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Attentional Demands in the Execution Phase of Curling in Novices and Experts

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Abstract

The purpose of this study was to determine the attentional demands of a curling delivery using a dual-task procedure. Skilled and novice curlers were asked to perform take outs and draws while attentional demands were measured using reaction time (RT) in the different phases of the throw. Results showed attentional demands for the draw and take out were highest at the beginning of the delivery. Compared to the draw, a significant rise of RT was shown at the end of the take out shot. Shot success was significantly higher for the take out condition in expert compared to novice curlers.

Keywords: attentional demands, curling performance, expert, novice, reaction time

1. Introduction

Research of attentional demands on athletes is an expanding area in the domain of motor control and learning with studies revealing the role of cognitive factors in the execution of motor movements in sports. While studies have attempted to examine attention at different stages of a particular voluntary movement, and the limited capacity to process information in sports, no studies have attempted to look at these components in the sport of curling.

Dual task paradigms were an early tool used by researchers for evaluating the relative attentional demands associated with different postural tasks and simple primary movement (Ells, 1973; Fraizer & Mitra, 2008; Posner & Keele, 1969; Woollacott & Shumway-Cook, 2002). This involved challenging attentional capacities; in particular the capacity of dividing attention between two tasks (Brown, Shumway-Cook, & Woollacott, 1999; Kerr, Condon, & McDonald, 1985; Manchester, Woollacott, & Zederbauer-Hylton, 1989). Using this general approach, several authors have demonstrated that attention required for establishing and maintaining good posture and also, as postural demands increase, the demands for attentional resources increase as well (Brown et al., 1999; Lajoie, Teasdale, Bard, & Fleury, 1993; Manchester et al., 1989; Woollacott & Shumway-Cook, 2002). Additionally, studies on gait initiation have concluded that more attention is needed when modifications of the speed, changes in direction, or precision are required and when supraspinal imputs are necessary to perform movements adapted to the environmental context (Brauer, Woollacott, & Shumway-Cook, 2001; Brown et al., 1999; Hyeong-Dong, 2009; Manchester et al., 1989; Siu & Woollacott, 2007).

Dual task paradigms have also been used to observe the temporal distribution of attention throughout a primary movement. For example, Wilke and Vaughn (1976) examined attentional demands in a simple dart throwing. Results from this study reported slower reaction time (RT) in the early segment of the movement compared to the faster RT shown in the later segments, indicating that processing capacity was occupied immediately following movement onset to a greater extent compared to later in the movement. Similarly, a study by Ells (1973) investigated the attentional demands of a primary task at three different phases of the movement. The participants in this study were asked to move a handle with one hand towards a target and respond to the RT stimulus with the other hand. Results from this experiment showed that cognitive demands were highest at the initiation and termination phases of the discrete manual movement, suggesting that the various phases of movement required a different level of attention. This study also showed that the relative degree of attention necessary for the execution of a movement is related to the accuracy, position and complexity of the movement. The results from these studies may lead us to believe that the curling delivery does require some attention and that not all phases have the same cognitive demands.

Another direct approach used in sports performance is to examine the difference between skill levels, comparing beginners and experts in a specific task. Studies have explored the notion that with learning through practice, skills can be performed automatically; this automation of movement appears to decrease cognitive involvement and effort in skilled players compared to novice players (Allard, 1993; Landers et al., 1994). Expert performers in hockey slap shot (Leavitt, 1979) and putting in golf (Beilock, Carr, MacMahon, & Starkes, 2002) have been characterized as : performing better than novice performers, showing progressively greater skill as a function of practice, demonstrating better sport-specific problem solving skills than novice performers, and exhibiting relative automaticity of action. In addition, experts have also shown to use an external focus of attention, resulting in superior performance and reduced attentional demands compared to novice performers who tend to adopt an internal focus of attention (Beilock, Carr, MacMahon, & Starkes, 2002; Gray, Neisser, Shapiro, & Kouns, 1991; Wulf, Chiviacowsky, & Lewthwaite, 2001; Wulf & Prinz, 2001).

The purpose of this experiment was to examine the attentional demands of each phase of a curling shot, compare the cognitive demands of two types of shots and compare the attentional demands between the skilled and novice players. The performance variables included were delivery speed, shot success percentages and measured distance in missed draw shots. It was hypothesized that attentional demands would be highest at phase 1 for both novice and expert groups due to the increased processing capacity of the regulators of balance, muscular strength for the push and cognitive factors to plan the sequence of movement. It was also hypothesized that the largest difference between both groups would occur in phases 2 and 3 where the expert group would show a shorter RT than the novice group as the execution movement becomes more automatic with practice. It was expected that the draw shot would demand more attention as rock weight; position and precision of the shot have shown to be highly important. It was assumed that the expert group would have a better shot success percentage, and smaller error when measuring the rock from the target. Finally, it was believed that the delivery speed of the expert group would be faster than the novice group as the expert group may have a more stable and controlled shot which would result in less resistance between the rock and the ice when sliding out of the hack.

2. Method

2.1 Participants

Nineteen participants (Mage = 46.7 years, age range: 30-62 years) completed the testing; ten from the skilled group (7 males, 3 females, Mage = 46.8 years, SDage = 7.0 years) and nine from the novice group (6 males, 3 females, Mage = 46.6 years, SDage = 9.0 years). Participants were recruited from two curling clubs (Sturgeon Falls Granite Club and Cumberland Curling Club) located in the Ottawa region. Two groups of participants were used for the research. The first group of ten participants included experienced curlers with five years or more of curling experience (Mexperience = 12.9 years, SDexperience = 7.3 years) and the second group included nine inexperienced participants with two seasons or less of curling experience (Mexperience = 1.8 years, SDexperience = 0.4 years). One year of experience was defined in this study as a complete season of curling.

All participants were in good health and functionally able to travel to the curling clubs by car or by walking from their home. For the participants' convenience and safety, all participants were asked to bring their own equipment to the experimental session. Approval from the Health Sciences Ethical Committee of the University of Ottawa was granted. A written consent from all the participants in the study was requested prior to stepping on the ice. The consent and protocol was in accordance with the declaration of Helsinki.

2.2 Materials and Procedures

The attentional demand of the curlers was measured by using RT during the execution of the different shots. A piezoelectric speaker was used which emitted a beep (1000 Hz, 50 ms duration, 100 db) to which the participants were asked to react by vocally answering top. To minimize sound dispersion and change in the distance between the participant and the speaker, the speaker was worn by the subjects using a belt. An MP3 recorder was used to record the beep itself and the voice of the participants when they answered to the auditory stimuli. The recorder was wrapped on the upper arm that was not being used to throw the rock. Reaction time was measured by comparing the beginning of the stimulus to the verbal response using the Audacity software. Laser photoelectric cells were used to record the speed of the participants for every shot. The first cell was placed at 574 cm from the edge of the ice sheet and the second cell was placed at exactly 183 cm from the first cell. Each cell was connected to a timing box which started the timer as the participant crossed the first cell and stopped the time when the participant crossed the second cell.

The single experimental session was the same for both the expert and novice groups. Participants attended one 60 minute experimental session. Prior to the experimental session, a warm-up period was performed with the participant throwing two or three practice shots to get comfortable with the ice and sliding. Then 70 shots were executed, 30 take outs, 30 draws (10 shots for each of the 3 phases of the shot) and 10 control trials. The first phase of the throw was characterized by the period in which the player came out of the hack when the foot slides under the body and behind the stone. It is then that the push leg is pulled and the foot is being turned inward. The arm holding the stone is stretched out. The second phase of the throw occurred when the player crossed the t-line. It is at this moment of the shot that the player is slid toward the target. The third and last phase of the throw occurred when the player arrived near the line of hog and performed the final flick of the wrist to release the rock (Figure 1).

Phase 1: Back line→→

Phase 2: T- line→→

Phase 3: Hog line→→

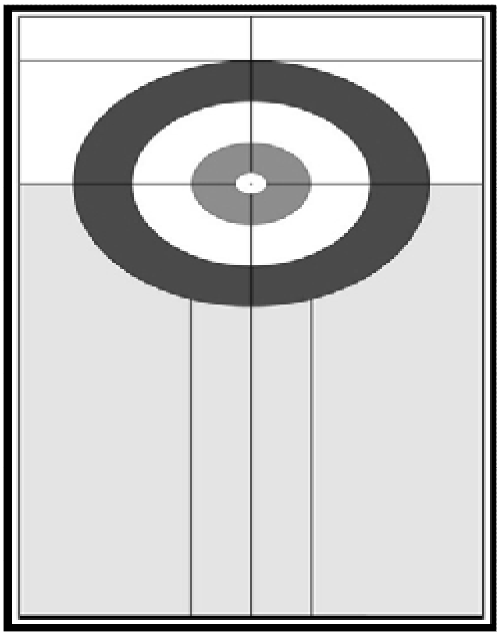

Figure 1. Locations of the auditory stimuli presented according to the three phases of the shot.

The 10 control trials consisted of 5 draws and 5 take outs that were randomly placed throughout the experiment without auditory stimuli to reduce anticipation. These control trials were not considered in the analysis. To emulate a real game setting, a research assistant called each shot to the participants from the end of the ice to reinforce to the participants that the shot was their priority. Participants were asked to complete two basic shots found in curling: the take out and the draw. For the take out, the players were asked to knock out a rock that was situated in the center of the house, right on the button. For the draw, players were asked to draw the rock to the center of the house, as close to the button as possible.

All participants were asked to execute each shot to the best of their abilities. The results were recorded by the skip at the end of each shot to determine if the shot was successful. For all take out shots, the outcome was considered successful if the opponent's rock was taken out of the house. For the draw, the outcome was considered successful if the rock stopped in the center of the house, on the button. If the rock did not stop in the center of the button, the result was not successful and the distance was then measured to analyze magnitude of error. All distances were recorded in centimeters by using a standard measuring tape. If the rock was short (did not cross the hog line) or was too heavy (went straight through the house) the longest distance was recorded which was 640 cm. To control for order effects, the sequence of shots were randomized.

2.3 Statistical Analysis

A three-way analysis of variance (ANOVA), including group by phase by type of shot with repeated measure on the last two factors was used to compare changes in RT, speed and shot success. A two-way ANOVA, including group by phase with repeated measures on the last factor, was used to compare changes in distance from center for the draw. A lowest significant difference (LSD) post-hoc analysis was used to determine the location of the differences when the ANOVA revealed significant differences with a p value less than or equal to .05.

3. Results

3.1 Reaction Time

The three-way ANOVA for the RT results revealed no significant effect of group, $F(2, 34) = .364$, $p = .851$, $\eta 2= .027$, a significant effect of phase, $F(2, 34) = 9.00$, $p < .001$, $\eta 2 = .673$, and no significant effect of shot type, $F(2, 34) = 0.109$, $p = .075$, $\eta 2 = .002$. The three-way ANOVA also revealed no significant interaction for group by shot type, $F(1, 17) = 0.763$, $p = .394$, $\eta 2 = .033$, no significant interaction for group by phase, $F(2, 34) = 1.663$, $p = .205$, $\eta 2 = .124$, but did show a significant interaction for shot type by phase, $F(2, 34) = 4.853$, $p = .014$, $\eta 2 = .119$ (see Figure 2). Finally, there was no significant three-way interaction for group by shot type by phase, $F(2, 34) = 0.855$, $p = .434$, $\eta 2 = .021$. A lowest significant difference (LSD) post-hoc analysis revealed that the RT for phase 1 of the shot was significantly longer than phases 2 ($p < .001$) and 3 ($p < .001$). There was no significant effect between phases 2 and 3 for the RT ($p > .05$). An LSD post-hoc analysis revealed a significant difference between phases 1 and 2 ($p < .001$) and phases 1 and 3 ($p < .001$) for the draw. Results from the take out revealed a significant difference between phases 1 and 2 ($p < .001$), phases 1 and 3 ($p = .031$) and phases 2 and 3 ($p = .012$). Results comparing shot type showed a significant difference between the two shots in phase 3 ($p = .028$) but did not reveal a significant effect between shots in phase 1 ($p = .141$) and phase 2 (p =

.131). Reaction time for phase 1 was longer than RT for phases 2 and 3 in both shot types, the only difference in RT between shot types was found in phase 3 of the delivery.

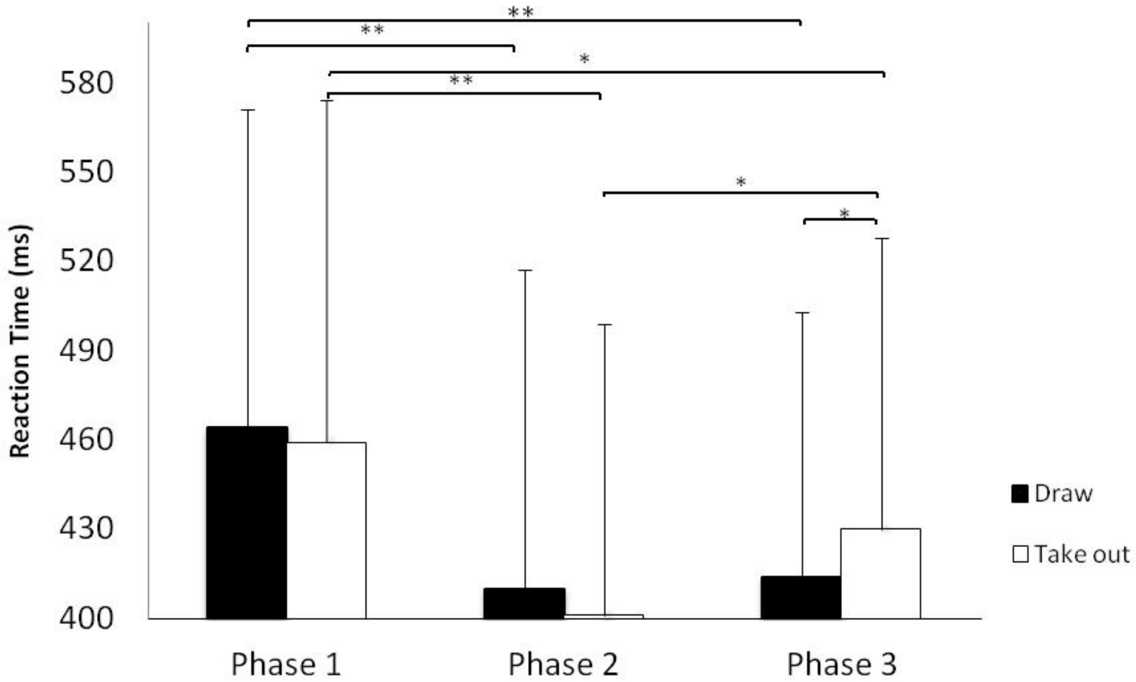

Figure 2. Mean RT (ms) to probe as a function of stimulus location and type of shot, *= <.05, **= p <.01.

3.2 Shot Success

The three-way ANOVA on shot success revealed a significant effect of group, $F(1, 17) = 12.60$, $p = .002$, $\eta^2 = .074$, no significant effect between phases, $F(1, 17) = 0.742$, $p = .483$, $\eta^2 = .003$ and a significant effect between shot type, $F(1, 17) = 155.7$, $p < .001$, $\eta^2 = .855$. The three-way ANOVA also revealed a significant interaction for group by shot type, $F(1, 17) = 10.917$, $p = .001$, $\eta^2 = .059$, no significant interaction for group by phases, $F(2, 34) = .2616$, $p = .771$, $\eta^2 = .001$ and no significant interaction were found between shot type and shot phases, $F(2, 34) = 1.072$, $p = .353$, $\eta^2 = .004$ (see Figure 3). There was a significant difference in the average shot success rate with the expert group attaining approximately 41 % and the novice group only 25 %. On average, shot success rate for the draw was significantly lower at 7 % compared to the take out at 59.5 %.

An LSD post-hoc analysis between shot success, group and type of shot showed no significant results between the groups for the draw shot ($p = .798$) but did show a significant difference between the groups for the take out shot ($p = .0013$). Both groups had significantly higher shot success during the take out than the dram shot ($p = .0001$). These results show that shot success for the take out was higher for both groups but significantly more for the experienced group.

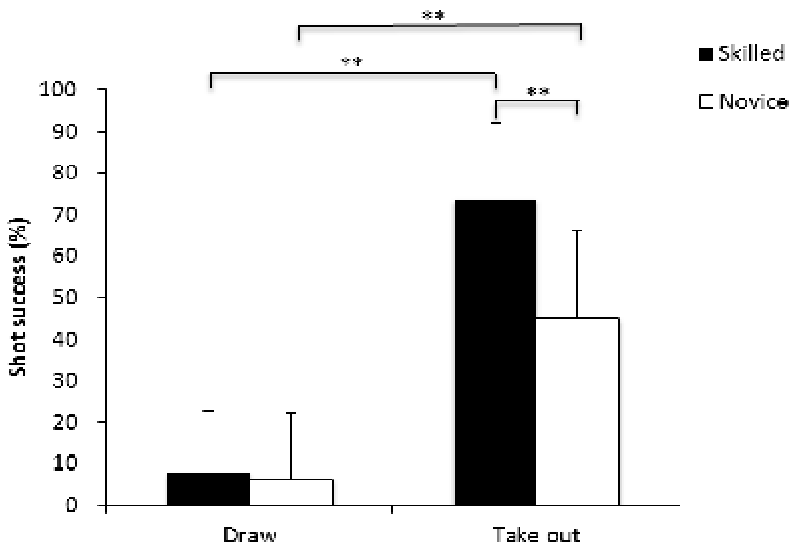

Figure 3. Mean shot success (%) as a function of skill level and type of shot, **= p <.01.

3.3 Distances from the Center

Distance was another variable that was measured to examine player performance. Distance was measured in centimeters from the button to the final position of the rock once it stopped during the draw phase. For example, if the rock was short (i.e., stopped before the hog line) or fast (i.e., through the house) extreme measures were given (640 cm).

The two-way ANOVA for group by phase for distance measurements revealed that there was no significant effect of group, $F(1, 17) = .041$, $p = .840$, $\eta^2 = .004$, no significant effect of phase, $F(2, 34) = 3.10$, $p = .060$, $\eta^2 = .45$, but a significant interaction group by phase, $F(2, 34) = 3.175$, $p = .030$, $\eta^2 = .54$. Figure 4 shows the results of an LSD post-hoc analysis that revealed no significant differences between phases 1 and 2 ($p = .727$), phases 1 and 3 ($p = .786$) or between phases 2 and 3 ($p = .536$) for the expert group. As for the novice group, significant differences were found between phases 1 and 2 ($p = .002$) and phases 1 and 3 ($p = .013$), but no significant differences were found between phases 2 and 3 ($p = .437$). No significant differences were found between the expert and novice groups in phase 1 ($p = .060$), phase 2 ($p = .067$) or 3 ($p = .638$). Figure 4 shows that the participants in the expert group had the same draw performance throughout all the phases while the novice group was farther from the button of the house when the stimulus was presented during phase 1. The difference between the two groups for phase 1 of the delivery was close to significance ($p = .060$), such that the distance from the button when the probe was presented at phase 1 of the delivery affected the novice group more than the expert group.

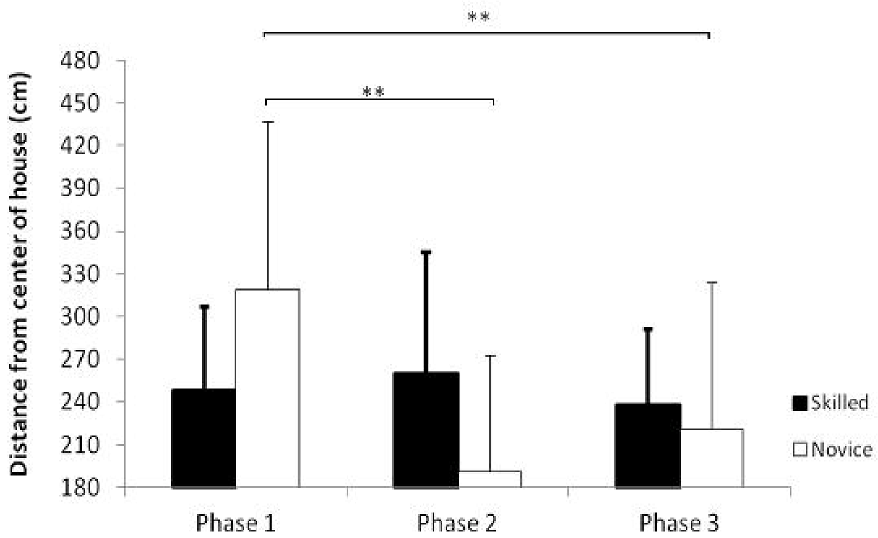

Figure 4. Mean distance from center (cm) of the house as a function of stimulus location and skill level, *= p <.05, **= p <.01.

3.4 Delivery Speed

The three-way ANOVA of group by phase by shot type for delivery speed revealed a significant effect of group, $F(1, 16) = 19.65$, $p < .001$, $\eta^2 = .77$, no significant effect of phase, $F(2, 32) = 1.94$, $p = .159$, $\eta^2 = .005$ and a significant effect of shot type, $F(1, 16) = 146.0$, $p < .001$, $\eta^2 = .187$. A significant interaction of group by shot type was also found, $F(1, 16) = 17.9$, $p < .001$, $\eta^2 = .023$ (Figure 5); however no significant interactions were observed between group by phase, $F(2, 32) = 1.08$, $p = .352$, $\eta^2 = .002$, or between shot type by phase, $F(2, 32) = 2.66$, $p = .085$, $\eta^2 = .01$. Finally, no significant group by shot type by phase interaction was found, $F(2, 32) = 0.19$, $p = .826$, $\eta^2 = .001$.

An LSD post-hoc analysis on the group by shot type interaction showed significant difference in delivery speed between the draw and the take out for the expert ($p < .001$) and also for novice group ($p < .001$). There was also a significant difference between the two experimental groups for the draw ($p < .001$) and the take out ($p < .001$).

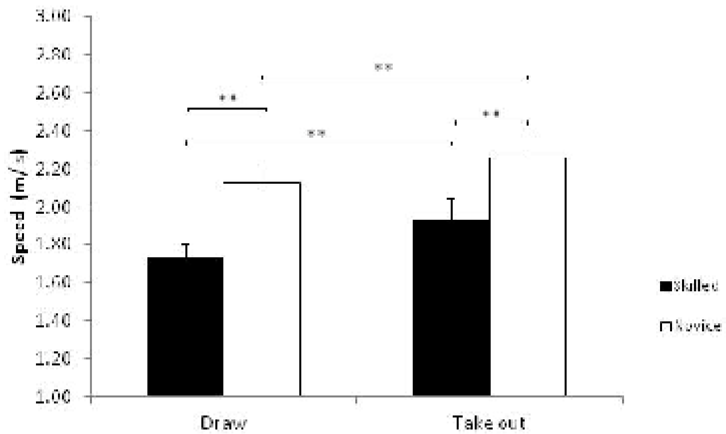

Figure 5. Mean delivery speed (m/s) as a function of shot type and skill level, **= p <.001.

4. Discussion

4.1 Attentional Demands

Taken together, the overarching hypothesis of this study was confirmed as attentional demands were higher in phase 1 of the curling delivery compared to phases 2 and 3 for both expert and novice groups. There are several possible factors to explain this difference. For instance, Wilke and Vaughn (1976) examined attentional demands and dart throwing and found that attentional demands were higher during movement initiation, suggesting that processing capacity was occupied. It could also be argued that the aiming requirements during the dart throwing task found in Wilke and Vaughn (1976) and in this curling study could be responsible of this greater attentional demand in phase 1. These results demonstrate that less attention is required during the execution of the movement (i.e., phase 2) and the termination of the movement (i.e., phase 3) compared to movement initiation (i.e., phase 1).

Using interference protocols, several authors have demonstrated similar results for the attentional demands throughout a controlled movement. A study by Ells (1973) revealed that not all components of a discrete arm movement require the same level of attention. He also showed that attentional demands were highest at the initiation stage of the movement response; however, these demands decreased as the arm movement progressed. Similar research on the termination of movement has shown that when the termination of movement is corrected, the attentional depends will depend on the required precision of the final movement (Posner & Keele, 1969). That is, when the final movement required more precision, more attentional demands are required. Some locomotor positioning studies have revealed there is an increase in attentional demands at the end of a pointing movement (Bardy & Laurent, 1991).

Another one of our hypotheses regarding attentional demands looked at the difference between the novice and expert groups. We believed that the biggest difference between both experimental groups would occur in phases 2 and 3 of the delivery. We predicted the novice players would have a longer RT, indicating higher attentional demands than the skilled curlers and the expert players would have a shorter RT in phases 2 and 3 because with practice the execution of movement becomes more automatic. However, our results did not show this difference. Perhaps the skills required for a curling shot were too complex and dynamic to become an automatic response. Similar research has also concluded that even after extensive single task practice, additional dual-task practice was needed for participants to perform two tasks simultaneously (Hirst, Spelke, Reaves, Caharack, & Neisser, 1980). The results from this study also compare to those of Rose and Christina (1990) who studied divided attention through the aiming phase of a discrete pistol shot at various skill levels. The skill levels that were compared in their study were novice, sub-elite and elite athlete and their findings showed that the probe RT was distributed similarly across all skill levels suggesting that attentional demands did not differ between groups.

Finally our last hypothesis concerning the attentional demands investigated the difference in RT between the draw shot and the take out shot. It was believed that the draw shot would demand more attention as it requires more precision whereby aiming, rock weight, rock position and ice reading are highly important factors that contribute to a more attention-demanding task and consequently more require more attentionaly demanding for of the player. Our findings from the three phases of the delivery for both types of shots hold some interesting results. No significant differences were found between the draw and the take out for the first phase and the second phase of the shot; however, there was a surprising result at the termination phase of the delivery. The RT of the take out at the termination phase increased significantly in comparison to the second phase of the shot while the RT for the draw in phase 3 was similar to phase 2. It was found that the level of attention required for the termination of movement was higher in the take out shot than in the draw. When examining both shots, it is possible that the draw shot used in our experiment required weight control more than aiming precision (at least in our experimental condition, since no other rocks were in the house for that specific condition). For the take out condition, weight was generally higher coupled with an aiming precision requirement, which may explain the increased attentional cost. Although it was not measured, perhaps curlers made final adjustments to the take out shots, which could have resulted in higher attentional requirements.

4.2 Performance Variables

4.2.1 Shot Success

The first hypothesis regarding shot success was that the expert players would perform at a higher level and have a better shot success rate than the novice players. The results provided support for this hypothesis as there was a significant difference between the two experimental groups with the expert players successful in 41 % of their overall shots whereas the novice group was only successful in 26 % of their shots. Given that the novice players were likely at the cognitive phase of the learning process, their performance was inconsistent and consequently less successful than the expert players. Furthermore, it is possible that the novice group tended to focus more internally on the technical aspects of the delivery instead of the delivery outcome, which is typical of less skilled players. The expert group was likely in the autonomous phase, resulting in a better shot success percentage as their delivery was more controlled. Other research has also found that expert players allocate more of their attention on external factors such as the outcome of the shot and thus generating a higher success rate (Schmidt, 1988). In comparing the success rate in relation to the type of shot, our results showed that the take out shot (i.e., 59 %) had a higher success rate than the draw shot (i.e., 28 %). These results are in line with our hypothesis that making a draw to the button in curling is extremely challenging. For instance, an accurate draw to the button requires the rock's weight and aiming to be precise. In a normal curling environment, the player delivering the rock can rely on a team of brushers, which will increase the success rate of the draw shot. Statistics from the Canadian Curling Association (2011) show that in normal curling phases, the draw and the take out success percentage should be similar, however, the absence of brushing in this study led to greater successful take out shot percentage. Our reason for not having brushers in this study was that we were looking at individual players' performance and not the performance of a curling team. Given that the rock sweepers can correct unsuccessful shots to a certain degree, this may have posed problems in this study; thus we decided to exclude the sweeping from our study. This ultimately increased the difficulty of making the draw shot. We did, however, discover interesting findings regarding the success percentage of each experimental group in relation to the type of shot that was being performed. The results indicated that there were no significant differences between the expert and novice players when they were performing a draw shot. As mentioned earlier, in the game of curling, a draw to the button is considered one of the most difficult shots, even expert level players have difficulty delivering this shot successfully. As expected, the expert players had a significantly higher success rate than the novice players for the take out shot, which can be explained by the level of skill of the experts. Through practice, expert players have learned the right amount of push force required to complete this type of shot. In addition, the expert players had a more balanced delivery than the novice player which guided their focus more externally, which resulted in better performance.

4.2.2 Distance from the Center

Distance was measured for the draw shot only and was used to examine players' performance. The distance (cm) was measured from the button to the final stopped position of the rock. For this study, if the players did not put their rock right on the button, the draw was considered a miss and the distance was measured. Results of the interaction for group by phase for the expert group revealed that there were no significant differences between the distance measured from the button of the house and the phase of where the probe was presented. These results indicate that regardless of when the probe was presented during the delivery, it did not affect the performance of the expert player as they all had similar distances on missed draws. Interestingly, the results for the novice group showed that the rock stopped significantly farther from the center when the probe was presented at the beginning of the movement (mean = 319 cm) compared to when the stimulus was presented at the second phase of the shot (mean = 191 cm) or the termination phase of the shot (mean = 221 cm). These results suggest that the attentional demands of the shot were highest during those stages of the shot, which resulted in the players having their most unsuccessful draw results. One explanation for this could be that the novice players may not have mastered a controlled and balanced delivery and may have needed to use more attentional resources on planning the shot. The probe presentation may have interrupted that planning to a greater extent in the novice compared to the expert group. The attentional demands are greatest at the initial phase of the movement and the novice players not only have a slower RT but they also missed their draw shot more often when the probe was presented to them at the initial phase of the delivery. This is congruent with the attentional resource theory and Wickens' (1989) work which showed that when two tasks are performed together and require a significant amount of attentional resources, the performance on either or both tasks may deteriorate.

4.2.3 Delivery Speed

As expected, there was a significant difference in the delivery speed between the take out and the draw shot because the takeout shot is delivered at high speed since its main purpose is to remove the opponents' stone from the playing surface. Contrary to the takeout, the draw is a very slow but precise shot which involves sending the stone down the ice and getting as close to the button as possible. There was also a significant difference between the two experimental groups for the delivery speed. The expert group had an average delivery speed of 1.83 m/s second while the novice group had an average speed of 2.18 m/s. It is possible that the novice group had a faster delivery speed than the expert group because the novice players may not have strong balance on the ice which may have created more friction on the ice and as a result, did not slide as far as the expert players did. Because novice curlers may not slide as far they need to, it is necessary that they come out faster from the hack. Since most novice players did not slide the whole distance we had to position the photoelectric cells at the beginning of the slide. Consequently, we did not consider the whole sliding surface.

5. Conclusions

Looking at the RT measurements and all of the performance variables as a whole, some interesting conclusions can be made. The results showed that expert players had a higher shot success and a slower delivery speed than the novice players. Making the link between these results and the attentional focus of the players, it is suggested that the expert players may have mastered the internal factors of the delivery and thus have their focus on the external element of the shot, directing their attention on the target, shot outcome and assuring a smooth delivery. These are all factors that have an attentional cost, adding to the cognitive demands of the delivery for this group. This may explain why the expert players had a slower delivery, and better shot success; however, the RT was similar between the expert and novice groups. Contrary to the expert group, the novice group had a lower shot success rate and a faster delivery speed than the expert group. The novice group also had a more internal focus of attention, as these players required more concentration on the numerous factors of the delivery, such as, muscle force, balance, rock control and delivery steps. Thus these internal factors also have a high attentional cost and consequently, the novice players devoted much of their processing resources to the delivery itself and not the shot outcome and the surrounding environment.

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