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Action observation and motor learning: the role of action observation in learning judo techniques

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10

11 **Author contributions**

12 VF, AD and CB-I conceptualized the study, supervised the data collection, analyzed the data and
13 wrote the manuscript.

14

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22

23

24 **Abstract**

25 Within the theoretical framework of embodied cognition, several experiments have shown the
26 existence of links between action observation and motor learning. Our aim was to assess the
27 effectiveness of an observational learning protocol (action observation training: AOT) of point-light-
28 display (PLD) in judoka. Twenty participants were given 7 days to learn Go-No-Sen. During this
29 time period, all of the participants received conventional kata training consisting of Uchi-komi and
30 Nage-komi (repetition of techniques) on tatami. In addition to this conventional learning, the
31 experimental group watched 5 minutes of PLD video representing the different kata techniques,
32 whereas the control group watched neutral videos during the same time period. After the learning
33 period, both the qualitative and biomechanical performances on the kata and the transfer abilities
34 were assessed. The results showed better biomechanical performance and transfer ability in the
35 experimental group than in the control group. Therefore, this first experiment suggests that
36 observational learning of PLD may be beneficial for the acquisition of judo techniques. Future
37 experiments will be needed to specify the mechanisms that are involved in this effect.

38 **Keywords:** markerless; complex skill; transfer; biomechanics; sport.

39

40 **Bullet points**

41 The observation of Point-light actions can improve the acquisition of judo techniques

42 The observation of Point-light actions has benefit on transfer abilities

43 The observation of Point-light actions has benefit on biomechanical performances

44

45

46 **1 Introduction**

47 More than 45 years ago, Johansson, (1973) invented the point-light-display (PLD) paradigm.
48 This paradigm consisted of filming people performing different actions (walking, running, etc.) in the
49 dark with LEDs placed on their joints, with the final video showing a set of moving points of lights.
50 Interestingly, although the display was rudimentary, these PLD videos implied a very fast recognition
51 of actions (Johansson, 1975), as well as the identification of the actors' characteristics, such as
52 identity (Beardsworth & Buckner, 1981; Loula et al., 2005), gender (Kozlowski & Cutting, 1977),
53 emotional state (Atkinson et al., 2004; Chouchourelou et al., 2006; Clarke et al., 2005) and intentions
54 (Martel et al., 2011). Most importantly, the recognition of PLD activates a specific neural network
55 that includes motor areas (e.g., Saygin et al., 2004) and belongs to the mirror neuron system (see for
56 a review Iacoboni & Dapretto, 2006; Jeannerod, 2001), thus suggesting the existence of a functional
57 equivalence between the observation and the production of actions (for a review, see Grèze &
58 Decety, 2001).

59 Following this view, several studies have shown that sensory-motor skills can be enhanced by
60 action observation training. For example, (Blandin et al., 1999) have shown that the observation of a
61 model produces significant improvements in both the reproduction of the learned movement pattern
62 in a retention task and in the transfer. In their study, they aimed to determine whether action
63 observation (AO) allowed for the acquisition of a relative time pattern accounting for generalized
64 motor programme (GMP) learning. The skill that was studied was a four-target pointing task, and the
65 measurements were made on retention and transfer tests over a new relative time period. The results
66 showed that the observation of an expert model (combined with physical practice) allows for the real
67 learning of the total time of movement and that this learning of relative time is transferable to a new

68 parameter, thus suggesting that action observation training is efficient in the learning of new motor
69 sequences. Interestingly, interest in action observation training has also been demonstrated in sports
70 such as volleyball (Weeks & Anderson, 2000), football (Horn et al., 2002), bowling (Breslin et al.,
71 2009), golf (D’Innocenzo et al., 2017) and rugby (Faelli et al., 2019). For example, in rugby, the
72 authors compared two training protocols with two groups of elite rugby players. The first group only
73 performed physical practice, and the second group performed action observation on the action to be
74 learned, along with physical practice. The results showed that both groups improved, but the action
75 observation group improved significantly more, with better accuracy and ball speed.

76 Therefore, several studies have shown that sensory-motor skills can be enhanced by action
77 observation training. However, most of the training materials have been made with classical videos
78 and not with the use of PLD (but see Horn et al., 2002), which renders the transformation of observed
79 sequences more difficult (Decatoire et al., 2019). Moreover, until now, the effectiveness of action
80 observation training has not been demonstrated in complex disciplines evolving in three-dimensional
81 space with direct body interactions. Actually, the efficacy of PLD observation has been already
82 demonstrated for individual movements such as cricket bowling (Breslin et al., 2009) or football
83 (Horn et al., 2002). However, we think that it is important to show that this efficacy can also be
84 observable in interactions. If some studies have shown that humans can recognize interaction in PLD
85 (Okruszek & Chrustowicz, 2020), we could imagine that the presence of multiple dots could affect
86 the mechanisms implied in learning by observation. More precisely, we hypothesis that the presence
87 of a pair of actors in the display can render the perceptual processing and identification of each actor
88 more difficult because their points of identification mix to form a mass. In consequence, it could be
89 more difficult to simulate the movement, to infer the goal of action and to predict the end of the
90 movement whereas these elements are known to be crucial for the success of learning (see for
91 example, Blakemore & Decety, 2001; Mattar & Gribble, 2005). In this same idea of simulation, the

92 presence of two interacting actors implies the need for significant mental flexibility to switch from
93 simulating the action of the attacker to those of the counter-attacker. The second element that could
94 disturb the observers is that judo movements take place in volumetric space; whereas some studies
95 have shown that the perception of biological movement is easier if a translational movement can be
96 infer like it is the case for walking for example (Bidet-Ildei et al., 2013). Therefore, the first objective
97 of the study was to demonstrate that PLD observation can also benefit for the learning of complex
98 motor skills in interaction.

99 Interestingly, some studies have focused on mental imagery in relation to judo practice (Campos
100 et al., 2001; Chalhaf, 2013). They demonstrated that mental imagery can improve the judo'ss
101 technical acquisitions, probably linked to the possibility to acquire an internal model even in the
102 absence of movement. However, mental imagery also has some drawbacks: how can we control what
103 the learner visualizes? How can the learner know what the important parameters of the action to be
104 performed are, and therefore how to help him/her in his/her learning? In contrast, in observation, we
105 can control all parameters of movement and so determine which is the most important for the
106 learning. Therefore, the second objective of our paper was to address this question by studying the
107 effects of action observation training through the PLD paradigm in the learning of a kata in judo.

108 The general hypothesis is that the observation group should perform better than the control group.
109 Consequently, we propose than the observation group should obtain better results in the retention and
110 transfer tasks and a biomechanical behaviour closer to those of the models, than the control group.

111 **2 Methods**

112 *Participants*

113 The a priori calculation of our sample size was performed with G*Power software (Faul et al., 2007)
114 based on a mixed measures ANOVA design and the results of a previous study (Faelli et al., 2019,

115 Cohen's $d = 1.11$). Statistical significance was set at $p < 0.05$, and power was set at 0.80. The results
116 indicated that 11 participants per group would be sufficient to provide an estimated power of 0.80.
117 However, given the CoVID-19 health crisis only twenty participants had to be included in the study.

118 The participants included twenty French experts¹ judokas in sports structures with a twice-daily
119 training frequency, divided into two groups with respect to homogeneity, according to the level of
120 practice, age and laterality of the fight. Ten judokas (age: Mean age (M) = 15, Standard deviation
121 (SD) = 0.5; sex: 7 males, 3 females; laterality: 9 right-handed, 1 left-handed) followed the combined
122 training protocol (action observation and physical practice), and 10 other judokas served as a control
123 group (age: M = 15, SD = 0.6; sex: 9 males, 1 female; laterality: 8 right-handed, 2 left-handed). All
124 of the participants gave written informed consent. Additionally, all of the participants had normal or
125 corrected-to-normal vision and were unfamiliar with the Kata proposed (because this corresponds to
126 the Kata asked for the 5th Dan in France), and none of the participants reported of taking any
127 medications or antidepressants or of following a major diet that may have affected their
128 concentration, according to a short questionnaire. The protocol was approved by a local human
129 subjects committee (N° 2021-02-05). The distribution that was proposed by the coaches was
130 confirmed by a Student's t-test on their performance on a known technique (O-soto-gari). The test
131 revealed no difference between the two groups ($t_{19} = .11$; $p = .91$).

132 Moreover, two experienced judokas (males, 22-years-old, national level in judo and students at the
133 Faculty of Sports Sciences in Poitiers, France) were used as references to build the PLD and to
134 biomechanically assess the performances of the participants.

135

136

¹ All judokas had a national level and had the first dan black belt.

137 *Materials*

138 For the construction of the stimuli, we first recorded the different techniques of Go-No-Sen
139 performed on a classical tatami by the two experienced judokas, which served as the models. The
140 motion-capture recordings were obtained from four Microsoft Kinect azure DK cameras (see
141 <https://docs.microsoft.com/fr-fr/azure/kinect-dk/hardware-specification>) placed at 1.10 m height and
142 separated by 12 m². Two laptops, which were each connected to two Kinects that were previously
143 calibrated with a light sphere of our design (≈ 6.36 cm in diameter), collected videos of the
144 techniques using iPiRecorder software. This software provides the ability to record synchronized
145 videos from multiple devices connected to several computers, using smartphone's Wi-Fi network
146 (Distributed recording). Microsoft Kinect azure DK cameras are cameras dedicated to space
147 computing. They consist of a classic color video camera associated with depth sensors for tracking
148 human movements in a defined space. The advantage of this system is that markers do not have to be
149 placed on the subjects, and its accuracy of capture has been previously demonstrated by Albert et al.,
150 (2020). This system is particularly well suited to the constraints that are associated with judo
151 movements (involving falls and numerous contacts between the two participants), which would have
152 caused marker occlusions. Once we had the recordings from the four Kinects, we merged them by
153 using the "Merge" option in the iPiRecorder software to create one recording. Subsequently, a
154 skeleton animation was created using iPi Mocap Studio software (Pro version enabling the tracking
155 of several actors), and then exported it in Biovision Hierarchy format (BVH) according to the Motion
156 Builder hierarchy. This file was finally converted to c3d format using the MATLAB Motion Capture
157 Toolbox (<https://github.com/lawrennd/mocap>) and the Biomechanical ToolKit developed by Barre &
158 Armand, (2014), in order to keep only PLD videos of the two judokas. The c3d videos were then
159 processed on PLAViMoP software (Decatoire et al., 2019) to obtain several views of the same

160 technique from the same c3d file (See Figure 6, appendix 3). Each video of the same technique was
161 collapsed by using Video Editor (from Microsoft) to obtain a working clip.

162 *Procedure*

163 The procedure consisted of 2 phases: training and post-learning evaluation.

164 Regardless of their allocation group (control vs experimental), all of the participants were trained at
165 lunchtime for 7 days over a period of two weeks.

166 Each day of training involved the same structure: the viewing of a 5-minute video clip, which was
167 immediately followed by 20 minutes of physical practice in a conventional training situation. The
168 penultimate day was different, and a review of all of the techniques was offered, in addition to the
169 technique of the day. Therefore, the last day of training, the AO group judoka watched all the
170 techniques previously learned in the program in addition to the technique of the day. On the other
171 days of the program, one technique per day was studied. At the end of the seventh day, the judokas
172 had studied the seven Go-No-Sen techniques that were selected for the study. The only difference
173 between the two groups was concerning the observation task: the experimental group watched a clip
174 in PLD, which was previously designed on the technique of the day, whereas the control group
175 watched a 5-minute clip of an International Judo Federation "top ippon".

176 At the end of the training protocol, all of the participants were evaluated on three tasks.

177 *A qualitative retention evaluation* - All of the participants were assessed on the quality of execution
178 of the kata by expert judges from a predetermined grid that was built from the resources of the judo
179 committee of the Vienne (86, France, see Appendix 1). The judges were not informed of the group of
180 participants (experimental vs control participants). In this evaluation, the aim was to quantify the
181 degree of learning in each group.

182 *Biomechanical evaluation* - Each participant had to perform two techniques of the Go-No-Sen kata
183 (O-soto-gari and Kubi-nage in closed situations) that were filmed with the Kinect cameras. The
184 recording process was identical to that used previously to make the stimuli. The kinematic
185 parameters computed from the c3d files are listed in the following “Data analysis” section.

186 *Transfer evaluation* - The last evaluation was a transfer evaluation. This last test consisted of
187 evaluations of each participant regarding the application of the techniques that were learned during
188 the kata in a combat situation (open situation). We proposed a training exercise for each condition.
189 For example, the judokas performed a Yakusoku Geiko with restriction to a role and a certain
190 technique. Uke was instructed to throw only certain techniques, including two figures in Go-No-Sen,
191 whereas Tori was free to respond as he wished. More precisely, six Ko-uchi-gari and six Ko-soto-
192 gake were randomly triggered without Tori's knowledge by Uke. The aim was to assess whether, in
193 following the training phase, it becomes more instinctive to perform the functional response of Go-
194 No-Sen according to the group.

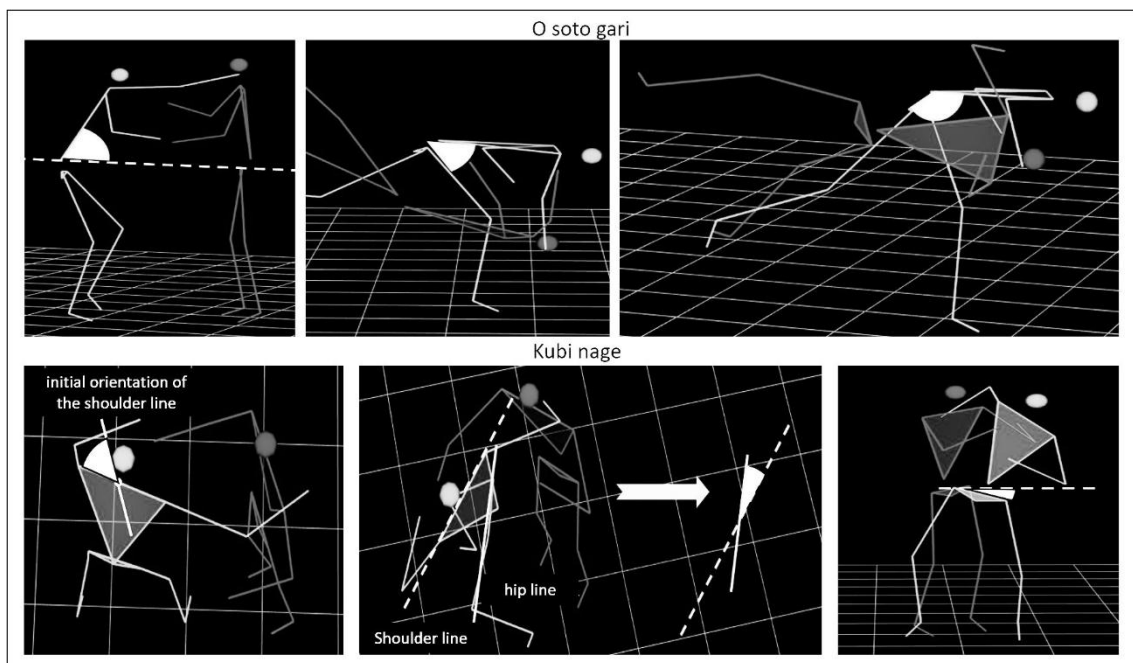
195 *Data analysis*

196 For the qualitative evaluation, we compared the number of participants that validated the Kata in
197 each group with Fisher's exact test. For this scenario, we considered that the candidate had validated
198 his or her kata if he or she did not endanger his or her partner and if he or she obtained, at the very
199 least, the average values in at least 3 out of 4 criteria.

200 For the biomechanical evaluation, we recorded the temporal evolutions of the 3D coordinates on
201 the different joints of each participant. Subsequently, we calculated for the root mean square error
202 (RMSE) between the participant's temporal evolution and the reference model's temporal evolution
203 for each parameter. For this scenario, we used MATLAB software and the btk library that was
204 developed by Barre & Armand, (2014). For O-soto-gari, we considered the relative angle between the
205 trunk and the supporting leg, the relative angle between the trunk and the reaping leg, the absolute

206 angle of the trunk with the horizontal and the total RMSE (top of Figure 1). For Kubi-Nage, we
 207 considered the rotation longitudinal angle, the torsion angle (the angle between the shoulder line and
 208 the hip line), the tilt angle of the lateral inclination of the pelvis and the total RMSE (bottom of
 209 Figure 1). For each technique (O-soto-gari and Kubi-Nage) and for each independent variable that
 210 was considered, we then compared the mean performance of each group by using an independent
 211 Student's t-test. To assure the homogeneity of the variances, we excluded analyses in which the
 212 participants had scores either superior or inferior to 1.5 standard deviations of his/her group (one
 213 participant for O-soto-gari and two participants for Kubi-nage).

214



215

216 *Figure 1: Biomechanical angle calculated for O. soto gari at the top and Kubi nage at the bottom of the figure. From left to right for O*
 217 *soto gari, the absolute angle of the trunk with the horizontal, the angle between the trunk and the supporting leg during the movement*
 218 *and the angle between the trunk and the mowing leg are shown. For Kubi nage, the longitudinal rotation angle, the torsion angle and*
 219 *the tilt angle are shown.*

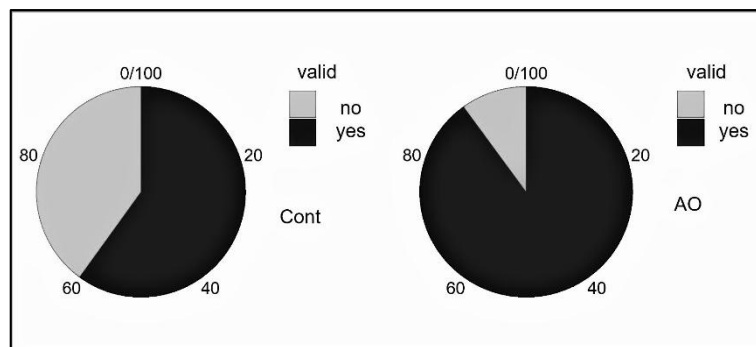
220 For the transfer evaluation, we calculated the percentage of success (i.e., percentage of
 221 successful Tai-otoshi after being attacked by Ko-soto-gake) for each participant, and we compared

222 the means for each group (experimental vs control groups). As the homogeneity of variances was not
 223 observed, this analysis was performed by using a Mann-Whitney U-test.

224 All of the analyses were performed with JASP statistical software, with one-sided p-value
 225 assumptions, testing the superiority of the AO group and a significance level of the p-value set at
 226 0.05. Effect sizes were calculated with the Cohen's d for all measures except for the transfer
 227 evaluation where it was calculated with the Rank-Biserial Correlation.

228 **3 Results of qualitative evaluation of the kata**

229 The results of the Fisher's exact test (Figure 2) did not reveal a significant effect of action
 230 observation for the kata validation, $F(18) = 1.702, p = .302$.

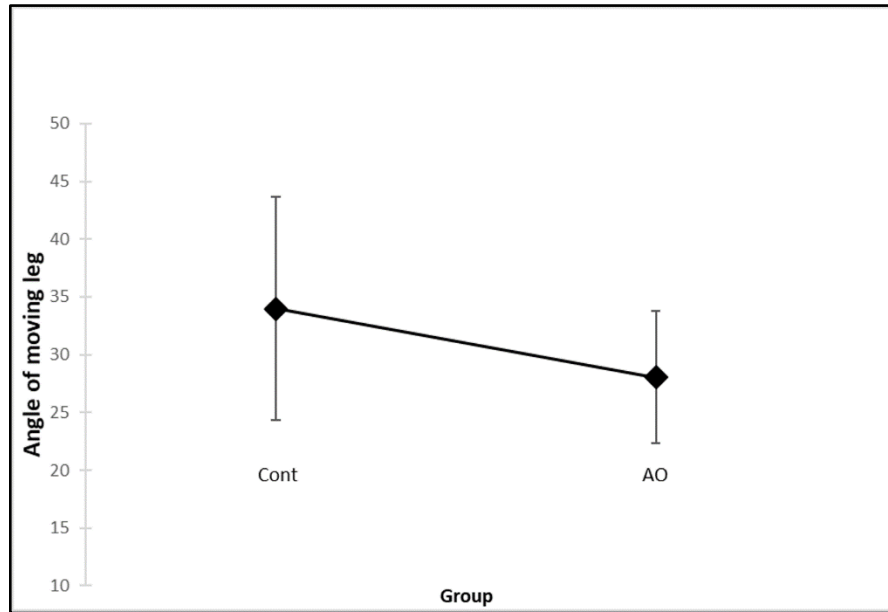


231
 232 *Figure 2: Distribution of the validation percentage according to group. On the left, the control group = Cont; on the*
 233 *right, the action observation group = AO.*

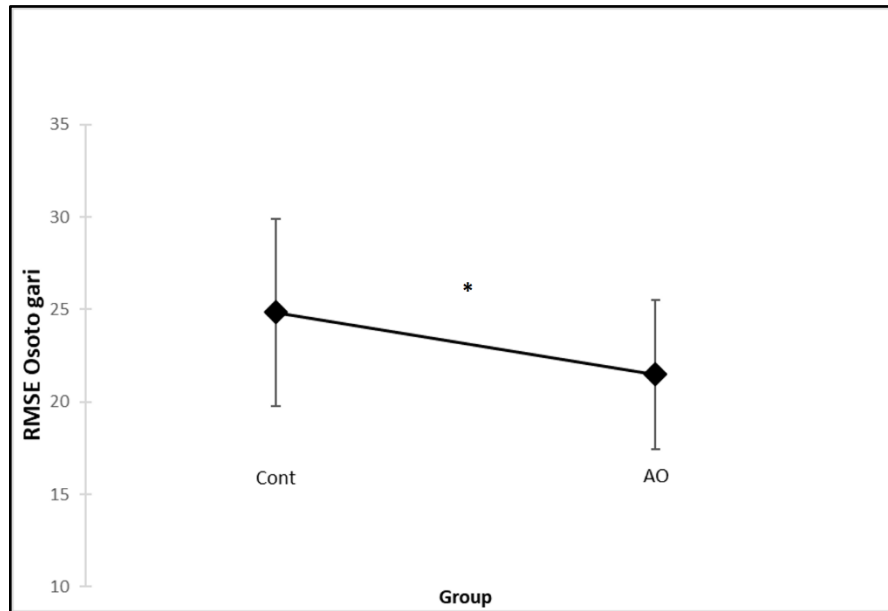
234 **Results of the O-soto-gari biomechanical assessment**

235 The analyses revealed no effect of group on the angle between the trunk and the supporting
 236 leg during the movement, $t(16) = 1.098, p = .144, 95\% \text{ CI} = [-2.21; \infty], d = .52$ or on the absolute
 237 angle of the trunk with the horizontal leg, $t(16) = 0.721, p = .241, 95\% \text{ CI} = [-2.82; \infty], d = .34$.
 238 However, Figure 3 shows that the difference trend for the angle between the trunk and the moving
 239 leg, $t(16) = 1.586, p = .066, 95\% \text{ CI} = [-0.60; \infty], d = .75$ was significant for the total RMSE, $t(16) =$

240 1.805, $p < .045$, 95% CI = [0.13; ∞], $d = .85$, thus suggesting that the AO group was more similar to
241 the model than the control group (Figure 3 bottom).



242



243

244 *Figure 3: Graph showing the results of root mean square errors on the angle of the trunk (at the top) and the mean square error*
245 *results over the whole movement for each group, compared to the model (at the bottom), with error bars at 95%. * Significant effect.*

246

247

248 ***Results of the Kubi-nage biomechanical assessment***

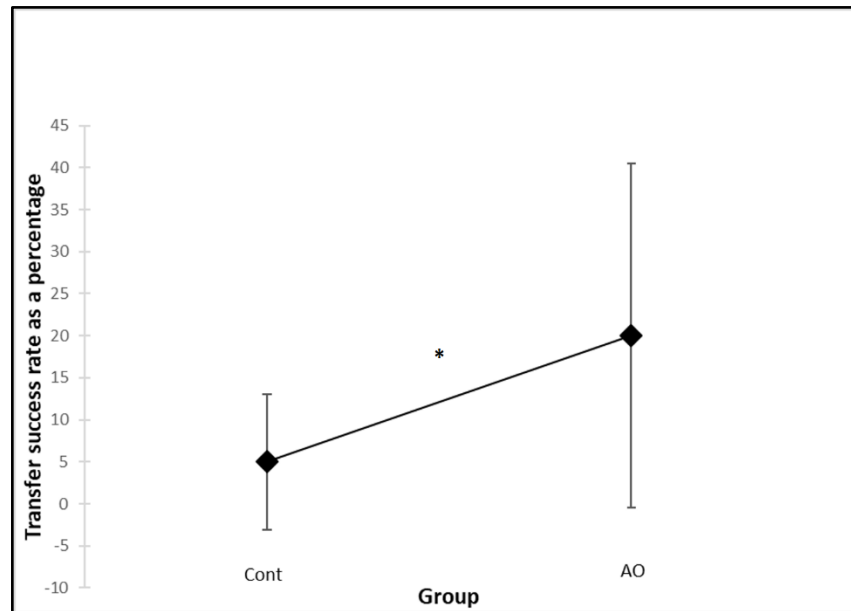
249 None of the results obtained on the evaluation of the Kubi-nage technique showed any significance or
 250 trend; therefore, the two groups were similar (longitudinal rotation angle: $t(17) = .750$, $p = .232$, 95%
 251 CI = [-9.50; ∞], $d = .345$; tilt angle: $t(17) = -1.487$, $p = .922$, 95% CI = [-4.19; ∞], $d = .68$, (M[AO_{tilt}
 252 angle]= 13.663 SD[AO_{tilt angle}]= 2.604 ; M[Cont_{tilt angle}]= 11.732, SD[Cont_{tilt angle}]= 1.020) ; torsion
 253 angle: $t_{17} = -0.541$, $p = .702$, 95% CI = [-3.880; ∞], $d = .25$; total RMSE: $t(17) = .388$, $p = .351$, 95%
 254 CI = [-5.05; ∞], $d = .18$).

255

256 ***Result of the transfer evaluation***

257 The analysis of the transfer evaluation (Figure 4) revealed a significant effect of action
 258 observation training, $U = 29$, $p < .043$, 95% CI = [- ∞ ; 5.67e-5], Rank-Biserial Correlation = -0.42.
 259 The AO group was significantly better than the control group at transferring the response actions that
 260 were learned in the kata situation into a combat situation M [AO] = 20%, SD [AO] = 20.4, M [Cont]
 261 = 5%, SD [Cont] = 8.

262



263

264 *Figure 4: Graph of the percentage of success according to group on the transfer task, with standard error. * Significant*
 265 *effect.*

266 4 Discussion

267 The aim of this study was to assess the impact of PLD action observation on the learning of a
 268 complex sequence of movements in judokas. For this scenario, we compared two groups on the
 269 learning of Go-No-Sen kata. Both groups benefitted from conventional training, based on the
 270 repetition of physical practice (Uchi-komi and Nage-komi). Moreover, the experimental group had
 271 visual sessions of PLD action observation, whereas the control groups had visual sessions of the “top
 272 ippon” of the federation. The results revealed better biomechanical and transfer performances for the
 273 experimental group than for the control group, thus confirming the positive impact of action
 274 observation on motor learning. Our results confirmed those obtained by (Blandin et al., 1999), who
 275 showed that physical training combined with observation allows for a better transfer. Indeed, it
 276 appears that the actions/responses that are learned in the blocked and predictable situation offered by
 277 the kata could be transferred by the AO group to an unpredictable situation. Accordingly, with the
 278 functional equivalence between the observation of actions and physical practice (Grèzes & Decety,
 279 2001), we can suggest that the observation of actions has made some traces in the sensorimotor

280 memory that would have been reactivated later during physical practice. This idea also agrees with
281 the theory of the ACT-IN model (Versace et al., 2014), which defines memory as a "tool" for
282 retrieving learned items to interact with the present context. Specifically, this conception of memory
283 requires a number of repetitions of similar experiences to engram sensorimotor traces to respond
284 quickly and correctly. As both groups had the same amount and quality of physical exercise, we can
285 suggest that the success of the AO group is that it would have benefited from a greater number of
286 'experience' repetitions, due to the principle of functional equivalence between practice and
287 observation. If we follow Blakemore and Decety (2001), we can speculate that our AO participants
288 have been able to simulate the interactions proposed and this despite the presence of two actors and
289 the volumetric space of the movement. Another hypothesis for our results is that action observation
290 could have generated an attentional focus on some parameters of the action, thus rendering physical
291 practice more efficient (see (Blandin, 2002). This last hypothesis is in accordance with the response
292 obtained in the poststudy questionnaire (see Appendix 2), wherein some participants said that the
293 PLD visualization allowed them "to visualize myself doing the technique", "to visualize the actions
294 and responses to be made" or "to see each step of the movement better, so we can imitate them.

295 Concerning the discrepancy between the biomechanical effects that were obtained with the O-
296 soto-gari and Kubi-nage techniques, we suggest that action observation enhances simple movements
297 and provides an attentional focus. Indeed, O-soto-gari is easier to perform than Kubi-nage. The
298 second hypothesis could be related to a methodological difference between the learning of the two
299 techniques. In contrast to O-soto Gari participants, who benefitted from two working sessions, Kubi-
300 nage was the last technique studied by the participants; therefore, the phase of learning and the post
301 evaluation was performed on the same day. Thus, it is possible that Kubi-nage had not been
302 improved because it does not benefit consolidation. Indeed, although the repetition of experiences
303 benefits learning, data, such as those of Krakauer & Shadmehr, (2006), has shown that the

304 consolidation of learning continues over a period of rest longer than 24 hours, including quality sleep
305 time.

306 Finally, when concerning the absence of significance in the qualitative evaluation, it is likely that
307 the effects of action observation were too subtle to be perceptible with a subjective evaluation (in this
308 scenario, the assessment of retention depends on the judges' assessments) that was coded with a
309 discrete scale (of 0, 1 and 2 points). Yet, because the health context of COVID-19 all expected
310 participants had not been included. It can therefore be assumed that some non-significance or trend is
311 due to a lack of power. However, it is nevertheless interesting to note that the results seem to support
312 the research hypothesis with more validation of the Kata by AO than the control group.

313 As in the study by Chalhaf, (2013), that have showed that mental imagery enabled the learning
314 of new judo techniques we showed that observation of point-light display also enabled this. This
315 could be explained by a greater number of repetitions of experiments due to functional equivalence
316 between mental imagery; action observation and physical practice. One alternative hypothesis could
317 be that action observation provoke an attentional focus on certain parameters of the action that are
318 crucial to learn the movement as faithfully as possible. This last hypothesis requires further study,
319 particularly in a performance optimisation context.

320 ***In conclusion***, our study demonstrated clear advantages of PLD action observation to learning
321 new complex motor sequences in combat sports. The combined training of a conventional physical
322 practice and a video observation of the point-light type allowed us to improve biomechanical
323 parameters and transfer competencies. To confirm and expand upon these results, it would be
324 interesting to replicate our protocol with a larger population and with more than two weeks of work
325 to confirm whether the nonsignificant results of the qualitative evaluation were related to a lack of
326 power and to correct the methodological concern for the Kubi-nage technique. Moreover, future
327 studies should address the role of functional equivalence and attentional focus on the effects.

328

329

330 **Author contributions**

331 XX, XX and XX conceptualized the study, supervised the data collection, analyzed the data and
332 wrote the manuscript.

333 **Conflict of Interest Statement**

334 The authors declare that the research was conducted in the absence of any commercial financial
335 relationships that could be construed as being potential conflicts of interest.

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339 make special mention to the student athletes XXX and XXX for the construction of the stimuli.

340

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435 **Appendix 1:** Judges' evaluation grid to be used for the evaluation of Kata by the judges during the
 436 course. This grid was designed from the resources of the Vienne (86, France).
 437

GO-NO-SEN Evaluation Grid		<u>Pseudonym :</u>	<u>Name of applicant</u>
Criteria selected	Observable		
Safety	Control of Uke when throwing		
	Endangerment with an improper throw		
	Control of attacks for Uke		
Attitude and Ceremonial	Respect for the chronology and execution of the ceremonial		
	Tori's attitude, posture and movement		
	Uke's attitude, posture and engagement		
Technical correctness	Chronology of techniques and attacks (Tori/Uke)		
	Respect of the techniques (technical errors and omissions)		
Technical Execution	Presence of imbalances before projection		
	Respect of the principle of response (GO-NO-SEN/SEN-NO-SEN)		
	Control and efficiency of techniques, parries and answers		
	Correctness and rhythm (attack/counterattack)		
	Control of ukemi for Uke		
	Efficiency, accuracy, sincerity and credibility of the defenses for Uke		
	Interaction of the couple, action/reaction and coordination of responses		

The candidate is "disqualified" in the case of	endangering his/her partner	
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The applicant is "rejected" if:	he/she does not obtain the average in at least 3 out of 4 criteria	
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The candidate is "passed" if:	He/she fulfs the conditions for 3 criteria	
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Rating: 0 = failures, 1 = correct/in progress, 2 = good/very good

Grid composed from the resources of the Vienne Judo Committee.

438 Appendix 2: Poststudy questionnaire.

439 Poststudy questionnaire

440 As part of the study you have just completed, we would like to know your opinion and feelings about
441 it.

442 2 Name and surname

Group

443 _____

Point-light-display

video

444

445 How would you rate each of the following criteria for the study?

446 You were interested in the overall study (Q1)

447 Not at all A lot

448 Do you think you have learned anything (Q2)

449 Not at all A lot

450

451 Do you think that what you have seen during the clips will help you in your learning (Q3)

452 Not at all A lot

453 Do you think that video observation can help you to be more efficient in your technique and judo
454 (Q4)

455 Not at all A lot

456 Have you watched a Go No Sen video outside of training? (Q5)

457 Yes No

458 In a few lines, can you explain how you think watching the videos can or could have helped
459 you?

460

461

462

463

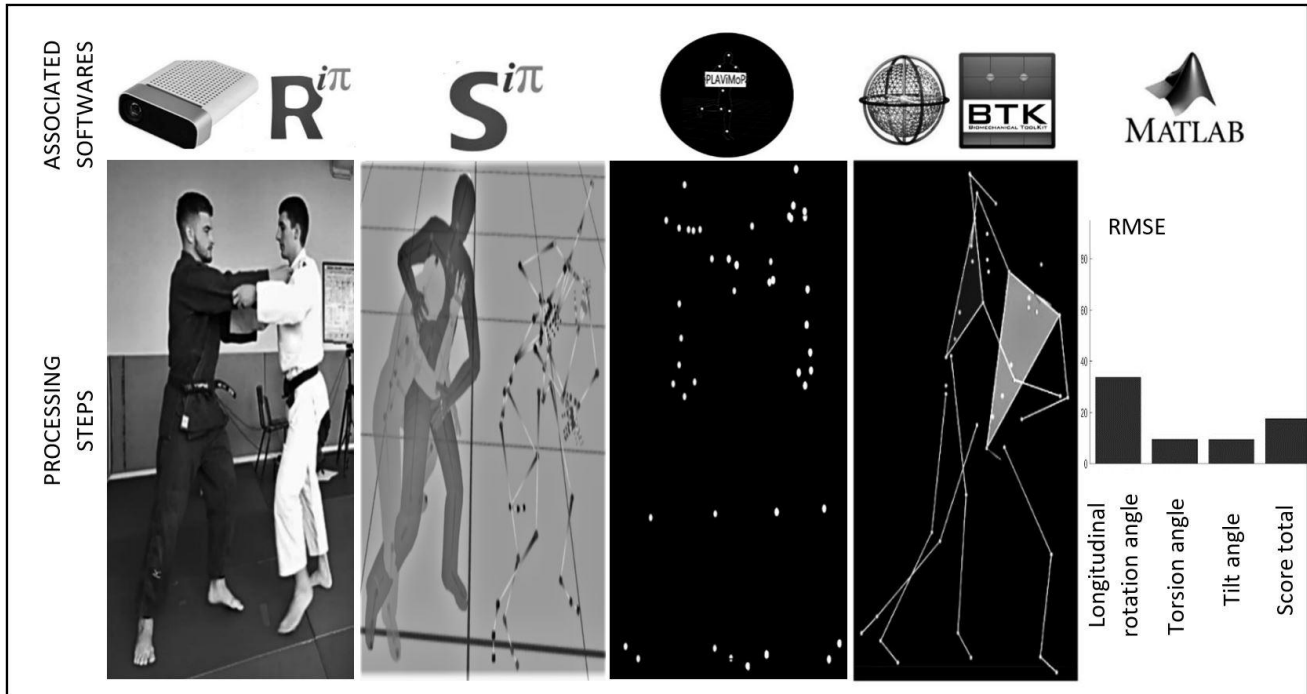
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466 Appendix 3: Additional figure

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Figure 6: Processing steps for the construction of the PLD and the biomechanical evaluation: 1) Video acquisition using 4 Kinect Azure and Ipi Recorder software, 2) Follow-up of the 3D coordinates and export of the skeleton in bvh file using Ipi Studio pro software, 3) Generation of the PLD using PLAViMoP software, 4) Generation of a c3d file using BTK library and Mokka software, and 5) Computation of the root mean square error (RMSE) on specific biomechanics parameters between the subject and the reference model using MATLAB software.