's environment.

The constrained action hypothesis was the theory proposed by Wulf, McNevin and Shea(26) to help explain this positive performance and learning effects. The hypothesis suggests that when an athlete focuses on the effect of a movement (external focus of attention) motor behaviours are allowed to happen automatically or without conscious control(7). Yet, when an individual focus internally and on the movement of their body, they interfere with the automatic process of motor behaviours. This interference leads to decreased accuracy, reduced power output, slower movements, and decreased motor performance(3).

A coaching cue can be neutral, external, or internal relative to where an athlete's attention is drawn. An external cue is defined as a cue that directs an individual to focus their attention on the effects of, the environment, or the specific outcome of a given movement, whereas an internal cue is one which directs their focus of attention on the body movements associated with the skill(20). For example, during a 100-meter sprint a coach could instruct the athlete to increase the turnover of their leg action. This would provide an internal focus of attention as it is directing the athlete's attention to a part if their body, in this case, their legs. However, the coach could also instruct an athlete to "minimize ground contact time" while running, which indirectly promotes an increased leg speed. As

this form of verbal cue directs their attention to the result of the movement (i.e., spending as little time on the ground as possible whist maximizing force output) it could prompt an external focus of attention(7). As shown in the previous meta-analysis performed looking at the effect of external and internal cues on sprint and jump performance, external cues positively affect an athlete's performance when compared to internal coaching cues. This has been shown multiple times during both jumping(2, 9, 22, 37, 38, 43, 44, 49, 51, 72, 85, 97, 110, 136, 139-144, 151, 166, 170-172) and sprinting(51, 70, 75, 145, 173). A positive effect has also been observed in balance and suprapostural tasks(2, 21, 23, 24, 27, 28), neuromuscular force expression(2, 36, 38, 128, 129)and a variety of motor skills (2, 40, 42, 47, 69, 71, 74, 88, 89, 130, 174).

External coaching cues have three key features: a distance, direction, and description(5). The distance relates to how far the focus point of the cue is from the participant's body, being either "far" or "close". For example, when an athlete is balancing a "close-distance", external cue, would be to focus on keeping the balancing board level, where as a "far-distance" external cue would be to concentrate on a fixed object in front of the athlete. There have been many studies that have investigated the effects of the distance of an external cue on various performance measures(21, 22, 57, 70, 73, 74, 86-90, 175). "Description" is often split into two types: action verbs or analogies. Whilst descriptions haven't been directly researched multiple studies have found analogies to be effective for motor skill learning (91-93). A study looking at skill learning in table tennis concluded that the use of analogies seemed to lead to less conscious control over the participants movements compared to internal cues, favouring a more automatic mode of control which is beneficial in skill performance(91). The direction of the cue it refers to whether the cue gestures to move "towards" or "away" from the focus point. So far, two studies have indirectly seen an increase in jump distance when given a "towards" cue when compared to using an "away" cue(22, 70, 111).

Considering the large amount of existing empirical evidence, it's fair to say an athlete's best performance would occur under an external focus of attention. For this to happen, a coach must use appropriate verbal instructions and feedback during practice and competition to help get the athlete to focus externally. Alternatively, if a coach provides verbal instructions and feedback which promote an internal focus of attention, which most likely will constrain motor activity, they are setting the athlete up to have a less than optimal performance(7).

One survey created by Porter et al. (7) was completed by 13 adult male and female USA track and field athletes asked about the cues and feedback they received during practice and what they focused on during competition. The collected data showed that 84.6% of the athletes reported that their coaches used instructions promoting an internal focus of attention during practice. It also

revealed that athletes utilized an internal focus of attention 69% of the time during competition (7). Therefore, the athletes questioned could potentially have performed better had they focused externally. There are a few suggested reasons as to why coaches seemingly choose to use less than optimal verbal instructions. Williams and Ford(176) suggest it is uncommon for coaches to read research on motor learning, nor is it common for more, so to speak, "old school" coaches to embrace findings and suggestions provided by sports scientists. In a doctoral thesis, Benz (19) surveyed 111 sprint and hurdle coaches with several questions relating to the types of verbal instructions they provided to athletes. The results indicate that more internal cues (54%) than external cues (42%) were used during practice, however in competition coaches provided fewer internal cues (20%) than external instructions (35%) or neutral (46%) whilst competing. These findings show that coaches were using more internal cues whilst training potentially resulting in a reduction in movement efficiency whilst sprinting as well as sprint specific motor skill learning.

Porter et al.(43), previously suggested that a large proportion of learning material produced to educate sports coaches, did not mention the benefit of using an external coaching cue to enhance athletic performance. When reviewed a few published books(177-180) used to educate track and field coaches showed a prevalent lack of information on the performance effects of both internal and external focus of attention. In the review, there was a large emphasis on the biomechanics of the movements. Therefore, it is unsurprising that the coaches working with athletes sampled for the previous survey by Porter et al(7) often provided instructions related to specific body movements. Overall, the literature seems to be failing to educate coaches on scientifically backed methods to communicate movement information to athletes. Compounding this is the fact that the USA Track and Field coaches' education syllabus lacked motor learning and control information even with sports science topics such as exercise physiology, biomechanics, and sport psychology being taught. Overall porter et al(7) felt there was a complete lack of help and guidance for coaches on how to teach motor skills to their athletes optimally.

Due to this, the purpose of the current study was to obtain an understanding of both coaches' and athletes' understanding of internal and external cues and to try to determine if there are specific groups which lack an understanding of coaching cues or, on the contrary, if this seems to be a broader issue amongst those involved in competing and coaching sport. To do this, a survey was sent to both coaches and athletes, differing from those of Porter et al(7) and Benz(19), who sent their surveys out to just one group each, to obtain a grasp of their understanding of the use of different coaching cues and how their performance could be affected. The results of the survey may point to a lack of content focusing on the application and practical use of coaching cues in the literature.

4.3 Methods

Subjects

The sample of athletes and coaches was drawn from varying sporting levels and backgrounds to allow for a wide range of responses and to attain a broader understanding of the general understanding of internal and external coaching cues in sport. The level of the athletes and coaches spanned from recreational all the way to professional and international competitors. Due to ethical constraints no individual under the age of 18 were included in the study. Participants were surveyed regarding their understanding of different cues and how they themselves would use them.

Procedure

An email was sent to coaches and athletes with a link to a cross-sectional survey along with a participant information sheet to ensure they understood the study they were taking part in. The survey contained a consent form to ensure that all respondents consented to participating in the study and for their responses to be anonymously analysed.

The questionnaire was dispersed using Qualtrics online survey software. Prior to the full survey, a preliminary pilot survey was sent out to the study supervisor and a small group of athletes (n=4) to ensure its suitability for research purposes. The first section of questions on the survey asked: 1. “Are you primarily a coach or an athlete?” 2. “What sex are you?” and 3.” How old are you?”. Based on the response to the first question, the participants were then sent to either: the coach history or the athlete history section. Both sections asked similar questions which were aimed at the specific demographic. The first question asked about the sport they played or coached, followed by asking at what level they coached or played this sport. The participants were then asked how long they had played or coached their sport and whether they’d received or given formal sprint and/or jump coaching followed by which coaching qualifications they had. In the coaching block there was an additional free text question asking, “What coaching cue would you use when an athlete is about to perform a maximal counter-movement jump using a force plate?”. This was to see what coaches would suggest when provided with an open-ended question with no selection options, as in the previous questions. Once finished with the first section, respondents then had to answer four scenario-based questions relating to different research papers findings and were also asked to provide a reason for their answers. The four scenarios were the same for both coaches and athletes but were appropriately worded for their own specific perspective. Respondents were presented with a scenario and were then asked to pick which type of cue they would provide to an athlete or focus on themselves. All the coaching cues provided as an option were picked from research papers having tested the effects of said coaching cues on the corresponding scenario. The questions related to: Counter-movement jump(41), broad jump(9), sprinting (51), and distance of the cue(9), using research from the referenced papers, respectively. The cues the respondents could choose from were based off the cues used in specific research papers such that the provided answer would be proven to confer documented performance

benefits. Table 7 shows the coaching cues used for each scenario along with the study in which t was picked from. Each scenario was followed by a free text question asking why the respondent chose their answer to further test their understanding and see what the reason for that answer was.

Table 7: Coaching cues provided as multiple-choice questions within the survey.

Task	Study	Coaching Cue		
		External	Internal	Neutral
Counter-Movement Jump	Wulf & Dufek 2009(41)	"Concentrate on the rungs of the Vertec, reaching as high as possible."	"Concentrate on the tips of your fingers, reaching as high as possible during the jumps."	
Standing Broad Jump	Porter et al. 2013 (9)	"Focus on jumping as far past the start line as possible."	"Focus on extending your knees as rapidly as possible."	"Perform the standing broad jump as you normally would."
10m Sprint	Porter et al. 2015(51)	"While you are running, focus on driving forward as powerfully as possible whilst clawing the floor with your shoe as quickly as possible as you accelerate."	"While you are running focus on driving one leg forward as powerfully as possible while moving your other leg and foot down and back as quickly as possible as you accelerate."	"Run as quickly as possible. "
Task	Study	External Distal	External Proximal	
Broad Jump (Distance of cue)	Porter et al. 2013(9)	"When you jump, focus on jumping as close to the cone as possible." (the cone is 3m away).	"When you jump, focus on jumping as far past the start line as possible."	

The final pair of questions, which were the same for both athletes and coaches, asked "Do you know the definition of an external cue?" Upon the selection of 'yes' the respondent was taken to the next question asking, "If yes, what is an external cue?". This came in the form of a free text box answer to ensure they understood the answer that they chose. Originally 130 subjects agreed to take part in the study, which led to 82 participants completing the full survey with no missing responses.

Statistical Analysis

The data from the survey responses was collated in an Excel spreadsheet (Microsoft Corporation, Redmond, WA) using the export function within Qualtrics. The average and percentages of each possible response (external, internal, or neutral) were calculated and reported for both athletes and coaches as well as for their specific sub-groups under the categories of age, sex, duration of coaching. These percentages were analysed and used to make conclusions on the habits of both players and coaches when it comes down to coaching cue selection. Open-ended answers were also exported into excel and sorted for a frequency count by searching for specific key words such as 'external' or 'target' as well as by being categorised as 'external', 'neutral', or 'internal'. Totals, means and percentages were calculated and analysed to analyse the respondents' reasons for the answers they gave.

Table 8 Demographic Data for Coaches Survey Responses

Demographic	Number of Participants	Percentage
	Age Group	
18-24	7	50%
25-34	3	21%
35+	4	28%
	Provides Sprint and Jump Training	
Yes	8	57%
No	6	43%
	Sex	
Male	13	79%
Female	3	21%
	Qualifications	
Undergraduate	1	7%
Masters	1	7%
ASCC	1	7%
UKSCA	3	21%
Level 3 Personal Trainer	3	21%
Other	11	79%
None	1	7%
	Sport	
Basketball	3	20%
Cricket	1	7%
Football	1	7%

Gymnastics	2	13%
Hockey	1	7%
Ice Hockey	1	7%
Rugby	1	7%
Strength and Conditioning	1	7%
Strongman	1	7%
Tennis	1	7%
Volleyball	2	13%
	Years Coaching	
0-3	1	7%
4-6	5	36%
7-9	1	7%
10+	7	50%
	Level of Athlete	
Amateur	4	29%
Intermediate	4	29%
Elite/Professional	6	43%

Table 9 Demographic data for athlete's survey responses

Demographic	Number of Participants	Percentage
	Age Group	
18-24	55	86%
25-34	9	14%
	Sprint and Jump Training	
Yes	30	47%
No	34	53%
	Gender	
Male	48	75%
Female	16	25%
	Qualifications	
Undergraduate	1	2%
Sports Level 1	7	11%
Sports Level 2	5	8%
Level 3 Personal Trainer	3	5%
Other	3	5%
None	45	70%
	Sport	
Athletics	1	2%
Basketball	5	8%
Cricket	1	2%
Football	3	5%
Gymnastics	2	2%
Hockey	15	23%
Karate	1	2%
Lacrosse	1	2%

Rugby	22	34%
Skeleton	1	2%
Swimming	1	2%
Volleyball	12	19%
	Years Playing	
0-4	8	13%
5-8	13	20%
9-12	22	34%
13+	21	33%
	Competition Level	
Amateur	11	17%
Intermediate	26	41%
Elite/Professional	27	33%

4.4 Results

Originally 130 subjects agreed to take part in the study, which led to 82 participants completing the full survey with no missing responses. All 82 respondents' demographic data for both the athletes (n=64) and coaches (n=14), respectively, is included in table 1&2. The three most common sports for athletes were rugby (34%), hockey (23%) and volleyball (19%). whilst for coaches it was basketball (20%), gymnastics (13%) and volleyball (13%). Of the 64 athletes, 42% were professional or elite.

Athletes' choices

To get a better understanding of athletes understanding of coaching cues and attentional foc1, subjects were asked a series of multiple-choice questions. The multiple-choice questions for athletes can be seen in appendix A. On average across the three scenarios, 44% of athletes chose the external cue, 18.3% and 37.6% chose neutral and internal cues, respectively. Question one asked which cue they were most likely to focus on when performing the counter-movement jump, 48% of athletes chose an external cue with 52% choosing an internal cue. Question two asked which cue they would focus on when performing a standing broad jump and 53% of athletes chose an external cue with 14% and 33% choosing a neutral or internal cue, respectively. Question three asked which cue they would focus on when performing a 10m sprint and 31% of athletes chose an external cue with 41% and 28% choosing a neutral or internal cue, respectively. When given the choice between two coaching cues with varying distance of attentional focus, more athletes chose the cue with a closer focus of attentions (55%) than one which is further away (42%).

Table 7 shows what percentage of each demographic of athlete chose the cue deemed to be superior based on research, split by factors such as gender, age, level etc.

For most groups, the results are similar. Those who possessed coaching qualifications of any level chose the superior cue 50% of the time whilst those without chose it 41% of the time.

Figure 3 shows how the number of years an athlete had played for affected their choices.

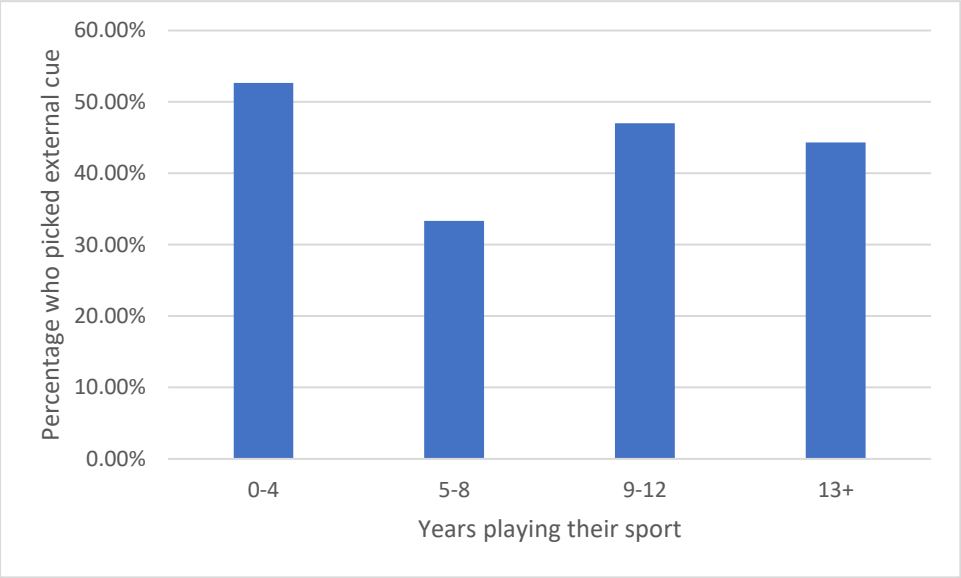

Figure 3: The effect of number of years playing a sport on picking an external cue.

Table 10 Percentage of athletes picking the superior cue

Demographic	Question 1	Question 2	Question 3	Average	Question 4

All Athletes	48%	53%	31%	44%	42%
		Age Group			
18-24	44%	51%	31%	42.75%	45%
25-34	78%	67%	33%	50%	22%
		Sprint and Jump Training			
Yes	67%	50%	37%	46%	30%
No	32%	56%	26%	41.8%	53%
		Sex			
Male	42%	54%	33%	42.3%	40%
Female	69%	50%	25%	48.5%	50%
		Sports Qualifications			
Yes	63%	63%	32%	50%	42%
No	42%	49%	31%	41%	42%
		Years Playing			
0-4	63%	63%	32%	50%	42%
5-8	46%	23%	31%	32.8%	31%
9-12	41%	73%	27%	47.8%	50%
13+	52%	48%	33%	42.8%	38%
		Competition Level			
Amateur	55%	64%	36%	54.75%	64%
Intermediate	38%	42%	19%	38.25%	54%
Elite/Professional	58%	59%	41%	45.00%	22%

Superior coaching cue referring to an external cue which was found to be superior in the previous meta-analysis.

Coaches' choices

The coaches were asked the same set of questions, phrased slightly different, as seen in appendix B. 50% of coaches chose an external cue whilst 36% chose an internal cue. 93% of coaches chose a cue with a distal focus of attention over one with a proximal focus. When asked to give a cue they would use to when coaching an athlete to do a maximum effort CMJ, only 36% gave one which had an external focus of attention with 29% and 21% choosing to give a cue with a neutral or internal focus, respectively. Table 7 shows how the demographic of the coaches affected their choice of cue split by factors such as sex, age and level they coach. S&C accredited coaches chose an external answer as found through research 80% of the time compared to 46% from those who aren't accredited. Coaches who said they coached athletes in speed training sessions in which they had to cue for sprinting and jumping, chose the superior answer 63% of the time compared to 47% for those who didn't coach any such sessions. Figure 4 shows a graph depicting how the number of years a coach had coached for affected their choice of answer. Coaches who had coached for between seven and nine years chose the external answer 80% of the time compared to 20% for coaches who had up to three years' experience. However, when asked the definition of an external cue, of the 79% of coaches who said they knew what it was, only 46% of them then gave a viable answer.

Table 11 Percentage of coaches who chose the superior cue

Demographic	Cue	Question 1	Question 2	Question 3	Average	Question 4
			Age Group			
18-24	14%	29%	43%	43%	43%	86%
25-34	0%	67%	67%	33%	53%	100%
35+	100%	100%	75%	25%	80%	100%
			S&C Accredited			
Yes	50%	100%	100%	50%	80%	100%
No	30%	40%	40%	30%	46%	90%
			Gender			
Male	36%	64%	64%	27%	56%	91%
Female	33%	33%	33%	67%	53%	100%
			Provides Sprint and Jump Training			
Yes	38%	75%	88%	25%	63%	88%
No	33%	33%	17%	50%	47%	100%
			Years Coaching			
0-3	0%	0%	100%	0%	20%	0%
4-6	20%	40%	20%	60%	48%	100%
7-9	100%	100%	100%	0%	80%	100%
10+	25%	50%	50%	25%	47%	86%
			Level of Athlete			
Amateur	25%	25%	75%	50%	55%	100%
Intermediate	25%	50%	50%	25%	45%	75%
Elite/Professional	50%	83%	50%	33%	63%	100%

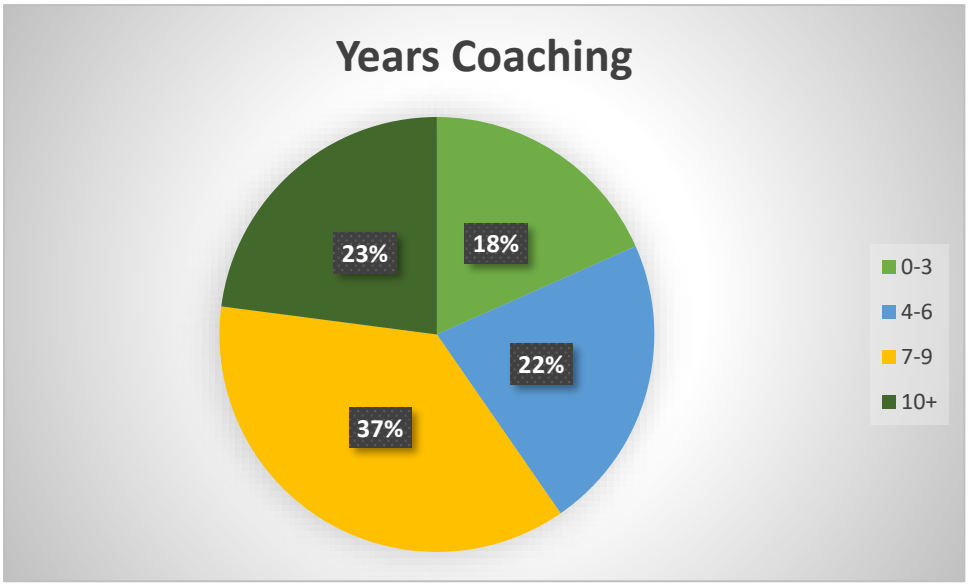

Figure 4 Percentage of coaches who chose the superior cue, split by number of years coaching

4.5 Discussion

The primary aim of this study was to evaluate coaches' and athletes' understanding of attentional focus for physical performance and, also, to see how coaches may be using coaching cues within the training and assessment of athletes. Data were gathered by using a survey sent to both athletes and coaches with no restrictions on ages or sports played. It was believed that coaches would have a better understanding of attentional focus and therefore would choose an external cue more often than athletes did. This was because the coaches should have all had some form of coaching education and hopefully, they would have an understanding that attentional focus can play an effect on the athletes' performance. It was also believed that coaches with a strength and conditioning (S&C) qualification as well as athletes who had had formal S&C coaching on sprints and jumps would pick the external cue more frequently due to the higher level of coaching education and more frequent exposure to cues like those in the survey.

The results of the study found coaches had a slightly greater understanding of attentional focus than athletes did, with 50% of coaches choosing an external cue whilst 44% of athletes did. Specifically, of all the groups, the coaches with S&C accreditations were most likely to choose an external cue for their athlete with 80% of them doing so. The survey used a dichotomous demographic question to ask whether or not the participant was primarily an athlete or a coach. Based on their response to that, a specific set of questions on their demographics were asked followed by their specific scenarios that they would typically encounter. Coaches were asked to provide a coaching cue they would use if an athlete was about to perform a counter-movement jump. This question was asked before they were given a set of scenarios with multiple choice responses to prevent question order bias (181). A majority of coaches (36%) gave an external cue whereas 29% and 21% gave a neutral or internal cue, respectively. This is a different result to that of the previous survey by Porter et al.(7) who found 84.6% of athletes reported their coaches used internal coaching cues. One reason for this may potentially be due to Porters survey (7) being completed by track and field athletes asking them what coaching cues their coaches used as opposed to asking the coaches themselves. The survey asked, "What does your coach tell you to focus/concentrate on the most when you are practicing your technique?". Porters survey also specifically asked the athletes what their coaches got them to focus on when working on technique. The questions used in this survey focused on performance testing or producing the greatest result possible, not on a session aiming to improve their technique. Coaches seemingly, from the results of Porter's survey, choose to use more internal coaching cues or feedback during technique sessions, whether this is best practice or not, according to their athletes.

Of the 3 multiple choice scenario-based questions asked within our survey, on average, 50% of coaches chose an external cue whilst 36% chose an internal cue. This finding shows coaching education to be in a much better place than previously found in other surveys. All the scenarios were taken from studies investigating the effects of internal and external coaching cues. Therefore, the

correct answer was deemed as the coaching cue which saw the greatest positive effect on performance compared to the other cues. All the studies found the external cue was the one that saw the greatest improvement on performance. For example, in a study by Wulf and Dufek (41) investigating the effect of an attentional focus on CMJ height, the external cue "concentrate on the rungs of the Vertec, reaching as high as possible" saw the greatest improvement in jump height. This was deemed to be due to the CAH which stated that when focusing externally the motor system isn't constrained like it is when under an internal focus. Therefore, the motor system can adjust to the various degrees of freedom, at the individual joints, autonomously to achieve the greatest effect (23). Focusing internally were found to generally be less successful due to an interference with the body's natural organization capabilities (41).

Coaches alone were asked at the end of the survey whether they knew the definition of an external cue and then to provide a definition. This was put at the end of the survey to prevent any form of bias on the multiple-choice questions. Of the 11 (79%) coaches who stated they knew the definition of an external cue, only 46% gave a viable and accurate definition of an external cue talking about a cue or instruction which draws the athletes' attention away from the body to something external, or to the effects of their movement. Examples of answers deemed as correct include: "Specific instructions driving attention away from the body to achieve a specific task I.E. touch my hand, spread the floor etc" and "Instructions that direct athletes to focus on the movement effect of an action." This could be considered a strong indicator of an individual's level of knowledge, as the ability of a participant to guess a correct answer, as per multiple choice questions. A definition of an external cue used consistently in research is "a cue that directs an individual to focus their attention on the effects or outcome of a given movement and the environment (5).

Research in the field of motor learning and, specifically, on the effects of altering attentional focus has consistently found that an external focus can yield greater motor skill performance, as compared to an internal focus (13). The benefits of this were previously reported by Benz (182) who outlined enhanced sprint speed, enhanced muscular endurance and enhanced vertical and horizontal jumping ability, along with 13 other similar advantages. This effect has also been shown in tests or events using an implement such as a golf club (73), a discus (50), and darts(183). The coaches choosing not to use these external cues may seemingly be doing so through lack of will to change or could simply be unaware of the benefits mentioned above. William and Ford(176) believed it was uncommon for coaches, especially Olympic weightlifting coaches, to read motor learning research, let alone consider the suggestions of scientists. The reported provision of internal verbal instructions, from coaches, by athletes, was attributed to coaches naivety to the suppressive effects of internal focus of attentions(7). A review of multiple published educational books(177-180) for track and field coaches showed an absence of information on the effects of differing attentional foci and how they

could be used to drive performance in athletes. The books possessed a strong biomechanical basis which potentially explains Porters' (7) finding that 84.6% of track and field athletes reported their coaches used internally focused cues when working on technique. Porter's paper, published in 2010, seemed to suggest that there was a lack of information on attentional focus manipulation especially within a practical coaching setting. Ericsson and Williams (184) suggested that the reason why motor learning research hadn't caught the attention of coaches was due to its theory-driven nature and because it provided no direct application to an athletic setting. 17 Strength and conditioning/sports performance scholars believed that the strength coaches had a subservient status to the primary sports coach and that this potentially hindered their physical development and preparation(185). Some coaches have been said to read very few scientific sources of information, as "science has little to offer" or "science has not caught up to what we do yet"(186). In another survey by Reade et al.(187) 41.9% of the high performance coaches asked stated that they somewhat agreed with the statement that "the research is not presented in formats that can be used easily by coaches" and 57.6% somewhat agreed that "the research being done is not easily accessible to coaches". This is potentially shown by only 46% of coaches being able to provide a viable definition of an external cue. Researchers such as Winkelman (5) have since then provided an instructional framework of internal and external cues with different structures for both absolute speed and acceleration development based on the specific kinematic and kinetic needs of the athlete, such as postural control and forward and backward leg swing. Accordingly, coaches use of such tools may have developed over time and publications such as this could be the catalyst behind the higher percentage of coaches using an external cue, as found in this study compared to the result of the previous survey by Porter et al. (7), as it has provided an accessible practical method of use.

The second objective of this study was to investigate athletes' own knowledge of attentional focus manipulation and to evaluate what they were more likely to focus on in the same given situations as the coaches. Of the three situations, athletes stated they would pick an external focus of attention 44% of the time which is less than that of the coaches but not by much. Kershner et al. (143) published a paper in which they looked at the effects of internal and external cues on CMJ height of Division 1 NCAA athletes, a key feature of which was a 'manipulation check' used to determine the effectiveness of a coaching cue to influence the participants attentional focus. The researchers asked the participants to perform a manipulation check survey during each rest period which simply asked them "What were you focusing on during the previous four trials? If you did not focus on anything in particular, leave the question blank". Participants were instructed to be honest, even if they did not focus on the instructions provided. The surveys were coded using the method described by Porter et al. (42) and each response was categorised as either: internal only, external only, mixed or other. Of 42 participants, during the external condition, 66.6% of participants reported focusing internally only.

Kershner (143) stated that the CAH helps explain this result as those in the internal focus condition demonstrated improved recall of the given instructions. This greater recall could be down to the processing of the internal cue in the conscious mind. Similarly, the internal cue may have sounded more complex and "foreign" causing the participants to think about it in more depth and to subsequently store it in their working memory. This finding was supported by Porter et al.(42) during a study looking at the effects on agility using manipulation check. It found that an external attentional focus was induced only 67% of the time during the external condition whereas an internal focus was induced 76% of the time during the internal condition. Even with the greater recall found with the use of an internal cue, it still came with the negative effect of constraining the participants motor system leading to a less effective movement pattern (143).

It may be possible that had all participants focused solely externally during the external condition the improvement in performance may have been greater. And from a coaching perspective, if the athletes were aware of the positive effects of external focus of attentions, there may be a greater improvement in their short- and long-term performance. Therefore, it may be pertinent for athletes, especially those who are considered to be 'elite', to be educated on the use of coaching cues just as they would be on a topic such as nutrition. Elite/professional athletes were just as likely to choose an external cue (52.7%) as amateurs (51.7%) with intermediates being slightly less likely (33%). The choices of athletes may be a reflection upon the level of the coach they trained under. This may explain why we found athletes who had received formal S&C training were more likely to choose a cue promoting an external attentional focus (51.3%) compared to those who had not received any formal S&C training (38%). To further support this point, S&C accredited coaches had the highest average of all demographics at 80%, which is a lot greater than those without an S&C accreditation (33%).

The results discussed provide a unique addition to research by providing empirical evidence on the provision of verbal instructions by coaches from a coach and athletes view as well as being split into different demographics to obtain an appreciation of the coaching strategies at different levels. This study provides an improvement to previous literature using the recommendations of Porter et als.(7) and surveying a larger population of athletes and sampling athletes in different sports as well as asking coaches themselves. The findings of this study suggest that a large number of coaches and athletes are choosing to focus their attention in a less than optimal manner and contradicts the findings of the motor learning literature. This is potentially due to a lack of education or engagement with academic frameworks which can simplify the findings and provide a theoretical basis for coaches to work from (5). Those involved in strength and conditioning were more likely to choose an external cue either as a coach (80%) or an athlete (51.3%), this was most likely due to the greater research basis involved in S&C as opposed to the typically "old school" nature of coaching in

other sports. The results of this study do however suggest that a larger percentage of coaches may understand motor learning research now compared to the time at which Porters et als. study (7) was performed given that 84.6% of athletes reported receiving instructions from coaches which exclusively produced an internal focus of attention during their survey. This may be down to the highly technical nature of track and field yet, even when in competition, 69.2% of athletes reported they focused solely internally. This, therefore, helps suggest that the education of athletes as well as coaches may aid performance across all competition levels.

Even though this study reveals the tendencies of coaches to provide specific instructions, as well as the attentional focus habits of athletes, the sample size of coaches recruited could be larger to allow for a breakdown of individual sports tendencies for providing instructional feedback. Unfortunately, in this study not enough coaches were asked from each sport to be able to make a statement on the specific tendencies of each sport. Therefore, future studies should look to survey a larger number of coaches especially from the same sport. This will allow for a greater in depth look at how the sport the coach coaches affects the coaching cues they use. Another direction research could go is to directly observe coaches and the instructions they provide to get an understanding of how differing situations may affect the choice of cue a coach provides and alongside the addition of a post-observation interview, an explanation and reasoning could be provided to determine why they chose to say what they did. Following on from the work of Porter et al.(42), utilising a manipulation check to find exactly what an individual was focusing on. Future studies could look to assess the effect of external and internal cues on an outcome measure such as sprint speed or jump height, but with four conditions instead of having just the two conditions of given an external or internal cue. The four conditions could be; given an external cue and reported focusing externally, given an external cue and reported focusing internally and vice versa. This may lead to a more accurate report of the effects of attentional focus. It isn't the coaching cue being said which effects the performance of an individual but it's their attentional focus that matter. Therefore, if a coach or researcher was to use an internal cue but they focused externally instead they may, and should, see a better performance than if they focused internally.

4.6 Conclusion

In conclusion, the findings of this study suggest that the instructional feedback of coaches has improved since previous studies however many coaches are not fully willing to engage with motor learning research, which finds that the use of cues that produce an external attentional focus in athletes is beneficial to the performance of both jumping and sprinting tasks. Previous research suggests that the available literature is based around cues that promote an internal focus of attention and the addition of papers studies providing an instructional framework seem to have had a benefit.

Despite this, not enough research has been carried out and/or been included in coaching education to significantly alter coaching's often "old school" tendencies.

Chapter 5: Overall Discussion

Attentional focus and the subsequent effects on performance and motor skill learning is a much-researched topic. The ability to focus on the outcome of a given movement, as opposed to the actual movement itself, has been shown to be beneficial in a range of different situations (182). The overall goal of this thesis was to establish a better understanding of how manipulating an athlete's attentional focus can affect their sprint and jump performance and how specific groups (i.e. younger vs older, experienced vs non-experienced) might performance differently when exposed to a specific vocal cue or attentional foci. Concurrently, another goal was to determine the level of understanding that both coaches and athletes possess in relation to manipulating attentional focus and their use of cueing within their specific sport and demographic. The aims as previously stated were:

1) To undertake a systematic review and meta-analysis to determine whether an external coaching cue positively affects an athlete's ability to jump and sprint.
2) Determine if these findings are reproducible across a range of demographics such that scientifically backed methods can be presented to coaches and practitioners to implement.
3) To investigate coaches' and athletes' understanding of attentional focus, and whether they are implementing them in their training, to provide further advice on coaching practice.

Prior to the research, it was hypothesised that an external attentional focus would be superior to an internal attentional focus and this superiority of an external focus would be consistent across all demographics/subgroups of the meta-analysis. It was anticipated that no group would see a greater improvement in performance under an internal focus. It was also expected that coaches would have a greater understanding of attentional focus manipulation than athletes, with coaches who possessed a strength and conditioning accreditations to have the greatest understanding of all the participants surveyed.

The first study, a systematic review and meta-analysis was carried out to determine the stance of the current research on the effects of external and internal attentional focus' on jumping and sprinting. Wulf et al.(3) wrote a 15 year review looking at the research up to that point and she concluded that the findings showed that the effects of external attentional focus' were generalizable for a range of skills, expertise levels, ages and health. However, this paper did not look at the effect sizes of each paper instead it just produced a narrative review and presented the research stating it was generalizable. A meta-analysis was performed by Makurak et al.(13) which attempted to produce an effect size for the effect of external and internal cues within sports science literature. Unlike our meta-analysis that was just performed, Makaruk et als. only included studies which measured the effect of

attentional focus on jumping performance as well as only including studies with participants who were over the age of 18 years. This therefore limits the ability for the paper to make a statement on the generalizability of the findings, not to mention the fact that no moderator or subgroup analysis was performed.

The result of our meta-analysis found that there was a small significant effect size [0.30 (0.19, 0.40)] in jumping and sprinting measures favouring the use of an external attentional focus. Several sub-group analyses were performed finding small to large positive effect sizes across all moderator variables all of which favoured the use of an external cue compared to an internal cue. Studies which utilised simpler cues found a greater effect size in comparison to more complex cues. Similarly, participants who were older than or equal to 21 years old saw a greater effect size than those who were younger than 21. Most importantly, all subgroups saw a positive effect size meaning that not a single subgroup performed better under an internal coaching cue. These findings agree with the expectation that that an external attentional focus would be superior to an internal attentional focus and that will be the same for all demographics, no group would see a greater improvement under an internal focus. Although no other studies have performed a moderator analysis to assess the generalizability of this effect and even with the inherent issues with their study, Makurak et al.(13) found a similar effect size (0.33[0.14,0.51]) to the one we found within the meta-analysis (0.30[0.19, 0.40]). The most widely accepted reason for this effect is the CAH which was mentioned within motor learning literature as early as 2001 where Wulf et al. (26) stated that focussing internally caused a conscious control of an individual's actions leading to a constraining of their motor system and an interference on their automatic control processes. On the other hand, an external focus promoted automaticity of the motor system along with more efficient motor planning(48). The results of our meta-analysis provide an analysis on the effects of differing attentional focus' on the performance of both jumping- and sprinting- based outcome measures. This contributes to the field of motor learning research by helping to show coaches the importance of providing augmented feedback which draws an athlete's attentional focus to an external focus such as the outcome of their movement as opposed to an internal focus and their own body. Within the moderator analysis some groups were found to have a larger effect size than others, yet these results didn't vary a lot ranging from 0.11(-0.26, 0.48) for studies including drop jumps to 0.43(0.27, 0.59) for studies including horizontal jumps. Although it may appear that focusing externally during certain situations, such as when performing horizontal jumps, will see a greater effect than for other situations importantly what it shows is that the positive effect size seen by using an external focus is generalizable. This generalizability was spoken about by Wulf et al. (3) yet this study provides empirical evidence to support the statement that a range of different groups should see a positive effect from the use of external cues.

After the findings of the meta-analysis, the next question that was asked was what level of understanding do both athletes and coaches have of the effects of attentional focus. The aim was to see what groups were most likely to choose to use an external over an internal cue. Therefore, the second study was a survey sent to both coaches and athletes of all levels. Previous surveys produced, such as a paper by Porter et al.(7) which surveyed male and female USA track and field athletes. Participants were asked to provide information on the cues and feedback they received during practice as well as what they would focus on in competition. The survey found 84.6% of athletes reported during practice their coaches would provide instructions which promoted an internal focus of attention. However, the results of the current survey found that 50% of coaches would choose to provide an external cue when an athlete was performing a sprint or jump whilst only 36% and 14% would choose an internal or neutral cue, respectively. This shows an improvement in the type of attentional cues being used by the coaches surveyed in our study compared to those surveyed during Porters study showing the coaches we asked may have a better understanding of motor learning research. When asked for the definition of an external cue, of the 11 (79%) who said they knew what the definition was, only 36% provided a definition which was viable, showing that the coaches surveyed may lack a theoretical base knowledge on motor learning research. These coaches may have been educated on the practical application of cueing, being told to use external cues when coaching, but may not know the scientific underpinning behind it. The addition of more motor learning research within coach education may help coaches improve their athletes' performance by the small margins which help them get to a higher level. The previous survey by Porter et al. also found athletes to focus internally 69% of the time whilst in competition. With the large number of studies showing a positive effect on performance when focusing externally, it's possible that if these athletes were to focus externally there could be a benefit to performance. This is where athlete education comes into play as even if a coach did provide an external cue for them to focus on its down to the athlete to keep focusing on it. Of the coaches with a S&C accreditation, 80% chose an external cue whilst 20% chose an internal cue. This is greater than for the coaches who did not have an S&C accreditation with only 36.6% of them choosing an external cue yet 15% chose a neutral cue and 50% chose an internal cue. This is similar in athletes, with 51.3% of athletes who have received S&C training choosing an external cue as opposed to only 38% who hadn't received any formal S&C training and chose an external cue. This seems to suggest that S&C coaches seem to have a better understanding of coaching. The education given to those looking to get their S&C accreditations may include more information on motor learning, specifically verbal cueing as a way of improving a coaches "tool box" as opposed to other sports coaching qualifications.

It was believed that the reason why motor learning research isn't as well understood and known as it should be is because the research and literature are seen as having " little to offer" and "has not caught

up to what we do yet"(186). 57.6% of the coaches somewhat agreed with the statement that "research is not presented in formats that can be used easily by coaches" and 41.9% "the research being done is not easily accessible to coaches"(187). This paper was back in 2010, the same year that Porter produced a survey on coaches cueing habits. Since then, researchers such as Winkelman (5) have worked on producing instructional frameworks and easily accessible forms of research that look to give coaches an insight into the positives effects of external attentional focus' as well as provided applied scenarios that offer external cues which can be used to help an athlete improve on certain, specific, areas the athlete needs to improve upon. Research such as that by Winkelman could potentially have had an influence on the improvement in the number of coaches using external cues with their athletes. The continued improvements in the education of coaches through updated, summarised literature which specifically look to bridge the gap between theoretical and applied sports science could have long term benefits to athlete's motor skill performance and learning.

The results of this research demonstrate the generalizability of the positive effects of external attentional foci as well as helping us get a better idea of the level of understanding both coaches and athletes have in relation to the current use of attentional focus. There are however a couple of limitations to each study. The meta-analysis included a sub-group analysis which used a large number of moderator variables. This can lead to an inflated chance of positive findings(167) due to making multiple comparisons across a wide number of study and participant characteristics. To offset this, each moderator was carefully selected based on the basis that it could have an impact on the main effect. The use of a median split on continuous data for the selected moderator sub-groups, such as number of attempts for a given cue in a study, may lead to reduced statistical power, and residuals cofounding (167, 168). When applying a median split to continuous data, it is assumed that a value near the median is the same as a value far away from it thus introducing a degree of bias to the calculation of effect size. It also leads to the suggestion that two numbers either side of the median split, whilst numerically vary similar, are within different groups. The survey had a limited number of coaches (n=16) take part; with more participants it would mean that not only would the findings be more accurate but if there were more coaches from each sport, we could get a better idea of the understanding coaches from each sport has. It would become possible to group coaches based on the sport they coach specifically allowing for a subgroup analysis to be performed.

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Appendix

Appendix A – Athletes Survey Multiple-Choice Questions

1) If you were about to perform a max counter-movement jump using a Vertec vertical jump measuring device, which of these cues is closest to what you are most likely to focus on?
    a. Concentrate on the tips of your fingers, reaching as high as possible during the jumps.
    b. Concentrate on the rungs of the Vertec, reaching as high as possible.
2) If you were about to perform a standing broad jump, which of these cues is closest to what you are most likely to focus on?
    a. Focus on extending your knees as rapidly as possible
    b. Focus on jumping as far past the start line as possible
    c. Perform the standing long jump as you normally would
3) If you were about to perform a 10m sprint, which of these cues is closest to what you are likely to focus on?
    a. While you are running focus on driving one leg forward as powerfully as possible while moving your other leg and foot down and back as quickly as possible as you accelerate.
    b. While you are running, focus on driving forward as powerfully as possible whilst clawing the floor with your shoe as quickly as possible as you accelerate
    c. Run as quickly as possible
4) Which of these cues would you believe to be more beneficial for you when performing a broad jump?
    a. When you jump, focus on jumping as close to the cone as possible (the cone is 3m away).
    b. When you jump, focus on jumping as far past the start line as possible.

Appendix B – Coaches Survey Multiple-Choice Questions

1) If an athlete was about to perform a max counter-movement jump using a Vertec vertical jump measuring device, which of these cues is closest to what you would say to them?
    a. Concentrate on the tips of your fingers, reaching as high as possible during the jumps.
    b. Concentrate on the rungs of the Vertec, reaching as high as possible.
2) If you were coaching the standing broad jump, which of these cues is closest to what you are most likely to use?
    a. Focus on extending your knees as rapidly as possible
    b. Focus on jumping as far past the start line as possible
    c. Perform the standing long jump as you normally would
3) If you are coaching an athlete to perform a 10m sprint, which of these cues is closest to what you are most likely to use?
    a. While you are running focus on driving one leg forward as powerfully as possible while moving your other leg and foot down and back as quickly as possible as you accelerate.
    b. While you are running, focus on driving forward as powerfully as possible whilst clawing the floor with your shoe as quickly as possible as you accelerate
    c. Run as quickly as possible
4) Which of these cues would you believe to be more beneficial for your athlete when performing a broad jump?

a. When you jump, focus on jumping as close to the cone as possible (the cone is 3m away).
b. When you jump, focus on jumping as far past the start line as possible.