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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27   **Abstract**

28   Manipulation of task constraints have previously been effective in task simplification

29   enhancing skill development. This study examines how manipulation of puck masses affects

30   movement behaviors in skilled and less skilled ice hockey players during a representative ice

31   hockey task. Fifty participants were separated into a skilled (n = 25) or less-skilled (n = 25)

32   group. Three trials per condition of an obstacle course and breakaway goal attempt were

33   completed in a counter-balanced design using three puck masses, categorised as: light (133g),

34   regulation (170g), and heavy (283g). Findings revealed that use of the light puck by less-

35   skilled participants reduced obstacle-course completion time ($p < .05$, $\eta^2_p = .781$) and error

36   occurrence ($p < .05$, $\eta^2_p = .699$) while improving shot accuracy ($p < .05$, $\eta^2_p = .430$) and goal

37   success ($p < .05$, $\eta^2_p = .092$) compared to the regulation and heavy puck. However, skilled

38   participants had a decrease in performance when deviating from the regulation puck for all

39   the dependent measures excluding an increase in goal success when using the light puck ($p <$

40    $.05$, $\eta^2_p = .430$). Findings demonstrated the functional coupling of puck mass and movement

41   behaviors are dependent on the skill level of the performer.

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51   **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, Hancok, & 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.

121

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 Sportscode Elite (Sportscode 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 though 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 catergorised as either light (133g), regulation (170g) and heavy

154 puck (283g) and player skill level catergorised 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 ± 4.08s) resulted in slower course

173 completion times compared to regulation puck (28.42 ± 4.03s) ($p < .001$, $d = 0.23$) and the

174 light puck (28.52 ± 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 ± 2.12s) compared to the

177 light puck (31.20 ± 1.88s, $d = 0.92$) and the regulation puck (32.05 ± 2.17s, $d = 0.47$).

178 However, use of both the light puck (25.84 ± 0.74s, $d = 1.19$) and heavy puck (25.61 ± 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 ± 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 ± 25.59%) had a

196 higher shot success rate than the heavy puck (67.66 ± 28.64%). There was also a main effect

197 for skill level $F(1, 48) = 17.330$, $p < .001$ with skilled (83.2% ± 18.81) having a higher shot

198 percentage than less skilled (64.5 ± 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 $F(1.648, 79.122) = 0.630$, $p > 0.05$, $\eta^2_p = .0.13$.

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

11

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.

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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