The Impact of Focus Of Attention (FOA) on Curling Rock Delivery

by

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Abstract

Application of focus of attention theory (FOA) to accuracy-oriented sports has shown goal oriented improvements but has not been investigated in curling. The present study investigated FOA application to curling stone delivery. Specifically, if in-turn and out-turn draws and take-out shots can aid in the performance of highly skilled Canadian curlers (HSCC). Right-handed HSCC (N=11; 4 female, M_{age}=27.23, SD_{age}=4.56) threw in-turn and out-turn draws and take-out shots with control, external and internal focus instructions. Dependent variables measured include draw end-point accuracy (constant error [CE], absolute constant error [ACE], radial error [RE], and variable error), take-out end-point accuracy (hits or miss; miss inside or miss outside), hog-to-hog time, time-on-line, velocity, and acceleration. Questionnaires explored focus strategies. Performance data was analyzed using repeated measures ANOVA with Tukey's Honestly Significant Difference post-hoc test for significant results, and planned comparisons for non-significant results. Take-out accuracy was analyzed using Cochranes Q and McNemar's test. Speed and accuracy correlations were analyzed using Pearson's correlation and Point-biserial correlation. Thematic analyses were conducted on questionnaires. Draw analysis revealed that control in-turns resulted in significantly lower CE, RE, and ACE scores than internal focus in-turns. Take-outs hit a significantly greater proportion of the time with an external focus out-turn compared to an internal focus. Velocity and acceleration at both hog-lines, and halfway were significantly slower for draws than take-outs. Hog-to-hog time was significantly more for draws than take-outs. The percent of time-on-line was significantly less for draws than take-outs. Draws released at slower speeds significantly correlated with worse CE scores. Take-outs released at faster speeds significantly correlated with successful hits. Focus strategies described by HSCC indicate the importance of shifting attentional foci throughout both delivery approaches and the importance of “touch and sensation” for draws. Empirical evidence that differentiates draws from take-outs are provided. An external focus was most beneficial for improving accuracy of take-outs supporting FOA theory (Wulf, McNevin, & Shea, 2001). An internal focus was detrimental to draw accuracy supporting the constrained action hypothesis (Wulf, Höb, & Prinz, 1998). Future research can examine broader foci for draws and explore what “touch and sensation” mean for HSCC.

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Abbreviation List

HSCC: highly skilled Canadian curlers

FOA: focus of attention

EMG: Electromyography

sEMG: surface electromyography

RMSE: root mean square error

MPF: mean power frequency

APA: anticipatory postural adjustments

VL: vastus lateralis

PM: pec major

ES: erector spinal

BCH: barbell-cervical-hip

CE: constant error

VE: variable error

RE: radial error

MSRS: movement specific reinvestment scale

MS: multiple sclerosis

OPTIMAL: optimizing performance through intrinsic motivation and attention for learning

n: sample size

Hz: hertz

F: ANOVA test statistic

M: mean

SD: standard deviation

HSD: honestly significant difference

t: paired samples t-test statistic

x^2: chi-squared statistic

η^2_p: partial effect size

m/s: meters per second

m/s^2: meters per second squared

ANOVA: analysis of variance

EFOT: External focus out-turn take-out

Curling

Curling can be dated back to 1530. Pieter Bruegal's paintings appear to display an activity similar to curling on a frozen lake (History of Curling, n.d.). Curling's origin began on frozen lakes in the winter, but moved indoors to curling specific rinks. The first rules were created in Scotland in 1839, and the first international game was in 1924 in the Chamonix France Winter Olympics (History of Curling, n.d.). The first international curling rules were drawn up in 1967 and undergo revisions each year.

The modern game of Curling is played in teams of four. The goal is to have the most points at the end of the game (The Rules of Curling and Rules of Competition, 2018). Points are collected for each stone that is closest to the tee inside of, or touching the house. Each team throws 8 stones weighing between forty-four and thirty-eight pounds. Each player throws two stones one at a time followed by the opposing teams player until all stones are thrown. The throws are made from the hack (Figure 1). After the stone crosses the tee line, sweepers from the same team may begin sweeping. Curling is played in teams of all women, all men, or mixed. Another way of curling is mixed doubles curling. In mixed doubles curling the team is composed of one male and one female. For those who use a wheelchair there are a few differences. Stones are thrown by hand or by using a delivery stick from a stationary wheelchair. Once one delivery option is chosen players must maintain that same throw style for the duration of the game. Another difference is that sweeping is not allowed in Wheelchair curling. The number of stones thrown and scoring are the same.

Curling Performance Gap

Canadians have placed on the Olympic podium every year, since the reintroduction of curling to the Olympics in 1998 (Curling, 1998). Canadian curlers even dominated the podium, in the 2014 Olympics and Paralympics (Curling, 2014). Unfortunately, the Canadian presence on the podium has declined since. In the 2018 winter Olympics the men and women's curling teams did not place (Curling, 2018). The only curling victory that year was in the mixed doubles category where Canada won gold. It is an achievement none the less, but a drastic change in comparison to previous years. A similarity is seen in wheelchair curling at the Paralympics. The event began in the 2006 winter Paralympics (Wheelchair curling, 2006) where Canada won gold, and has won gold every year up until 2018 (Wheelchair curling, 2018). Here the team won bronze, which is a performance decrement in comparison to previous years. Therefore, the re-attainment of podium status in all Canadian curling at the next Olympics and Paralympics is a priority.

In an effort to combat the podium decline Canadian curling coaches have observed where performance has been lacking. One notable performance observation is that elite Canadian curlers are not making all shots that are considered "makeable" (Peckman, 2019). The shots that should be consistently made are the draw and the take-out shot. The draw shot is a high finesse and low force shot. Athletes use this throw to curl around other stones to reach their final resting place. The take-out shot is a high force, and low finesse shot. Athletes use this to clear opponent's stones from the house.

One strategy that can make a positive impact on performance is ensuring that an athlete's focus of attention is where it can lead to the highest calibre of performance and movement efficiency. From a research perspective there is a lack of work centred on curling as a sport.

However, the research that exists does explore a vast array of topics such as curling and emotional regulation (Tamminen, & Crocker, 2013), teamwork (Collins, & Durand-Bush, 2018), gender roles in sport (Allain, & Marshall, 2018), strength and conditioning (Behm, 2007), attentional demands of curling (Shank & Lajoie, 2013), motor control of Paralympic curlers (Laschowski, Mehrabi, & McPhee, 2018), tactical strategies (Park, & Lee, 2013), coaching (Paquette, & Sullivan, 2012), and the physics of curling ice (Shegelski, Reid, & Niebergall, 2000). The body of literature on curling is in its early stages. Further research is needed especially in relation to improving performance in curling competition and training.

The attention demands of curling and the motor control of Paralympic curlers are areas that requires further exploration. The attentional demands of curling have been investigated in the draw and take-out shots (Shank, & Lajoie, 2013). Optimizing motor control for a Paralympic curler (Laschowski, Mehrabi, & McPhee, 2018) has also been studied. Laschowski et al. (2018) modeled the forward dynamics of a Paralympic curler to allow for optimal biomechanical analysis of Paralympic athletes. Comparing their computed model to their experimental participant they found that angular joint acceleration was most indicative of stone trajectory. Minimizing angular joint acceleration led to optimal trajectories.

In Shank and Lajoie's (2013) study the objective was to examine if the draw and take-out shot utilized different cognitive and attentional demands. The throws were divided into three phases. Phase one was characterized by leaving the hack, phase two was crossing the t-line, and phase three as the wrist flick. Participants threw 10 control shots, thirty draw shots and thirty take-out shots. They were asked to vocally respond when they heard a beep. There was no beep in the control shots. For each type of shot each phase was dissected. A beep would occur ten times in phase one, ten times in phase two, and ten times in phase 3. Reaction time to the beep was recorded, as well as rock speed, and end point accuracy. Shank and Lajoie (2013) found that reaction time was slowest in phase one for both types of shots. The only significant difference between reaction time and shot type was in phase three. Here the take-out shot was significantly slower at responding compared to the draw shot. The expert group shot success was significantly greater than the novice group. The success rate of the take-out shot was greater than the draw shot. Distance from centre was shown to significantly affect the novice's performance more than the experts. The novice group performed poorer. The take-out shot speed was faster than the draw speed, and novices threw faster compared to the experts. What is clear from this study is that a difference exists between novice and expert attentional demands. Experts were able to react to the secondary task without affecting their performance. Breaking down their focus and attention strategy would be the next step in understanding expert curlers performance, which the proposed study can achieve. Attention and motor control are of especial interest to the study being proposed, as there is a whole section of motor control and learning dedicated to attention. That is the focus of attention literature.

Focus of Attention

Focus of attention (FOA) research considers what aspect of movement individuals should focus on to increase learning, and improve performance. Focus of attention is manipulated in research by directing attention to either internal components of a movement or to external components. An internal FOA directs attention of a performer to their body movements (Wulf, Höb, & Prinz, 1998). An external FOA directs attention to the movement outcome, or to the environment (Wulf, et al., 1998). An example of an internally directing cue for a task such as long jump is “focus your attention on extending your knees as rapidly as possible”, and an externally directing cue is “focus your attention on jumping as far past the start line as possible” (Porter, Ostrowski, Nolan, & Wu, 2010 p. 1748).

Focus of attention research began with Wulf, Höb, and Prinz (1998) after Weigelt and Wulf’s (1997) experiment that was interested in the ideal application of instruction. Weigelt and Wulf used a ski-simulator task to better understand instruction timing. Participants were divided into two groups where either no further instruction was given or additional instructions of applying force after moving past centre was given. The participant’s goal was to move the ski simulator in large amplitudes to the beat of a metronome. They found that when participants were given further instructions relating to the movement they could not maintain as large and as fast of a back-and-forth movement as those with no additional instruction.

After Weigelt and Wulf’s (1997) experiment Wulf made an observation while windsurfing (Wulf et al., 1998). She noticed that her fall rate was lower when she focused on the horizon or the board instead of her body movements. This led to the two-part study by Wulf, Höb, and Prinz (1998) who were interested in the learning application of an external focus compared to an internal focus. Part one utilized a ski-simulator where participants were required to move the platform in large amplitudes to the left and right. Wulf and colleagues tested their question under three conditions: control, internal focus, and external focus. The control received no further instructions besides move the platform left and right as far as they could go. The internal group was told to apply force to the outer foot, and the external group was told to apply force to the outer wheels. Participants were divided into one of the three groups. On the ski-simulator their movement amplitude and frequency were recorded and compared on practice days one, two, and again on day three during their retention test where no instructions were given. In the entirety of the study an external focus was found to be beneficial over an internal focus on performance, and an external focus was significantly more beneficial than an internal focus or no instruction on retention. Movement amplitudes were greater with an external focus, and no effect was found on frequency between groups.

In experiment two the same research question was explored but with the use of a stabilometer to examine if FOA could be applied to a balance task. The participants were divided into those three groups again. Their degrees off centre were recorded. On practice days no significant difference was found between the groups. There was a significant difference on retention where an external focus leads to greater performance. From this study, it appears that an external FOA leads to greater performance and learning on a ski-simulator, and to greater learning on a balance task.

One issue with Wulf and colleagues (1998) study on learning and the application of FOA is that only a retention test was used to assess learning. No transfer test was applied. The learning effects may not have been fully explored, but the performance effects are visible.

Focus of Attention Task and Population

The Wulf, et al. (1998) study was the foundation of FOA research. Balance and FOA strategies have been examined under multiple balance tasks as well as populations since then. The FOA literature has since expanded into other tasks, primarily sporting related. The tasks that have been tested are interested in learning, performance, and movement efficiency. The majority of the populations that have been studied are novices unfamiliar with a task. In some studies novices and experts have been compared. Besides the able-bodied population a few special populations have been considered such as those with Multiple Sclerosis, Parkinson’s, and those recovering from a stroke. Support for utilizing an external focus is found consistently throughout the literature within varying tasks and populations. In studies that compare novices to experts different FOA strategies may better serve different skill levels.

Balance

The initial research in FOA was on balance tasks. A stabilometer (Wulf, et al., 1998), an inflatable disk (Wulf, 2008), and more recently a lower-extremity Fitts' task (Aloraini, et al., 2019), are different ways balance has been tested. In 2003, McNevin, Shea, and Wulf studied the balance effect of different external cue locations on a stabilometer. They divided their university student participants into an internal group, a near external group, a far outside external group, and a far inside external focus group. The internal group was asked to focus on their feet, the near external group was asked to focus on markers in front of their feet, the far inside external group was asked to focus on markers between their feet, and the far outside external group was asked to focus on markers near the edge of the stabilometer. Root mean square error (RMSE) and mean power frequency (MPF) were recorded to assess ability to stay level and responsiveness of the participants. They found that the far inside and far outside focus groups were the best at making smaller and more frequent corrects to their movements leading to greater ability to stay horizontal.

A few years later Wulf (2008) assessed elite balance acrobats ability to perform under different focus conditions. She asked her Cirque du Soleil performers to balance on inflatable disks for ten seconds with no focus instruction, with internal focus instructions, and with external focus instructions. Their centre of pressure was recorded and converted to RMSE, and MPF. The elite acrobats were able to perform consistently under each focus condition. The only difference was that the no focus condition lead to the greatest ability to correct movement error. The elite performers were resistant to focus instructions affecting their performance, but when allowed to focus with no outside guidance they were more efficient in correcting movement.

Another population explored in balance was with older adults in Chiviacowsky et al. (2010) study using a stabilometer. They divided their older adults into an internal focus group and an external focus group. The internal group was asked to focus on keeping their feet horizontal, and the external group was asked to keep the markers on the stabilometer horizontal. They found older adults could balance for longer when they focused on an external cue.

Jackson & Holmes (2011) also used a stabilometer to assess balance ability. They recruited adults, and divided them into four groups based on focus condition and task objective. They had an internal (feet) and external (board) focus for either maintaining a foot level task objective or a board level task objective. They were interested in what effect similar and opposite foci matched with task objective had on performance. They found that when focus and task objective matched performance was better. The best performance was when focus and task objective were both on external components.

A study that utilized both balance and foot pointing comparing older adults and young adults lower extremity Fitts' task performance under internal and external focus instruction was conducted by Aloraini et al. (2019). They asked each participant to step on the target presented to them as fast as possible. Focus was directed to the feet movements for the internal conditions, and to the target for the external conditions. Both feet were tested during standing and seated under each focus condition. The targets varied in size and distance from the starting line. They found that an external focus lead to less end point variability, greater peak velocity and time to peak velocity, and earlier anticipatory postural adjustments (APA) of tibialis anterior and soleus. They also found that target distance lead to the greatest accuracy variability. Older adults APAs were slower than younger adults, but their APAs sped up when focus was directed externally. An external FOA can improve balance in older adults and young adults.

Sport

As balance tasks gained support for adopting an external FOA, the robustness of this theory began to be tested. Various sporting skills have been examined such as swimming (Stoate & Wulf, 2011), sprinting (Porter, Wu, Crossley, Knoff, & Cambell, 2015), jumping (Porter, Ostrowski, Nolan & Wu, 2010), strength training (Lohse, Sherwood, & Healy, 2014), basketball (Zachry, Wulf, Mercer, & Bezodis, 2005), volleyball (Wulf, McConnel, Gartner & Schwarz, 2002), soccer (Ford, Hodges, & Williams, 2015), golf (Perkins-Ceccato, Passmore, & Lee, 2003; Pelleck & Passmore, 2017; Wulf & Su, 2007), darts (Sherwood, Lohse, & Healy, 2014), and baseball (Casteaneda & Gray, 2007).

Swimming

Swimmers were able to swim faster when the focus was directed externally to the water or the goal of swimming fast (Freudenhaim, et al., 2010; Stoate & Wulf, 2011). The measure of interest in both swim studies was total time to swim one length of a pool. In Freudenhaim, et al (2010) study they recruited novice swimmers and were interested in if there was a difference in performance between different internal focus strategies and an external focus. The two different internal strategies had participants focus on their arm movements, and the other on their leg movements. They found no difference between the internal strategies swim times, but they found faster times with an external focus on pushing the water back. Stoate and Wulf (2011) too found that swim times were faster within the external focus group as well as the control condition within their expert swim population. The control prompt was to swim as fast as possible to the other end of the pool. However, the control cue fits under an external focus definition, which could have lead to their swimmers interpreting it as an external cue. Stoate and Wulf's (2011) results lead to further support for applying an external focus.

Sprinting

Sprinting is another task that an external FOA leads to greater performance and efficiency of movement. Total time, and reaction time are typical measures in sprinting. Novice, intermediate, and expert populations have been examined for a sprint start followed by a sprint. Porter and colleagues (2015) recruited novice participants for their study and were interested in their 20m-sprint time under a control condition, internal and external focus conditions. In control conditions participants were to focus on sprinting as fast as possible. Internal focus conditions had participants focus on leg and foot power, and the external focus had attention directed toward forward drive by clawing the floor. They found that an external focus was more beneficial over an internal and control condition in novice sprinters. An additional study in sprinting research considered more experienced athletes (Winkelman, Clark, & Ryan, 2017). They recruited soccer players familiar with sprinting, but who have never trained to sprint like a track and field athlete. They were asked to sprint 10 and 20m under an internal, external and control conditions. They were interested in sprint time as well as kinetic variables of total force, vertical force, and horizontal force at sprint start. They only found a significant difference with sprint time. An external focus as well as the control condition led to significantly faster sprint times. When examining true sprinters off the block a difference in focus conditions was seen (Kovacs, Miles, Baweja, & Kovacs, 2018). The sprinters were asked to perform a sprint start and sprint 6m as fast as possible under external, internal, and no focus conditions. Reaction time, premotor reaction time, motor reaction time of the rear and front foot, and time to peak force were measured. They defined premotor reaction time as the time from gunshot to rear foot vastus lateralis (VL) activation. They defined motor reaction time as the time between rear foot VL activation and force production. They found that premotor reaction time under an external and no focus condition lead to a faster response than an internal focus condition. Front leg premotor reaction time was significantly faster in an external focus condition and total reaction time of rear and front foot was faster with an external focus condition. In another study with both experts and novices, reaction time off the block, and total sprint time was faster supporting the use of an external FOA over an internal focus and control condition (Ille, Selin, Do, & Thon, 2013).

Jump task

An external focus is found to be beneficial in standing long jump, and more beneficial with cues that direct attention further from the body. Novices in particular have been the focus of this task in the literature. Many experiments thus far have utilized a within-participant design, however Porter et al. (2010) conducted their experiment with a between-participants design. They asked their novice jumpers to perform a standing long jump. They split their population into two groups as evenly matched by age, height, gender, and weight. Jump distance was the only variable of interest. They found that a greater distance could be jumped when asked to focus externally on jumping away from the line compared to the internal condition asked to focus on extending their knees as fast as possible. Wu, Porter, and Brown (2012) expanded on Porter et al. (2010) study with a within participant study design and the inclusion of force production as an outcome measure along with distance jumped. External FOA support was found for increasing jump height but no difference was found in force production. The Ducharme, et al. (2016) standing long jump experiment also supports an external FOA. Distance jumped was recorded as well as vertical reaction force at take-off with a force platform, and projection angle by reflective markers and video analysis. Each participant jumped under each condition. They found that when utilizing an external focus jump distance increased, and projection angle was lower compared to control and internal focus conditions. There was no significant difference of force production. It appears that in a jump task force production may not be why externally focused jumpers can jump further, but that a more efficient jump angle is used.

Research in standing long jump and FOA has been interested in the effects of varying distances of an external cue. Porter, Anton, and Wu (2012) asked their novice population to jump under three different focus conditions. Their control condition asked participants to jump as well as they could, their near external condition had participants jump as far past the starting line as possible, and their far external condition had participants jump to as close to the distant cone as possible. They found that an external far condition was the best strategy compared to a close external and control condition.

Weightlifting

The strength training literature on FOA has tested many different types of strength tasks such as simple tasks of a bicep curl (Vance, et al., 2004) to more complex movements like a snatch (Schutts, et al., 2017). Within these tasks what is occurring within the neuromotor system is visible with the use of electromyography (EMG), and force production measures. A simple weight lifting task of a bicep curl was used to examine range of motion, muscle activation, power, and speed under external and internal FOA conditions (Vance, et al., 2004). With an external FOA agonist and antagonist co-contraction decreased, range of motion increased, and speed of movement increased. Lohse, Sherwood, and Healy (2014) investigated a lower extremity simple strength task. Seated plantar flexion under an external focus lead to lower co-contraction of agonist-antagonist muscles as well as a greater ability to maintain task instruction.

In the simple task of an isometric mid-thigh pull, participants familiar with weight lifting for two years were recruited from numerous sporting backgrounds (Halperin, et al., 2016). They were tested under a control condition where they were instructed to focus on going fast, an external condition where they were instructed to push the ground fast, and an internal condition where they were asked to focus on contracting their leg fast. They measured ground reaction force and found a significantly greater force production under an external condition compared to both the internal and control conditions.

Kristiansen and colleagues (2018) used an EMG as an efficiency measure while testing an internal and external FOA effect on bench press. All participants participated in control, external, and internal trials. Surface electromyography (sEMG) data was collected on the pectoralis major (PM), anterior deltoid, biceps brachii, triceps brachii lateral head and medial head, latissimus dorsi (LD), and erector spinae (ES). Under an external FOA the mean sEMG amplitude of PM was significantly greater, and under an internal FOA the mean sEMG amplitude of LD, and ES. Compared to baseline testing the utilization of either an internal or external FOA was significantly better. One issue with this study is their lengthy cueing script, which may have resulted in forgetting of instructions.

Snatch kinematic variables were compared when asking participants to focus internally on their elbow movements compared to externally on the bar path. Those variables were barbell-cervical-hip (BCH) angle, vertical barbell velocity, peak instantaneous horizontal barbell velocity, and peak instantaneous vertical elbow velocity. They found that under an internal focus the peak elbow vertical velocity, and BCH angle at maximum height was significantly greater, and that under an external focus the peak barbell horizontal velocity was significantly greater. This finding leads to further support for adopting an external FOA as a low BCH angle at max height is a more efficient movement, just as a greater horizontal bar movement leads to greater movement control (Schutts, et al., 2017).

Basketball

The basketball free throw is another task supported by an external focus. University students with one year of basketball experience were recruited (Zachry, Wulf, Mercer, & Bezodis, 2005). The free throw was tested with an internal focus directing toward the wrist motion, and with an external focus directing attention to the centre of the backboard. Muscle activity of the medial biceps brachii, long head of the medial triceps brachii, the medial deltoid, and flexor carpi radialis was recorded. Motion analysis of the throw, and successful baskets made was recorded. They found that shot accuracy increased and muscle co-contraction between biceps brachii and triceps brachii wass minimized under an external focus (Zachry, et al., 2005).

Volleyball

Volleyball serves have been studied in a novice population as well as a recreationally involved population (Wulf, McConnel, Gartner, & Schwarz, 2002). Participant's accuracy at hitting a target was recorded under an internal focus that directed attention to the shoulder, arm, wrist and hand movements, or externally to the outcome of hitting the ball. In practice and retention both the novices and skilled players showed greater accuracy under an external focus. Only the expert group showed greater quality of movement under an external focus in retention.

Soccer

Kicking a soccer ball to a target was the task used in part two of Wulf et al. (2002) study. Part two only recruited novice's players and had them direct attention to the leg while kicking for internal focus, and aiming the ball to the target for the external foci condition. The researchers gave feedback directed to internal or external foci depending on the group either 100% of the time or only 33% of the time. Accuracy measures were obtained and they found that an external focus lead to greater accuracy in practice with no difference between feedback amount, but an internal feedback 33% of the time was greater than 100% of the time. In retention an external focus was still more accurate. There was no difference between feedback frequencies. The only difference was in the internal focus groups where less feedback led to greater performance.

Focusing on any internal focus can have detrimental effects in dribble time in highly skilled and less skilled soccer players (Ford, Hodges, & Williams, 2005). Ford and colleagues (2005) asked participants to dribble fast as a control, to focus on a task relevant internal focus (foot dribbling) by responding to which foot kicked the ball during an auditory tone, a task irrelevant internal focus (arm movement) by responding to which arm was closest to the distant cone during an auditory to, and a dual task of dribbling while reading phrases. Less attentional resources were available in the soccer task when asked to focus on arm and foot movements as more errors occurred in these trials.

Golf

Golf putting is a task that has been studied in the FOA literature from its early days and continues to be studied. Putting to different sized targets (Wulf, Lauterbach, and Toole, 1999), to one target from different distances (Pelleck & Passmore, 2017), or chipping from different distances (Perkins-Ceccato, et al., 2003) are the three variations used. An early study of Wulf, et al. (1999) asked novice golfers to putt to four different sized targets. They divided their golfers into two groups, an internal and external foci group. The internal focus group were asked to focus on their arm swing, and the external focus group was asked to focus on the club movement. In both practice and retention the externally focused group performed better.

A few years later Perkins-Ceccato and colleagues (2003) used a golf-chipping task from four different distances. They recruited novices as well as experts. Each participant chipped under an external and internal foci while wearing visual occlusion goggles to prevent feedback and therefore learning from trial to trial. Accuracy measures (average error, and variable error) were recorded. A difference between novice and experts was found. Novices performed with less variability under internal foci, and experts performed with less variability under external foci.

Wulf revisited the golf-putting task with Su in 2007 where they examined experts and novices. They had them putt under a control, internal, and external focus condition to four different sized targets like (Wulf, et al., 1999). They found that novices in practice did not show a difference, but one day later on retention an external foci led to greater performance. The experts performed a similar experiment, but had their targets even smaller to account for their increased skill level. Their accuracy was greater under an external foci with no differences between internal and control conditions.

Similar to balance and standing long jump the support for an external FOA became large so researchers began exploring how far an external focus should ideally be. Kearney (2015) investigated this with a putting experiment. The internal focus condition was any thought directed to body movement. Proximal external was toward the club, and distal external was toward the ball path. Manipulation checks were conducted during, and after the experiment with a visual analog scale for questions examining if participants were able to focus as directed. They found that participants were able to follow the focus instructions. They also found that a distal external focus lead to the greatest accuracy in putting. However the lack of specific internal instructions may have affected the results because novices unfamiliar with the task were used.

Different types of internal instruction may make a difference as Pelleck and Passmore (2017) show.

Pelleck and Passmore (2017) used a golf-putting task to two different distances. They recruited experts and novices to perform under three foci conditions: 1. Internal movement, 2. Internal stance, and 3. External. Their internal movement foci directed attention to the hands and elbow, internal stance directed attention to weight distribution between both feet, and external directed attention to the target. They recorded accuracy measures (absolute error (AE), constant error (CE), and variable error (VE)) as well as surface EMG activity of Tibialis anterior and extensor carpi radialis. They recorded Root-mean-square and variability. They found a difference between novice and expert golfers. Novice golfers performance was negatively affected by the internal stance conditions where as experts were not affected. Novice golfers muscle activation of their upper extremity was more variable under an internal movement focus. The backswing movement time was increased in novice golfers under an internal movement focus. This same finding was found in expert golfers, but only at the furthest distance to putt. The internal movement focus also increased the fore swing time to peak acceleration in both experts and novices. It appears that experts and novices utilize internal cues differently.

Darts

Throwing darts is another task with much support for an external FOA over an internal FOA. Darts as a task for FOA research is interested in accuracy measures, as well as movement quality using EMG and motion analysis. Lohse, Sherwood, and Healy (2010) asked their novice participants to throw darts under an internal and external focus. The internal directed focus to the arm movement, and the external directed focus to the target and dart. Motion analysis of the elbow and shoulder were recorded as well as sEMG activity of the biceps and triceps and end point accuracy. They found better accuracy performance, faster preparation time, and reduced muscle activity of the triceps and biceps under an external focus. Motion analysis showed no significant difference between an internal and external focus in darts.

A study that recruited novices as well as experts was Schorer and colleagues (2012). They were further interested in what affect knowledge of results contributes to the FOA literature. They utilized visual occlusion goggles part of the time under two internal conditions and one external condition. Internal condition one had them focus on the movement return, internal condition two had them focus on dart release, and external had them focus on the bull's eye. They found that the best performance was under an external focus for both experts and novices, and that without knowledge of results performance decreased under internal condition one and the external condition, but performance improved under internal condition two. The kinematic motion analysis showed no clear result for what affect knowledge of results plays. However the back swing performance of experts was faster than baseline under internal condition two and the external condition. The lack of clarity in this study may be due to the wording of the focus cues. Neither of the internal focus cues referred to the self directly especially in internal condition two, which resulted in similarities to the external focus conditions. This could be due to the dart reference in the cue. It appears that a difference in external focus is evident here as opposed to differing internal foci. Knowledge of results also appears to affect performance in both experts and novices.

Shafizadeh, Platt, and Bahram (2013) found further support for an external FOA in dart throwing in those who physically practiced the skill in acquisition and those who observed in acquisition. They related their self-efficacy scores to the focus condition and those in the external condition were more confident in their ability to make the shot.

Sherwood, Lohse, and Healy (2014) had a novel approach to directing attention. They asked their novice participants to judge their performance based on throwing angle (internal), and on outcome (external). The two internal judgements were on either elbow angle at launch or shoulder angle. The two external judgements were on horizontal accuracy to centre or vertical accuracy to centre. They found that novices could judge their movements more accurately and consistently under either external focus. In part two of their experiment they added more practice days and no vision trials. They found that vision improved performance, but that the increase in practice was not significant.

Hitchcock, and Sherwood (2018) study recruited novice darts players and asked them to focus on the dart flight for the external focus conditions, and to their elbow angle during the internal focus conditions. They found that during the positive acceleration of a dart throw co-contraction of the bicep and triceps decreased in the external condition, but no difference was found in the negative acceleration phase. Hitchcock and Sherwood (2018) also found that the mean radial error of endpoint accuracy was lower for the external focus trials.

Baseball

Baseball studies examined baseball-batting tasks and FOA examined the task in relation to the environmental goal and the skill goal under an internal and external focus, and baseball pitching. Casteaneda and Gray (2007) recruited skilled and less skilled baseball players to examine a dual-task in a baseball-batting simulator. They were interested in if skill level affects what component of the task to focus on. They asked participants to focus on the skill, and on the environment effect of the batting task. They did so under both an internal and external foci where an internal focus had participants focus on their hands, an external focus to focus on the bat swing. The environmental specific focus asked participants to focus on the ball after the swing, and to an irrelevant auditory tone. They found that highly skilled players performed best under an environmentally external focus, and external skill focus. Less skilled players showed no difference between skill focus and FOA, and a significantly better performance under an environmental irrelevant condition. It appears that a difference between skill levels does exist as skilled players performed best when cued to the environmental goal of movement, and low skilled players performance decreased under environmental focus movements.

Another baseball study examined coaching instruction during pitching training (Van Der Graaff, et al., 2018). Coaches were recorded during training sessions and their instructions and feedback were categorized into internally directing focus and externally directing focus. The players throw velocity was recorded during this process, and a movement specific reinvestment scale (MSRS) questionnaire and baseball specific questionnaire that examined focus preference. Of the coaching statements only 42% directed attention to FOA, and of that 42% only 31% utilized an external focus even though the coaches were aware of the validity of external FOA. The MSRS questionnaire showed that players had a preference toward internal focus. Velocity measures could not be matched with internal and external instructions, since it was not a variable tested, as this was an exploratory study. It is an example that shows that although the literature supporting external FOA is robust it is not always implemented in practice. Further studies on knowledge translation and uptake are warranted.

Learning and Focus of Attention

In the literature on FOA the predominant populations studied are novices. Learning a skill occurs when knowledge of results are available (Salmoni, Schmidt, & Walter, 1984). Without knowledge of results all that is seen from attempt to attempt is performance. Knowledge of results in crucial for updating the motor program model between attempts (Salmoni, et al., 1984). In the literature the learning effect is tested with retention and a transfer test after one or more practice days. Balance studies (Chiviacowsky, Wulf, & Wally, 2010), have tested with a transfer and retention tests and found support for an external FOA. Learning a dart-throwing task through observational or physical practice with an external focus was found to promote greater learning over an internal focus (Shafizadeh, Platt, & Bahram, 2013). Although the proposed study is not interested in learning, the distinction between learning and performance is necessary. The proposed study is interested in the performance and movement efficiency effects in Olympian and Paralympian curling athletes under an internal and external FOA. Precautions have been taken to eliminate the possibility of a learning effect through elimination of knowledge of performance and knowledge of results. Skilled movement should occur consistently and as efficiently as possible.

Focus of Attention Performance Variables

Performance factors that have been examined in the literature include measures of balance ability, distance moved, event time, and accuracy. Studies analyzing balance ability have measured how long a performer stays balanced (Chiviacowsky, et al., 2010; Jackson & Holmes, 2011). Distance jumped has been measured as a long jump performance criterion for novice jumpers (Porter, Ostrowski, Nolan, & Wu, 2010). Time to complete a running task or swim task have been studied (Porter, Wu, Crossley, Knopp, & Campbell, 2015; Stoate & Wulf, 2011). Accuracy measures are interested in how close to a target a performer can get such as in golf, or darts (Perkins-Ceccato et al. 2003; Pelleck & Passmore, 2017; Wulf & Su, 2007; Wulf, Lauterback, & Toole, 1999; Sherwood & Healy, 2014; Lohse, et al., 2014). An external FOA even has a positive effect on enduring and fatiguing tasks such as a wall sit to failure (Elohse, &

Sherwood, 2011). Participants in the external condition lasted longer and rated their perceived exertion lower compared to internally focused participants.

Focus of Attention Efficiency Variables

Efficiency measures are used to gain an understanding on the underlying neuromotor mechanisms affected by FOA. In the literature EMG activity, speed, force production, jump distance, and movement coordination are a few that have been considered. Simple tasks like an isometric contraction (Lohse, et al., 2014) to complex tasks such as a long jump (Porter, et al., 2010) have been investigated. In Schutts, Wu, Vidal, Hiegel, and Becker's (2017) study biomechanical markers were used to visualize and calculate joint angles during the Snatch lift. Schutts et al. (2017) study provided a visual and auditory cue. They found that joint angles were lower, and that horizontal barbell velocity was higher under an external focus. Lower joint angles, while moving the bar faster are indicative of a more controlled and efficient movement. In long jump projection angle, and force, have been studied as efficiency variables (Ducharme, Wu, Lim, Porter, & Geraldo, 2016). Participants were able to jump further while using a lower jump take-off angle compared to internal focus and no focus conditions.

Efficient movement can be studied with the use of EMG. Lohse, Sherwood, and Healy (2011) measured sEMG activity of the soleus and its antagonist muscle (tibialis anterior) while performing a seated plantar flexion task against a force platform. Under an internal focus greater co-contractions of the antagonist muscle, and greater difficulty at maintaining 30% contraction were found. Reduced motor efficiency can be seen when using an internal FOA compared to an external FOA. In dart throwing, variables such as joint angle, and muscle activity via sEMG signal have been used (Lohse, et al., 2010). Reduced muscle co-contraction between the triceps and biceps were found.

Another finding of the FOA research is that the further an external cue directs attention from the body, the smaller the amplitude and more frequent corrections are made to balance (McNevin, et al., 2003). The McNevin, et al. (2003) initial study had participants focus internally, and to three external locations (outer edge of the stabilometer, directly in front of the participants feet, and in the centre of the stabilometer). An external far out-side, and far in side were the most beneficial strategy followed by the near foot condition, then the internal condition. Support for further away cueing has also been supported by Kearney (2015) with a golf task, and standing long jump (Porter, et al., 2012).

Elite Athlete Population

Within the sport related skills a majority of the research has been done on novices. By comparison the elite athlete/performer population has not been studied as thoroughly. Another understudied population are those with a disability. The proposed study is interested in both able bodied and disabled world-class athletes, as what they need to focus on may be different from novices (Perkins-Ceccato, et al., 2003).

What classifies individuals as skilled, or experts varies from study to study. A year or more of participation in a chosen sport is a criteria of expertise for some studies (Halperin, et al. 2016). University level sport (Stoates & Wulf, 2011; Kovacs, Miles, & Baweja, 2018), world class performance (Wulf, 2008), and a golf handicap score for golfers has been used as a skill benchmark (Perkins-Ceccato, et al., 2003; Wulf & Su., 2007; Pelleck & Passmore, 2017). Although, different criteria exist for what classifies a performer as skilled the distinction from skilled and novice performers is established in the FOA literature. The research conducted on elite athletes under different FOA instructions is concerned with how experts perform under different foci as well as if there is a difference between novice and experts.

University level athletes are commonly recruited as skilled athletes in the FOA literature. Stoates and Wulf (2011) recruited university level swimmers and their community swim team counterparts for their study. They found that skilled swimmers swam faster under both an external condition and no foci condition compared to an internal foci condition. University level sprinters (Kovacs, Miles, & Baweja, 2018) were able to react faster off the block with an external foci. University level baseball players (Castaneda & Gray, 2007) could bat more accurately under an external foci directed at skill outcome over internal conditions and irrelevant external foci in a simulated baseball batting task.

Golf tasks are another stream of the sporting literature that recruits highly skilled athletes. These studies recruited golfers with a golf handicap score between 0 and 8 (Perkins-Ceccato, et al., 2003; Wulf & Su, 2007; Pelleck & Passmore, 2017). Perkins-Ceccato et al. (2003) has shown that attention should be directed appropriately based on skill level. The novice participants performed more accurately under an internal focus condition, and the experts performed more accurately under an external focus.

More recently Pelleck and Passmore (2017) conducted a golf study with experts and novices. They were interested in different internal foci that direct attention to the task relevant and irrelevant components. They found a difference between the internal conditions and the external focus condition based on skill level. Novices were negatively affected to a greater degree under an internal relevant focus, and treated an internal irrelevant focus and external focus similarly. Experts appeared more resilient to changes in their performance between the different foci strategies, however a detrimental affect was seen to their fore swing peak acceleration time under a relevant internal focus.

In a study of world-class performers Wulf (2008) examined what focus was more beneficial for Cirque du Soleil acrobats. The acrobats were asked to balance on an inflated rubber disk under an internal foci, an external foci, and control condition. No performance difference was found however there was a movement efficiency difference. The no foci trials resulted in greater ability to correct movement (MPF). The elite athletes were able to control their performance under the varying foci instructions. They were more adaptable to different conditions just like Pelleck and Passmore (2017) golf experts. However, there was no questionnaire utilized to examine what the acrobats were actually thinking about. The internal instructions had participants focus on their feet movements; the external instructions had participants focus on the disc movements, and the control instructions were to focus on standing still. The control condition allowed expert acrobats greater ability to correct their movements.

Conceptual Model

Matching the skill complexity to the skill level of an individual is important for growth in that skill (Guadagnoli, & Lee, 2004). The challenge point framework (Guadagnoli, & Lee, 2004) can explain why some novices perform better initially with an internal focus (Perkins-Ceccato, et al., 2003). The challenge point framework states that the success rate of executing a skill properly is higher with increasingly skilled performers. For learners to increase their skill level they must be challenged optimally. The optimal challenge point of a learner is based on skill level of the learner, task difficulty, and potential available information. A task must always optimally stress a a performer to allow for learning. A task that is too easy or too hard relative to an individual will not allow for progress. Therefore, matching the task objectives with the appropriate focus may help a learner reach their optimal challenge point (Jackson & Holmes, 2011).

Theorists on motor control provide possible explanations on why an external focus may be more beneficial and why an internal focus is so detrimental. These thoughts go back as far as James (1890) when he was considering how people execute actions. He shared his thoughts that movement execution can be categorized based on thoughts directing movement to their remote location or the resident ones. The remote aspects are toward what people see, hear, or sense, and the resident aspects are to the movement kinaesthetic. He suggested that an action is performed with greater ease if the remote location of an action is the focus.

Action Identification Theory

Later on the action identification theory was proposed. It is composed of three processes that affect one another (Vallacher & Wegner, 1987). There is the identification level, sensitivity to higher level identity, and degradation to lower level identity when a high level cannot be maintained. They describe a low-level action identity as performing an action while focusing on the sub-movements necessary to create it. A high-level action identity is described as executing an action while considering the purpose of the action. Action identification is affected by the action context, the performers experience with this action, and the difficulty of the task. The action identification theory supports Perkins-Ceccato and colleagues (2003) novice participants who performed better under an internal focus. Their skill level was more suited for a low level identity.

Deautomization of Skills Hypothesis

However an explanation for what happens when experts revert back to a low level identification is not explained with the Action Identification theory. When experts switch from a high level identification to a low level one it is commonly known as choking. Choking in elite sport became a topic of interest and the deautomization of skills hypothesis was proposed (Masters, 1992). The hypothesis predicts that action execution with a movement execution focus leads to detrimental performance compared to action goal foci. Support for the deautomization of skills hypothesis is seen in Ford, Hodges, and William (2005) soccer experiment. They found that attentional resources were less available while dribbling a soccer ball and focusing on any body movements. More errors occurred in their second task of reading phrases when the focus was on the body compared to no focus conditions. Their performance resembles what occurs in choking as an internal focus negatively affected their dribble speed.

Common Coding Theory

A few years later Prinz (1997) proposed the common coding theory. Here the movement is more effective if planned with the intention of the action goal as opposed to the movement components. Action and perception are linked and complementary when the focus of an action is on the movement goal. However an explanation for why an action goal focus is more beneficial over a movement focus is not provided.

Constrained Action Hypothesis

Studies that took movement execution and mental representation to a new understanding were Wulf and Weigelt (1997), Wulf et al. (1998), and Wulf, et al. (1999). They changed the semantics from residual and remote, high level identification and low-level identification to internal and external FOA. The explanation that accompanies FOA occurred in 2001 with the constrained action hypothesis proposed by Wulf and colleagues. They presented the idea that there is a performance and a processing difference when asked to focus on the bodily movements of a skill compared to the goal of movement of a skill. They suggest that the processing difference is due to constraints placed on the movement execution system when the focus is directed to the body, and the freeing of constraints when the focus is on the movement goal. The constrained action hypothesis is tested experimentally with the use of a probe task. In the Wulf et al. (2001) experiment their primary task was to balance on a stabilometer, and their probe task was to react as fast as possible to an auditory stimulus by pressing a button. A faster probe reaction time was expected and found when utilizing an external focus during the balance task. Here the processing system was expected to work more naturally and automatically. A slower probe reaction time was expected and found under an internal focus balance task. Here the processing system was expected to work under conscious control because bodily movements were the focus. The body focus affected the processing system leading to unnatural and constrained movements. The probe task acted as a way to test how automatic a movement was and therefore how much attention was left over while performing a primary task. More automatic primary tasks leave greater attention for a second task therefor leading to faster reaction times (Wulf, et al., 2001; Kal, Van Der Kamp, & Houdijks, 2013).

Optimal Theory

A new and more holistic interpretation on skill learning and efficient execution is with the optimizing performance through intrinsic motivation and attention for learning (OPTIMAL) theory of motor learning. Here FOA is one component of the larger social-cognitive-affective-motor concept. The OPTIMAL theory of motor learning agrees with the constrained action hypothesis and goal-action coupling. They expand on the constrained action hypothesis and highlight the ease of the brain to immediately and consistently focus on the self when presented with the chance. Wulf and Lewthwaite (2016) attribute this ability of the brain as further reasoning to why an internal focus is so disruptive to performance and automaticity of movement.

General Summary

In summary, the evidence for an external focus leading to improved performance is robust. It is also clear that performers of different skill levels may utilize the focus instructions differently. The proposed study wishes to further explore the differences skill level may have in utilizing focus instructions in the sport of curling. Curling is not well studied in the sport sciences literature. Curlers are forced to switch between two very different types of throws and due to this their focus strategies may differ between the two shots. The proposed study sought to fill these gaps and contribute to expanding the research on FOA, curling, and high-level athletes.

Hypothesis

The primary hypothesis of this study was that performance in curling stone delivery will improve among HSCC when utilizing an external FOA approach. Specifically, for draw shots it was anticipated that when adopting an external FOA shot accuracy toward the button would increase, and delivery variability would decrease. This hypothesis was based on performance changes associated with other accuracy driven tasks requiring low velocity and high finesse (Bell & Hardy, 2009; Wulf & Su, 2007; Pelleck & Passmore, 2017). Specific to take-out shots it was predicted that an external FOA would improve accuracy and reduce delivery variability. This hypothesis was based on variables of interest from a more ballistic type of activity such as dart throwing (Hitchcock & Sherwood, 2018; Lohse, et al., 2014).

Objectives

The purpose of this study was to improve the delivery and end result of curling stones thrown by highly skilled Canadian curlers. According to Curling Canada, Canadian curlers are not making all "makeable" shots (G. Peckham. Personal communication, April 12, 2019). The two types of curling throws that should be consistently made are the draw and take-out shots. The specific objectives of the study are as follows:

1. Determine if the application of FOA theory is advantageous to one or both types of shots in HSCC.
2. Determine what aspects of performance are changed or facilitated by the utilization of FOA theory.

Method

Participants

This study recruited right-handed highly skilled Canadian curling athletes (N=11; 4 female, M_{age}=27.23, SD_{age}=4.56), through Curling Canada.

An apriori power calculation was performed to ensure that the available participants for the study met minimal sample size power. A statistical power level of 0.8 and an alpha set to 0.05 was utilized. The power calculation was utilized from existing expert golf putting outcome means and standard deviations. An appropriate power was determined to use a minimum sample size of 9 people per group.

Inclusion Criteria

To be included in this study the following criteria had to be met. Participants needed to be highly skilled Canadian curling athletes (identified by Curling Canada) based in Manitoba, who were in contention for the 2022 Winter Olympics or were identified as next generation curlers who were preparing for the next Winter Olympic games (2026) at the time of testing. All athletes were right-handed, had normal, or corrected to normal vision, hearing, and physical ability.

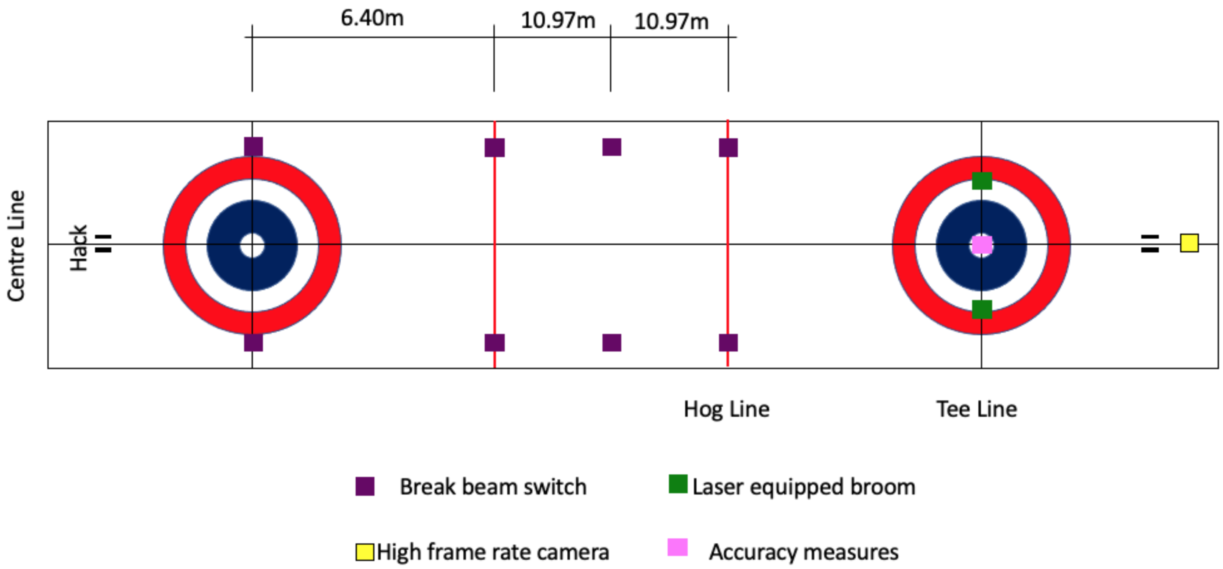
Exclusion Criteria

Exclusion criteria included curlers who were not contenders for the Winter Olympics (2022/2026), non-Manitoba based curlers, left-handed curlers due to brain laterality differences (Gotts, et al., 2013), those who did not meet COVID guidelines at the time of testing, and any curlers who had an injury preventing them from curling as they would in competition.

Apparatus

Figure 1

Equipment Location Superimposed on Ice Schematic



Participants curled on standard curling ice (Figure 1) which was maintained by one ice technician. Participants wore visual occlusion goggles and headphones. The location of on-ice equipment can be seen in Figure 1. The experiment began when the instructional cue was given. The delivery began when the participant pushed off the hack. The stone had to be released prior to the first hog line. Once the stone was thrown and it passed through the break-beam switch on the first hog-line it triggered the goggles to block vision, and the headphones to play white noise. Four break beam switches were placed on the ice. The trigger break beam switch was 6.4 meters before the first hog line, one at the first hog line (BB1), one at the halfway point (BB2), and one at the second hog line (BB3). These break beam switches recorded the time that the stone passed. The trigger break beam triggered a high frame rate camera (IL5-H, Fastec Imaging, Canada) recording at 200Hz located at the opposite hack. A laser equipped curling broom target was utilized with the camera to record how long the stone stayed centred with the laser and the number of rotations. The camera recorded for 25s to ensure that the stone passed the second hog line. When the stone came to a complete stop its endpoint distance was measured with a laser measuring device (Pad Laser, PeakCurl, Switzerland) and the degree from 0° with a goniometer. The goniometer orientation can be seen in Figure 2. At the point when the stones endpoint was measured, and the stone was cleared from the ice, the visual occlusion goggles, and headphones wore turned off allowing participants to see and hear once again.

Procedure

The ice was prepared prior to the start of each experimental day, and again part-way through the day by the same ice technician over the course of the study. The ice technician would scrape the ice and pebble the ice as a part of their preparation. Upon arrival to day one testing, participants underwent informed consent as approved by the University of Manitoba research ethics board. Participants were then asked to fill out the "Pre-experiment survey" (Appendix A), which asked questions about their typical focus strategies. Following informed consent procedures, participants had time to practice on the ice and gain a feel for the ice conditions. Practice duration was self-regulated. Participants were then equipped with the visual occlusion goggles and the headphone.

The experiment included 60 experimental trials spread across two days. Day one was comprised of the control conditions, and one focus condition. Day two was comprised of the remaining focus condition. The curlers were asked to throw 5 stones per condition similar to golf studies (Wulf & Su, 2007; Pelleck & Passmore, 2017). Participants were asked to deliver two types of curling shots: 1) the draw; and 2) the take-out. Each using the two different turn conditions: 1) an in-turn; and 2) an out-turn depending on how the stone should curl to reach the target. Focus test conditions included control, internal, and external FOA instructions while performing: 1) an in-turn draw; 2) an out-turn draw; 3) an in-turn take-out and 4) an out-turn take-out.

The control condition always occurred first on day one. The control condition had no additional instructions other than telling the participants which throw and turn style to use. The control condition was first to avoid contaminating participants with cue's they may not typically use. Following the control condition one focus condition (internal or external) was completed on day one. During internal focus conditions participants were instructed to "focus on your hand and arm movements during your delivery". During the external focus conditions participants were instructed to "focus on the distant broom during your delivery". Two counterbalanced blocks of 20 trials per focus condition with two counterbalanced blocks of 10 trials per turn condition consisted of all delivery combinations in a semi-random order. Semi-random due to the probability of a draw or take-out occurring first being equal, but once chosen the throws would alternate. To determine if participants were focusing where they were instructed to, a researcher asked after each throw if they felt that they were able to utilize the instructed focus (Kearney, 2015), and if they had any comments on their throw.

Broom placement indicated the expectation of an in-turn or out-turn. To facilitate a draw to the button the target broom was placed at the 8-foot line either to the left or right of centre. During take-out shots, a target stone was placed on the 8-foot line, and the laser equipped target broom was placed directly in front of the stone to allow for laser visibility.

Participants wore visual occlusion goggles and headphones to ensure that learning would not take place (Salmoni, Schmidt, & Walter, 1984). The goggles blocked vision after the stone crosses the first hog-line (Perkins-Ceccato, et al., 2003). Concurrently, the headphones would prevent auditory feedback of the delivery stone sliding, or hitting the target stone, by playing white noise until the stone's endpoint was measured and the stone was cleared from the house.

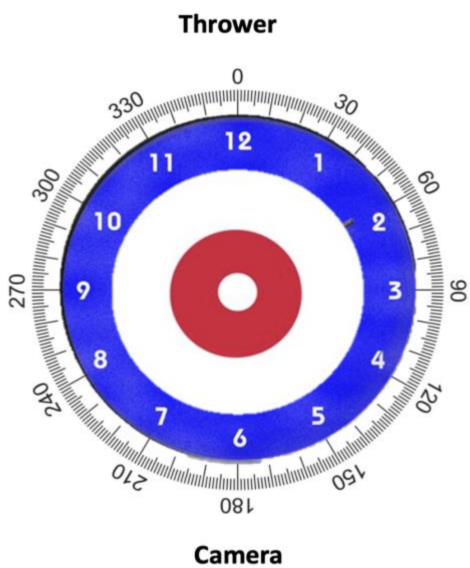
The experiment concluded with a post-experiment survey (Appendix B) that assessed ability to maintain focus instructions (Kearney, 2015), and how the experimental foci conditions compared to their usual focus strategy.

Dependent Variables

Performance Measures

Figure 2

Distal Hack Degrees from Center Orientation



Accuracy for all shots were measured by the mean time on broom, and variability (standard deviation) of time on broom during stone delivery. Time on broom was measured using a laser positioned immediately in front of the target curling broom in tandem with a high frame rate camera (IL5-H, Fastec Imaging, Canada) recording at 200Hz.

At endpoint, accuracy was laser measured (Laser Rock Measure, Curling Innovations Canada, Canada) for the distance from centre and a goniometer was used to record the degree from 0° as oriented in Figure 2. The measurements were interpreted utilizing traditional error measures (Constant Error, Absolute Constant Error, Radial Error and Variable Error) for the draw shot, relative to the centre of target. The measurements taken on the ice were the difference from the goal of movement (0cm) and were used for Radial Error (Schmidt, Lee, Winstein, Wulf, & Zelaznik, 2019). Radial error (RE) is the absolute deviation from the target and gives information on overall accuracy. The Radial error measure was used to determine constant error (CE). Constant error considers direction of deviation from the target. In this experiment overshooting the tee-line resulted in a positive score, and undershooting the tee-line resulted in a negative score. Absolute Constant Error is an absolute transformation of the CE to remove direction. Absolute Constant Error removes the possible canceling effect of CE scores and provides information on the average amount of bias from centre. Variable Error was used to provide information on how much deviation was present for the curlers compared to the condition mean. Variable Error was determined by the equation (Schmidt, et al., 2019):

$$Variable\ Error = \sqrt{\frac{\Sigma(x_i - M)^2}{n}}$$

Where Σ means the total sum. x_i is equal to a curlers trial measurement (RE) with i being the trial number. *M* is the curlers mean RE, and *n* is the total number of trials per condition.

Endpoint accuracy for take-out shots were recorded as a dichotic response; successful hit or miss. Of those misses, a dichotic response direction was recorded as toward the inside of the house or the outside of the house.

Kinematic Measures

Throw speed and throw speed variability for all shots were measured as the stone crossed the first hog line, the halfway point, and the second hog line. Each of the aforementioned lines were instrumented with a break-beam switch triggering a timestamp in the E-Prime Software (E-prime 3.0, Psychology Software Tools, Sharpsburg, PA). The distance between the break beams was recorded to allow for velocity measurements which were calculated by dividing the distance over time. The acceleration measurements were calculated by dividing the distance over time squared. The distance from the trigger break beam to hog line one was 6.40m, from hog line one to halfway was 10.97m and from halfway to hog line two was 10.97m.

Statistical Tests

Statistical outcomes were calculated using jamovi v.1.6 (The jamovi project, 2021). Significance (alpha) was set to $p<0.05$. Outliers were determined and removed if they were 2.5 standard deviations (SD) from the mean. Comparison violations to sphericity (Mauchly's W test of Sphericity, $p<0.05$) were corrected using the Greenhouse-Geisser procedure. For significant main effects Tukey's Honestly Significant Difference (HSD) post-hoc test was applied when an ANOVA was implemented on continuous variables, and for categorical data a McNemar test with a Holms-Bonferroni correction for Cochran Q tests. For non-significant interactions planned comparisons were conducted to examine relevant focus, throw, or turn effects.

Accuracy

For endpoint accuracy of draw deliveries, a continuous measure of distance in centimeters using traditional error measures (Constant Error, Absolute Constant Error, Radial Error and Variable Error) were recorded relative to the centre of target. For each error measure the mean accuracy was compared using a 3 focus (control, internal, external) x 2 handle (in-turn, out-turn) repeated measures ANOVA model.

For endpoint accuracy of take-out deliveries Cochrane's Q test and McNemar's test were used to compare a 2 accuracy (successful hit, miss) x 3 focus (control, internal, external) x 2 handle (in-turn, out-turn). Misses to the inside of the house or to the outside of the house were presented in a summary table.

For delivery accuracy, mean time of the stone on the line indicated by the broom pad was measured. A 3 focus (control, internal, external) x 2 handle (in-turn, out-turn) x 2 shot type (take-out, draw) ANOVA model was utilized.

Stone Travel Time, Velocity and Acceleration

Stone velocity (m/s) and acceleration (m/s^2) were measured at three time stamps (first hog line, centre line, and second hog line). At each distance we utilized a 3 focus (control, internal, external) x 2 handle (in-turn, out-turn) x 2 shot type (take-out, draw) ANOVA model.

The same ANOVA model was used on the mean time (ms) of the stone to travel from hog-to-hog.

Stone Rotation

Stone rotation was measured by counting the number of handle turns from the first hog line to the second hog line. A 3 focus (control, internal, external) x 2 handle (in-turn, out-turn) x 2 shot type (take-out, draw) ANOVA model was utilized.

Questionnaire

Categorical variables are described in Table 11, 12, 13, and 14. A thematic analysis was conducted on any open-ended questions. Population demographics are presented in a summary table (Table 1, & Table 2).

Results

Eleven participants were included for results analysis (cis female n=4 cis male =7) with an average age of 27.23 (SD=4.56). The population demographics can be seen in Table 1 and 2 describing their roles and turn preference respectively. One participant could not participate in day two of the study due to COVID-19 pandemic restrictions resulting in 10 participants (cis female n=4, cis male n =6) with an average age of 27.7 (SD=4.57) for the internal focus conditions, and for the post-experiment questionnaire.

A total of 3.75% of trials from draw shot accuracy scores were rejected for overshooting the house and hitting the hack or the end of the sheet of ice. A total of 0.3125% of trials were rejected for prematurely removing the stone from the ice prior to completing measurements. A total of 1.563% of trials from accuracy scores were rejected for exceeding 2.5 SD of the mean. A total of 0.781% of trials from BB1 speed and acceleration scores each were rejected due to an absence of triggering. A total of 0.781% of trials from BB2 speed and acceleration scores each were rejected due to an absence of triggering. A total of 2.344% of trials from BB3 speed and acceleration scores each were rejected due to an absence of triggering. A total of 2.344% of trials from hog-to-hog time were rejected due to an absence of triggering. A total of 29.531% of trials from time on line time were not able to be included due to camera file corruption or recording error. A total of 30.781% of trials from rotation were not able to be included due to camera file corruption or recording error. A total of 0.156% of rotation trials were rejected for exceeding 2.5 SD of the mean. A total of 1.875% of trials for takeout accuracy data were not included due to equipment misfires.

Table 1

Quantity of Curlers by Position.

Position	Amount
Lead	2
Second	3
Third	3
Skip	3

Table 2

Quantity of Curlers by Turn Style Preference.

Turn Preference	Amount
In-turn	7
Out-turns	1
In-turn for draw/ Out-Turn for take-outs	2
No preference	1

The average ice and air temperatures are listed in Table 3. A one-way repeated measures ANOVA was conducted for control radial error scores to see if there was a day effect and thus potentially an ice effect. There were no observable significant main effect on day [$F(2,4)=2.04$, $p=0.245$, $\eta^2_p=0.505$].

Table 3

Mean and Standard Deviation of Ice and Air Temperature (℃)

	Mean	SD
Ice Temperature (°C)	-6.89	17.29
Air Temperature (°C)	5.72	17.50

Draw Accuracy

Table 4

Mean and Standard Deviation of Constant Error (cm), Radial Error (cm), Absolute Constant Error (cm), and Variable Error (cm) of End Point Accuracy of Draws as a Function of Focus and Turn Style.

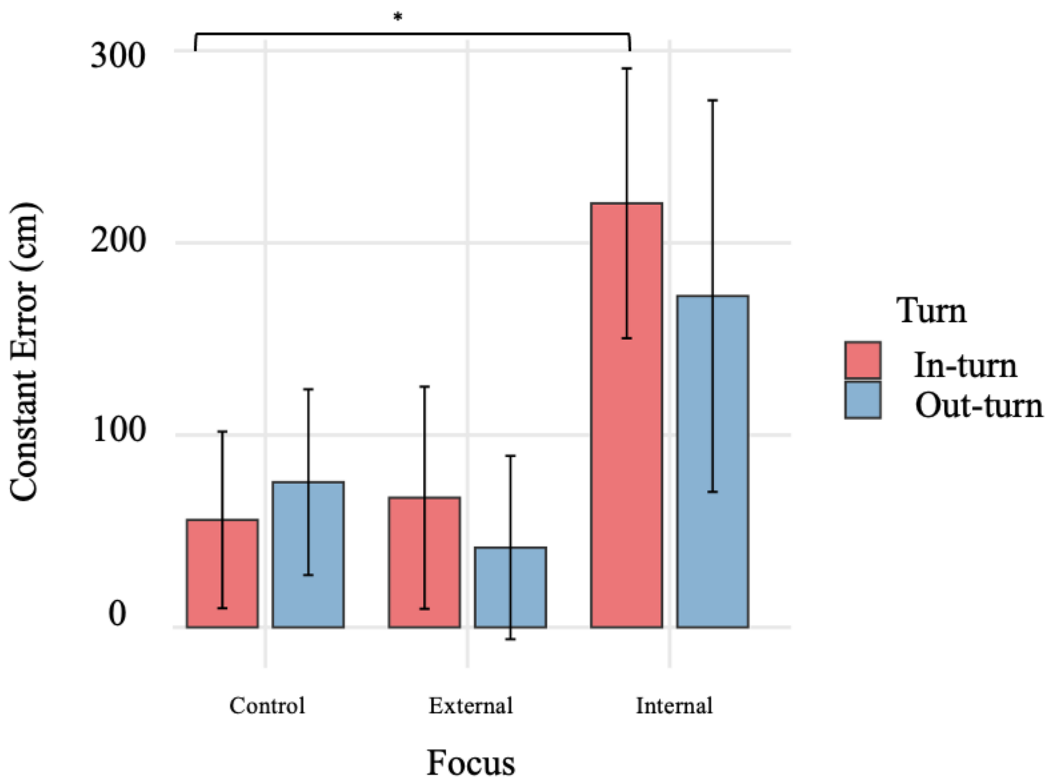
	Constant Error (cm)		Radial Error (cm)		Absolute Constant Error (cm)		Variable Error (cm)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Control In-turn Draw	-55.8	152	143	87.4	117	108	72.2	41.1
Control Out-turn Draw	-75.5	160	114	66.5	119	195	91.1	88
Internal In-turn Draw	-221	222	263	177	242	363	106	71.7
Internal Out-turn Draw	-172	322	285	226	269	416	104	61.3
External In-turn Draw	-67.4	192	183	104	150	227	81.2	51.2

External Out-turn Draw	-41.5	158	144	73	134	184	62.3	23.8

Constant Error (CE)

Figure 3

Constant Error (cm) of Draw Endpoint Accuracy as a Function of Focus and Turn Style.



Note. Standard error of the mean is represented in the figure by error bars. Asterisks indicates a significant planned comparison.

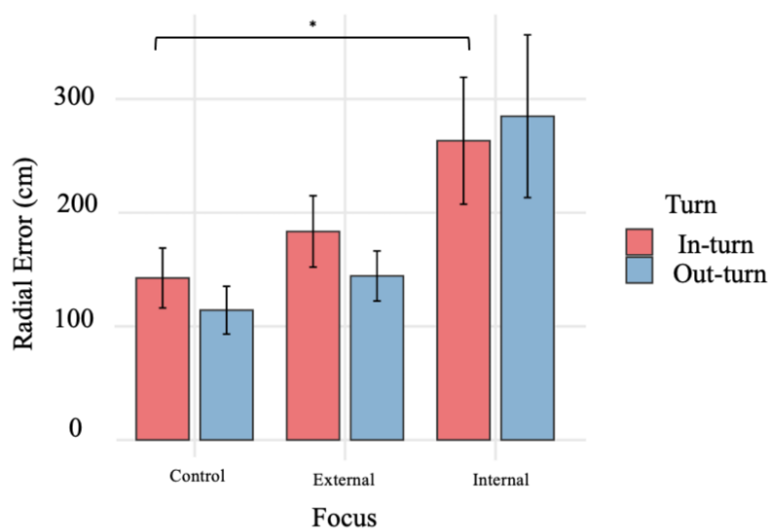
A two-way repeated measures ANOVA was performed to analyze the effect of focus and turn style on the constant error scores for draws. Mauchly's Test of Sphericity indicated that the sphericity assumption had been violated for the focus factor, $x^2(2)=0.384$, $p=0.035$, therefore a Greenhouse-Geisser correction was implemented. Analysis revealed that there was not a statistically significant main effect between focus $F(1.24, 9.90)=1.097$, $p=0.337$, $\eta^2_p=0.049$, turn style $F(1,8)=0.758$, $p=0.409$, $\eta^2_p=0.008$, or an interaction effect between Focus*Turn Style, $F(2,16)=0.112$, $p=0.894$, $\eta^2_p=0.001$.

Planned comparisons between focus conditions revealed that a control in-turn draw (M=-55.8cm, SD=152cm) had significantly lower CE score (t(9)=-2.2830, p=0.048, Cohen's d=-0.7219) than an internal focus in-turn draw (M=-221cm, SD=222cm) as seen in Figure 3.

Radial Error

Figure 4

Radial Error (cm) of Draw Endpoint Accuracy as a Function of Focus and Turn Style



Note. Standard error of the mean is represented in the figure by error bars. Asterisks indicates a significant planned comparison.

A two-way repeated measures ANOVA was performed to analyze the effect of focus and turn style on Radial Error scores for draws. Mauchly's Test of Sphericity indicated that the sphericity assumption had been violated for the focus factor, $x^2(2)=0.321$, $p=0.019$, and therefore a Greenhouse-Geisser correction was implemented.

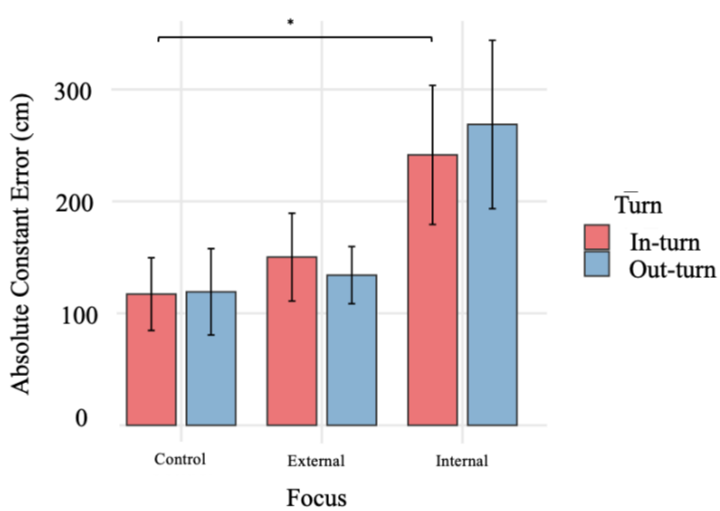
Analysis revealed that there was not a statistically significant main effect between focus $F(1.19,9.53)=3.358$, $p=0.094$, $\eta^2_p=0.296$, turn style $F(1,8)=0.161$, $p=0.699$, $\eta^2_p=0.020$, or interaction effect between Focus*Turn Style, $F(2,16)=0.447$, $p=0.647$, $\eta^2_p=0.053$.

Planned comparisons between focus conditions revealed that a control In-turn draw (M=143cm, SD=87.4cm) had significantly lower RE score (t(9)=-3.205, p=0.011, Cohen's d = -1.013) than an Internal focus in-turn draw (M=263cm, SD=177cm) as seen in Figure 4.

Absolute Constant Error

Figure 5

Absolute Constant Error (cm) of Draw Endpoint Accuracy as a Function of Focus and Turn Style



Note. Standard error of the mean is represented in the figure by error bars. Asterisks indicates a significant planned comparison.

A two-way repeated measures ANOVA was performed to analyze the effect of focus and turn style on Absolute Constant Error scores for draws. Analysis revealed a statistically significant main effect for focus $F(2,18)=3.7497$, $p=0.044$, $\eta^2_p=0.294$, but not for turn style $F(1,9)=0.0155$, $p=0.917$, $\eta^2_p=0.001$. There was not a statistically significant interaction effect between Focus*Turn Style $F(2,18)=0.4178$, $p=0.665$, $\eta^2_p=0.044$.

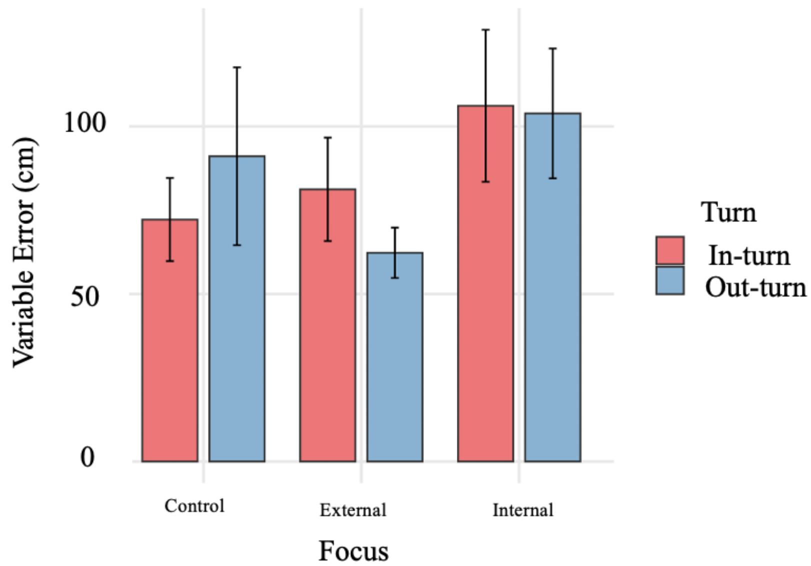
Post hoc testing for focus comparisons with Tukey's HSD correction revealed that absolute constant error scores for control were not significantly different than an internal focus $t(9)=-2.597$, $p=0.068$ or external focus $t(9)=-0.904$, $p=0.651$ and that an external focus and internal focus $t(9)=1.608$, $p=0.291$ did not significantly differ.

Planned comparisons between focus conditions revealed that a control in-turn draw (M=117cm, SD=108cm) had significantly lower absolute constant error score ($t(9)=-2.8405$, $p=0.019$, Cohen's $d=-0.8982$) than an internal focus in-turn draw (M=242cm, SD=120cm) as seen in Figure 5.

Variable Error

Figure 6

Mean Variable Error (cm) of End Point Accuracy as a Function of Focus and Turn Style



Note. Standard error of the mean is represented in the figure by the error bars.

Analysis revealed that there was not a statistically significant main effect between focus $F(2,16)=2.840$, $p=0.088$, $\eta^2_p=0.262$, turn style $F(1,8)=0.796$, $p=0.398$, $\eta^2_p=0.091$, or an interaction effect between focus*turn style, $F(2,16)=0.237$, $p=0.792$, $\eta^2_p=0.029$.

Planned comparisons between focus conditions did not reveal any significant differences as seen in Figure 6.

Take-Out Accuracy

Cochran's Q test was used to determine if the percentage of successful hits differed among focus conditions for in-turn take-outs and again for out-turn take-outs. McNemar's test with a Holms-Bonferroni adjustment was applied as a post-hoc for significant results.

McNemar's test was used to determine if there was a difference between the proportion of successful hits to misses for comparisons of in-turn take-outs to out-turn take-outs. The number of successful hits as well as misses can be found in Table 5.

Table 5

Number of Successful Hits, Misses, Misses Toward the Inside of the House and Misses Toward the Outside of the House for Take-outs

	Successful Hit	Miss	
		Miss Outside	Miss Inside
Control In-turn Take-out	44	11	
		2	9
Control Out-turn Take-out	41	12	
		1	11
Internal In-turn Take-out	37	10	
		6	4
Internal Out-turn Take-out	35	15	
		7	8
External In-turn Take-out	43	10	
		4	6
External Out-turn Take-out	53	2	
		0	2

Hit/Miss

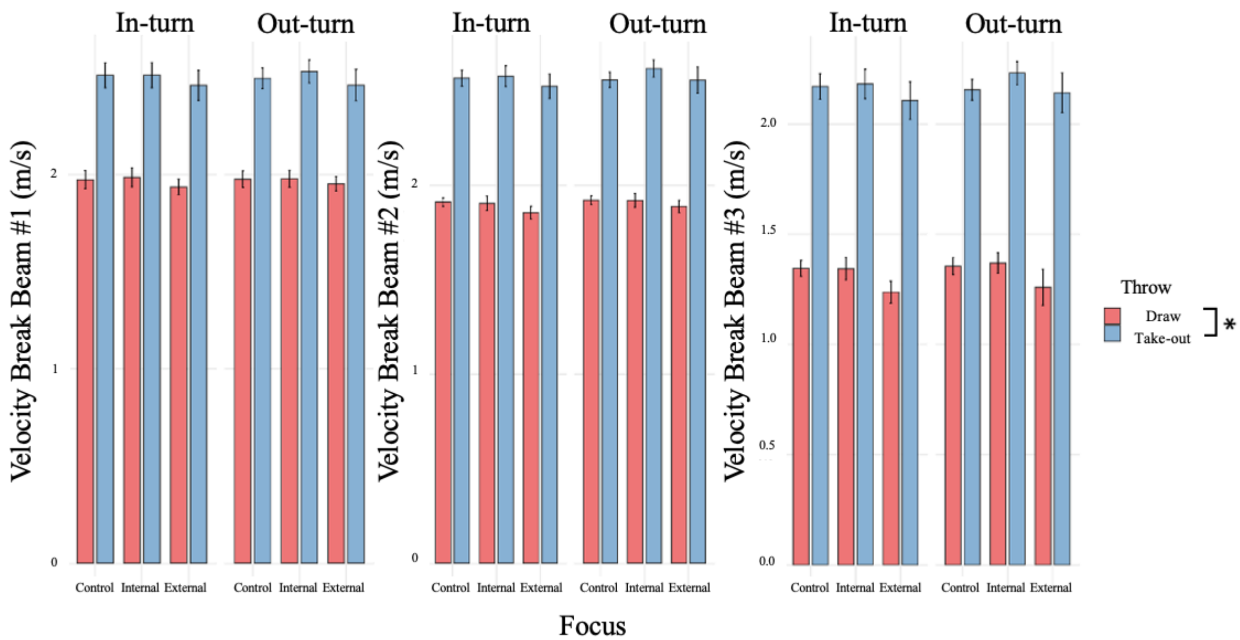
Cochran's Q test revealed that the percentage of hits was not significantly different [$x^2(2)=0.091$, $p=0.956$] between control, internal focus, and external focus when an in-turn was applied. The percentage of hits was significantly different [$x^2(2)=13.778$, $p=0.001$] between out-turn foci conditions. McNemar's test was used as a post-hoc test with a Holms-Bonferroni adjustment. Analysis revealed a statistically significant difference [$\chi^2(1)=9.00$, $p_{Holms\text{-}Bonferroni}=0.009$] between the proportion of successful hits and misses observed between an internal out-turn takeout and an external out-turn takeout. An internal out-turn take-out successfully hit 70.2% of the time and an external out-turn take-out successfully hit 96.4% of the time. Although no significant difference was observed between a control out-turn takeout and an external out-turn take-out the comparison was approaching a significant difference prior to a Holms-Bonferroni adjustment [χ^2 (1)=3.57, p=0.059].

A significant difference [χ^2 (1)=5.33, p=0.021] was observed between the proportion of successful hits and misses between an external in-turn takeout and an external out-turn take out. An external in-turn take-out successfully hit 81.1% of the time and an external out-turn take-out successfully hit 96.4% of the time.

Stone Velocity

Figure 7

Mean Velocity at BB1, BB2, and BB3 as a Function of Focus, Throw and Turn Style



Note. Standard error of the mean is represented in the figure by the error bars. Asterisks indicates a significant difference.

Table 6

Mean and Standard Deviation of BB1, BB2, and BB3 Velocity as a Function of Focus, Throw, and Turn Style

	BB1 Velocity (m/s)		BB2 Velocity (m/s)		BB3 Velocity (m/s)	
	Mean	SD	Mean	SD	Mean	SD

Control In-turn Draw	1.97	0.156	1.91	0.0730	1.35	0.119
Control Out-turn Draw	1.98	0.140	1.92	0.0777	1.36	0.127
Internal In-turn Draw	1.94	0125	1.85	0.109	1.24	0.157
Internal Out-turn Draw	1.95	0.115	1.89	0.103	1.26	0.259
External In-turn Draw	1.99	0.163	1.90	0.126	1.34	0.167
External Out-turn Draw	1.98	0.146	1.92	0.121	1.37	0.152
Control In-turn Take-out	2.51	0.212	2.57	0.142	2.17	0.193
Control Out-turn Take-out	2.49	0.175	2.56	0.136	2.16	0.156
Internal In-turn Take-out	2.46	0.245	2.52	0.203	2.11	0.269
Internal Out-turn Take-out	2.46	0.256	2.56	0.220	2.14	0.284
External In-turn Take-out	2.51	0.215	2.58	0.181	2.18	0.220
External Out-turn Take-out	2.53	0.196	2.62	0.149	2.23	0.172

Velocity at the First Hog-line

A three-way repeated measures ANOVA was performed to analyze the effect of throw, focus and turn style on velocity at the first hog line. Analysis revealed a statistically significant main effect for throw $F(1,9)=211.97371$, $p<0.001$, $\eta^2_p=0.959$, but not for focus $F(2,18)=0.84911$, $p=0.444$, $\eta^2_p=0.086$ or turn style $F(1,9)=0.00870$, $p=0.0928$, $\eta^2_p=0.001$. Analysis revealed a statistically significant interaction effect for Focus*Throw*Turn $F(2,18)=3.95276$, $p=0.038$, $\eta^2_p=0.305$. There was not a statistically significant interaction effect between Focus*Throw $F(2,18)=0.77330$, $P=0.476$, $\eta^2_p=0.079$, Focus*Turn Style $F(2,18)=0.46024$, $p=0.638$, $\eta^2_p=0.049$, or Throw*Turn $F(1,9)=0.01890$, $p=0.894$, $\eta^2_p=0.002$.

Post hoc testing for throw comparisons with Tukey's HSD correction revealed that the curler's velocity at BB1 when throwing draws (M=1.95m/s, SD=0.138m/s) were significantly slower than take-outs (M=2.48m/s, SD=0.210m/s) $t(9)=-14.6$, $p_{Tukey}<0.001$.

Post hoc testing for focus*throw*turn comparisons with Tukey's HSD correction revealed that draws were performed at significantly slower speeds than take-outs as seen in Figure 7. The mean and standard deviations at BB1 can be found in Table 6. Control in-turn draw deliveries had a BB1 speed that was significantly slower [$t(9)=-17.43564$, $p_{Tukey}<0.001$] than a control in-turn take-out deliveries. Control out-turn draw deliveries had a BB1 speed that was significantly slower [$t(9)=-21.22648$, $p_{Tukey}<0.001$] than a control out-turn take-out deliveries. Internal focus in-turn draw deliveries had a BB1 speed that was significantly slower [$t(9)=-11.60344$, $p_{Tukey}<0.001$] than an internal focus in-turn take-out deliveries. Internal focus out-turn draw deliveries had a BB1 speed that was significantly slower [$t(9)=-10.20906$, $p_{Tukey}<0.001$] than an internal focus out-turn take-out deliveries. External focus in-turn draw deliveries had a BB1 speed that was significantly slower [$t(9)=-13.79005$, $p_{Tukey}<0.001$] than an external focus in-turn take-out deliveries. External focus out-turn draw deliveries had a BB1 speed that was significantly slower [$t(9)=-13.31461$, $p_{Tukey}<0.001$] than an external focus out-turn take-out deliveries.

Velocity at Half

A three-way repeated measures ANOVA was performed to analyze the effect of throw, focus and turn style on velocity at the halfway point. Analysis revealed a statistically significant main effect for throw $F(1,9)=333.0606$, $p<0.001$, $\eta^2_p=0.974$, but not for focus $F(2,18)=1.1566$, $p=0.337$, $\eta^2_p=0.114$ or turn style $F(1,9)=1.9902$, $p=0.192$, $\eta^2_p=0.974$. Analysis revealed that there was not a statistically significant interaction effect between focus*throw $F(2,18)=0.7193$, $P=0.501$, $\eta^2_p=0.074$, focus*turn style $F(2,18)=2.1552$, $p=0.145$, $\eta^2_p=0.193$, throw*turn $F(1,9)=0.0828$, $p=0.780$, $\eta^2_p=0.009$, or focus*throw*turn $F(2)=1.7487$, $p=0.202$, $\eta^2_p=0.163$.

Post hoc testing for throw comparisons with Tukey's HSD correction revealed that the curlers speeds at break beam 2 when throwing draws (M=1.90m/s, SD=0.102m/s) were significantly slower [$t(9)=-18.2$, $p_{Tukey}<0.001$] than take-outs (M=2.57m/s, SD=0.169m/s).

Planned comparisons revealed that draw deliveries were significantly slower than take out deliveries at BB2 as seen in Figure 7. The mean and standard deviations at BB2 can be found in Table 6. Control in-turn draw deliveries had a BB2 speed that was significantly slower [$t(10)=-18.00$, $p<0.001$, Cohen's $d=-5.42$] than a control in-turn take-out deliveries. Control out-turn draw deliveries had a BB2 speed that was significantly slower [$t(10)=-20.5$, $p<0.001$, Cohen's $d=-6.17$] than a control out-turn take-out deliveries. Internal focus in-turn draw deliveries had a BB2 speed that was significantly slower [$t(9)=-15.6$, $p<0.001$, Cohen's $d=-4.94$] than an internal focus in-turn take-out deliveries. Internal focus out-turn draw deliveries had a BB2 speed that was significantly slower [$t(9)=-13.0$, $p<0.001$, Cohen's $d=-4.10$] than an internal focus out-turn take-out deliveries. External focus in-turn draw deliveries had a BB2 speed that was significantly slower [$t(10)=-15.4$, $p<0.001$, Cohen's $d=-4.66$] than an external focus in-turn take-out deliveries. External focus out-turn draw deliveries had a BB2 speed that was significantly slower [t(10)=-20.7, p<0.001, Cohen's d=-6.23] than an external focus out-turn take-out deliveries.

Velocity at the Second Hog-line

A three-way repeated measures ANOVA was performed to analyze the effect of throw, focus and turn style on velocity at the second hog line. Mauchly's Test of Sphericity indicated that the sphericity assumption had been violated for the focus*throw*turn interaction factor, $x^2(2)=0.243$, p=0.003 , and therefore a Greenhouse-Geisser correction was implemented. Analysis revealed a statistically significant main effect for throw F(1,9)=356.7065 p<0.001, n2p=0.975, but not for focus F(2,18)=1.7946, p=0.0.195, η^2_p =0.166 or turn style F(1,9)=0.5340, p=0.484, η^2_p =0.056. Analysis revealed that there was not a statistically significant interaction effect between focus*throw F(2,18)=0.5586, p=0.582, η^2_p =0.058, focus*turn Style F(2,18)=0.7818, p=0.473, η^2_p =0.0.80, throw*turn F(1,9)=0.0889, p=0.772, η^2_p =0.010, or focus*throw*turn F(1.14, 10.24)=0.6866, p=0.445, η^2_p =0.071.

Post hoc testing for throw comparisons with Tukey's HSD correction revealed that the curler's velocity at the second hog-line when throwing draws (M=1.31m/s, SD=0.169m/s) were significantly slower [t(9)=-18.9, p_{Tukey}<0.001] than take-outs (M=2.17m/s, SD=0.213m/s).

Planned comparisons revealed no significant velocity differences when comparing focus conditions at the second hog-line. Although no significant differences were seen control out-turn take-outs when compared to external out-turn take-outs approached significance [t(10)=-2.1202, p=0.060].

Planned comparisons revealed no significant velocity differences when comparing turn styles. Although no significant differences were seen external in-turn take-outs when compared to external out-turn take-outs approached significance [t(10)=-2.15, p=0.057, Cohen's d = -0.648].

Planned comparisons revealed that draws were significantly slower than take-outs when comparing throws as seen in Figure 7. The mean and standard deviations at BB3 can be found in Table 6. Control in-turn draw deliveries had a BB3 speed that was significantly slower [t(10)=-19.04, p<0.001, Cohen's d=-5.742] than a control in-turn take-out deliveries. Control out-turn draw deliveries had a BB3 speed that was significantly slower [t(10)=-23.05, p<0.001, Cohen's d = -6.950] than a control out-turn take-out deliveries. Internal focus in-turn draw deliveries had a BB3 speed that was significantly slower [t(9)=-15.72, p<0.001, Cohen's d = -4.972] than an internal focus in-turn take-out deliveries. Internal focus out-turn draw deliveries had a BB3 speed that was significantly slower [t(9)=-10.89, p<0.001, Cohen's d = -3.444] than an internal focus out-turn take-out deliveries. External focus in-turn draw deliveries had a BB3 speed that was significantly slower [t(10)=-17.54, p<0.001, Cohen's d = -5.289] than an external focus in-turn take-out deliveries. External focus out-turn draw deliveries had a BB3 speed that was significantly slower [t(10)=-20.19, p<0.001, Cohen's d = -6.088] than an external focus out-turn take-out deliveries.

Release Velocity and Draw Delivery Constant Error Score Correlation

Table 7

Pearson's Correlation for Draw Delivery Constant Error Score and Release Velocity

Condition	Pearson's Rho	p-value
Control In-turn Draw	0.879	<0.001*

Control Out-turn Draw	0.559	0.074
Internal In-turn Draw	0.654	0.040*
Internal Out-turn Draw	0.473	0.167
External In-turn Draw	0.815	0.002*
External Out-turn Draw	0.857	<0.001*

Note. An asterisk indicates a significant correlation

Figure 8

Pearson's Correlation for Control In-turn Draw

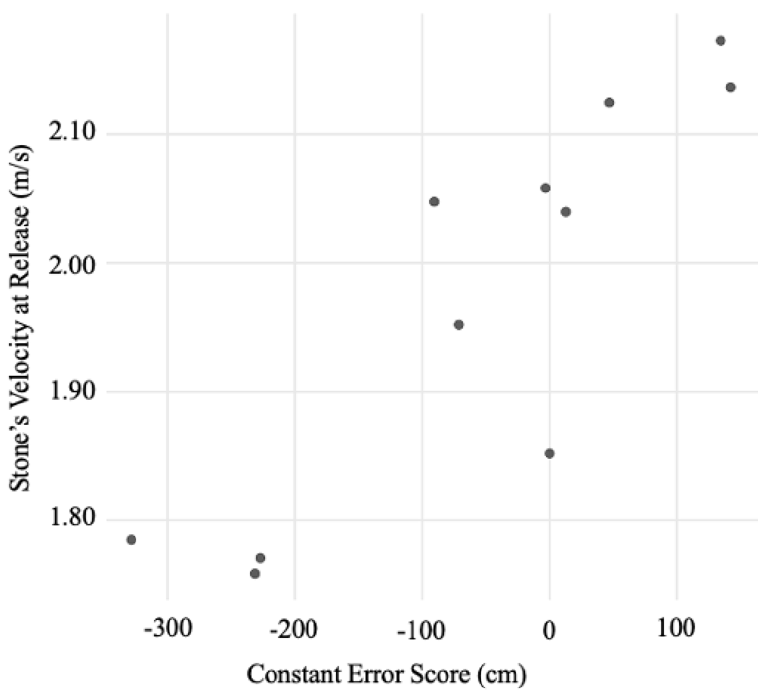


Figure 9

Pearson's Correlation for Control Out-turn Draw

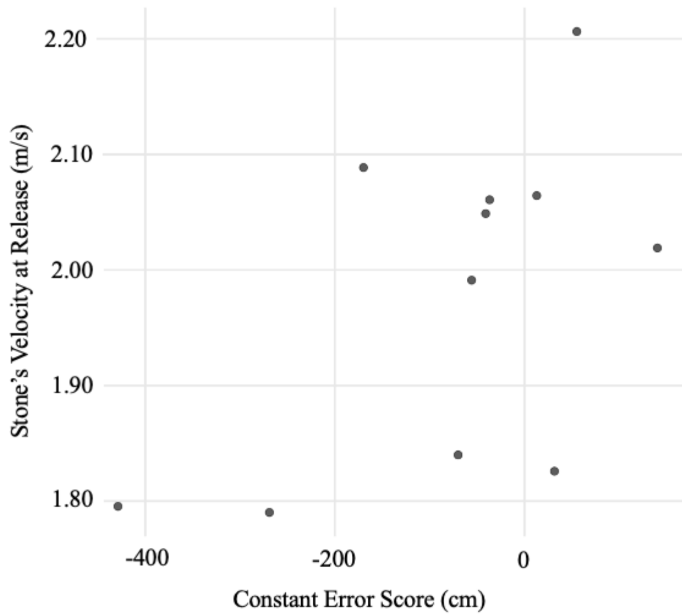


Figure 10

Pearson's Correlation for Internal Focus In-turn Draw

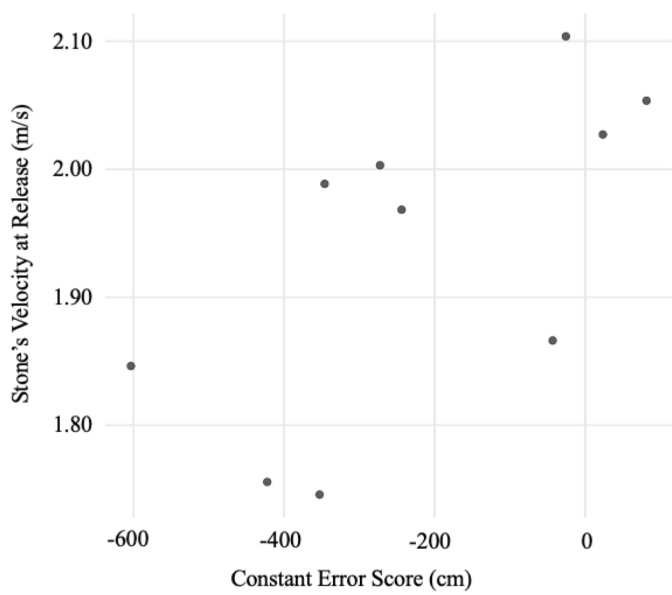


Figure 11

Pearson's Correlation for Internal Focus Out-turn Draw

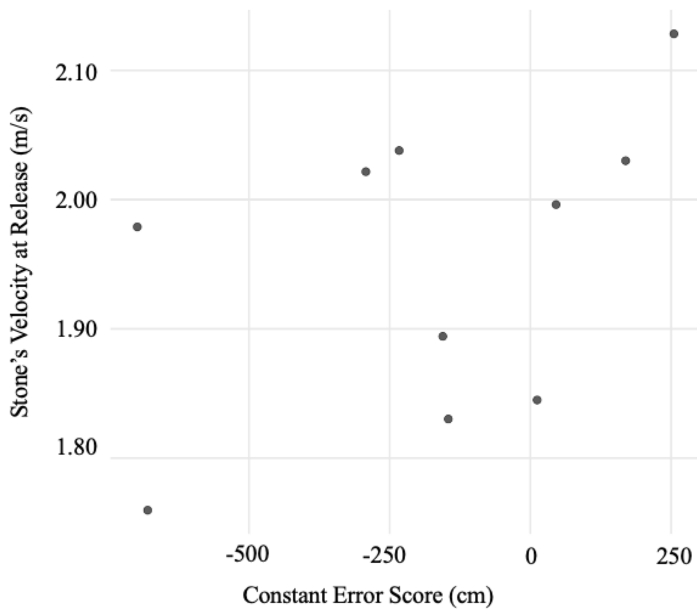


Figure 12

Pearson's Correlation for External Focus In-turn Draw

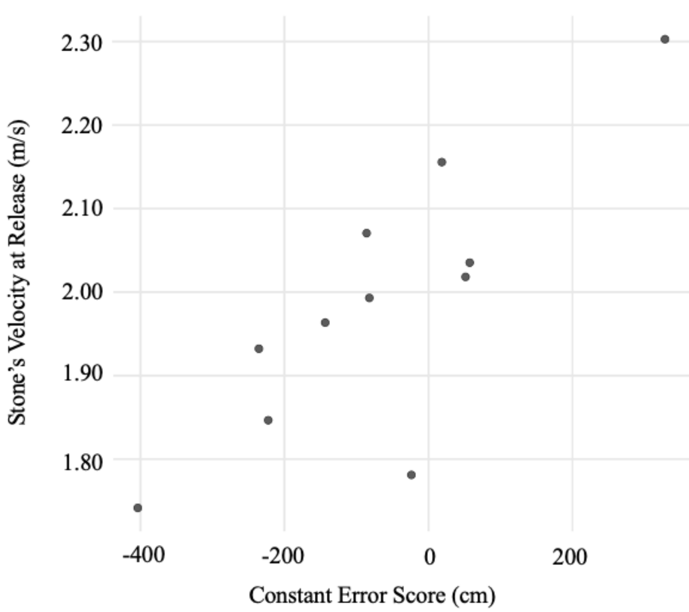
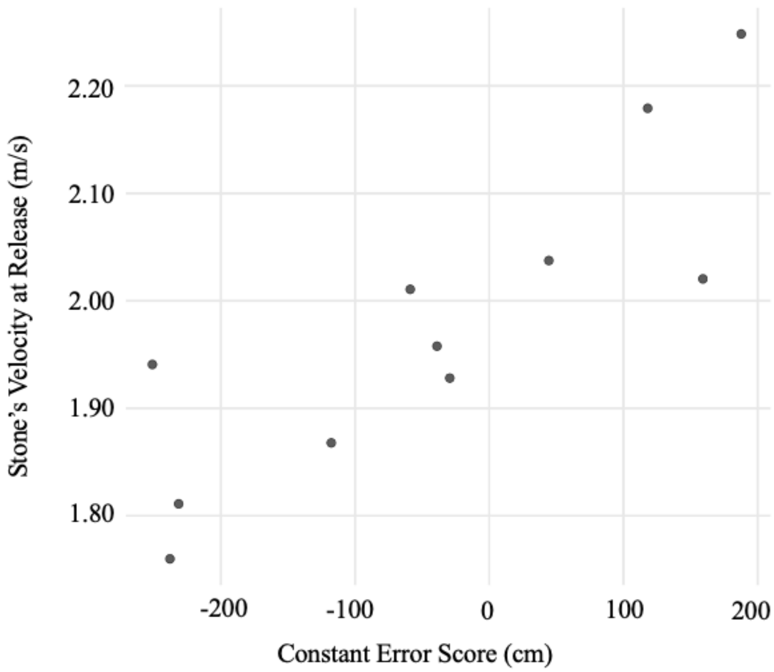


Figure 13

Pearson's Correlation for External Focus Out-turn Draw



Pearson's rho was used to assess mean velocity at release (BB1) and mean CE score correlation for all draw deliveries which can be found in Table 7 and seen in Figure 8, 9, 10, 11, 12, and 13. Velocity at release and CE score for control in-turn draws (rho=0.879, p<0.001), internal in-turn draws (rho=0.654, p=0.040), external in-turn draws (rho=0.815, p=0.002), and external out-turn draws (rho=0.857, p<0.001) were found to significantly correlate with more negative CE scores occurring at slower velocities.

Release Velocity and Take-out Delivery Accuracy Correlation

Point-biserial correlation was ran between take-out accuracy and velocity at release (BB1) for the raw data scores of each condition. The results of the point-biserial correlation can be found in Table 8 and seen in Figure 14, 15, 16, 17, 18, and 19.. There was a statistically significant correlation between take-out accuracy and velocity at release (BB1) for control in-turn take-out shots, $r_{pb}(55)=0.492$, $p<0.001$, with successful hits (M=2.562m/s, SD=0.187m/s2) occurring at greater speeds than misses (M=2.304m/s, SD=0.178m/s). There was a statistically significant correlation between takeout accuracy and velocity at release for control out-turn take-out deliveries, $r_{pb}(53)=0.479$, $p<0.001$, with successful hits (M=2.540m/s, SD=0.152m/s) occurring at greater speeds than misses (M=2.329m/s, SD=0.206m/s). There was a statistically significant correlation between take-out accuracy and velocity at release for internal focus in-turn take-outs, $r_{pb}(50)=0.419$, $p=0.002$, with successful hits (M=2.511m/s, SD=0.203m/s) occurring at greater speeds than misses (M=2.269m/s, SD=0.283m/s). There was a statistically significant correlation between take-out accuracy and velocity at release for internal focus out-turn take-outs, $r_{pb}(49)=0.629$, $p<0.001$, with successful hits (M=2.563m/s, SD=0.200m/s) occurring at greater speeds than misses (M=2.210m/s, SD=0.206m/s). There was a statistically significant correlation between take-out accuracy and velocity at release for external focus in-turn take-outs, $r_{pb}(55)=0.289$, $p=0.033$, with successful hits (M=2.540m/s, SD=0.195m/s) occurring at greater speeds than misses (M=2.380m/s, SD=0.264m/s).

Table 8

Point-Biserial Correlation for Take-out Accuracy and Release Velocity

Condition	r_{pb}	p value
Control In-turn Takeout	0.492	<0.001*
Control Out-turn Takeout	0.479	<0.001*
Internal In-turn Takeout	0.419	0.002*

Internal Out-turn Takeout	0.629	<0.001*
External In-turn Takeout	0.289	0.033*
External Out-turn Takeout	0.076	0.580

Note. an asterisk indicates a significant correlation

Figure 14

Point-Biserial Correlation for Control In-turn Takeout

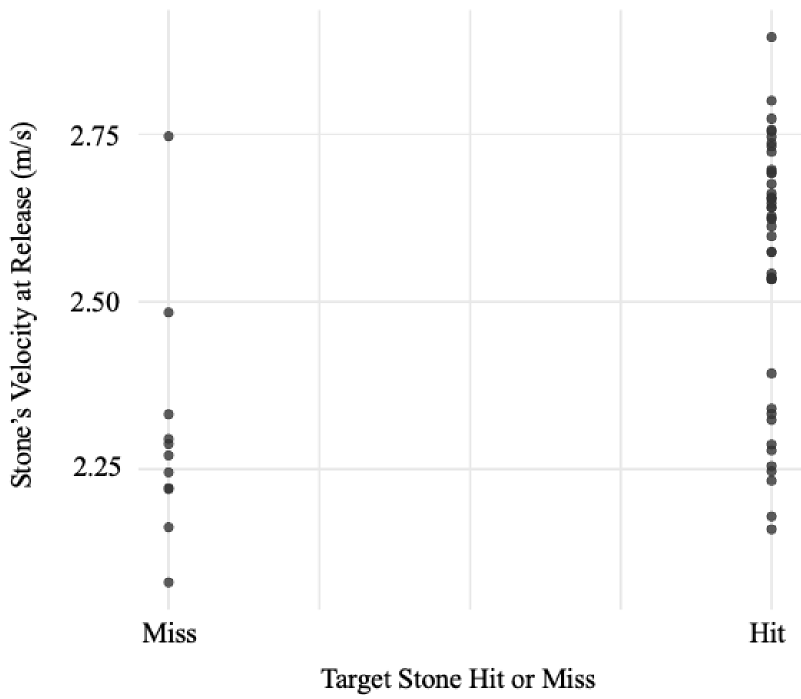


Figure 15

Point-Biserial Correlation for Control Out-turn Takeout

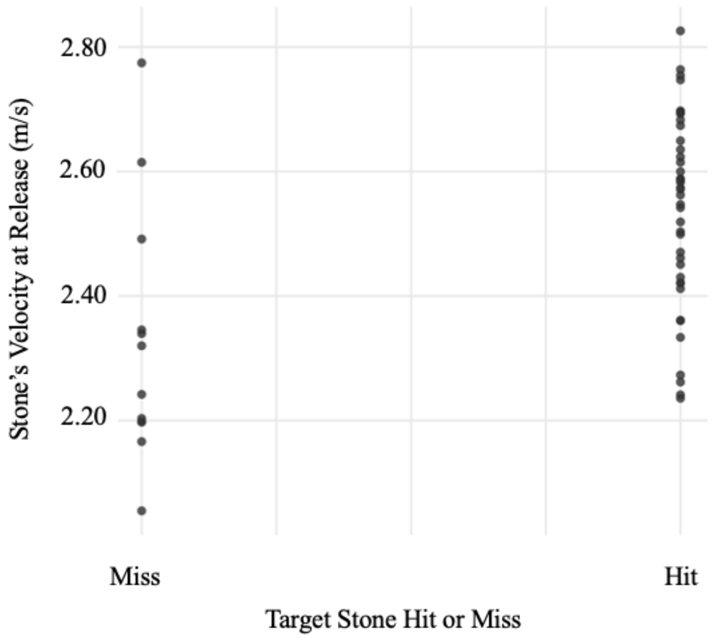


Figure 16

Point-Biserial Correlation for Internal Focus In-turn Takeout

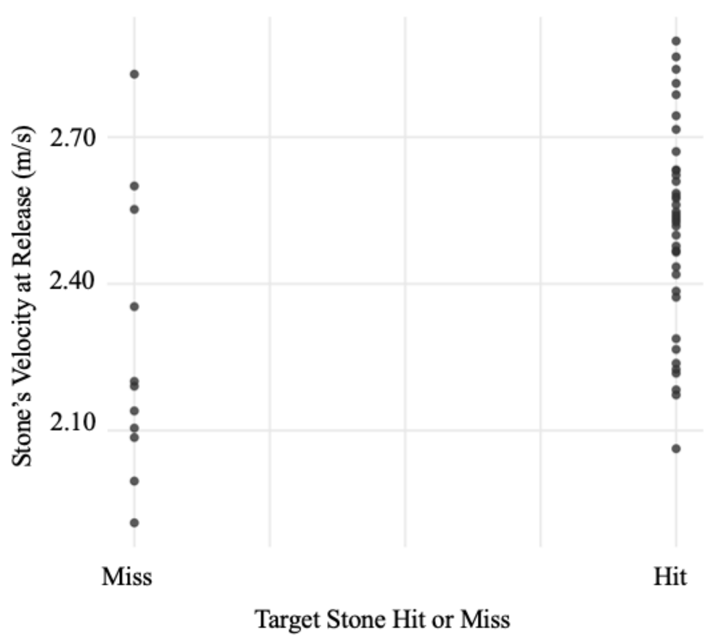


Figure 17

Point-Biserial Correlation for Internal Focus Out-turn Takeout

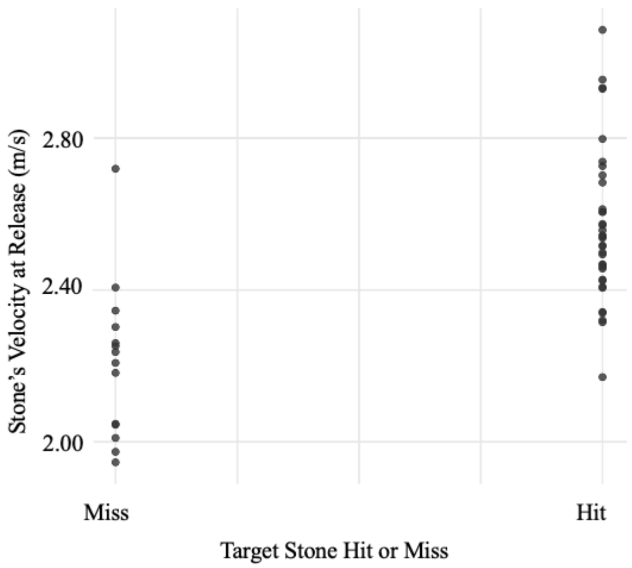


Figure 18

Point-Biserial Correlation for External Focus In-turn Takeout

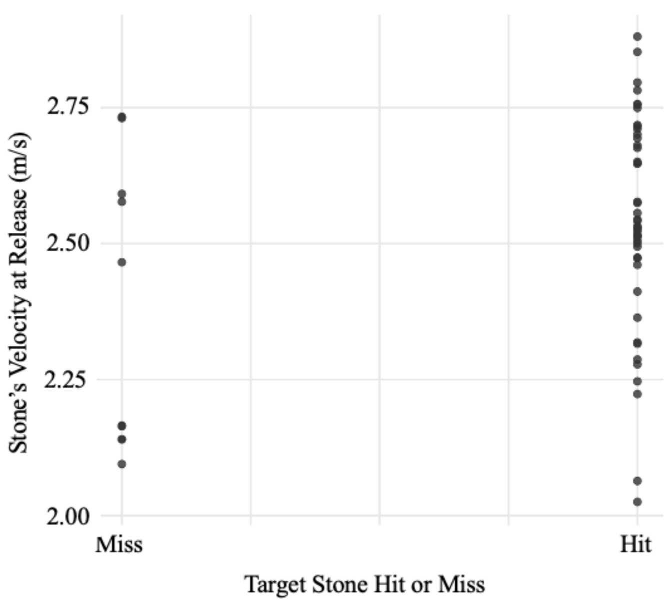
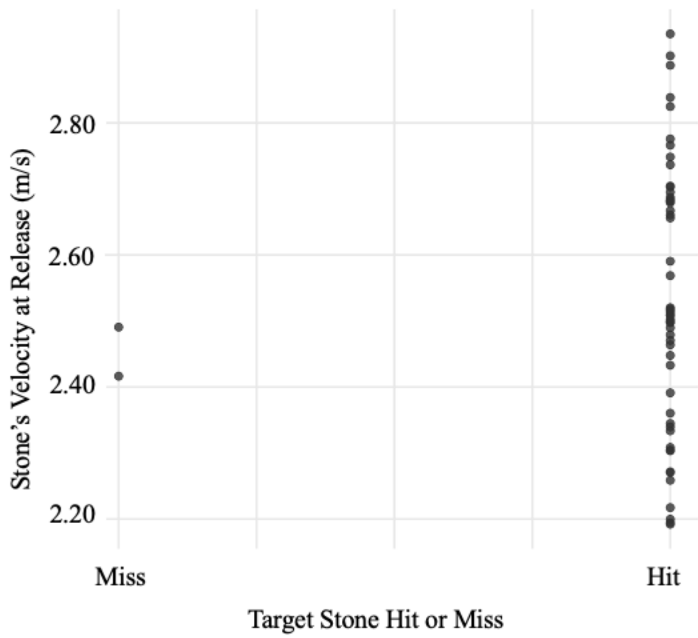


Figure 19

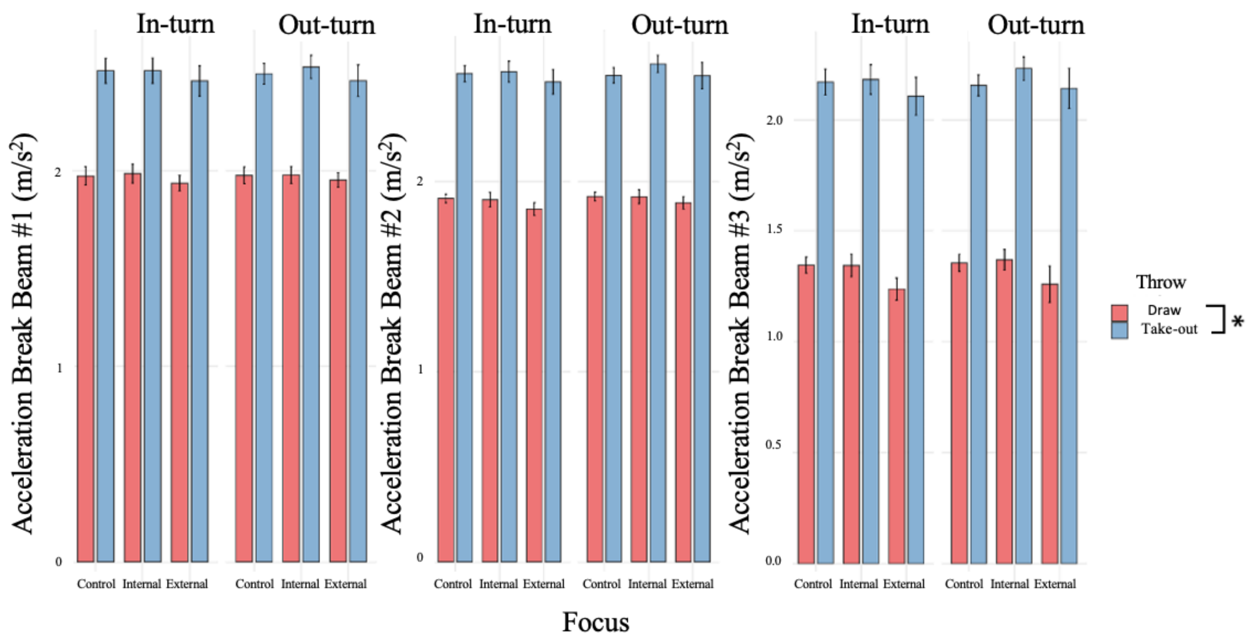
Point-Biserial Correlation for External Focus Out-turn Takeout



Stone Acceleration

Figure 20

Mean Acceleration at BB1, BB2, and BB3 as a Function of Focus, Throw and Turn Style.



Note. Standard error of the mean is represented in the figure by the error bars. Asterisks indicates a significant difference.

Table 9

Mean and Standard Deviation of BB1, BB2, and BB3 Acceleration as a Function of Focus, Throw, and Turn Style

	BB1 Acceleration (m/s^2)		BB2 Acceleration (m/s^2)		BB3 Acceleration (m/s^2)	
	Mean	SD	Mean	SD	Mean	SD
Control In-turn Draw	0.612	0.0953	0.333	0.0259	0.167	0.0291

Control Out-turn Draw	0.613	0.0867	0.337	0.0275	0.170	0.0317
Internal In-turn Draw	0.588	0.0747	0.315	0.0374	0.143	0.0357
Internal Out-turn Draw	0.598	0.0694	0.326	0.0353	0.151	0.0525
External In-turn Draw	0.620	0.102	0.332	0.0457	0.167	0.0436
External Out-turn Draw	0.615	0.0912	0.337	0.0433	0.173	0.0404
Control In-turn Take-out	0.991	0.164	0.603	0.0651	0.433	0.0753
Control Out-turn Take-out	0.978	0.135	0.598	0.0625	0.426	0.0602
Internal In-turn Take-out	0.953	0.186	0.584	0.0907	0.411	0.100
Internal Out-turn Take-out	0.955	0.198	0.600	0.102	0.426	0.109
External In-turn Take-out	0.992	0.165	0.608	0.0869	0.438	0.0848
External Out-turn Take-out	1.01	0.156	0.627	0.0725	0.457	0.0702

Acceleration at the First Hog-line

A three-way repeated measures ANOVA was performed to analyze the effect of throw, focus and turn style on acceleration at the first hog-line. Analysis revealed that there was a statistically significant main effect for throw $F(1)=129.19666$, $p<0.001$, $\eta^2_p=0.935$, but not for focus $F(2)=0.81008$, $p=0.460$, $\eta^2_p=0.083$ or turn style $F(1)=1.24e\text{-}8$, $p=1.000$, $\eta^2_p=0.000$.

Analysis revealed that there was a statistically significant interaction effect between focus*throw*turn $F(2)=3.70467$, $p=0.045$, $\eta^2_p=0.292$, but not focus*throw $F(2)=0.84022$, $P=0.448$, $\eta^2_p=0.085$, focus*turn style $F(2)=2.1552$, $p=0.145$, $\eta^2_p=0.193$, or throw*turn $F(1)=0.00281$, $p=0.959$, $\eta^2_p=0.000$.

Post hoc testing for throw comparisons with Tukey's HSD correction revealed that the curlers acceleration at the first hog line when throwing draws ($M=0.599 m/s^2$, $SD=0.0850 m/s^2$) were significantly lower than throwing take-outs ($M=0.971 m/s^2$, $SD=0.162 m/s^2$) $t(9)=-11.4$, $p_{Tukey}<0.001$.

Post hoc testing for focus*throw*turn comparisons with Tukey's HSD correction revealed that draws were performed at a significantly lower accelerations than take-outs as seen in Figure 8. The mean and standard deviations of acceleration at BB1 can be found in Table 9. Control in-turn draw deliveries had a BB1 acceleration that was significantly slower [$t(9)=-12.8579$, $p_{Tukey}<0.001$] than a control in-turn take-out deliveries. Control out-turn draw deliveries had a BB1 acceleration that was significantly slower [$t(9)=-15.6583$, $p_{Tukey}<0.001$] than a control out-turn take-out deliveries. Internal focus in-turn draw deliveries had a BB1 acceleration that was significantly slower [$t(9)=-9.4355$, $p_{Tukey}<0.001$] than an internal focus in-turn take-out deliveries. Internal focus out-turn draw deliveries had a BB1 acceleration that was significantly slower [$t(9)=-8.2016$, $p_{Tukey}<0.001$] than an internal focus out-turn take-out deliveries. External focus in-turn draw deliveries had a BB1 acceleration that was significantly slower [$t(9)=-11.4788$, $p_{Tukey}<0.001$] than an external focus in-turn take-out deliveries. External focus out-turn draw deliveries had a BB1 acceleration that was significantly slower [$t(9)=-11.0070$, $p_{Tukey}<0.001$] than an external focus out-turn take-out deliveries.

Acceleration at Half

A three-way repeated measures ANOVA was performed to analyze the effect of throw, focus and turn style on acceleration at the halfway point. Analysis revealed a statistically significant main effect for throw F(1)=233.616, p<0.001, η^2_p =0.963, but not for focus F(2)=1.110, p=0.351, η^2_p =0.110 or turn style F(1)=1.832, p=0.209, η^2_p =0.169. Analysis revealed that there was not a statistically significant interaction effect between focus*throw F(2)=0.824, P=0.455, η^2_p =0.084, focus*turn style F(2)=2.257, p=0.133, η^2_p =0.200, throw*turn F(1)=0.374, p=0.556, η^2_p =0.040, or focus*throw*turn F(2)=1.987, p=0.166, η^2_p =0.181.

Post hoc testing for throw comparisons with Tukey's HSD correction revealed that the curlers speeds at the halfway point when throwing draws (M=0.329m/s^2, SD=0.0360m/s^2) were significantly slower [t(9)=-15.3, p_{Tukey}<0.001] take-outs (M=0.605m/s^2, SD=0.0784m/s^2)

Planned comparisons revealed no significant acceleration differences when comparing focus conditions or turn styles as seen in Figure 8. The mean and standard deviations of acceleration at BB2 can be found in Table 9. Control in-turn draw deliveries had a BB2 acceleration that was significantly slower [t(10)=-15.9, p<0.001, Cohen's d = -4.80] than a control in-turn take-out deliveries. Control out-turn draw deliveries had a BB2 acceleration that was significantly slower [t(10)=-17.4, p<0.001, Cohen's d = -5.24] than a control out-turn take-out deliveries. Internal focus in-turn draw deliveries had a BB2 acceleration that was significantly slower [t(9)=-13.0, p<0.001, Cohen's d = -4.12] than an internal focus in-turn take-out deliveries. Internal focus out-turn draw deliveries had a BB2 acceleration that was significantly slower [t(9)=-10.8, p<0.001, Cohen's d = -3.41] than an internal focus out-turn take-out deliveries. External focus in-turn draw deliveries had a BB2 acceleration that was significantly slower [t(10)=-13.4, p<0.001, Cohen's d = -4.03] than an external focus in-turn take-out deliveries. External focus out-turn draw deliveries had a BB2 acceleration that was significantly slower [$t(10)=-17.7$, $p<0.001$, Cohen's $d = -5.35$] than an external focus out-turn take-out deliveries.

Acceleration at the Second Hog-line

A three-way repeated measures ANOVA was performed to analyze the effect of throw, focus and turn style on acceleration at the second hog. Analysis revealed a statistically significant main effect for throw $F(1)=194.177$, $p<0.001$, $\eta^2_p=0.956$, but not for focus $F(2)=1.512$, $p=0.247$, $\eta^2_p=0.144$ or turn style $F(1)=0.763$, $p=0.405$, $\eta^2_p=0.078$. Analysis revealed that there was not a statistically significant interaction effect between focus*throw $F(2)=0.651$, $p=0.533$, $\eta^2_p=0.067$, focus*turn style $F(2)=1.268$, $p=0.305$, $\eta^2_p=0.123$, throw*turn $F(1)=0.305$, $p=0.594$, $\eta^2_p=0.033$, or focus*throw*turn $F(2)=2.771$, $p=0.089$, $\eta^2_p=0.235$.

Post hoc testing for throw comparisons with Tukey's HSD correction revealed that the curlers acceleration at the second hog line when throwing draws ($M=0.160m/s^2$, $SD=0.0394m/s^2$) were significantly lower [$t(9)=-13.9$, $p_{Tukey}<0.001$] than take-outs ($M=0.432m/s^2$, $SD=0.0820m/s^2$).

Planned comparisons revealed no significant acceleration differences when comparing focus conditions. However when comparing control out-turn take-out to external out-turn take-out, the control out-turn take-out condition was approaching a significantly lower acceleration [$t(10)=-2.13$, $p=0.059$, Cohen's $d = -0.642$] compared to the external focus out-turn take-out condition.

Planned comparisons revealed that acceleration for an external focus in-turn take-out were performed at a significantly lower accelerations [$t(10)=-2.25$, $p=0.049$, Cohen's $d = -0.677$] than an external focus out-turn take-out.

Planned comparisons revealed that draws accelerated significantly less than take-outs as seen in Figure 8. The mean and standard deviations of acceleration at BB3 can be found in Table 9. Control in-turn draw deliveries had a BB3 acceleration that was significantly slower [$t(10)=-14.64$, $p<0.001$, Cohen's $d = -4.416$] than a control in-turn take-out deliveries. Control out-turn draw deliveries had a BB3 acceleration that was significantly slower [$t(10)=-18.18$, $p<0.001$, Cohen's $d = -5.483$] than a control out-turn take-out deliveries. Internal focus in-turn draw deliveries had a BB3 acceleration that was significantly slower [$t(9)=-11.50$, $p<0.001$, Cohen's $d = -3.638$] than an internal focus in-turn take-out deliveries. Internal focus out-turn draw deliveries had a BB3 acceleration that was significantly slower [$t(9)=-10.17$, $p<0.001$, Cohen's $d = -3.217$] than an internal focus out-turn take-out deliveries. External focus in-turn draw deliveries had a BB3 acceleration that was significantly slower [$t(10)=-13.95$, $p<0.001$, Cohen's $d = -4.207$] than an external focus in-turn take-out deliveries. External focus out-turn draw deliveries had a BB3 acceleration that was significantly slower [$t(10)=-16.77$, $p<0.001$, Cohen's $d = -5.056$] than an external focus out-turn take-out deliveries.

Stone Travel Time

Table 10

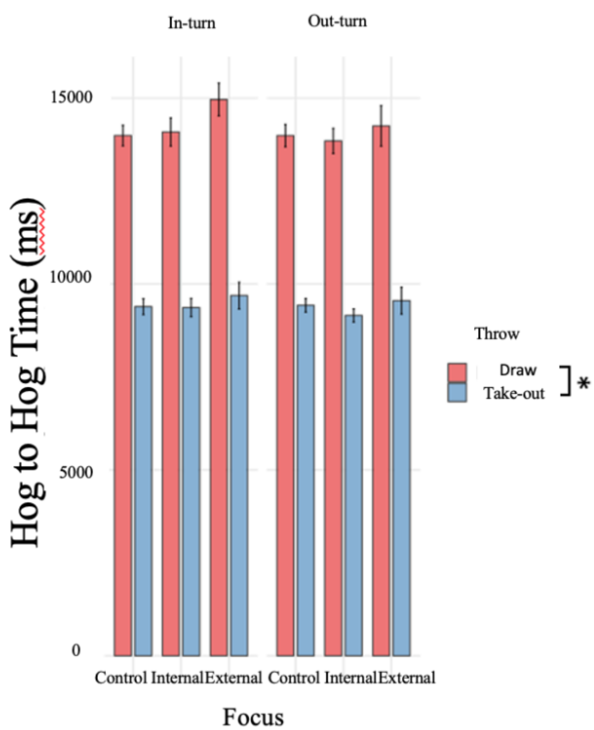
Mean and Standard Deviation of Hog-to-Hog Time (ms) and Percent of Time on Line (%) as a Function of Focus, Throw, and Turn Style

Condition	Hog to Hog Time (ms)		Percent of Time on Line (%)	
	Mean	SD	Mean	SD
Control In-turn Draw	13993	923	56.7	18.5
Control Out-turn Draw	13992	999	44.9	14.0
Internal In-turn Draw	14962	1398	49.9	13.5
Internal Out-turn Draw	14251	1632	50.8	17.1
External In-turn Draw	14087	1251	53.8	21.2
External Out-turn Draw	13846	1120	56.2	12.5
Control In-turn Take-out	9390	712	82.6	26.2
Control Out-turn Take-out	9427	605	62.8	24.2
Internal In-turn Take-out	9687	1141	74.7	34.8
Internal Out-turn Take-out	9552	1143	74.5	21.1
External In-turn Take-out	9364	822	69.1	31.6
External Out-turn Take-out	9154	587	82.0	28.7

Hog-to-Hog Time

Figure 21

Mean Hog-to-Hog Time (ms) as a Function of Focus, Throw and Turn Style.



Note. Standard error of the mean is represented in the figure by the error bars. Asterisks indicates a significant difference.

A three-way repeated measures ANOVA was performed to analyze the effect of throw, focus and turn style on hog-to-hog time. Analysis revealed statistically significant main effect for throw $F(1)=1516.564$, $p<0.001$, $\eta^2_p = 0.995$, but not for focus $F(2)=0.885$, $p=0.432$, $\eta^2_p = 0.100$ or turn style $F(1)=0.935$, $p=0.362$, $\eta^2_p = 0.105$. Analysis revealed that there was not a statistically significant interaction effect between focus*throw $F(2)=0.154$, $P=0.859$, $\eta^2_p = 0.019$, focus*turn style F(2)=1.144, p=0.343, η^2_p =0.125, throw*turn F(1)=0.266, p=0.620, η^2_p =0.032, or focus*throw*turn F(2)=1.144, p=0.343, η^2_p =0.125.

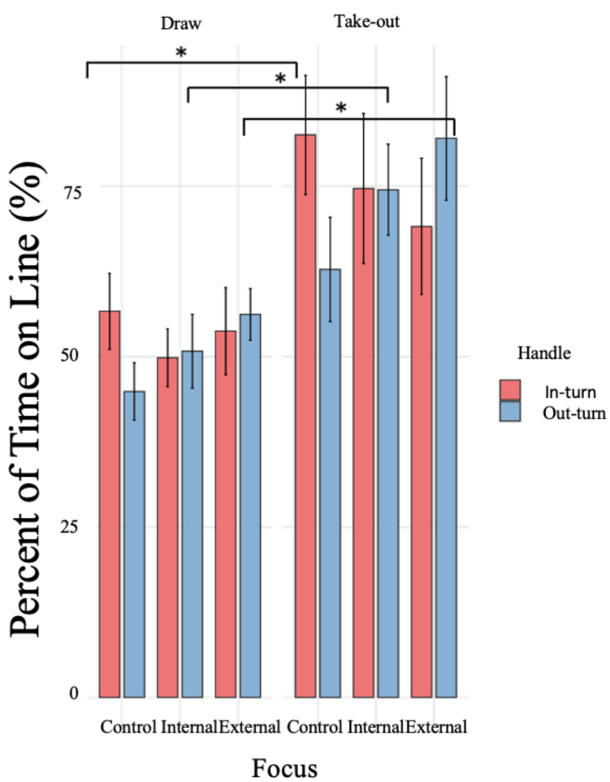
Post hoc testing for throw comparisons with Tukey's HSD correction revealed that the curlers hog-to-hog time when throwing draws (M=14234ms, SD=1230ms) were significantly greater [t(8)=38.9, p_{Tukey}<0.001] than take-outs (M=9479ms, SD=837ms).

Planned comparisons revealed no significant hog-to-hog time differences when comparing focus or turn styles as seen in Figure 9. The mean and standard deviations of hog-to-hog time can be found in Table 10. Planned comparisons revealed that draws were significantly slower than take outs. Control in-turn draw deliveries had a hog-to-hog time that was significantly slower [t(10)=21.53, p<0.001, Cohen's d = 6.49] than a control in-turn take-out deliveries. Control out-turn draw deliveries had a hog-to-hog time that was significantly slower [t(10)= 20.98, p<0.001, Cohen's d = 6.33] than a control out-turn take-out deliveries. Internal focus in-turn draw deliveries had a hog-to-hog time that was significantly slower [t(9)= 16.82, p<0.001, Cohen's d = 5.32] than an internal focus in-turn take-out deliveries. Internal focus out-turn draw deliveries had a hog-to-hog time that was significantly slower [t(8)= 23.08, p<0.001, Cohen's d = 7.70] than an internal focus out-turn take-out deliveries. External focus in-turn draw deliveries had a hog-to-hog time that was significantly slower [t(10)= 17.21, p<0.001, Cohen's d = 5.19] than an external focus in-turn take-out deliveries. External focus out-turn draw deliveries had a hog-to-hog time that was significantly slower [t(10)= 17.98, p<0.001, Cohen's d = 5.42] than an external focus out-turn take-out deliveries.

Time on Line

Figure 22

Mean Percent of Time on Line as a Function of Focus, Throw and Turn Style



Note. Standard error of the mean is represented in the figure by the error bars. Asterisks indicates a significant difference.

A three-way repeated measures ANOVA was performed to analyze the effect of throw, focus and turn style on percent of time on the line.

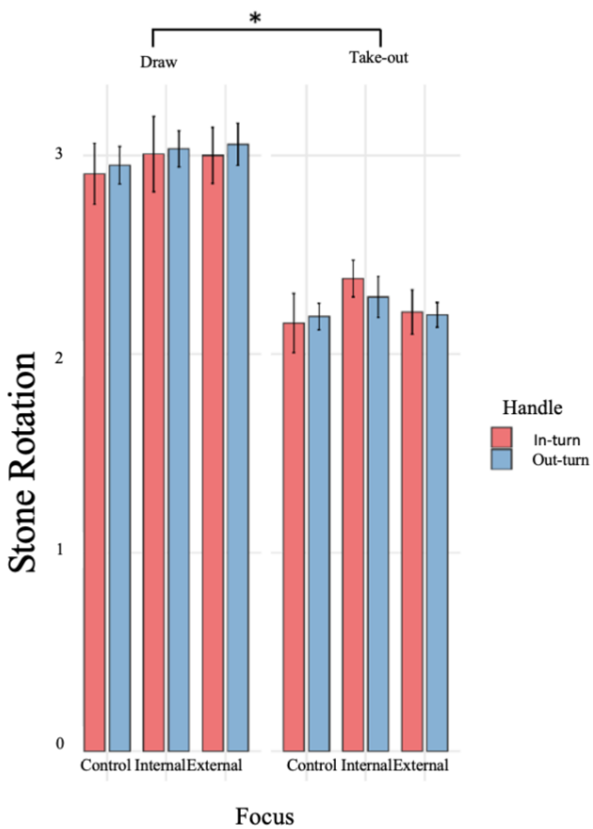
Analysis revealed that there was not a statistically significant main effect for throw $F(1,6)=5.3265$, $p=0.060$, $\eta^2_p = 0.470$, focus $F(2,12)=0.0370$, $p=0.964$, $\eta^2_p = 0.006$ or turn style $F(1,6)=0.0706$, $p=0.799$, $\eta^2_p = 0.012$. Analysis revealed that there was not a statistically significant interaction effect between focus*throw $F(2,12)=0.0612$, $P=0.941$, $\eta^2_p=0.010$, focus*turn style $F(2,12)=3.0553$, $p=0.085$, $\eta^2_p=0.337$, throw*turn $F(1,6)=0.0815$, $p=0.785$, $\eta^2_p=0.013$, or focus*throw*turn $F(2,12)=0.8898$, $p=0.436$, $\eta^2_p=0.129$.

Planned comparisons revealed no significant percent of time on line differences when comparing focus or turn styles as seen in Figure 10. The mean and standard deviations of percent of time on line can be found in Table 10. Planned comparisons revealed that control in-turn draw compared to control in-turn take-out, internal out-turn draws compared to internal out-turn take-outs, and external out-turn draws compared to external out-turn take-outs had significantly slower draw deliveries than take-out deliveries. Control in-turn draw deliveries had a percent of time on the line that was significantly less [$t(8)=-3.08$, $p=0.015$, Cohen's $d = -1.025$] than a control in-turn take-out deliveries. Internal focus out-turn draw deliveries had a percent of time on the line that was significantly less [$t(9)=-4.11$, $p=0.003$, Cohen's $d = -1.300$] than an internal focus out-turn take-out deliveries. External focus out-turn draw deliveries had a percent of time on the line that was significantly less [$t(9)=-3.45$, $p=0.007$, Cohen's $d = -1.092$] than an external focus out-turn take-out deliveries. Although not all draw and take-out comparisons were significant there were a few that were approaching significance. A control out-turn draw was approaching a significantly lower percent of time on line [$t(9)=-2.19$, $p=0.056$, Cohen's $d = -0.692$] when compared to a control out-turn take-out. An external in-turn draw was approaching a significantly lower percent of time on line [$t(9)=-2.19$, $p=0.056$, Cohen's $d = -0.693$] when compared to an external in-turn take-out.

Stone Rotation

Figure 23

Stone Rotation as a Function of Focus, Throw and Turn Style



Note. Standard error of the mean is represented in the figure by the error bars. Asterisks indicates a significant difference.

A three-way repeated measures ANOVA was performed to analyze the effect of throw, focus and turn style on the number of rotations between the two hog lines as seen in Figure 11. Analysis revealed that there was a statistically significant main effect for throw $F(1,4)=30.5452$, $p=0.005$, $\eta^2_p=0.884$, but not for focus $F(2,8)=0.7819$, $p=0.490$, $\eta^2_p=0.164$ or turn style $F(1,4)=0.2254$, $p=0.660$, $\eta^2_p=0.053$. Analysis revealed that there was not a statistically significant interaction effect between focus*throw $F(2,8)=1.7109$, $P=0.241$, $\eta^2_p=0.300$, focus*turn style $F(2,8)=0.0816$, $p=0.922$, $\eta^2_p=0.020$, throw*turn $F(1,4)=3.7898$, $p=0.123$, $\eta^2_p=0.487$, or focus*throw*turn $F(2,8)=0.0875$, $p=0.917$, $\eta^2_p=0.021$.

Post hoc testing for throw comparisons with Tukey's HSD correction revealed that stones rotated significantly more [$t(8)=38.9$, $p_{Tukey}<0.001$] when throwing draws (M=3.07, SD=0.415) than take-outs (M=2.34, SD=0.297).

Planned comparisons revealed no significant rotation differences when comparing focus or turn styles. Planned comparisons revealed that draws rotated significantly more than take outs when comparing throws. Control in-turn draw deliveries (M = 2.91, SD = 0.486) rotated significantly more [$t(8)=3.70$, $p=0.006$, Cohen's d = 1.23] than control in-turn take-out deliveries (M=2.16, SD=0.448). Control out-turn draw deliveries (M=2.95, SD=0.313) rotated significantly more significantly more [$t(8)= 9.46$, $p<0.001$, Cohen's d = 3.15] than a control out-turn take-out deliveries (M=2.19, SD=0.201) . Internal focus in-turn draw deliveries (M=3.01, SD=0.600) rotated significantly more [$t(8)= 3.67$, $p=0.006$, Cohen's d = 1.22] than an internal focus in-turn take-out (M=2.38, SD=0.277) deliveries. Internal focus out-turn draw deliveries (M=3.03, SD=0.271) rotated significantly more [$t(7)= 9.80$, $p<0.001$, Cohen's d = 3.47] than an internal focus out-turn take-out deliveries (M=2.29, SD=0.311). External focus in-turn draw deliveries (M=3.00, SD=0.466) rotated significantly more [$t(7)= 8.08$, $p<0.001$, Cohen's d = 2.86] than an external focus in-turn take-out deliveries (M=2.21, SD=0.316). External focus out-turn draw deliveries (M=3.06, SD=0.352) rotated significantly more [$t(9)= 6.94$, $p<0.001$, Cohen's d = 2.20] than an external focus out-turn take-out (M=2.20, SD=0.197) deliveries

Questionnaire

Pre-Experiment Questionnaire

Table 11

Pre-Experiment Questionnaire Themes for Draws

Draw Themes	Code/# of times stated
External Focus	Broom/6
	Visualizing the line of delivery/4
	House or target/4
	Ice conditions/1
	Weight/1
Internal Focus	Leg drive/4
	Body position/3
Blended Focus	External then internal/7
	"broom, then body position" P4
	"On the broom and making sure I drive the rock right at the broom at the start of my slide. Focus on leg drive out. Power" P1
	"On the house, where I need the rock to be. Called weight. Leg drive. Comparison to previous draws I threw. The right 'mass' (heavy or light)" P3
	"Speed of the draw path/ice path. Speed of my leg/trunk drive coming out of the hack" P7

	"Focus on where the shot needs to end and how that kick speed should feel" P9 "Broom, visualizing line of delivery. Breathing and kick speed" P2
	Internal then external/1 "Kick speed and line of delivery" P8
Multiple Foci	External then internal/7 (see Blended Foci)
	Internal then external/1 (see Blended Foci)
	External Foci/2 "Ice condition. Ice speed. Release of rock. Broom location." P5 "Primarily the broom, I analyze the path briefly, and then prior to delivery exclusively the target. The location I want it to end up/the weight I want to throw relative to a benchmark in terms of how many feet more or less" P6
	Internal Foci/1 "I focus on weight for the shot. I visualize what I think the slide should feel like. The ideal slide and feel" P11

Table 12

Pre-Experiment Questionnaire Themes for Take-out Deliveries

Take-out Themes	Code/# of times stated
External Focus	"Broom"/14 "Line of delivery"/8

	"rock"/3
	"ice"/4
	"weight"/4
	"backline"/1
Internal Focus	Sensation of a good release/4
	"leg drive"/3
	"hand and arm adjustments"/1
	"straight shoulders"/1
Blended Foci	Internal and external/ 8
	"rock placement in the hack, body position, then at the broom" P4
	"Focus on line and trying to never kick too hard initially to allow for a positive release" P9
	"Broom. Kick speed, focus on release for weight thrown" P2
	"Typically focus on the distant broom and rock during my delivery followed by arm/hand adjustments that are required to hit the broom" P7
	"The intended target, as well as glancing at the rock to analyze the ice I've been given. Hitting the broom and throwing the correct weight. Thinking about a crisp release" P6
Multiple foci and order of foci	Internal then external/5 (see Blended Foci)
	Multiple external/5
	"on the broom making sure my rock stays on line" P3
	"Broom location. Release of rock. Ice conditions" P5
	"Broom, visualizing line of delivery" P8

	"At the broom. What the ice will do" P10
	"Typically focus on the back line during the early part of my delivery followed by the distant broom during the rest of my delivery" P7

Five participants reported that they think about where their focus was after their throws. Six participants reported that they do not think about where their focus was after a throw. Ten participants reported that they maintain their focus strategy when they make a successful shot, and one reported that they do not. Seven participants reported that they maintain their focus strategy if they have a non-successful shot, and four reported that they do not maintain their focus point.

Major themes identified in the pre-experiment questionnaire for draws are listed in Table 11 and included: 1) external focus; 2) internal focus; 3) blended focus; and 4) multiple foci locations. External foci points were discussed 16 times from nine curlers with the "broom" mentioned 6 times, "visualizing the line of delivery" 4 times, the "house" or "target" 4 times, the "ice conditions" 1 time, "weight" once, and the "hog-line" once. Internal foci points were discussed 8 times from seven curlers. The curlers mentioned "leg drive" 4 times, and "body position" 3 times. Seven of eleven curlers had a blended focus approach where they discussed aligning to external targets, but also emphasized the importance of sensation for draws. Curler P9 said that they "Focus on where the shot needs to end and how that kick speed should feel" and P1 said they focus "On the broom and making sure I drive the rock right at the broom at the start of my slide. Focus on my leg drive out. Power". All the curlers discussed multiple foci points that change throughout the delivery such as P6 who wrote "Primarily the broom, I analyze the path briefly, and then prior to delivery exclusively the target" or P5 who listed "ice conditions", "ice speed", "release of rock", and "broom location".

Major themes identified in the pre-experiment questionnaire for take-outs are listed in Table 12 and include: 1) external focus; 2) internal focus; 3) blended focus; and 4) multiple foci and order of focus. External foci locations were discussed 34 times from all curlers. The "broom" was mentioned by every curler and was discussed 14 times. Maintaining "line of delivery" was discussed 8 times, the "rock" 3 times, "ice" 4 times, "weight" 4 times, and the "backline" once. Internal foci locations were discussed by 8 curlers but were never discussed alone. The internal cues mentioned were "hand and arm adjustments" once, the "sensation of a good release" four times, "leg drive" in relation to the correct speed three times, and a cue for maintaining "straight shoulders" once. Internal foci were always spoken of in tandem with external cues which brought up the theme of blended foci. A blended focus was utilized by five curlers and was discussed as focusing externally on accuracy (toward the broom or line of delivery) and also internally on the body (the leg, hand, or arm sensations). With the blended focus, curlers discussed how they ordered their foci. Initially curlers focused on the target then shifted to body sensations like the hand and arm releasing the stone or the leg drive associated with the proper speed. Curler P7 described their blended foci order as "Typically focus on the distant broom and rock during my delivery followed by arm/hand adjustments that are required to hit the broom". Other curlers provide a similar story by writing "rock placement in the hack, body position, then at the broom" (P4) or "Focus on line and trying to never kick too hard initially to allow for a positive release" (P9).

Manipulation Check

Curlers reported that they were able to adhere to internal focus instructions an average of 98% of the time (SD=3.50%). Curlers reported that they were able to adhere to external focus instructions an average of 97.7% of the time (SD=6.07%).

Post-Experiment Questionnaire

Table 13

Post-Experiment Questionnaire Themes for Draw Deliveries

Draw Themes	Code/# of times stated
Importance of touch for draws	Body focus helped with draw weight/4
	Touch/feel is important/7 "I feel like this matches the way I typically throw my draws. I have specific cues as to when to relax my arm, and often judge the stones based on my hand-feel when I release" P4 "I like focusing on weight and arm movement. Touch is so important on draws" P11 "Line is slightly less important with draws so focusing on for body motion helps with draw weight" P9 "When I would focus internally I felt like I had a better feel for the weight I was throwing" P1 "Hand/arm/torso is typically what I think about during draw shots as weight is more important than line" Online email guy "Internal. Helped me to focus on the weight and feel" P8

	"I always use an arm extension for draws so it was easier to focus on arm/hand movement since that is usually where my focus shifts at the end of my delivery" P3 "Internal. Helped me to focus on the weight and feel" P11
Blended and shifting focus	"the broom is always a focal point, for draws and takeouts. The broom becomes a lesser focus for draws right before I kick out as I am thinking about draw weight. I often think about my release/hand movement at the end of all throws so that's a focal point" P3 "Typically, I focus on my arm from the hack to the top of the 12 foot. Then, I tend to focus on the broom until I release, then change back to internal. I feel like I use both focus techniques during my delivery" P4 "I focus on the position of my arm before I throw. I also focus on it when I bend it during my delivery and then external I also focus on the broom." P1

Table 14

Post-Experiment Questionnaire Themes for Take-out Deliveries

Take-out Themes	Code/# of times stated
External focus for line maintenance	"Line is very important for takeouts so focusing on the broom is more important" P9

	"I really worry about line for the takeouts. Weight comes more naturally" P11 "Overall it was easier to focus external or internal for takeouts compared to draw. I typically focus on the broom for hits so it felt more natural" P3 "Hitting the broom is very important with hits, so this is where I focused. I also feel I don't' have as much feel wit hit weight, so it makes more sense to focus externally" P1
Blended Focus	"Felt that external is more second nature and felt internal was more beneficial to my overall shot making" P8 "While I felt that external focus I slid at the broom more frequently, my delivery with internal focus felt smoother and more natural. I felt like I had a cleaner release" P4

On average participants reported that they believed they adhered to the focus instructions 86% of the time (SD=9.167%). On average participants rated instruction difficulty as a 1.75/10 where 0 meant "no difficulties", and 10 as "extremely difficult". The themes identified relating to instruction difficulty were 1) instruction clarity; 2) alignment with pre-experiment focus; and 3) difficulty. Three curlers wrote that it was easy to follow the instructions because of "clear instructions". Three curlers discussed how it was easy to follow instructions because the focus strategies used in the study already aligned with their typical focus strategy. One curler elaborated further and said, "Draws were harder as I would partly focus on draw weight" (P3).

Three curlers discussed difficulties they had with following instructions. One from P3 who had difficulties with draws. One curler discussed difficulties due to the headphones being “troublesome” and the third wrote that it was “easier to follow after a while once I developed a feel” (P4). One curler did not elaborate in detail and wrote “very easy to follow” (P5).

Major themes identified in the post-experiment questionnaires for draws are listed in Table 13 and include: 1) the importance of touch; and 2) a blended and shifting focus. After completing the study 7/10 curlers reported preferring an internal focus for draws because of the importance of “touch and sensation”. Curler P4 said “I feel like this matches the way I typically throw my draws. I have specific cues as to when to relax my arm, and often judge the stones based on my hand-feel when I release”. Curler P11 added to the narrative by saying “I like focusing on weight and arm movement. Touch is so important on draws”. Those who preferred an external focus mentioned that they were “more used to focusing on the broom/further away target” (P2). All the curlers discussed how the study aligned with their typical focus strategy at some point in their delivery (pre-shot routine, aligning in the hack, while sliding, or during release). One curler preferred purely an external focus and wrote that they “focus on the broom. I try not to think about arm movement as that should come naturally” P10. A blended focus was discussed more heavily in the pre-experiment questionnaire but was reiterated in the post experiment questionnaire by a few curlers. Culer P3 added to the narrative by writing “the broom is always a focal point, for draws and take-outs. The broom becomes a lesser focus for draws right before I kick out as I am thinking about draw weight. I often think about my release/hand movement at the end of all throws so that’s a focal point”, as well as P4 who wrote “Typically, I focus on my arm from the hack to the top 12 foot. Then, I tend to focus on the broom until I release, then change back to internal. I feel like I use both focus techniques during my delivery”.

Major themes identified in the post-experiment questionnaire for take-outs are listed in Table 14 and include: 1) External focus for line maintenance; and 2) a blended focus. After completing the study 8/10 participants reported that they preferred an external focus for take-outs. Those who preferred an internal focus (2/10) discussed choosing so due to an external focus already being “second nature, so internal cues were more beneficial to overall shot making” (P8). Participant P4 preferring an internal focus because it felt “natural and smooth” but the external was useful for sliding “at the broom more frequently”. There was never an instance where an internal focus was preferred alone. Quotes from P8 and P4 add to the theme of utilizing a blended focus. All the curlers added to the theme of external focus for line maintenance with phrases like “I really worry about line for the takeouts” (P11), and “I typically focus on the broom for hits so it felt more natural” (P3). They emphasized how natural focusing on the broom or target is for take-out throws, and that it is what keeps them aligned in the hack. Curler P1 discussed how it is even difficult to “feel” for take-outs and that is why they preferred an external focus when they wrote “hitting the broom is very important with hits, so this is where I focused. I also feel I don’t have as much feel with hit weight, so it makes more sense to focus externally”.

Discussion

The objectives of this study were to positively change highly skilled Canadian curler’s draw and take-out deliveries in the following ways. First, by being able to consciously allocate their attentional resources to the strategy found to be the most useful for draws, and take-outs respectively. Second, by identifying what aspects of performance are changed or facilitated by FOA.

The first objective of the study sought to improve the quality of instructional information provided by curling coaches, teammates, or even the self-guidance of the athlete during training and competition. These instructions were applied to a low velocity high finesse shot (draws), and a high velocity low finesse shot (take-outs). Based on the best available evidence from other accuracy target natured sports such as darts (Hitchcock & Sherwood, 2018; Sherwood, Lohse & Healy, 2014) and golf (Bell & Hardy, 2009; Wulf & Su, 2007, Pelleck & Passmore, 2017), podium-level performance in curling may be re-attained if increased accuracy and reduced performance variability can be achieved in a FOA curling task. Further support can be seen in other sporting examples such as swimming, soccer, and basketball (Stoate & Wulf, 2011; Jackson, et al., 2006; Gorman, et al., 2018).

An external focus facilitates motor skill automaticity and thus, improves performance as described by FOA theory (Wulf, et al., 2001). An external focus is well researched with dozens of papers in the area consistently demonstrating an advantage in learning and performance (Chua, Lewthwaite, Kim, & Wulf, 2021). Tasks involving balance, coordination, and aiming have all utilized the theory (Wulf 2013). Additionally, FOA has been applied in the study of elite and expert athletes yielding measurable performance improvements (Stoate & Wulf, 2011, Pelleck & Passmore, 2017). Of relevance to curling, the application of FOA has been applied to target accuracy sports, such as golf and dart throwing (Hitchcock & Sherwood, 2018; Sherwood, et al., 2014; Bell & Hardy, 2009; Wulf & Su, 2007; Pelleck & Passmore, 2017). Golf, like curling, has accuracy that is dependent on the conditions of the environment, for example stimp readings, or the speed of the greens (Pelleck and Passmore, 2017) in golf could be thought of in similar terms as condition of the ice in curling. While parallels can be drawn between golf and curling, HSCC performance was mixed between the draw and takeout.

The first hypothesis of this study was that draw deliveries when externally instructed would result in stones closer to the target and have less end-point variability. The second hypothesis was that take-out deliveries when instructed with an external focus would hit more frequently. The first hypothesis was not supported as draw endpoint accuracy performance did not improve when given external focus instructions over control conditions. On the other hand, the second hypothesis was supported. Take-outs were able to successfully hit more often with external focus instructions compared to internal focus instructions, and there was a trend approaching a statistically significant greater hit percentage over the control condition.

The study at hand provides support for the use of an external focus over an internal focus for take-out shots. An external focus out-turn takeout (EFOT) significantly outperformed internal focus out-turn take-outs. Although no significant differences from control were observed, when an EFOT was compared to out-turn control a trend approaching a significant hit difference in favour of EFOT was observed. These results are consistent with what the curlers reported in their pre- and post-experiment questionnaires where all curlers discussed utilizing an external focus for take-outs. Eight curlers utilized a blended focus where they focused on both internal and external components of the curling stone take-out delivery. A blended strategy typically began with external foci and ended with an internal cue if a blended strategy was utilized. At the end of the study, eight out of ten curlers preferred an external focus for take-outs. The two who preferred an internal focus did acknowledge an external component. One mentioned that an external focus was more helpful for staying on line, and the other that an external focus is second nature. The accuracy results for take-outs add to the growing body of literature in support of external cues as outlined in FOA theory (Wulf, et al., 2001) and recently reviewed by Chua and colleagues (2021). A potential future study could examine how hit percentage data collected internally from Curling Canada compares to our study. This comparison could provide further insight into the visual and auditory feedback curlers use compared to our study where we removed this feedback. This comparison can also provide insight into the effect sweeping has on hit percentage compared to no sweeping.

In contrast to take-outs, the study at hand does not directly add to the body of literature supporting the use of an external focus for draw shots. There were no significant performance benefits observed. However, the themes identified in the pre-experiment questionnaire suggest external foci are a part of HSCC control focus strategy. When considering the pre-experiment questionnaire responses, it can be argued that control trials and external trials may not have that different. Control and external focus share some elements with nine of the eleven curlers using an external focus for draws. Of those nine, seven curlers used internal foci along with external foci for draws resulting in a blended focus strategy for draws.

The singular focus strategies implemented with the curlers did not influence their performance when given an external cue compared to control, but an internal cue negatively affected the curlers performance. It is thought that an internal focus overrides or interferes with automatic processing of information resulting in poor performance as described by the constrained action hypothesis (Wulf, et al. 1998). The study at hand supports the constrained action hypothesis since internal focus strategies negatively affected the accuracy performance of draw deliveries for HSCC. The accuracy results revealed that with in-turn draws specifically, an internal focus led to significantly shorter and less consistent endpoint results when compared to in-turn control draws. Similarly, an internal focus resulting in constraining effects has been seen in other accuracy-oriented sports like golf (Pelleck & Passmore, 2017). The post-experiment questionnaire asked the curlers which focus strategy they preferred at the completion of the study. Seven out of ten reported that they preferred an internal strategy. When asked ‘why’, the theme of “importance of touch and sensation” for draws arose. The curlers did not elaborate on “touch” but when discussing “sensation”, it was always in reference to body feedback relating to push off speed. The way curlers are discussing why they prefer internal focus is reminiscent of Brick, MacIntyre, and Campbell’s 2014 classification system for endurance sports. The curlers discuss sensations and use words like “crisp release”, or “the right mass? (heavy or light)” which are in reference to what the sensory feedback on release should be. The curlers discuss internal focus in ways that Brick and colleagues (2014) categorize as “associative” because the curlers discuss internal focus in a sensory and self-regulatory way. When internal cues (Wulf, et al. 1998) or associative features (Brick, et al. 2014) are studied, both are found to disturb automated processes. Future studies can utilize an interview approach to further examine this emphasis on “touch”. An interview approach can allow for deeper elaboration as opposed to questionnaires.

Curlers are in a unique situation where they spend a long duration of time moving with their projectile in comparison to other target natured sports. There is a considerable amount of time to ruminate on multiple variables and sensations allowing for real-time adjustments before truly releasing the stone. Some curlers discussed their temporal thought process and gave statements such as focusing “Primarily on the broom. I analyze the path briefly, and then prior to delivery exclusively the target” (P6), or “At the broom, then body position” (P4) for draws. Take-outs were discussed with a blended point of view as well by eight curlers with statements such as “Typically focus on the distant broom and rock during my delivery followed by arm/hand adjustments that are required to hit the broom” (P7) or “The intended target, as well as glancing at the rock to analyze the ice I’ve been given. Hitting the broom and throwing the correct weight. Thinking about a crisp release” (P6). These statements provide further insight to the idea that a curling delivery is multifaceted and focusing on a single cue is not natural at high levels of sport. There is emerging literature on expertise and foci revealing that a broad approach to FOA application is needed as opposed to singular focus strategies (Bernier, Trottier, Thienot, & Fournier, 2016; Woodard, Markwell, & Faribrother, 2021).

A multifaceted approach is reported in expertise research and seen in the questionnaire responses among curlers, but it is not clear when curlers think about which cues. Future studies can explore cues as discussed by the curlers where they transition between different external cues, from external to internal, and from internal to external. A call for FOA research to shift away from singular focus to a multifaceted approach has emerged for high performing athletes (Bernier, et al., 2016; Woodard, et al., 2021) and thus further examination is warranted especially when considering the curlers draw performance.

A concerning finding in this study was the quantity of curlers who reported that they do not think about where they focus. More concerning is the quantity of curlers reporting maintenance of their focus strategy when they miss. Curlers reported a greater preference for internal focus cues for draws after participating in this study, but the internal conditions resulted in poorer accuracy. Coaching curlers to reflect on the outcome of shots paired with deliberate reflection on their focus strategy could make a difference in performance. It is not beneficial to repeat non-successful strategies especially if curlers gravitate toward internal cue coaching instruction for draws. It is human nature to gravitate toward language on the self as discussed in OPTIMAL theory (Wulf, & Lewthwaite, 2016), but it is warned repeatedly to be avoided.

The second objective of this study was to identify what aspects of performance are changed or facilitated by FOA. The performance variables affected by FOA for draw deliveries were constant error scores, radial error scores, and absolute constant error scores. The performance variable affected by FOA for take-out deliveries was the successful hit to miss ratio. Already discussed were the foci coaching cues that can be utilized. To summarize, take-outs should be coached with external orienting cues, and draws coached with language that avoids internal oriented cues.

Regardless of focus or turn style, the results revealed in this study demonstrate differences between draws and take-outs. Hog-to-hog time, velocity, and acceleration of draws were significantly slower than take-outs. Although these results do not add new knowledge it does provide empirical evidence for the on-ice observation of draws moving slower than take-outs. One contradictory finding to line maintenance for take-outs was that take-outs rotated significantly less than draws. A strategy for maintaining line in take-outs is to throw with a large number of rotations as seen in Team Mouat of Scotland and is supported in the curling literature (Shegelski & Niebergall, 1999). Among HSCC this cue may not be necessary as they can maintain line with a low number of rotations. A potential explanation could be that the cue to “add more spin” could have served its purpose in the early stages of learning, and are no longer required at the expert level an interpretation that is congruent with the Challenge Point Framework (Guadagnoli, & Lee, 2004). Another explanation is simply further empirical evidence for the movement of a curling stone. Since draws move at a lower velocity they have an increased time duration to rotate prior to reaching their end point. However, it is important to note a methodological difference between this study and common curling practice. The rotations it this study were only counted from hog-to-hog lines which is not a common distance of rotation count among curlers, although from a scientific standpoint it allowed identical distance measurement for comparing draw and take-out deliveries. The time from release to shot end is the distance curlers use to count rotations; thus our count missed the extra rotation(s) that occurred past the second hog line however our draw and take-out comparisons were distance matched.

To further investigate if there is a need to train draws and take-outs differently we examined if there was a relationship between release speed and accuracy for all draws and take-outs. Take-outs were found more likely to hit if the velocity at release was faster. This correlation was noted for all control conditions, all internal conditions, and for an external focus with an in-turn, but not for an external focus with an out-turn. It is important to note that an external out-turn takeout successfully hit a greater amount of time than it missed. The miss trials had 2 observations whereas hits had 53 observations thus making the results of the external focus out-turn take-out speed and hit correlation unreliable. The results of this study demonstrate that it is more likely that a successful hit will occur if the stone is released at greater velocities. This study provides evidence for the need to train take-outs with fast speeds out of the hack.

Draws were found to travel short of the button if their release speed was slower for control in-turn draws, internal focus in-turn draws, external focus in-turn draws, and external focus out-turn draws. A slower release is intuitively logical with falling short of the target in a practical curling context. The results of this study provide empirical validation of this intuitive concept.

There was no correlation for control out-turn draws or internal focus out-turn draws. A possible explanation for this is that most curlers self-reported that they preferred in-turns resulting in out-turns being far less practiced. When reviewing take-outs, external focus out-turn take-outs hit a significantly higher proportion of shots than in-turns. In-turns again were reported as the preferred turn style for take-outs for most curlers. It is not clear why in-turn take-outs did not result in a greater amount of hits. It is possible for take-outs that handle is less important due to the ballistic nature of the shot.

The purpose of this study was to improve the attentional focus and delivery performance of highly skilled Canadian curlers. Focus of attention was applied to the draw and take-out shot to investigate if FOA could make positive performance changes. This study added to the body of literature on focus of attention by addressing issues associated with dichotic task instruction. Based on the nature of curling stone delivery there is adequate time for focus to be volitionally shifted. External cues were found to benefit the proportions of successful take-out hits, supporting the FOA literature on the benefits of an external cue (Wulf, et al. 2001). An internal FOA had a constraining effect (Wulf, et al. 1998) as seen in the curlers draw performance. The questionnaires revealed that a multi-faceted focus strategy for control conditions reflected what was typically utilized by HSCC adding to the growing body of literature on experts utilizing a dynamic shift between multiple focus strategies.

Limitations

The study at hand, like all studies, does not come without limitations. The first limitation was that we recruited a small sample size of only 11 HSCCs. However, we were recruiting from an already small population of HSCCs across Canada. There were factors such as the COVID-19 pandemic resulting in air travel and facility restrictions, ice scheduling limitations, and the curling season. It was difficult to find a time between curling championships where a large amount of curlers were available. We did calculate that the minimum sample size needed per condition was 9 curlers, and since this was a within subjects design each curler participated in each condition. We were able to meet our minimum sample size requirements. It is important to note that we cannot completely rule out the potential for type II errors since our sample size was low. At times, we had to omit as high as 30% of trials for some variables which brings us closer to running the risk of being underpowered.

Another limitation was that the study had low ecological validity. Typically, curlers can depend on sweepers, but this study did not use sweepers. Professional curlers also usually have fans in the stands, but our study design did not incorporate this factor. These limitations are in relation to competition scenarios, but often practice conditions are done in isolation without sweepers or fans.

Due to the anticipated length of each experimental session, the two-day study design, ice availability constraints, as well as the availability of curlers only three to four participants could be tested per day. Although the ice technician used was skilled and the same person for the duration of the study, it was still a challenge for the ice technician be able to reproduce the exact same ice and temperature conditions each day. As an internal quality assurance, we compared the mean and standard deviation of the groups each day and we reported the ice and air temperature mean and standard deviations to combat this limitation. Even with these quality assurance protocols in place, ice is a factor that the curlers deal with every time they train and compete. The self-regulated warm up prior to each test session was used to calibrate the curlers to the ice conditions of the day.

A limitation specific to rock movement was that the break beam time stamps and resulting velocity measurements only considered one vector in curling rock movement. The speed measurements only account for the motion down the ice, and not the lateral curl of the stone which is most notable in draw type shots.

Another limitation of the study was that there was no guarantee that the participants answered honestly to the questionnaire or that they would give detailed answers. However, the study population recruited were high-level athletes who were invested in their sport at the time of testing. It is likely that they would answer honestly and attempt each condition to the best of their ability because the results of this study were in their best interest. Many of the curlers mentioned, in discussions after the conclusion of the experiment, that they were happy that curling research was being conducted. They acknowledge a lack of research done on their sport, so were pleased to participate. These off-ice discussions provide some anecdotal evidence that the curlers did care about the quality of the experiment. When this anecdotal evidence is paired with the manipulation checks, and post-experiment questionnaire results we see that curlers did appear to use the focus strategy instructed most of the time. A limitation specific toward the questionnaire is that answers were short. An interview could remedy short responses and provide prompts for further discussion.

Lastly the equipment used in the study were not natural to curling. The athletes do not train and compete while wearing goggles, and headphones, so they may have felt encumbered while they were curling. One participant reported that the headphones pushing on their ears was the greatest barrier to comfort, but was still able to participate and complete their session.

Conclusion

The findings of this study provide empirical evidence to coach draw and take-out shots differently. Draws were found to move at slower speeds, with a greater number of rotations, and with a lower percentage of time on line when compared to take-out shots. Draws that were released at slower speeds came short of the button (target) than those thrown at faster speeds. Take-outs when released at faster speeds were more likely to result in a successful hit.

The findings of this study related to focus of attention are mixed and bring forth additional questions. The two objectives of this study were to examine if FOA was advantageous to one or both types of shots, and what aspects of performance are changed by FOA. FOA was found to be advantageous to one type of shot, the take-out. The performance variables changed by FOA were end-point accuracy for both draw and take-out shots. Take-outs when given an external cue “focus on the far broom” resulted in a greater proportion of successful hits. The second hypothesis of this study was supported as an external focus was found to benefit take-out shots. The first hypothesis of this study was not supported as external instructions did not significantly affect draw performance. When FOA was applied to draw shots, the internal instructions “focus on your hand and arm movements” resulted in worse endpoint accuracy. The internal focus draw throws were considerably shorter and had greater variability. The questionnaires revealed a multifaceted thought process for draws and take-outs. The theme of the “importance of touch and sensation” for draws brought further questions in regard to what curlers meant when they said “touch”. Future studies can examine “touch and sensation” to a deeper degree to provide insight into why so many curlers spoke to the importance of “touch and sensation” for draws. Future studies can also examine shifting foci strategies to further examine the multifaceted thought process during curling stone delivery revealed in this study. To further explore the multifaceted nature of shifting focus conditions a study could be designed that directs athletes through a specific sequence of alternating task instructions during the delivery.

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Appendix A

Pre-Experiment Survey

1. For Draws where do you typically focus?

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2. For Take-outs where do you typically focus?

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3. What do you think about prior to throwing draws?

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4. What do you think about prior to throwing take-outs?

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5. After you throw do you think about where your focus was?

Yes________ No__________

6. If you make a shot do you keep your focus point?

Yes________ No__________

7. If you do not make a shot do you change up your focus point?

Yes________ No__________

Appendix B

Post-Experiment Survey

1. How difficult was it to follow the focus instructions? Please mark on the scale. A “0” means that it was extremely easy, and a “10” means that it was extremely difficult. Can you give a reason for why you think that is?

0______1______2______3______4_______5_______6_______7_______8_______9_______10

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2. Please give a percentage on how many trials you think you were able to match the focus we instructed you with what you actually focused on.

__________%

3. After completing this study which type of focus did you prefer for the **<u>draws</u>** (Check one)? Why?

External____________ Internal____________

____

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4. After completing this study which type of focus did you prefer for **take-shots** (Check one)? Why?

External____________ Internal____________

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5. Did any of the focus instructions match what you typically focus on before throwing? Please explain how it did or how it did not.

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Appendix C

Informed Consent

Research Project Title: The Impact of Focus Of Attention (FOA) on Curling Rock Delivery

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This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

Purpose of this Study:

The purpose of this study is to examine what affect different focus of attention strategies have compared to the current focus strategy of curlers on performing a draw and take-out shot as executed in Curling. The objectives of this study are to better understand the effects an internal focus of attention strategy and external focus of attention strategy have on performance of curlers. This comparison will help determine ideal focus of attention strategies, which can be applied in practice and performance for Olympic and Paralympic curlers.

Please note: This study will be used for the student investigators thesis project.

Procedures Involved in this Study:

This study consists of 2 experiment days.

Day 1 includes experimental set-up, followed by four conditions: 1.) Control in-turn draw; 2.) Control out-turn draw; 3.) Control in-turn take-out; 4.) Control out-turn take-out. Total time for day 1 will take 60 minutes.

Day 2 includes experimental set up, the remaining 8 conditions 5.) Internal focus in-turn draw; 6.) External focus in-turn draw; 7.) Internal focus out-turn draw; 8.) External focus out-turn draw; 9.) Internal focus in-turn take-out; 10.) External focus in-turn take-out; 11.) Internal focus out-turn draw; 12.) External focus out-turn take-out, and the post-experiment survey. Total time for day 2 will take 120 minutes. The experiment will take place at the Granite Curling Club in Winnipeg, Manitoba.

Experimental Set-up:

- 5-10 minutes practice to familiarize your self with the ice conditions of the day while wearing the visual occlusion goggles, and headphones.

- You will be fitted with visual occlusion goggles and headphones to block your vision and ability to hear after you have crossed the first hog line up until we have measured the resting point of the thrown stone.

- You will be fitted with Infrared Emitting Diodes(IREDs) located on your wrist and shoulder, and if you are a Paralympian you will be fitted with one addition IRED located on your delivery stick. This allows for tracking your movement during the experiment.

- You will fill out a self-awareness questionnaire upon completion of the test conditions.

Control conditions:
During the control conditions we will instruct participants to "throw an (in-turn/out-turn) (draw/take-out)" depending on the condition

Internal focus of attention conditions:
During the internal focus conditions we will instruct you to "Focus on your hand and arm movements during your delivery".

External focus of attention conditions:
During the external focus conditions we will instruct participants to "Focus on the distant broom during your delivery".

Recording Devices:

During all trials, time, rock speed, Kinematic data of the trunk/arm/delivery stick(Paralympians), end point accuracy will be measured.

Benefits of Participation:
Apart from the opportunity to learn the effects of different focus of attention strategies for a draw and take-out shot of Curling, and a monetary honourarium for travel and accommodation costs there are no direct benefits to you from participating. The honourarium is $200 per participant. There is the possibility to gain more of an honourarium if you are the 1st, 2nd, or 3rd most accurate female or male curler. First place will receive $1000, second place will receive $750, and third will receive $500.

Risks to Participation and Associated Safeguards
During this test there is the potential that you may fatigue due to the amount of stones asked to be thrown. However, this amount is similar to the amount of stones thrown in a typical practice. A researcher will be constantly observing the experiment and you have the ability to terminate the test at any time you feel uncomfortable. Please let the researcher know if you have any concerns.

This research is being conducted during the COVID-19 Pandemic. All reasonable steps to minimize the risk of transmitting COVID-19 through this experiment will take place over the course of this study. Upon
entering the Granite Curling Facility masks will be worn at all times, and hands will be sanitized. The Granite Curling Facility will scan and record your immunization QR code and confirm your identity with a government issued identification card. The researcher and the participant will be screened for symptoms of COVID-19 by the experimenter before entering the building. Once screened and no one is suspected of COVID-19 and QR codes have been scanned then both the researcher and the participant will sanitize their hands once again. The researcher will guide the participant to the ice while maintain 2m distancing. The experiment will not proceed if COVID-19 is suspected from either the researcher or the participant. A record of all participants, the time and date at which they entered and exited the Granite Curling Facility will be kept in a secure location until the end of the study. Two weeks upon study completion this information will be deleted. If COVID-19 exposure is suspected, you will be informed of the suspected date of transmission and when you participated in this experiment, and we will recommend that you seek a COVID-19 test.

Anonymity and Confidentiality of Data:

Two sets of data will be collected. Anonymized data for the results of this experiment, and confidential
personally identifying information which will be used to contact you should COVID-19 exposure be
suspected.

You will be identified only by a participant identification code, which contains no personally identifiable information. These codes contain only a number and cannot be linked back to any specific person.

Please note that if you agree to participate in this study you also agree to allow Curling Canada to release the following personal information: Current injuries and your self-awareness score. In this study we want to ensure that there are no current injuries that prevent you from curling to your full ability, and we want to see what affect, if any, your self-awareness score has to do with your performance and FOA preference. This information is only for the purposes of this study and to members of the research team.

This consent form and the bottom portion of the participant feedback form, which will contain your name and signature, will be kept in a locked filing cabinet in the principal investigator's office for three years after the completion of the study (the principal investigator's office is located behind two locked doors). Only the principal investigator, the principle investigators advisory, and research assistants, will have access to the consent and feedback forms. **After this time, the consent will be destroyed via a file shredder.**

The principal investigator (graduate student), research assistants and advisor will have access to the data (accuracy data, time to each line, total time, kinematic movement data, and high frame rate camera data) collected during this study. This information, which is coded, will be retained for three years following the publication of a research manuscript based on the collected data on a password protected computer in the principal investigator's office.

The confidential personally identifying data can be linked back to a specific person. To protect your personal identifying information, it will be kept within electronic documents on a secure university of Manitoba computer. Only the Primary investigator, the research assistant, and the graduate students advisor will have access to this data. They will access it only if COVID-19 exposure is suspected to have occurred during the experiment If this personally identifying data should be exposed to the wrong person, they may be aware of your contact information

Remuneration:
No remuneration will be provided.

Changing Your Mind about Participation

You may withdraw from this study at any time without any negative consequences. To do so, indicate this to the researcher or one of the research assistants by saying, "I no longer wish to participate in this study", or a similar statement. In the event of your withdrawal, all data collected from your participation will be deleted and both participant and researcher copies of the informed consent form will be destroyed. If you choose to withdraw from the study you will still receive the full honorarium.

Please note that once data analysis begins you may not longer withdraw from the study as it will be impossible to re-identify yourself amongst the rest of the data. This date will be May 30th, 2020.

Participant Feedback

After your participation in the study, you will have the opportunity to discuss the research with the principal investigator, should you have any questions. As the raw data collected take some time to process in order to obtain any interpretable results, you will have the option of indicating that you would like a summary of the research results following the completion of the study. Results should be available by May of 2022, you will be able to provide either a mailing address or email address to which we will send the results.

Dissemination of Results:

Results of this study will be presented at academic conferences. Data will also be published in manuscript. Data will be presented as group average values – there will be no information presented that could identify you as a participant in this study.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Coordinator at 204-474-7122 or humanethics@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.

Participant's Signature _________________________ Date ____________

Researcher and/or Delegate's Signature ___________________ Date ___________

Data Dissemination

Do you wish to receive a written summary of the study results upon completion of our data analysis? If yes, please provide your e-mail address below.

Yes______________ No______________

E-mail address:____