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Effect of puck mass as a task constraint on skilled and less-skilled ice hockey players performance

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Abstract

Manipulation of task constraints have previously been effective in task simplification enhancing skill development. This study examines how manipulation of puck masses affects movement behaviors in skilled and less skilled ice hockey players during a representative ice hockey task. Fifty participants were separated into a skilled (n = 25) or less-skilled (n = 25) group. Three trials per condition of an obstacle course and breakaway goal attempt were completed in a counter-balanced design using three puck masses, categorised as: light (133g), regulation (170g), and heavy (283g). Findings revealed that use of the light puck by less-skilled participants reduced obstacle-course completion time ($p < .05$, $\eta^2_p = .781$) and error occurrence ($p < .05$, $\eta^2_p = .699$) while improving shot accuracy ($p < .05$, $\eta^2_p = .430$) and goal success ($p < .05$, $\eta^2_p = .092$) compared to the regulation and heavy puck. However, skilled participants had a decrease in performance when deviating from the regulation puck for all the dependent measures excluding an increase in goal success when using the light puck ($p < .05$, $\eta^2_p = .430$). Findings demonstrated the functional coupling of puck mass and movement behaviors are dependent on the skill level of the performer.

Key Words: *Affordances, ecological dynamics, perception action coupling, weighted puck*

Effect of puck mass as a task constraint on ice hockey performance

Ice hockey is a fast, explosive, and dynamic sport, however, is often difficult for beginners due to the need for complex skills such as skating, puck-handling, and shooting (Armentrout & Kamphoff, 2011; Côté, Vierimaa, Hancok, & Imtiaz, 2014; Imtiaz, Hancock, Vierimaa, & Côté, 2014). Task simplification has been described as an effective method for facilitating the acquisition of motor skills in a variety of team (Silva et al., 2014; Hadlow, Pinder, & Sayers, 2017) and individual (Wood, Vine, & Wilson, 2013; Kachel, Buzard, & Reid, 2015) sports. Theoretically, task simplification can be underpinned by Newell's (1986) constraint model that states the emergence of behavior could be guided through the confluence of task, environmental, and organismic constraints (Renshaw, Chow, Davids, & Hammond, 2010). Therefore, through task simplification, appropriate and progressive skill development can be targeted (Hadlow, Pinder, & Sayers, 2017), as by manipulating specific characteristics of the task, performers are required to search for the movement response that delivers the desired performance outcome (Renshaw, Davids, Shuttleworth, & Chow, 2009; Headrick, Renshaw, Davids, Pinder, & Araújo, 2015).

The composition of equipment has been used as a method of task simplification in ball sports. For example, Arias, Argudo and Alonso (2012) demonstrated that a lighter ball enabled youth basketball players to direct attention from ball-control to game interpretation. The focus on game interpretation is a crucial development point as the ability to specify key affordances enables decision making and accelerated acquisition of desired movement behaviors (Poltavski & Biberdorf, 2014). However, these findings are attributed to age-appropriate modifications due to the inability of young players to cope with the physical demands (regular ball mass). Future research should address how task constraints affect skill development of adult participants. However, modifications that simplify performance, must be representative of the constraints innate to the skill as this preserves perception-action couplings that are functional at the regulation version of the sport (Buszard, Reid, Masters, & Farrow, 2016). One such method of task simplification that could be appropriate for skill progression in ice hockey is to manipulate the puck mass, with recent communication suggesting the use of a lightweight puck facilitates skill development in less-skilled youth players (Amidon, 2014). However, these constraint manipulations are yet to be investigated in a systematic research design or in the development of less-skilled adult ice hockey players.

Few studies have investigated the impact of puck mass on ice hockey performance, with the exception of Stark, Tvoric, Walker, Noonan and Sibla (2009) whom used a variety different puck masses to study the impact on physical performance. The use of weighted pucks resulted in enhanced grip endurance and stick-handing ability. However, due to the nature of construction, the metallic puck experienced ~ 40% less friction on the ice compared to the regulation vulcanised rubber pucks and therefore did not represent the puck specific affordances present in a game situation (e.g., friction between the puck and ice) (XPuck, 2000; Pinder, Davids, Renshaw, & Araújo, 2011).

The shift of focus away from the puck is a major defining point between skilled and less-skilled performers. Skilled players demonstrate coupling between perception and action allowing them to control and play the puck without direct attention (Poltavski & Biberdorf, 2014), as through playing experience, skilled players become attuned to their equipment and affordances specific to the performance environment (e.g., inter and intra team movement synergies) (Pinder et al., 2011). In this sense, the use of the lightweight puck should aid acquisition of skilled movement in the less-skilled group as performers shift attention to tactical concepts (Jacobs & Michaels, 2007). Conversely, the use of lightweight pucks may alter the skilled players learnt coupling and lead to a reduction in performance. Hence, it is important for practice design to clarify the efficacy of puck mass constraint across skill levels to further understand how motor capabilities innate to playing experiences influence the degree of coupling between perception and action during constraint-based practice in ice hockey.

Therefore, the aim of this study was to examine performance between skilled and less-skilled participants when using three pucks, light (133g), regulation (170g) and heavy (283g). It is hypothesised that use of the lightweight puck will aid skating and stick-handling performance for the less skilled group, but have a negative impact on the performance of the skilled participants. The lightweight puck will also allow less skilled participants to experience more shooting success, while skilled players will be impacted negatively as they will not be familiar with the mass of the puck.

Method

Participants

Fifty participants volunteered for the study and were stratified into a skilled or less-skilled group. Skilled participants (n = 23 male, 2 female, Mage: 21.96 ± 2.3 years) had 82.6 ± 23.4 months playing experience and identified as playing in the British University Ice hockey Association (BUIHA) tier 1-2 checking leagues with a minimum of three years' competitive experience. Less Skilled participants (n = 24 male, 1 female, Mage: 21.7 ± 2.4 years) had 25 ± 8.6 months playing experience and identified as playing in the BUIHA tier 3-4 non-checking league. Ethical approval was granted by the local research ethics committee and all participants provided written informed consent.

Procedures

Participants were individually tested and performed in three conditions consisting of varying puck masses, a light (133g), regulation (170g) and heavy puck (283g). A counter-balanced cross-sectional design was employed to reduce learning effects with each participant completing three trials with their designated puck for that session, with one week's rest given between each session.

Each session had two phases, first, participants performed an obstacle course (based on Stark et al., 2009) that created tasks representative of a game situation: (a) starting from a stopped position, (b) maintaining puck control through wide turns (c) keeping the puck under control through a tight and fast region, and finally (d) performing a figure-eight around the final cones and returning through the course (see Figure 1). Time to completion of the obstacle course (Stark et al., 2009) and error count (defined as the frequency of which the performer(s) lost control of the puck) was recorded.

The second phase involved participants starting with the puck on the mid-way line, skating as fast as possible down the rink, through a speed trap, before skating into the shooting zone (indicated by cones on ice) and taking a shot against the goalkeeper. The same two goalkeepers (matching the skill level of each participant group) were used throughout testing with each shot being video recorded. For each trial the shot was identified as being on or off-target and then resulting in a goal or a miss/save. The video data of the trials was analysed post-collection using Sportscode Elite (Sportscode Elite, Version 10.1, Sportstec, Australia) to confirm shot outcomes and calculate percentage shot accuracy and goal success.

Reliability Testing

Cohen's (1960) kappa statistic was employed to analyse intra-observer reliability of the notational analysis data for shot outcome. Analysis was verified though the reassessment of 100 actions, in which the analyst coded on two separate occasions, respecting a four week interval to reduce learning effects (Altman, 1990). Respecting the criteria described in Fleiss, Levin and Paik (2013), the kappa statistic was k = 0.96, which corresponds to an '*excellent'* intra-observer agreement.

Data Analysis

A total of 450 trials were captured across all participants. Two independent variables were analysed, the puck mass catergorised as either light (133g), regulation (170g) and heavy puck (283g) and player skill level catergorised as either skilled and less-skilled. Normality was assumed using the Kolmogorov-Smirnov test and a parametric method of analysis was employed. Separate two way mixed (within: puck mass; between: skill level) design Analysis of Variances (ANOVA) were conducted on each dependent variable; obstacle course time (s), obstacle course errors, sprint speed (m/s), shot accuracy (%) and shot outcome (%). Where the assumption of sphericity was violated, a Greenhouse-Geisser correction was employed. Partial ETA-Squared (η^2_p) was presented to calculate estimations of main effects on the ANOVAs and the following benchmark values were used to classify the effect size: small effect = 0.01, medium effect = 0.06, large effect = 0.14 (Cohen, 1988). Post-hoc analyses were employed where appropriate using a bonferroni correction coefficient and Cohen's *d* was utilised as a measure of effect size for post hoc testing. The following categories were used to classify effect size values for Cohens *d*: small effect = 0.2, medium effect = 0.5, large effect = 0.8 (Cohen, 1988).

Results

Obstacle Course Completion Time

A main effect for skill was displayed, with skilled participants completing the course quicker than less skilled $F(1, 48) = 226.899$, $p < .001$, $\eta^2_p = .825$). A main effect for puck mass on course completion time was also present, $F(2, 96) = 170.845$, $p > .001$, $\eta^2_p = .781$. Post-hoc tests revealed that the heavy puck (29.34 ± 4.08s) resulted in slower course completion times compared to regulation puck (28.42 ± 4.03s) ($p < .001$, $d = 0.23$) and the light puck (28.52 ± 3.06s, $d = 0.23$). A puck mass x skill level interaction was present for course completion time $F(2, 96) = 226.363$, $p < .001$, $\eta^2_p = .825$ (See Figure 2). Less-skilled participants completion time increased with the heavy puck (33.05 ± 2.12s) compared to the light puck (31.20 ± 1.88s, d = 0.92) and the regulation puck (32.05 ± 2.17s, d = 0.47). However, use of both the light puck (25.84 ± 0.74s, d = 1.19) and heavy puck (25.61 ± 0.86s, d = 0.88) by the skilled participants was found to increase course completion time in comparison to the regulation puck (24.78 ± 1.01s).

Obstacle course error occurrence

A main effect for skill was displayed, the skilled group had less errors than the less-skilled group, $F(1, 48) = 6.595$, $p = .013$, $\eta^2_p = .121$. Puck mass also had a main effect on frequency of error occurrence $F(2, 96) = 48.565$, $p < 0.001$, $\eta^2_p = .503$. The heavy puck (3.22 ± 1.51 errors) resulted in more errors than the regulation puck (2.02 ± 1.34, $p < 0.001$, d = 0.84) and the light puck (1.8 ± 1.24, $p < .01$, d = 1.02). A puck mass x skill level interaction was present $F(2,96) = 68.054$, $p < .001$, $\eta^2_p = .586$ (See Figure 3). For the less skilled group, errors became more frequent as puck mass increased, where as the skilled group had more errors for the light puck (2.48 ± 1.15 errors, d = 1.02) and heavy puck (2.16 ± 0.85 errors, d = 0.84) compared to the regulation puck (1.4 ± 0.95 errors).

Shot accuracy percentage

A main effect of puck mass on shot accuracy $F(1.336, 64.151) = 4.402$, $p = .029$, $\eta^2_p = .084$ was displayed. Post-hoc tests revealed the regulation puck (76.36 ± 25.59%) had a higher shot success rate than the heavy puck (67.66 ± 28.64%). There was also a main effect for skill level $F(1, 48) = 17.330$, $p < .001$ with skilled (83.2% ± 18.81) having a higher shot percentage than less skilled (64.5 ± 23.7%). A puck mass x skill level interaction was also present $F(1.336, 64.151) = 18.109$, $p < .001$, $\eta^2_p = .275$. (see Figure 5).

Goal success percentage

Results showed a main effect for puck mass on goal success $F(21.648, 79.122) = 22.966$, $p < 0.001$, $\eta^2_p = .324$. Goal success rate decreased as the puck became heavier, light puck (46.28 ± 25.11%), regulation puck (33.66 ± 22.59%) and heavy puck (20.46 ± 22.01) (all $p < 0.05$). There was also a skill effect, $F(1, 48) = 51.053$, $p < 0.001$, $\eta^2_p = .515$, with skilled (45.81 ± 21.16%) scoring more goals than less skilled (21.21 ± 17.9%). However, no puck mass x skill level interaction was present $F(1.648, 79.122) = 0.630$, $p > 0.05$, $\eta^2_p =.0.13$. (see Figure 4).

Sprint speed performance

There was a main effect for skill $F(1, 48) = 233.043$, $p < 0.001$, $\eta^2_p = .829$, with skilled (11.31 ± 1.08 m/s) participants having a high speed than less skilled (8.31 ± 0.42 m/s). There was also a main effect for puck $F(1.113, 53.403) = 7.482$, $p < 0.05$, $\eta^2_p = .135$. Post hoc testing showed the light puck resulted in quicker times (10.02 ± 1.89 m/s) compared to the heavy puck (9.58 ± 1.58 m/s, $d = 0.25$). Time for the regulation puck (9.82 ± 1.68 m/s) was also quicker than the heavier puck (9.58 ± 1.58 m/s, $d = 0.14$). There was no puck x skill interaction for sprint speed $F(2, 96) = 1.590$, p > 0.05, $\eta^2_p = 0.032$).

Discussion

This study examined how manipulating puck mass affected representative ice hockey performance and emergent functional movement behaviors in skilled and less skilled performers. Overall, findings demonstrate a reciprocal relationship between puck mass and performance, with varying effects evident between skill levels, supporting the ecological proposal that self organisation tendencies are innate to characteristics of the learner and shaped by interacting constraints (Renshaw et al., 2009).

Less-skilled performers improved course completion time and reduced their errors when using the light puck, suggesting how task simplification helped learners maintain the representative actions of ice hockey at a speed closer to skilled performers. This outcome supports the proposal as the light puck reduced the demand on the participant allowing for an improvement in stick-handling, which in turn reduced the occurrence of errors and could aid in preventing some of the initial participation challenges faced by less skilled players (Soberlak & Cote, 2003; Armentrout & Kamphoff, 2011). Hence the use of a light puck as a task constraint may aid technique development and engagement in the sport (Armentrout & Kamphoff, 2011). Our data concurs with research suggesting that manipulating task constraints, (i.e., changes to equipment, lighter pucks) could be implemented as a representative tasks in ice hockey coaching to gradually increase each player's functional performance behaviors during game play scenarios (Arias et al., 2012).

Shot accuracy and outcome also provided insight into the effect of puck mass on shooting as the results found that use of a lightweight puck by the less-skilled participants increased goal-scoring success. This follows expectations proposed by Arias et al. (2012) that task simplification reduces the technical demand of the participant during skill execution. Here, the constraint afforded by the lighter puck may direct a participant's attention away from puck control and towards the tactical placement of the shot in order to score (Jacobs & Michaels, 2007). This could be an important practical point for ice hockey coaches as typically less-skilled participants compete in competitions where less importance is place on the ability to control the puck without direct attention, as aggressive physical contact from the opposition will result in a penalisation of that player. Therefore, less-skilled participants have less need to control the puck without direct attention and the altering of puck mass might result in less reliance on technical proficiency, shifting towards a more tactical development. These findings concur with previous research in tennis, which demonstrated how changes to an affordance landscape (reduced ball compression) can facilitate emergence of a rich range of performance behaviors in learners, without specific, prescriptive instructions being provided (Kachel et al., 2015).

The manipulation of the puck mass for skilled participants resulted in negative performance effects, with obstacle course completion time increasing for the light and heavy pucks in comparison to the regulation puck. As expected, decreases in the skilled participant's obstacle course completion time can be attributed to the disturbance the different pucks cause to their stable perception-action couplings (Poltavski & Biberdorf, 2014). At a skilled level, competition allows for aggressive physical contact, players must be aware of their opposition when in control of the puck and hence must attune both to the puck but also opposition. It is suggested that through experience, skilled participants have become attuned to the mass and feel of the regulation puck allowing them to shift attention away from the puck in order to perceive any approaching danger and act accordingly. However, as demonstrated by Stark et al. (2009) a lighter puck exhibits less friction on the ice when completing the obstacle course and therefore moves further than the regulation puck with the same force. This change to the coupling caused a higher error rate for the skilled participants and increased the completion time. If constraints remain the same then highly stable movement patterns may develop, however, adaptations to constraints such as a change in puck mass can lead to some functional instabilities in learners resulting in motor system re-organisation, and new patterns of behavior emerging (Pinder et al., 2011; Headrick et al., 2015). Here, with limited experience using a light puck, skilled participant were unable to functionally (re) organise their skating behaviour quickly enough to satisfy the task constraints.

Skilled participants demonstrated a decrease in performance in terms of longer course completion time and loss of shot accuracy when using both the lightweight and heavy pucks. Poltavski and Biberdorf (2014) suggested skilled players exhibit a pre-determined coupling between the amount of force needed and desired location of shot. Results here, show that the change in puck mass disturbed this coupling, causing shots to miss the goal. Contrary to the expected hypothesis, skilled participants elicited improvements in goal scoring success when using the light puck, and a further decrease in performance as puck mass increased. However, Stark et al. (2009), suggests that the use of a light puck affords skilled participants opportunities to shoot the puck much faster with the same amount of force they usually employ for a shot with a regulation puck. This concurs with the results of the current study, as the majority of skilled participants missed the first shot but successfully scored on the following two shots. This suggest skilled participants were able to functionally adapt to the mass of the puck for the shooting task, unlike, the skating component. These results support the constraints-led approach, that affordances (opportunities for action) provided for individuals will facilitate active exploration, generating emergent functional movement solutions, dependent on skill level and on the constraints imposed on them (Chow, Davids, Button, & Renshaw, 2016). Our results suggest that the skill of shooting, was able to be functionally adapted quicker than that of skating. Hence, future practice designs could look to manipulate task constraints focused on skating skills, to help develop skilled athletes ability to become more adaptive in this essential skill.

The findings in our study highlight the importance of the representative sampling of participants (Brunswik, 1956), when examining how manipulation of task constraints interact with the individual and the task design, to shape emergent behaviors. If researchers wish to examine the effect of specific interacting constraints manipulations, careful sampling of the affordance landscape and participants is required (Rietveld & Kiverstein, 2014). The findings in this study can also impact on the safety of these less-skilled participants as this task constraint caused performers to focus less on the puck and more on the tactical concepts of the game. This change in focus is a crucial point in skill development that may reduce injuries and prepare them for the introduction of aggressive physical contact. Future research should consider extending the study over time as the use of a cross-sectional design did enable learning changes to be monitored to see if the effects varied over time as this would provide further evidence if task constraints such as puck mass benefit learning.

Conclusion

In summary, the data reported here provides further rationale for the use of task constraint to guide behavior and aid skill development. More specifically, this research provides evidence to the use of a lightweight puck to aid the learning of less-skilled participants and its use to promote the focus shift from technical ability to tactical proficiency, which is key in the transition to skilled ice hockey performance. Moreover, creativity in manipulating task constraints is needed in pedagogical practice to facilitate continuous adaptations of learners to changes in an affordance landscape (Davids, Shuttleworth, Araújo, & Gullich, 2017)

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