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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; Chouhourelou 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's  
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 experts<sup>1</sup> 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.

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136

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<sup>1</sup> 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 m<sup>2</sup>. Two laptops, which were each connected to two Kinects that were previously  
143 calibrated with a light sphere of our design ( $\approx 6.36$  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.

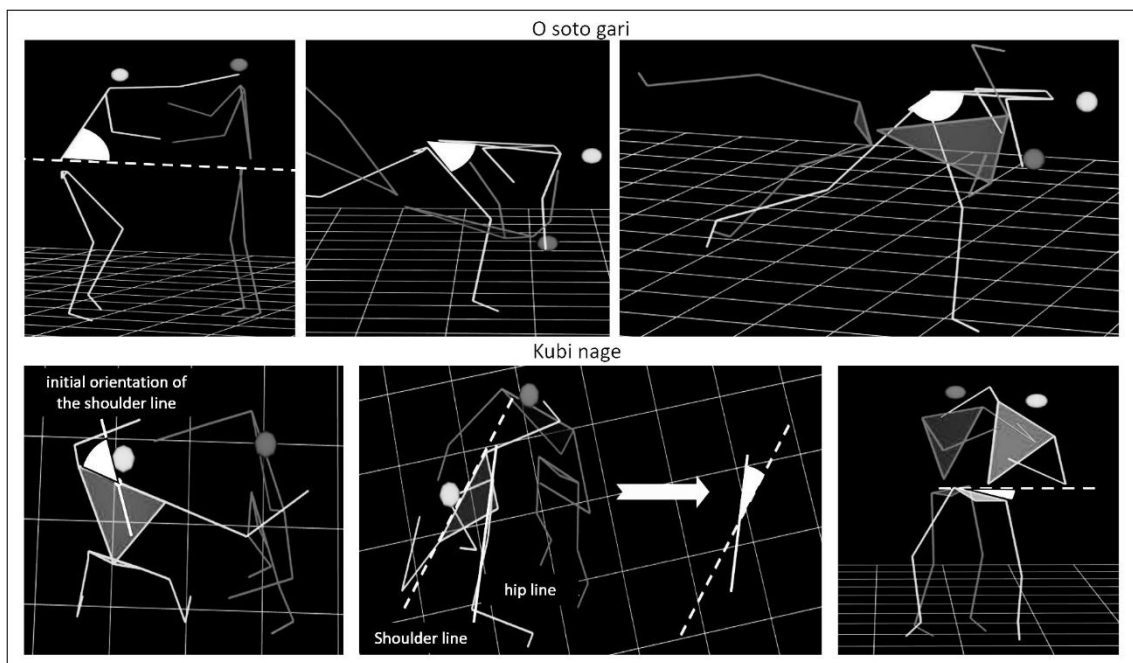
### 195 *Data analysis*

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.*

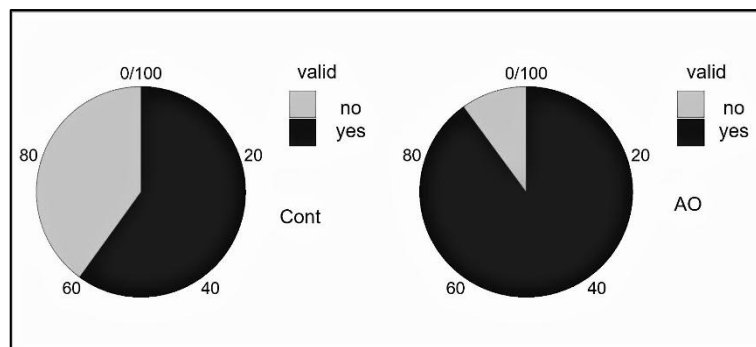
220 For the transfer evaluation, we calculated the percentage of success (i.e., percentage of  
 221 successful Tai-otoshi after being attacked by Ko-soto-gake) for each participant, and we compared

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,  $F(18) = 1.702, p = .302$ .



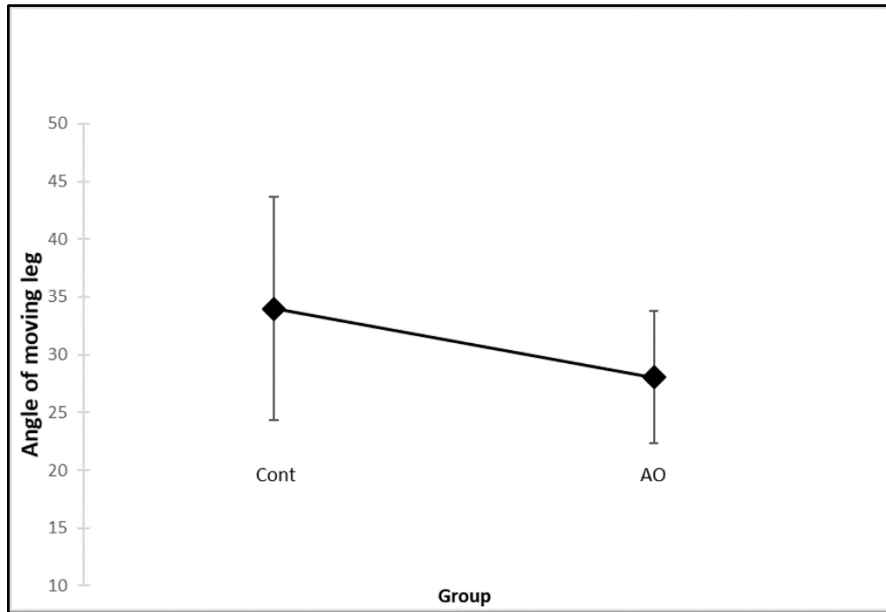
231  
 232 *Figure 2: Distribution of the validation percentage according to group. On the left, the control group = Cont; on the*  
 233 *right, the action observation group = AO.*

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

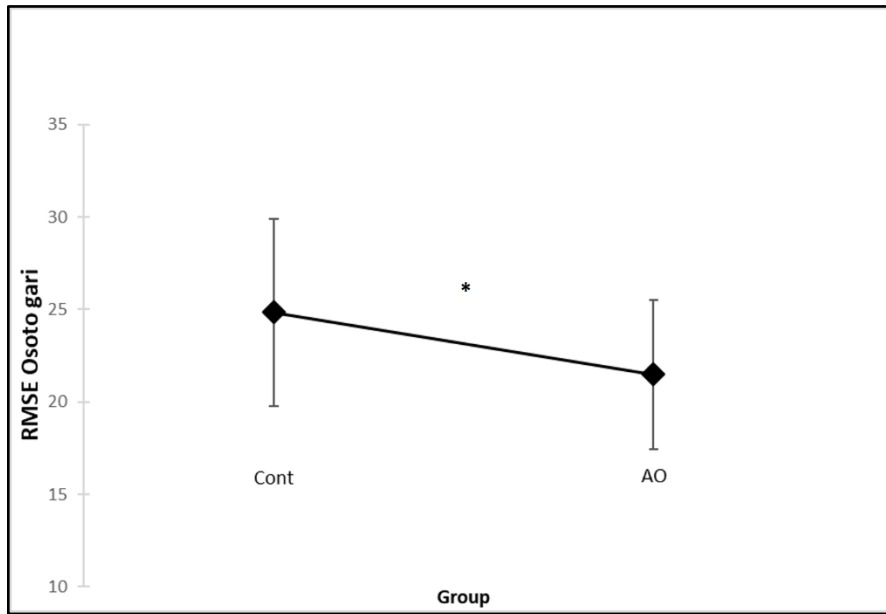
235 The analyses revealed no effect of group on the angle between the trunk and the supporting  
 236 leg during the movement,  $t(16) = 1.098, p = .144, 95\% \text{ CI} = [-2.21; \infty], d = .52$  or on the absolute  
 237 angle of the trunk with the horizontal leg,  $t(16) = 0.721, p = .241, 95\% \text{ CI} = [-2.82; \infty], d = .34$ .  
 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;  $\infty$ ],  $d = .85$ , 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***

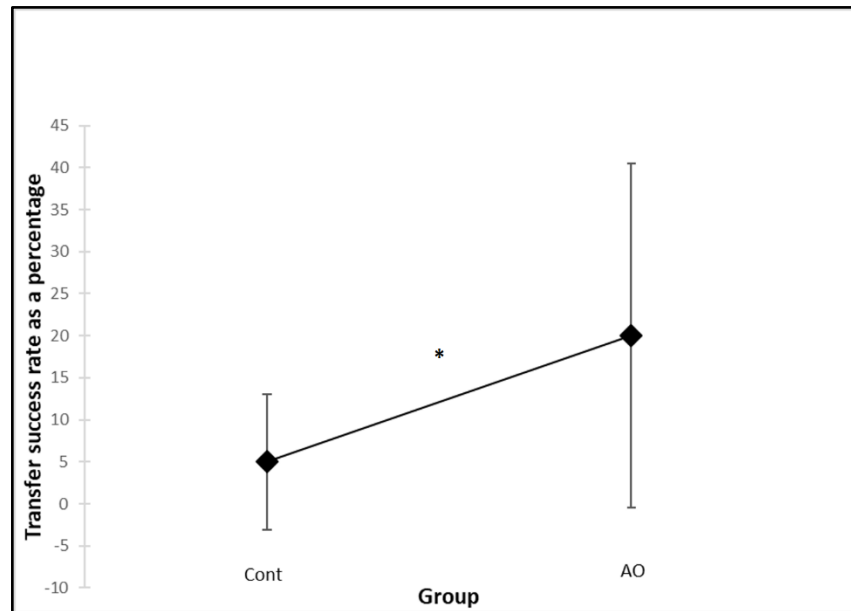
249 None of the results obtained on the evaluation of the Kubi-nage technique showed any significance or  
 250 trend; therefore, the two groups were similar (longitudinal rotation angle:  $t(17) = .750$ ,  $p = .232$ , 95%  
 251 CI = [-9.50;  $\infty$ ],  $d = .345$ ; tilt angle:  $t(17) = -1.487$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

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 = [- $\infty$ ; 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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340

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- 433
- 434

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		
<b>Safety</b>	Control of Uke when throwing		
	Endangerment with an improper throw		
	Control of attacks for Uke		
<b>Attitude and Ceremonial</b>	Respect for the chronology and execution of the ceremonial		
	Tori's attitude, posture and movement		
	Uke's attitude, posture and engagement		
<b>Technical correctness</b>	Chronology of techniques and attacks (Tori/Uke)		
	Respect of the techniques (technical errors and omissions)		
<b>Technical Execution</b>	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	
---------------------------------	--	--

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 .....

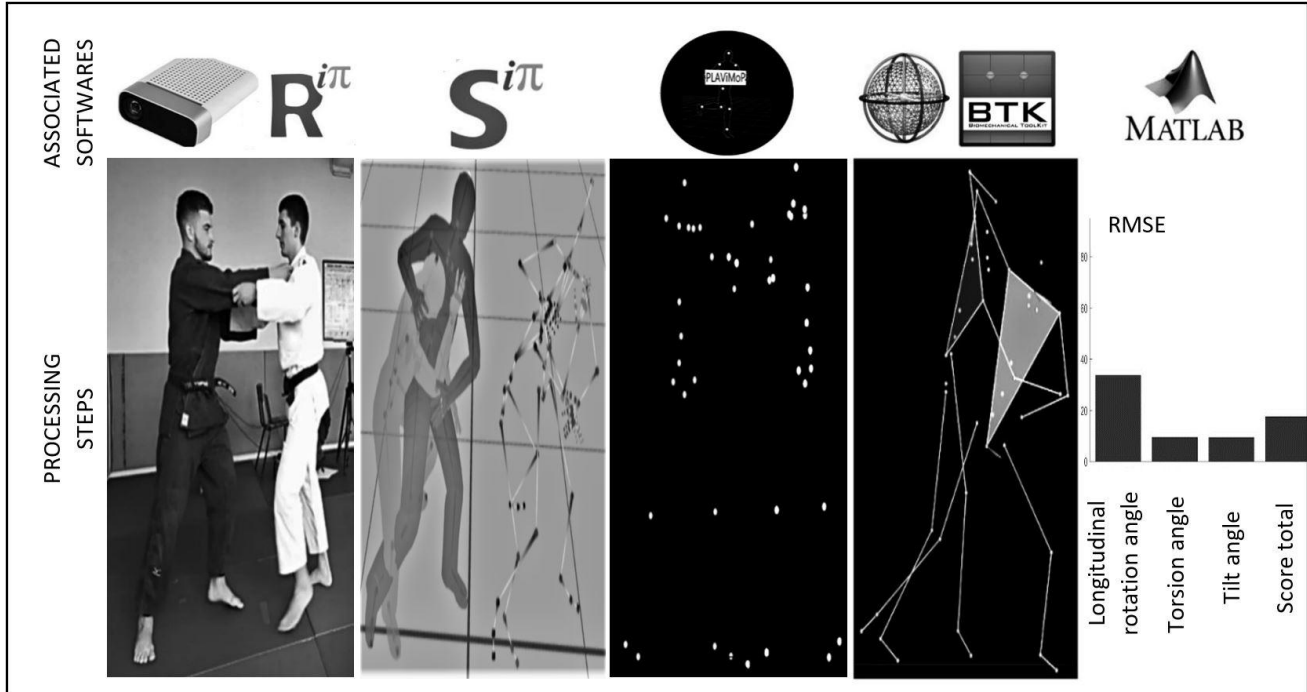
464

465

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.