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Title: Examining Movement Specific Reinvestment and Performance in Demanding Contexts

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1 *Introduction*

2

3 The Theory of Reinvestment (Masters & Maxwell, 2008; Masters, Polman, &
4 Hammond, 1993), Constrained Action Hypothesis (Wulf, McNevin, & Shea,
5 2001) and Explicit Monitoring Theory (Beilock & Carr, 2001) have been
6 developed to explain the role of conscious processing in motor learning and
7 performance. With respect to skilled performance, these theories propose that
8 directing attention to movements can impair performance. The Theory of
9 Reinvestment, which is the main focus of this paper, proposes that certain
10 contingencies (e.g., psychological pressure, movement errors) can cause
11 individuals to use task relevant knowledge acquired earlier in learning to attempt
12 to consciously monitor and control automated movements, which can lead to
13 impaired performance (Masters & Maxwell, 2008). For example, when preparing
14 for an important putt a skilled golfer might attempt to consciously control the
15 correct force with which to hit the ball, an aspect that may be better controlled
16 automatically.

17 An individual's propensity for reinvestment can be quantified using the
18 Reinvestment Scale (RS) (Masters et al., 1993) or a more recent scale that
19 specifically relates to movement, the Movement Specific Reinvestment Scale
20 (MSRS) (Masters, Eves, & Maxwell, 2005). Both scales have been shown to
21 identify individuals who are more likely to reinvest (Chell, Graydon, Crowley, &
22 Child, 2003; Jackson, Ashford, & Norsworthy, 2006; Jackson, Kinrade, Hicks, &
23 Wills, 2013; Malhotra, Poolton, Wilson, Ngo, & Masters, 2012; Masters et al.,
24 1993; Maxwell, Masters, & Poolton, 2006). Moreover, the scores on the RS have
25 been shown to positively correlate with amount of task relevant knowledge

26 accumulated and negatively correlate with performance under pressure (Maxwell
27 et al., 2006; Poolton, Maxwell, & Masters, 2004).

28 Development of the MSRS revealed two factors, suggesting that
29 movement specific reinvestment represents two different dimensions of conscious
30 processing. Conscious motor processing reflects a tendency to consciously control
31 the mechanics of movements, whereas movement self-consciousness reflects a
32 tendency to monitor 'style' of movement (Masters et al., 2005). It has been
33 proposed that movement self-consciousness describes conscious monitoring
34 (conscious attention is directed to movements without an intention to control
35 movements) and conscious motor processing describes conscious control
36 (Malhotra, Poolton, Wilson, Omuro, & Masters, 2015). Jackson et al. (2006) made
37 a conceptual distinction between two modes of conscious processing during
38 movement, in which conscious monitoring of movement can occur independently
39 from conscious control of movement. For example, under normal circumstances a
40 golfer might monitor a certain aspect of movement (e.g., pay attention to the
41 putter face angle), but following a missed putt she/he might attempt to control this
42 aspect of the movement during subsequent putts (e.g., consciously attempt to keep
43 the putter face angle square to the ball). Jackson et al. (2006) suggested that the
44 degree to which either behavior occurs is dependent on the performance context
45 and/or task complexity.

46 Previous work by Malhotra and colleagues suggests that the demanding
47 nature of a motor task is likely to determine when conscious monitoring and
48 control occur. Malhotra, Poolton, Wilson, Fan, and Masters (2014), for example,
49 found that movement self-consciousness was positively associated with

50 completion times of a relatively less demanding laparoscopic task¹ during
51 practice. On a more demanding laparoscopic task² (cross-handed laparoscopy),
52 however, conscious motor processing was positively associated with completion
53 times. Additionally, Malhotra et al. (2015) found that when task demands were
54 higher, in early-practice, both movement self-consciousness and conscious motor
55 processing were positively associated with performance. However, later in
56 practice when the task was presumably less demanding, movement self-
57 consciousness was positively associated with performance. Analysis of the
58 underlying kinematic mechanisms suggested that individuals with higher scores
59 on both dimensions of movement specific reinvestment displayed lower
60 variability of impact velocity and putter face angle, which culminated in better
61 performance. It was argued that a higher propensity for movement self-
62 consciousness potentially conferred superior ability to utilize exteroceptive and
63 kinesthetic feedback to assess the discrepancy between actual and desired levels
64 of performance (Schmidt, 2008), whereas, a higher propensity for conscious
65 motor processing conferred superior ability to adapt movements to achieve
66 success.

67 One factor that could determine whether movement self-consciousness
68 will positively (Malhotra et al., 2015) or negatively (Malhotra et al., 2014) impact
69 performance is the situational context. Participants in the Malhotra et al. (2014)
70 study were medical students who may have placed high importance on looking
71 like a surgeon when performing the laparoscopic task, and thus performed slower

¹ Laparoscopy is a minimally invasive surgical procedure that requires the insertion of surgical instruments through small incisions in the relevant area of the patient's body (Hunter & Sackier, 1993).

² Performance of the cross-handed laparoscopic surgery task was perceived as more mentally and physically demanding (measured using the SURG-TLX scale; Wilson et al. (2011) than the standard laparoscopic surgery task.

72 under high task demands. Conversely, participants who performed novel tasks in
73 the Malhotra et al. (2015) study might have perceived the learning process as
74 motivational, rather than demanding, which would explain the positive impact of
75 movement self-consciousness on performance.

76 Taken together, these findings suggest that movement self-consciousness
77 can be evoked in both more and less demanding performance contexts, whereas,
78 conscious motor processing is more likely to be evoked in situations that raise
79 performance demands. There is very limited research, however, that has examined
80 how the dimensions of movement specific reinvestment interact to influence
81 performance under particularly demanding contexts like psychological pressure.
82 For example, Huffman, Horslen, Carpenter, and Adkin (2009) examined the role
83 of both dimensions in a pressure context. Inducing postural threat by asking
84 individuals to stand on a raised platform evoked movement self-consciousness
85 (concern for posture) and conscious motor processing (conscious control of
86 posture), which resulted in changes in posture (i.e., leaning further away from the
87 edge of the platform). Therefore, it might be expected that under pressure a high
88 propensity to consciously monitor and control relatively well-practiced
89 movements can disrupt performance by interfering with normally automated
90 motor processes.

91 The main aim of the current research was to further our understanding of
92 how both dimensions of movement specific reinvestment influence skilled motor
93 performance under demanding conditions. The two experiments presented in this
94 paper examined the differential roles of movement self-consciousness and
95 conscious motor processing in a golf-putting task under pressure (Experiment 1)

96 and in a quiet standing task under relatively low and high attention demands
97 (Experiment 2).

98 *Experiment 1*

99 In Experiment 1, we asked trained participants to perform a golf-putting
100 task under a more demanding high-anxiety condition (i.e., financial incentive) and
101 a less demanding low-anxiety condition. It has been suggested that overall
102 performance outcome measures (e.g., hit or miss) might be too crude to reveal
103 changes associated with conscious processing (Pijpers, Oudejans, Holsheimer, &
104 Bakker, 2003) so kinematic measures were assessed alongside putting proficiency
105 to gain a better understanding of the mechanisms that underpin each dimension of
106 movement specific reinvestment. Movement variability was used as a kinematic
107 measure to examine if a predisposition for movement self-consciousness and/or
108 conscious motor processing leads to more or less consistent putting
109 characteristics. Given that putting success on a flat surface is primarily determined
110 by magnitude of force and putting direction, variability (*SD*) of impact velocity
111 and putter face angle at impact (determines 80% of direction of putting stroke;
112 Karlsen, Smith, & Nilsson, 2008) were chosen as the main kinematic measures
113 (Malhotra et al., 2015; Pelz, 2000; Sim & Kim, 2010).³

114 Overall, psychological pressure induced by the high-anxiety condition was
115 expected to heighten levels of perceived anxiety and result in impaired
116 performance. However, both Processing Efficiency Theory (PET) (Eysenck &

³ Although recent research has discussed whether movement variability is functional or dysfunctional for performance (Bradshaw et al., 2009; Land & Tenenbaum, 2012; Lohse, Sherwood, & Healy, 2010), this is an issue that is beyond the scope of the current paper.

117 Calvo, 1992) and Attentional Control Theory (ACT, Eysenck, Derakshan, Santos,
118 & Calvo, 2007) propose that anxiety might also serve a motivational role,
119 increasing the allocation of on-task supplementary processing resources (i.e.,
120 effort) that maintain performance effectiveness. While it is not entirely clear what
121 these theories meant by ‘effort’ (Edwards, Kingston, Hardy, & Gould, 2002;
122 Hardy, Mullen, & Jones, 1996), allocation of additional processing resources to a
123 task does not necessarily guarantee that performance is maintained under
124 pressure; increased effort may lead to conscious motor processing as predicted by
125 the Theory of Reinvestment, in which case performance should be disrupted
126 (Cooke, Kavussanu, McIntyre, & Ring, 2010; Edwards, Kingston, Hardy, &
127 Gould, 2002; Wilson, Smith, & Holmes, 2007). In order to understand the
128 relationship between effort, movement specific reinvestment and performance
129 under pressure, we also incorporated a measure of perceived effort in this study.

130 Consistent with Malhotra et al. (2015), we expected that the less
131 demanding, low-anxiety condition would evoke movement self-consciousness
132 rather than conscious motor processing. Specifically, it was predicted that
133 movement self-consciousness would be positively associated with putting
134 proficiency. However, the high-anxiety condition was expected to evoke both
135 movement self-consciousness and conscious motor processing (Huffman et al.,
136 2009). In particular, propensity to consciously monitor (movement self-
137 consciousness) and control (conscious motor processing) movements was
138 expected to disrupt relatively automated movements.

139 Kinematic measures were assessed on an exploratory basis and thus no a
140 priori predictions were made with regard to these measures. A high propensity for
141 consciously controlling movements (i.e. conscious motor processing) might lead

142 to ‘constraining’ (reduced variability) of the motor system (McNevin, Shea, &
143 Wulf, 2003), such that high scorers on this dimension might display reduced
144 variability of movements. Alternatively, if a high propensity for conscious motor
145 processing leads to conscious control of movements (i.e., making adjustments to
146 movements to achieve optimal performance), we might expect high scorers on this
147 dimension to display greater variability of movements. Given our limited
148 understanding of the mechanisms that underpin movement self-consciousness, it
149 was difficult to make concrete predictions with respect to its relation to kinematic
150 mechanisms.

151 *Methods*⁴

152 *Participants*

153 Thirty undergraduates (16 males, 14 females; age: $M = 20.48$, $SD = 1.38$ years)
154 from [REDACTED] volunteered to participate in this study. All
155 participants were novice golfers with no official golf handicap. Ethical approval
156 for the study was provided by the Institutional Review Board and written
157 informed consent was obtained from all participants.

158 *Apparatus*

159 Participants used a standard golf putter (length 89 cm) to putt golf balls to a
160 standard size hole (10.80 cm) from a distance of 2 m. The experiment was
161 conducted on an artificial indoor putting green with a hole located 0.72 m from
162 the end of the putting green. Kinematics of the putter were acquired using a three
163 dimensional ultrasound SAM PuttLab system (SAM PuttLab, Science Motion
164 GmbH, Munich, Germany, www.scienceandmotion.de; Land, Tenenbaum, Ward,

⁴ Portions of the data (learning trials) were used in a previous study (Malhotra et al., 2015)

165 & Marquardt, 2013; Toner & Moran, 2011), which has an overall sampling
166 frequency of 210 Hz.

167 Psychological Measures

168 Participants completed the Movement Specific Reinvestment Scale (MSRS)
169 before attending the training session. The MSRS comprises two subscales (5 items
170 each) that assess conscious motor processing and movement self-consciousness.
171 The movement self-consciousness (MS-C) subscale includes items, such as, “I am
172 concerned about my style of moving” and the conscious motor processing (CMP)
173 subscale includes items, such as, “I am aware of the way my body works when I
174 am carrying out a movement”. Each item is rated on a 6 point Likert scale (1 =
175 strongly disagree to 6 = strongly agree) such that the scores range from 5-30
176 points for each subscale. The MSRS has acceptable test-retest reliability and
177 internal consistency: MS-C ($r = .67$, Cronbach’s $\alpha = 0.78$) and CMP ($r = .76$,
178 Cronbach’s $\alpha = 0.71$).

179 *Effort*

180 The NASA Task Load Index (NASA-TLX) is a multi-dimensional scale that has
181 been used to measure workload in human factors research (Hart & Staveland,
182 1988). It comprises six bi-polar dimensions that measure mental demands,
183 physical demands, temporal demands, own performance, effort and frustration. In
184 this experiment we only report scores from the effort dimension (i.e., how hard
185 did you have to work to accomplish your level of performance?) Responses to the
186 effort scale are made on a 20 point Likert scale anchored between very low and
187 very high.

188 *State Anxiety*

189 State Anxiety was measured using the short version of the State Trait Anxiety
190 Inventory (STAI; Marteau & Bekker, 1992). This scale has acceptable internal
191 consistency (Cronbach's $\alpha = 0.82$). The six item Likert scale (1= Not at all to 4 =
192 Very much so) requires participants to respond to items like "I feel calm" and "I
193 feel tense". Scores range from 6-24 points.

194

195 Kinematic Measures

196 The SAM PuttLab system was used to measure between-putt variability (*SD*) of
197 putter face angle at impact and impact velocity for the low-anxiety and high-
198 anxiety conditions.

199 Performance Outcome Measures

200 Putting proficiency was measured on the basis of number of putts successfully
201 holed in the low-anxiety and high-anxiety conditions.

202 Procedure

203 Participants completed the MSRS before attending two training sessions held on
204 separate days. Participants were offered a financial incentive of █████\$1 per
205 successful putt with an opportunity to earn a maximum of █████\$300, in order to
206 keep the levels of motivation high throughout learning and as a precursor to our
207 anxiety manipulation. On Day 1, participants completed 10 putts to familiarize
208 themselves with the task after which they putted 20 blocks of 10 putts each. On
209 Day 2, participants completed 10 blocks of 10 putts each. After completion of
210 training, participants were informed about the amount of money they earned and
211 then they were provided a 15 min rest and invited back for a testing phase. In the

212 testing phase participants performed 10 putts each in a low-anxiety and a high-
213 anxiety condition. In the low-anxiety condition participants were simply asked to
214 try their best. In the high-anxiety condition participants were informed that it was
215 crucial that they putted as accurately as possible as each missed putt would result
216 in a loss of 10 percent of their earnings and missing all the putts would result in a
217 loss of their entire earnings. The high-anxiety condition always followed the low-
218 anxiety condition (not counterbalanced) because it was expected that participants
219 would be unmotivated during performance in the low-anxiety condition if it
220 followed a condition linked to a financial incentive.

221 Participants were required to complete the STAI scale after receiving the
222 instructions and before making the putts in each of the anxiety-provoking
223 conditions. Upon completion of the 10 putts participants were asked to complete
224 the NASA-TLX scale.

225 Data Analysis

226 A multivariate analysis of variance (MANOVA) was conducted to assess the
227 impact of anxiety conditions (low-anxiety and high-anxiety) on psychological
228 (STAI and effort), putting proficiency (number of putts successfully holed) and
229 kinematic (*SD* impact velocity and *SD* putter face angle at impact) measures,
230 followed by separate univariate ANOVA's for each variable.

231 Pearson's product moment correlation coefficients were conducted in
232 order to assess the associations between the MS-C, CMP dimensions and putting
233 proficiency, *SD* impact velocity and *SD* putter face angle at impact. Significant
234 correlations were followed up by separate standard linear multiple-regressions.

235 The associations were checked for linearity and homoscedacity and a
 236 visual examination of standard scatterplots verified that there were no violations
 237 of these assumptions. Bivariate correlations of the two predictor variables ($r =$
 238 .580) suggested that they did not have a very strong linear relationship but to
 239 ensure that this correlation did not affect the regression analysis, collinearity
 240 diagnostics were calculated. The variance inflation factor and tolerance statistics
 241 indicated that the assumption of multi-collinearity was not violated. The data were
 242 checked for outliers using Cook's distance and none of the cases were found to
 243 exert undue influence over the parameters of the model.

244 *Results*

245 The repeated measures MANOVA revealed a significant multivariate effect of
 246 condition (low-anxiety/high-anxiety), $F(5, 25) = 7.91, p < .001, \eta^2_p = .61$. Separate
 247 univariate ANOVA's revealed a significant effect of condition on state anxiety,
 248 $F(1, 29) = 16, p < .001, \eta^2_p = .36$, effort, $F(1, 29) = 9.86, p = .004, \eta^2_p = .25$, and
 249 SD putter face angle at impact, $F(1, 29) = 12.18, p = .002, \eta^2_p = .30$, but not on
 250 SD impact velocity, $F(1, 29) = 1.35, p = .254, \eta^2_p = .05$, or on putting proficiency
 251 $F(1, 29) = 0.94, p = .340, \eta^2_p = .03$. State anxiety scores were significantly higher
 252 in the high-anxiety ($M = 14.20, SD = 3.74$) compared to the low-anxiety ($M =$
 253 $11.50, SD = 2.42$) condition. Perceived effort was higher in the high-anxiety ($M =$
 254 $12.87, SD = 4.61$) compared to the low-anxiety ($M = 10.97, SD = 4.40$) condition.
 255 SD putter face angle at impact was lower in the high-anxiety ($M = 1.16, SD =$
 256 0.57) than the low-anxiety condition ($M = 1.48, SD = 0.62$).

257 Descriptive data and Pearson's correlation coefficients between MS-C,
 258 CMP and putting proficiency and kinematic measures are presented in Table 1.
 259 MS-C was positively correlated with putting proficiency ($p = .016$) and negatively

correlated with *SD* impact velocity ($p = .041$) in the low-anxiety condition but in the high-anxiety condition it was not significantly correlated with putting proficiency ($p = .303$), *SD* impact velocity ($p = .334$) or *SD* putter face angle at impact ($p = .161$). CMP was not significantly associated with putting proficiency, *SD* impact velocity or *SD* putter face angle at impact in the low-anxiety or high-anxiety conditions (p 's $> .05$).

Given that the only significant correlations were between the MS-C dimension of movement specific reinvestment, and putting proficiency and *SD* impact velocity, multiple regressions were only carried out for these variables. Table 2 presents the model statistics, beta coefficients, t statistics and squared semi-partial correlations for the regression analyses predicting putting proficiency and *SD* impact velocity from MS-C and CMP during the low-anxiety condition. The overall multiple regression model for predicting putting proficiency in the low-anxiety condition explained 20.2% of the variance, $F(2, 27) = 3.42$ $p = .047$ (see Table 2a). MS-C made a significant contribution to the model and uniquely explained 17.6 % of variance in putting proficiency, $t(27) = 2.44$, $p = .021$. Higher scores on the MS-C subscale were associated with greater putting proficiency. CMP made no significant contribution to the model, $t(27) = -0.65$, $p = .519$. The overall multiple regression model for predicting *SD* impact velocity in the low-anxiety condition was not significant, $F(2, 27) = 3.01$ $p = .117$ (see Table 2b).

Discussion

In line with previous studies, our experimental manipulation raised levels of perceived anxiety and effort in high-anxiety compared to low-anxiety conditions (Cooke, Kavussanu, McIntyre, Boardley, & Ring, 2011; Mullen & Hardy, 2000; Wilson, Chattington, Marple-Horvat, & Smith, 2007). However, anxiety had no

285 effect on putting proficiency. Although these findings are not consistent with our
286 predictions, previous studies have found that anxiety doesn't always impair
287 putting performance (Cooke et al., 2011; Mullen & Hardy, 2000). Additionally,
288 anxiety resulted in participants demonstrating lower variability of putter face
289 angle but anxiety did not affect variability of impact velocity.

290 Movement self-consciousness was positively associated with putting
291 proficiency under low-anxiety conditions and there was a trend for it to be
292 associated with lower variability of impact velocity. It has been previously
293 suggested that movement self-consciousness may confer a state of heightened
294 awareness in which individuals with a high propensity are better able to utilize
295 feedback to assess current states of performance (Malhotra et al., 2015).
296 Conscious motor processing was not associated with performance under low-
297 anxiety conditions. This is not surprising, given that reinvesting task relevant
298 knowledge in the control of movements (i.e., conscious motor processing) is more
299 likely to occur in situations that raise performance demands (for a list of
300 contingencies that can cause reinvestment, see Masters & Maxwell, 2008), rather
301 than in neutral situations (i.e., the low-anxiety condition in our study).

302 Demanding contexts that emphasize the need to perform well are expected
303 to evoke conscious control of movements (Huffman et al., 2009), but our findings
304 revealed that conscious motor processing was not associated with putting
305 proficiency or movement variability during the high-anxiety conditions. The
306 Theory of Reinvestment (Masters & Maxwell, 2008) argues that anxiety
307 provoking situations have potential to evoke conscious control of movements,
308 which inadvertently leads to '*deautomatization*' of the movement. Thus, the effect
309 of conscious motor processing is more prominent for skills that are at least

310 partially automated (Deikman, 1966; Ford, Williams, & Hodges, 2005).
311 Participants in our study might not have had partially automated movements.
312 However, given that previous studies (Maxwell et al., 2006) have demonstrated
313 the debilitating effects of reinvestment on golf putting performance following a
314 similar number of practice putts this should not be the case. Another possibility is
315 that the anxiety manipulation in this study was not severe enough to evoke
316 conscious motor processing.

317 Although the performance context might not have been demanding enough
318 to evoke conscious control of movements, it might still be expected to encourage
319 conscious monitoring of movements (Huffman et al., 2009), but our findings
320 suggest otherwise. Movement self-consciousness was not associated with putting
321 proficiency or movement variability under conditions that heightened anxiety.
322 Why did the low-anxiety condition, but not the high-anxiety condition, potentially
323 evoke conscious monitoring?

324 In the current study, participants experienced increased levels of perceived
325 anxiety and effort yet maintained their level of performance. These findings are in
326 line with Processing Efficiency Theory (PET, Eysenck & Calvo, 1992) and
327 Attentional Control Theory (ACT, Eysenck et al., 2007), which propose that
328 anxiety might also serve a motivational role, increasing the allocation of on-task
329 supplementary processing resources (i.e., effort) to maintain performance. Thus, it
330 is possible that the participants were left with no spare attentional resources for
331 movement self-consciousness. It has been suggested that the act of ‘reinvesting’
332 can draw upon attentional resources of the working memory system; a limited
333 capacity attention system that temporarily stores and manages information
334 (Buszard, Farrow, Zhu, & Masters, 2013; Lam, Masters, & Maxwell, 2010).

335 Consequently, Experiment 2 sought to investigate the role of attention demands
336 on movement self-consciousness.

337 *Experiment 2*

338 The findings from Experiment 1 suggested that raised levels of anxiety caused
339 participants to allocate supplementary processing resources (i.e., effort) to the
340 task, leaving them with few attention resources for movement self-consciousness.
341 Experiment 2 was conducted to examine the role of attention demands on
342 movement self-consciousness.

343 Participants were asked to perform quiet standing on a force platform
344 when attention demands were low (i.e., single-task condition) and when attention
345 demands were high (i.e., dual-task condition). Dual-tasking was expected to make
346 demands of working memory resources that were similar to the demands made by
347 anxiety and effort.

348 We employed a quiet standing (balance) task for two main reasons. First,
349 the use of a fundamental movement skill, such as balance, ensured that
350 participants would be equally competent at the task, without the need for lab-
351 based training. Second, a closed motor skill in which the goal is the movement
352 itself was likely to evoke movement self-consciousness. The ability to balance is
353 the basis of human movements and has commonly been regarded as one of the
354 most automatic motor skills; however, research has revealed that this fundamental
355 motor skill does indeed demand attention (Lajoie, Teasdale, Bard, & Fleury,
356 1993).

357 Consistent with Experiment 1, we expected that movement self-
358 consciousness would be positively associated with performance in the single-task.

Specifically, a high propensity for movement self-consciousness was expected to enable individuals to more effectively monitor their stance to ensure fewer movements. However, the dual-task condition was expected to consume working memory resources (in a similar manner to anxiety) that would normally be available for movement self-consciousness; consequently, we expected that performance in the dual-task condition would not be associated with movement self-consciousness. Performance of a fundamental movement skill in a non-demanding environment was not expected to encourage conscious intervention in the control of movements. Hence, we did not expect conscious motor processing to influence performance in single- or dual-task conditions.

Methods

Participants

Fifty-two healthy undergraduate students (27 males, 25 females; age $M = 20.94$, $SD = 2.55$ years) participated in the study for course credits. Ethical approval for the study was provided by the Institutional Review Board and written informed consent was collected from each participant.

Apparatus

A force platform (Zebris FDM-S 1.5, Medical GmbH, Germany; 55cm x 40cm x 2.1 cm; 50 Hz sampling rate) was used to measure postural stability during quiet standing under single- and dual-task (tone-counting) conditions. The force platform was positioned approximately 1 m away from the wall. LabVIEW Application Builder 2010 (National Instruments Inc.) was used to create an application for the tone-counting task. The high-pitched (1000 Hz) and low-

382 pitched (500 Hz) tones were presented in a randomized order with a frequency of
383 1 s from speakers connected to a HP Pavilion laptop.

384 Measures

385 Similar to Experiment 1, participants were asked to complete the Movement
386 Specific Reinvestment Scale (MSRS) before attending the study. It has been
387 suggested that the use of multiple postural stability measures can complicate the
388 interpretation of data (Fraizer & Mitra, 2008), so we examined only variability of
389 center of pressure in medio-lateral (SD_x) and anterior-posterior planes (SD_y).
390 These measures have been widely used as postural sway measures and have
391 shown effects with regard to quiet standing performance under cognitive dual-task
392 conditions (Riley, Baker, & Schmit, 2003; Riley, Baker, Schmit, & Weaver, 2005)
393 and were automatically calculated by the software program (WinFDM).

394 The tone-counting task required participants to monitor high- and low-
395 pitched tones and subsequently report the number of high-pitched tones presented
396 during a 1 min period of quiet standing on a force platform. The tone-counting
397 task has been shown to be sufficiently demanding and to hinder the use of
398 working memory in controlling the primary motor task (e.g., Maxwell, Masters, &
399 Eves, 2003; Maxwell, Masters, Kerr, & Weedon, 2001).

400 Procedure

401 Participants were required to perform two quiet standing tasks (60 s each) on a
402 force platform. The instructions for the single-task condition were “Stand as still
403 as possible”.⁵ Instructions for the dual-task condition were “Stand as still as
404 possible and count the number of high-pitched tones”. The tone-counting task was

⁵ We acknowledge that these instructions evoke an internal focus of attention, but the same instructions were given in the dual-task condition as well so we think this is of no consequence.

introduced and practiced before participants performed the balance tasks. If participants' responses varied by greater than ± 5 tones from the actual number of tones presented, they were asked to perform the task again. None of the participants needed more than two practice trials.

Data analysis

Balance performance under single- and dual-task-conditions was compared using repeated measures MANOVA. Significant results were followed up by separate univariate ANOVAs. Pearson's product moment correlation coefficients were conducted to assess associations between all measures. Separate standard linear multiple regression analyses were conducted to follow up significant correlations between movement self-consciousness (MS-C), conscious motor processing (CMP) and the performance measures. Statistical significance was set at $p < .05$ for all tests. The assumptions of linearity, homoscedacity and multicollinearity were checked for violations. Cook's distance was used to check the data for outliers. None of the cases were found to exert undue influence on the model.

Results

Overall tone-counting proficiency, computed as absolute percentage proficiency between the reported and actual number of high-pitched tones presented (Maxwell et al., 2001), was 97.8 ($SD = 3.92$).

The repeated measures MANOVA of postural sway variables revealed a non-significant multivariate effect of condition, $F(2, 50) = 4.11, p = .022, \eta^2 p = .14$. Follow up univariate analysis revealed that sway variability in the anterior-posterior direction was significantly higher in the dual-task than the single-task condition $F(1,51) = 7.25, p = .010, \eta^2 p = .13$. There was no significant difference

429 for the sway variability in the medio-lateral direction between conditions, $F(1,51)$
430 $= 2.72, p = .105, \eta^2 p = .05$.

431 Pearson's correlation coefficients between the performance measures and
432 MS-C and CMP are presented in Table 3. The results show a significant
433 correlation between CMP and MS-C ($r = .56, p = .001$). MS-C correlated
434 negatively with single-task sway variability in the medio-lateral direction ($r = -$
435 $.35, p = .012$), but not with dual-task sway variability. No significant correlations
436 were found between MS-C and sway variability in the anterior-posterior direction
437 (SDy) and CMP was not significantly correlated with either of the sway variability
438 measures in single-task or dual-task conditions (p 's $> .05$).

439 Given that the only significant correlations were between the MS-C
440 dimension of movement specific reinvestment and sway variability in the medio-
441 lateral direction in the single-task condition, multiple regression analyses were
442 only carried out for these variables. The model statistics, beta coefficients, t
443 statistics and squared semi-partial correlations for the regression analysis
444 predicting sway variability in the medio-lateral direction in the single-task
445 condition are presented in Table 4. The overall multiple regression model for
446 predicting sway variability in the medio-lateral direction in the single-task
447 condition explained 12% of the variance, $F(2, 51) = 3.33, p = .044$. MS-C made a
448 significant contribution to the model and uniquely explained 8.8 % of variance,
449 $t(51) = -2.21, p = .032$. Higher scores on the MS-C subscale were associated with
450 lower sway variability in the medio-lateral direction. CMP did not significantly
451 contribute to the model, $t(51) = 0.14, p = .887$.

452 *Discussion*

453 The main aim of this study was to examine the role of attention demands on
454 movement self-consciousness. The high levels of tone-counting accuracy
455 suggested that participants complied with the dual-task instructions. Consistent
456 with previous research (Shumway-Cook & Woollacott, 2000; VanderVelde,
457 Woollacott, & Shumway-Cook, 2005), quiet standing performance was not
458 affected by the dual-task.

459 Movement self-consciousness was positively associated with quiet standing
460 performance under the single-task condition. Participants with a higher propensity
461 for movement self-consciousness displayed lower sway variability in the medio-
462 lateral direction. The anatomical makeup of the lower limbs results in greater
463 sway variability in the anterior-posterior direction during quiet standing
464 (Mochizuki, Duarte, Amadio, Zatsiorsky, & Latash, 2006) which might have
465 made it easier for participants to monitor sway in the medio-lateral direction.
466 When participants were asked to perform under the attention demanding dual-task
467 condition, however, movement self-consciousness no longer influenced sway
468 variability. These findings support the proposition that the lack of influence of
469 movement self-consciousness under the high-anxiety condition in Experiment 1
470 was due to the attention demanding nature of anxiety. Conscious motor processing
471 has been shown to influence quiet standing performance in demanding
472 environments (i.e., postural threat) that are likely to encourage conscious control
473 of movements (Huffman et al., 2009), but in non-demanding environments it was
474 not expected to evoke conscious control of movements and our findings revealed
475 that this was the case.

476 *General Discussion*

477 The Theory of Reinvestment is one of the established explanations for why
478 performance decrements occur under pressure. The conceptual advancement of
479 reinvestment (to movement specific reinvestment) has led to the emergence of
480 two dimensions of personality that are expected to influence performance of
481 different tasks and possibly under different circumstances. In Experiment 1, we
482 examined the roles of the two dimensions of movement specific reinvestment in a
483 more demanding high-anxiety condition (i.e., financial incentive) and a less
484 demanding low-anxiety condition. Conscious motor processing did not influence
485 performance under either low-anxiety or high-anxiety conditions. The influence of
486 movement self-consciousness was evident in the low-anxiety but not the high-
487 anxiety condition. Experiment 2 was carried out to examine the role of attention
488 demands on movement self-consciousness.

489 Consistent with the findings of Malhotra et al. (2015), the results from
490 Experiment 1 revealed that participants with a higher propensity for movement
491 self-consciousness displayed greater putting proficiency in the low-anxiety
492 condition. Although the anxiety manipulation in our study raised levels of
493 perceived anxiety, it did not disrupt putting proficiency. In accordance with PET
494 and ACT (Eysenck, 1992; Eysenck et al., 2007), increased anxiety was
495 accompanied by increased effort and maintained performance which suggests that
496 effort probably depicted allocation of supplementary processing resources to the
497 task. While researchers have suggested that increased effort may at times lead to
498 conscious processing (Edwards et al., 2002; Eysenck et al., 2007), our findings
499 suggest that such a process did not occur in this instance. Other factors, such as

500 the severity of anxiety or motivation, might determine when effort leads to
501 conscious motor processing.

502 In Experiment 2, participants were asked to perform a quiet standing task
503 while concurrently performing an attention demanding dual-task. Movement self-
504 consciousness positively influenced performance on the quiet standing task in the
505 single-task condition but its influence was diminished in the more demanding
506 dual-task condition. While balance has been considered to be an automatic motor
507 skill, there is some evidence to suggest that it does indeed require some amount of
508 attention (Lajoie et al., 1993). A quiet standing task in which the goal is the
509 movement itself was very likely to result in self-focused attention and possibly
510 evoke movement self-consciousness. Given that the goal of the task was to
511 consciously monitor movements (stand as still as possible) it is not surprising that
512 participants with a higher propensity to consciously monitor their movements
513 (high movement self-conscious participants) performed better. These findings are
514 congruent with the acclimatization hypothesis (Baumeister, 1984), which suggests
515 that individuals should perform better in situations that evoke their normal
516 behaviour. In the dual-task condition, however, participants were no longer able to
517 be movement self-conscious. The performance of a concurrent tone-counting task
518 seemed to reduce the attention capacity available for movement self-
519 consciousness. Previous literature has suggested that reinvestment is an attention
520 demanding process (Buszard et al., 2013; Lam et al., 2010) and this study lends
521 support to this proposition, specifically with regard to movement self-
522 consciousness.

523 Our study is not without its limitations. The anxiety manipulation in
524 Experiment 1 did not disrupt performance. It is possible that training with a

525 monetary incentive might have evoked a certain level of anxiety that acclimatized
526 performers to anxiety provoking conditions (Baumeister, 1984). However, this
527 seems unlikely as participants reported increased levels of anxiety from low to
528 high anxiety conditions. Researchers have raised concerns about the difficulties
529 associated with evoking anxiety in laboratory settings that is comparable to real
530 world settings (Williams, Vickers, & Rodrigues, 2002). Future work that
531 examines the influence of the two dimensions of movement specific reinvestment
532 on performance needs to be carried out in more ecologically valid settings.
533 Although impact velocity and putter face angle at impact are the most crucial
534 stroke parameters that determine putting success on a flat surface (Pelz, 2000; Sim
535 & Kim, 2010), it is possible that they do not adequately reflect the processes
536 underpinning conscious motor processing and movement self-consciousness.
537 While some studies have been successful in identifying changes in movement
538 patterns that may reflect conscious processing (Nieuwenhuys, Pijpers, Oudejans,
539 & Bakker, 2008; Pijpers, Oudejans, & Bakker, 2005; Pijpers et al., 2003) others
540 (Mullen & Hardy, 2000) have failed to do so. This remains an issue to be tackled
541 by future studies. With regard to kinematics, another limitation is that the
542 variability measure might have been somewhat confounded by performance as
543 better performance may result in lower variability as a consequence of not
544 requiring to correct movements. Similarly, in Experiment 2 we did not measure
545 muscle activity during the quiet standing task, which might have provided more
546 information about the mechanisms that underpin movement self-consciousness
547 (Weinberg & Hunt, 1976).

548 While previous research has shown that conscious control of movements
549 can potentially impair skilled performance (Beilock, Carr, MacMahon, & Starkes,

2002; Gray, 2004; Masters et al., 1993; Maxwell et al., 2006), our results show that a high propensity for conscious monitoring of movements (not necessarily control) might be beneficial. Movement self-consciousness appears to be a desirable trait that is positively associated with performance on a variety of tasks; however, this only holds true in non-attention demanding contexts. Previous studies have implied that the propensity for movement self-consciousness is not immutable (Wong, Masters, Maxwell, & Abernethy, 2008), suggesting that it can be trained. A possible way to train movement self-consciousness could be through ‘associative training’ (Shusterman, 2011; Toner & Moran, 2014) in which a performer is made aware of the proprioceptive feelings associated with different movements. Future work is required to empirically verify the effectiveness of associative training in sport contexts.

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Table 1.
Descriptive data and correlation coefficients among all measures

	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9	10
1. MS-C	20.10	3.85										
2. CMP	20.47	4.02	.58**	-								
<u>Low-Anxiety</u>												
3. Putting Proficiency	6.27	2.53	.44*	.16	-							
4. <i>SD</i> Impact velocity	89.90	42.82	-.38*	-.15	-.19	-						
5. <i>SD</i> Putter face angle at impact	1.48	0.62	-.29	-.30	-.38*	.17	-					
<u>High-Anxiety</u>												
6. Putting Proficiency	6.70	2.02	.19	-.07	.44*	-.10	-.31	-				
7. <i>SD</i> Impact velocity	82.07	38.04	-.18	-.11	-.21	.59**	.29	-.30	-			
8. <i>SD</i> Putter face angle at impact	1.16	0.57	-.26	-.26	-.26	.25	.65**	-.26	.39*	-		

*** $p < .001$, ** $p < .01$, * $p < .05$

MS-C, movement self-consciousness; CMP, conscious motor processing

Table 2.
Multiple regression analysis predicting (a) putting proficiency and (b) *SD* impact velocity from MS-C and CMP during the low-anxiety condition

		<i>Variables</i>	β	<i>t</i>	sr^2_{unique}		
Low-Anxiety							
a.	Putting Proficiency	MS-C	0.34	2.44*	.18		
		CMP	-0.09	-0.65	.01		
		Intercept = 1.24					
						R ² = .202	
						R ² _{adj} = .143	
						R = .450*	
b.	SD Impact Velocity	MS-C	-4.81	-1.99	.13		
		CMP	1.07	0.46	.01		
		Intercept = 164.61					
						R ² = .147	
						R ² _{adj} = .084	
						R = .383	

*** $p < .001$, ** $p < .01$, * $p < .05$
MS-C, movement self-consciousness; CMP, conscious motor processing

Table 3.
Descriptive data and correlation coefficients among all postural stability measures

	<i>M</i>	<i>SD</i>	1	2	3	4	5	6
1. MS-C	20.02	4.52						
2. CMP	20.52	4.16	.56**	-				
3. <i>SD</i> of M/L sway, mm (ST)	21.28	13.32	-.35*	-.18	-			
4. <i>SD</i> of M/L sway, mm (DT)	19.28	12.71	-.21	-.17	.78**	-		
5. <i>SD</i> of A/P sway, mm (ST)	30.50	17.09	.04	-.01	.09	.14	-	
6. <i>SD</i> of A/P sway, mm (DT)	35.59	17.17	-.06	-.10	.15	.08	.68**	-

*** $p < .001$, ** $p < .01$, * $p < .05$

MS-C, movement self-consciousness; CMP, conscious motor processing

M/L, medio-lateral; A/P, anterior-posterior

ST, single-task; DT, dual-task

Table 4.
Multiple regression analysis predicting *SD* of M/L sway from MS-C and CMP in the (a) single-task and (b) dual-task conditions

<i>Variables</i>	β	<i>t</i>	sr^2_{unique}
SD of M/L sway (ST)			
MS-C	-0.36	-2.21*	.09
CMP	0.02	0.14	.00
Intercept = 40.90			R ² = 0.12
			R ² adj = 0.08
			R = 0.35*

****p* < .001, ***p* < .01, * *p* < .05
MS-C, movement self-consciousness; CMP, conscious motor processing
M/L, medio-lateral
ST, single-task