

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

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1 **Effect of puck mass as a task constraint on skilled and less-skilled ice hockey players**
2 **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*

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

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

67 The composition of equipment has been used as a method of task simplification in
68 ball sports. For example, Arias, Argudo and Alonso (2012) demonstrated that a lighter ball
69 enabled youth basketball players to direct attention from ball-control to game interpretation.
70 The focus on game interpretation is a crucial development point as the ability to specify key
71 affordances enables decision making and accelerated acquisition of desired movement
72 behaviors (Poltavski & Biberdorf, 2014). However, these findings are attributed to age-
73 appropriate modifications due to the inability of young players to cope with the physical
74 demands (regular ball mass). Future research should address how task constraints affect skill
75 development of adult participants. However, modifications that simplify performance, must
76 be representative of the constraints innate to the skill as this preserves perception-action

77 couplings that are functional at the regulation version of the sport (Buszard, Reid, Masters, &
78 Farrow, 2016). One such method of task simplification that could be appropriate for skill
79 progression in ice hockey is to manipulate the puck mass, with recent communication
80 suggesting the use of a lightweight puck facilitates skill development in less-skilled youth
81 players (Amidon, 2014). However, these constraint manipulations are yet to be investigated
82 in a systematic research design or in the development of less-skilled adult ice hockey players.

83 Few studies have investigated the impact of puck mass on ice hockey performance,
84 with the exception of Stark, Tvoric, Walker, Noonan and Sibla (2009) whom used a variety
85 different puck masses to study the impact on physical performance. The use of weighted
86 pucks resulted in enhanced grip endurance and stick-handing ability. However, due to the
87 nature of construction, the metallic puck experienced ~ 40% less friction on the ice compared
88 to the regulation vulcanised rubber pucks and therefore did not represent the puck specific
89 affordances present in a game situation (e.g., friction between the puck and ice) (XPuck,
90 2000; Pinder, Davids, Renshaw, & Araújo, 2011).

91 The shift of focus away from the puck is a major defining point between skilled and
92 less-skilled performers. Skilled players demonstrate coupling between perception and action
93 allowing them to control and play the puck without direct attention (Poltavski & Biberdorf,
94 2014), as through playing experience, skilled players become attuned to their equipment and
95 affordances specific to the performance environment (e.g., inter and intra team movement
96 synergies) (Pinder et al., 2011). In this sense, the use of the lightweight puck should aid
97 acquisition of skilled movement in the less-skilled group as performers shift attention to
98 tactical concepts (Jacobs & Michaels, 2007). Conversely, the use of lightweight pucks may
99 alter the skilled players learnt coupling and lead to a reduction in performance. Hence, it is
100 important for practice design to clarify the efficacy of puck mass constraint across skill levels
101 to further understand how motor capabilities innate to playing experiences influence the

102 degree of coupling between perception and action during constraint-based practice in ice
103 hockey.

104 Therefore, the aim of this study was to examine performance between skilled and
105 less-skilled participants when using three pucks, light (133g), regulation (170g) and heavy
106 (283g). It is hypothesised that use of the lightweight puck will aid skating and stick-handling
107 performance for the less skilled group, but have a negative impact on the performance of the
108 skilled participants. The lightweight puck will also allow less skilled participants to
109 experience more shooting success, while skilled players will be impacted negatively as they
110 will not be familiar with the mass of the puck.

111 **Method**

112 **Participants**

113 Fifty participants volunteered for the study and were stratified into a skilled or less-
114 skilled group. Skilled participants (n = 23 male, 2 female, Mage: 21.96 ± 2.3 years) had 82.6
115 ± 23.4 months playing experience and identified as playing in the British University Ice
116 hockey Association (BUIHA) tier 1-2 checking leagues with a minimum of three years'
117 competitive experience. Less Skilled participants (n = 24 male, 1 female, Mage: 21.7 ± 2.4
118 years) had 25 ± 8.6 months playing experience and identified as playing in the BUIHA tier 3-
119 4 non-checking league. Ethical approval was granted by the local research ethics committee
120 and all participants provided written informed consent.

122 **Procedures**

123 Participants were individually tested and performed in three conditions consisting of
124 varying puck masses, a light (133g), regulation (170g) and heavy puck (283g). A counter-
125 balanced cross-sectional design was employed to reduce learning effects with each

126 participant completing three trials with their designated puck for that session, with one
127 week's rest given between each session.

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

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

143

144 **Reliability Testing**

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

151 **Data Analysis**

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

167 **Results**

168 **Obstacle Course Completion Time**

169 A main effect for skill was displayed, with skilled participants completing the course
170 quicker than less skilled $F(1, 48) = 226.899, p < .001, \eta^2_p = .825$). A main effect for puck
171 mass on course completion time was also present, $F(2, 96) = 170.845, p > .001, \eta^2_p = .781$.
172 Post-hoc tests revealed that the heavy puck ($29.34 \pm 4.08s$) resulted in slower course
173 completion times compared to regulation puck ($28.42 \pm 4.03s$) ($p < .001, d = 0.23$) and the
174 light puck ($28.52 \pm 3.06s, d = 0.23$). A puck mass x skill level interaction was present for
175 course completion time $F(2, 96) = 226.363, p < .001, \eta^2_p = .825$ (See Figure 2). Less-skilled

176 participants completion time increased with the heavy puck ($33.05 \pm 2.12s$) compared to the
177 light puck ($31.20 \pm 1.88s$, $d = 0.92$) and the regulation puck ($32.05 \pm 2.17s$, $d = 0.47$).
178 However, use of both the light puck ($25.84 \pm 0.74s$, $d = 1.19$) and heavy puck ($25.61 \pm 0.86s$,
179 $d = 0.88$) by the skilled participants was found to increase course completion time in
180 comparison to the regulation puck ($24.78 \pm 1.01s$).

181

182 **Obstacle course error occurrence**

183 A main effect for skill was displayed, the skilled group had less errors than the less-
184 skilled group, $F(1, 48) = 6.595$, $p = .013$, $\eta^2_p = .121$. Puck mass also had a main effect on
185 frequency of error occurrence $F(2, 96) = 48.565$, $p < 0.001$, $\eta^2_p = .503$. The heavy puck (3.22
186 ± 1.51 errors) resulted in more errors than the regulation puck (2.02 ± 1.34 , $p < 0.001$, $d =$
187 0.84) and the light puck (1.8 ± 1.24 , $p < .01$, $d = 1.02$). A puck mass x skill level interaction
188 was present $F(2,96) = 68.054$, $p < .001$, $\eta^2_p = .586$ (See Figure 3). For the less skilled group,
189 errors became more frequent as puck mass increased, where as the skilled group had more
190 errors for the light puck (2.48 ± 1.15 errors, $d = 1.02$) and heavy puck (2.16 ± 0.85 errors, $d =$
191 0.84) compared to the regulation puck (1.4 ± 0.95 errors).

192

193 **Shot accuracy percentage**

194 A main effect of puck mass on shot accuracy $F(1.336, 64.151) = 4.402$, $p = .029$, $\eta^2_p =$
195 $.084$ was displayed. Post-hoc tests revealed the regulation puck ($76.36 \pm 25.59\%$) had a
196 higher shot success rate than the heavy puck ($67.66 \pm 28.64\%$). There was also a main effect
197 for skill level $F(1, 48) = 17.330$, $p < .001$ with skilled ($83.2\% \pm 18.81$) having a higher shot
198 percentage than less skilled ($64.5 \pm 23.7\%$). A puck mass x skill level interaction was also
199 present $F(1.336, 64.151) = 18.109$, $p < .001$, $\eta^2_p = .275$. (see Figure 5).

200

201 **Goal success percentage**

202 Results showed a main effect for puck mass on goal success $F(21.648, 79.122) =$
203 $22.966, p < 0.001, \eta^2_p = .324$. Goal success rate decreased as the puck became heavier, light
204 puck ($46.28 \pm 25.11\%$), regulation puck ($33.66 \pm 22.59\%$) and heavy puck (20.46 ± 22.01)
205 (all $p < 0.05$). There was also a skill effect, $F(1, 48) = 51.053, p < 0.001, \eta^2_p = .515$, with
206 skilled ($45.81 \pm 21.16\%$) scoring more goals than less skilled ($21.21 \pm 17.9\%$). However, no
207 puck mass x skill level interaction was present $F(1.648, 79.122) = 0.630, p > 0.05, \eta^2_p = .013$.
208 (see Figure 4).

209

210 **Sprint speed performance**

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

218

219 **Discussion**

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

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

238 Shot accuracy and outcome also provided insight into the effect of puck mass on
239 shooting as the results found that use of a lightweight puck by the less-skilled participants
240 increased goal-scoring success. This follows expectations proposed by Arias et al. (2012) that
241 task simplification reduces the technical demand of the participant during skill execution.
242 Here, the constraint afforded by the lighter puck may direct a participant's attention away
243 from puck control and towards the tactical placement of the shot in order to score (Jacobs &
244 Michaels, 2007). This could be an important practical point for ice hockey coaches as
245 typically less-skilled participants compete in competitions where less importance is place on
246 the ability to control the puck without direct attention, as aggressive physical contact from the
247 opposition will result in a penalisation of that player. Therefore, less-skilled participants have
248 less need to control the puck without direct attention and the altering of puck mass might
249 result in less reliance on technical proficiency, shifting towards a more tactical development.
250 These findings concur with previous research in tennis, which demonstrated how changes to

251 an affordance landscape (reduced ball compression) can facilitate emergence of a rich range
252 of performance behaviors in learners, without specific, prescriptive instructions being
253 provided (Kachel et al., 2015).

254 The manipulation of the puck mass for skilled participants resulted in negative performance effects,
255 with obstacle course completion time increasing for the light and heavy pucks in comparison to the
256 regulation puck. As expected, decreases in the skilled participant's obstacle course completion time
257 can be attributed to the disturbance the different pucks cause to their stable perception-action
258 couplings (Poltavski & Biberdorf, 2014). At a skilled level, competition allows for aggressive
259 physical contact, players must be aware of their opposition when in control of the puck and hence
260 must attune both to the puck but also opposition. It is suggested that through experience, skilled
261 participants have become attuned to the mass and feel of the regulation puck allowing them to shift
262 attention away from the puck in order to perceive any approaching danger and act accordingly.

263 However, as demonstrated by Stark et al. (2009) a lighter puck exhibits less friction on the ice when
264 completing the obstacle course and therefore moves further than the regulation puck with the same
265 force. This change to the coupling caused a higher error rate for the skilled participants and increased
266 the completion time. If constraints remain the same then highly stable movement patterns may
267 develop, however, adaptations to constraints such as a change in puck mass can lead to some
268 functional instabilities in learners resulting in motor system re-organisation, and new patterns of
269 behavior emerging (Pinder et al., 2011; Headrick et al., 2015). Here, with limited experience using a
270 light puck, skilled participant were unable to functionally (re) organise their skating behaviour quickly
271 enough to satisfy the task constraints.

272 Skilled participants demonstrated a decrease in performance in terms of longer course
273 completion time and loss of shot accuracy when using both the lightweight and heavy pucks.

274 Poltavski and Biberdorf (2014) suggested skilled players exhibit a pre-determined coupling
275 between the amount of force needed and desired location of shot. Results here, show that the
276 change in puck mass disturbed this coupling, causing shots to miss the goal. Contrary to the
277 expected hypothesis, skilled participants elicited improvements in goal scoring success when

278 using the light puck, and a further decrease in performance as puck mass increased. However,
279 Stark et al. (2009), suggests that the use of a light puck affords skilled participants
280 opportunities to shoot the puck much faster with the same amount of force they usually
281 employ for a shot with a regulation puck. This concurs with the results of the current study,
282 as the majority of skilled participants missed the first shot but successfully scored on the
283 following two shots. This suggest skilled participants were able to functionally adapt to the
284 mass of the puck for the shooting task, unlike, the skating component. These results support
285 the constraints-led approach, that affordances (opportunities for action) provided for
286 individuals will facilitate active exploration, generating emergent functional movement
287 solutions, dependent on skill level and on the constraints imposed on them (Chow, Davids,
288 Button, & Renshaw, 2016). Our results suggest that the skill of shooting, was able to be
289 functionally adapted quicker than that of skating. Hence, future practice designs could look to
290 manipulate task constraints focused on skating skills, to help develop skilled athletes ability
291 to become more adaptive in this essential skill.

292 The findings in our study highlight the importance of the representative sampling of
293 participants (Brunswik, 1956), when examining how manipulation of task constraints interact
294 with the individual and the task design, to shape emergent behaviors. If researchers wish to
295 examine the effect of specific interacting constraints manipulations, careful sampling of the
296 affordance landscape and participants is required (Rietveld & Kiverstein, 2014). The findings
297 in this study can also impact on the safety of these less-skilled participants as this task
298 constraint caused performers to focus less on the puck and more on the tactical concepts of
299 the game. This change in focus is a crucial point in skill development that may reduce
300 injuries and prepare them for the introduction of aggressive physical contact. Future research
301 should consider extending the study over time as the use of a cross-sectional design did

302 enable learning changes to be monitored to see if the effects varied over time as this would
303 provide further evidence if task constraints such as puck mass benefit learning.

304 **Conclusion**

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

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