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The *Alligator game*

Effects of bodily stake on decision making

Keywords: Decision making, Motor game, Game theory, Aquatic apnea, Sports science students, Bodily stake

Abstract

Experimental Game Theory generally studies the intelligence of decisions within fictional laboratory situations that appeal to the imagination of the participants. We always wonder what these choices will give when they have to be implemented in real life. This paper studies the effect of physical involvement on decision-making.

Fifty-eight athletes confront each other two by two during a paradoxical motor game in a swimming pool: the *Alligator game*. Choices must be made underwater. Depending on whether they break the surface before or after a line 15m from the wall, they win a certain number of points according to a matrix known to them. Participants also play this game beforehand in the locker room.

Statistical analysis of the 174 water confrontations shows that players are playing (i) neither as theory would predict (Nash's equilibrium), (ii) nor as they had predicted. The best free-divers maximize their earnings by forcing the decisions of the other players.

Thus, the choices made are, above all, subordinated by the person's ability to put them into place: "without technique, no tactics". The conclusions provided by Experimental Game Theory would gain in robustness if they also considered the relevant performance proficiency levels.

1 Introduction

The success of Game Theory comes from its multiple fields of investigation: military, political, economical, evolution of the species... Human and social sciences have also largely used the potential of this interactive decision-making mathematical theory (Shubik, 1982, Binmore, 2008). Digitally confronting 10 strategies over 200 plays, Axelrod (1997) shows that the "vivre et laisser vivre" (tit-for-tat) de Rapoport (2012) is the best way to act within the Prisoner's dilemma (Tucker, 1950). Axelrod presents this dilemma as the archetype of a great number of social situations (including the confrontations in the trenches during the First World War). In Evolution Theory, Dawkins (2016) goes so far as to claim that the repetitive game of "Hawk versus Dove" (Aradhye et al., 2017) is the most important discovery since the works of Darwin (1859). Dawkins explains how species that seem at first glance dominated survive in a stable manner (Evolutionary Stable Strategy) amongst the dominant species. Dawkins titles his work "Nice Guys Finish First", going against the ethological knowledge of the time.

The enthusiasm triggered by Game Theory must not hide enormous simplifications. Furthermore, in its origin, it is neither more nor less than a formalization of reality, meaning a retrospective refined simplification of what occurs. Game Theory models interactive situations based on a gain matrix, the usefulness of which is fictitious and does not take into account player psychology (Colman, 2003). The case of *Schelling point* (1980) is revealing. Asking his students to play with an unknown partner that they have to find in a large city without being able to communicate, Schelling establishes that the majority answer in the same place, the same day and at the same time. However, there exists an infinite amount of Nash

45 equilibriums (1950), such as solutions where neither partner wants to change their tactic if the
46 other doesn't change theirs (Aumann and Brandenburger 2016).

47 In the last few years, studies in Experimental Game Theory (Crawford, 2002) have gotten
48 things back on track by introducing variables that are subjective to the games resolution. The
49 effects of conformity to the norm (Harsanyi, 1975; Steven and Moffitt, 2017), group context
50 (Roszkowska et al., 2017), in-group reputation (Obayashi, 2018; Ren et al., 2018; Roddie,
51 2019), emotions read on the faces of other players (Eckel and Wilson, 2003), emotions
52 mobilized by the social decision making (Sanfey, 2007), but also the effects of gender
53 (Schwartz-Shea, 2002), age (Sutter and Kocher, 2007), etc. introduce a finer granularity to the
54 analysis.

55 However, physical involvement has rarely been considered (Parlebas, 2005) and when it is,
56 the engaged motricity is close to that of e-sports (Braun et al., 2009). This is nonsensical for
57 games that lead to years in prison (*Prisoners Dilemma*), affect life expectancy (*Chickie run*
58 *game*, Xia, 2017) or lead to the disappearance of a species (*Hawk vs. Dove*).

59 Indeed, in many common human interactions, decision making can be troubled by the
60 presence of bodily stake. A stake is what is bet at the start of the game play (in sport or a
61 game) or a situation (for other everyday personal and professional contexts) – voluntary or not
62 – that one must not lose. For Actuarial mathematics (that serve as a base example for
63 insurance calculations), the risk is the stake multiplied by its probability of occurring (Said,
64 2016).

65 Aquatic apnea presents a recognized physical stake (Muth et al., 2005). It is part of such
66 sports where mastery allows the acquisition of a skill-set favorable to personal safety, such as
67 against the risk of drowning (McCool et al., 2008; Stallman et al., 2017). During a pre-
68 experiment at their University, we asked 18 sports science students (students from a *STAPS*
69 course; *STAPS* being the abbreviation of “Sciences et Techniques des Activités Physiques et
70 Sportives”) to swim the longest distance possible underwater. Except for a few, the swimmers
71 did not get past 20 meters (m) and most surfaced around 15m. The measurement of their
72 oxygen (O_2) saturation levels – 10 seconds before and 10 seconds after the apnea – revealed
73 that these young people had only used 5% ($SD = 2.3$) of their O_2 reserves during their
74 underwater trajectory (versus around 40% for an experienced free diver measured in the same
75 conditions)... In all, the STAPS students were well under their maximum free diving
76 capacities. They are not aware of the possibilities of dynamic action in immersion. Physical
77 involvement disrupts perceptions. Subjecting 373 collegiate physical education students to
78 challenges in a swimming pool, Moran et al. (2012) obtained the same results.

79 We can ask ourselves whether the mastery of dynamic apnea can improve rationality of the
80 choices taken when faced with incertitude. To do this, we put into place a 2 player and non-
81 null sum game in a swimming pool – game since named the *Alligator game* for the reasons
82 that will be developed in the Discussion section.

83 During their apnea, each swimmer will need to choose between two tactics for which the
84 payoffs will be tributary to the choices of the other player. Their performance level in apnea is
85 measured beforehand. The participants also play this game outside of the pool. We can thus
86 control the link between motor skills and decisions.

87 The main hypothesis is that motor intelligence (the correctness of choices made in mobile
88 activity) is subordinated by bodily stake. The secondary hypothesis are: (i) ways of play are

89 dissonant depending on whether there is a bodily stake or not (game out of the water vs. game
90 immersed in apnea); (ii) when the objective risk is better understood – by the expert free-
91 divers – the decisions are more rational; (iii) when it is less understood – by beginner free-
92 divers – the decisions in the water are more absurd.

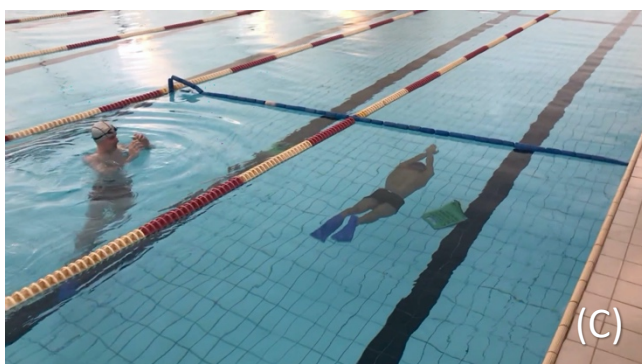
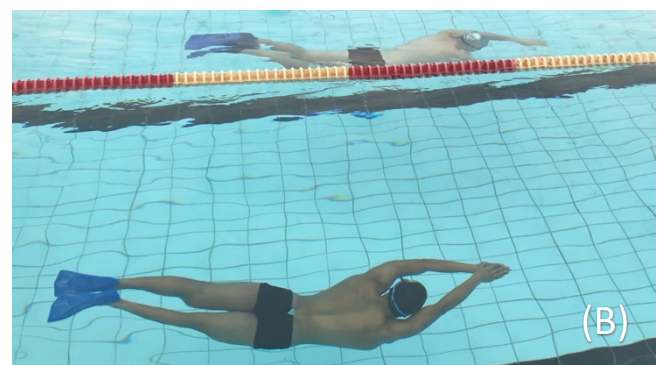
93 2 Materials and Methods

94 2.1 Procedure

95 Swimmers compete round by round in the swimming pool. They go two by two, each in a 2.5
96 meter (m) wide corridor.

97 Placed at the bottom of the water, an object represents the 15 meter (m) line from the starting
98 wall. Fins on feet, the swimmers leave at the same time on a signal (Figure 1). They can only
99 move underwater. Depending on whether they emerge before or after the 15m line, they gain
100 points according to a matrix (Figure 2) they know. The game is repeated. The players
101 alternatively play line-player or column-player. The number of turns is not known to them.

102 **Figure 1. The Alligator game.** Photo (A): game on. On the left the player 1 (line). To the
103 right is the player 2 (column). Photo (B): during the first 15 meters. Photo (C): decision
104 making. Photo (D): unveiling of the game. Player 1 (line player) goes up after 15m and gets
105 +4. Climbed before the 15m line (C), player 2 scores +2 (see Figure 2).



106

107

108 **α** / If the swimmers both surface before the 15m line (Figure 5, North West square: (<15M
109 APNEA, <15M APNEA)): the line-player gets +2 points and the column-player gets +3. **β** / If
110 line-swimmer plays >15M APNEA whilst the column-swimmer surfaces before the 15m
111 (South-West square), their score is improved: +4 for the line swimmer and +2 for the column
112 player. **γ** / If both swimmers surface after the 15m (South-East square), the line-swimmer only

113 gets +1 point, when the column swimmer gets their best score possible: +4. δ / Finally, if they
 114 play (<15M APNEA, >15M APNEA) as seen in the North-East square, the line-swimmer gets
 115 +3 points and the column player only +1. We owe this dilemma type matrix or paradoxical
 116 game to the mathematician Marc Barbut (1967).

117 **Figure 2. Payoffs associated with the 2 line tactics (<15M APNEA and >15M APNEA)**
 118 **according to the 2 column tactics (<15M APNEA and >15M APNEA).** The first number in
 119 each parenthesis corresponds to the payoff of the line-player, the second to the payoff of the
 120 column player. The matrix is unsymmetrical. With each combination, one of the two players
 121 is unsatisfied.

Matrix	<15M APNEA	>15M APNEA
<15M APNEA	(2, 3)	(3, 1)
>15M APNEA	(4, 2)	(1, 4)

122

123 If the free-divers were logical virtual players, they would first and foremost avoid the worst
 124 case scenario. The tactic of “lesser evil”, called *Maximin* by Von Meumann and Morgenstern
 125 (1944) is, for the two swimmers, $Max(+1, +2) = +2$. This allows the player to escape the
 126 worst score: +1. The combination of both *Maximin* tactics leads to the following play: $\alpha =$
 127 (<15M APNEA, <15M APNEA) = (+2, +3). This strategy is not balanced and the line-player
 128 would gain to change tactics if the column-player maintains their surfacing before the 15m.
 129 The *Minimax*, on the other hand, is defined by the Minimum of maximum satisfaction; it is
 130 given by $Min(+3, +4) = +3$. Simultaneous pursuit of these *Minimax* also finishes with $\alpha = (+2,$
 131 $+3)$. In this game, cautious behavior is neither satisfactory nor balanced.

132 As a true vicious circle, the game offers no Nash’s Equilibrium (1950) when regarding
 133 strategy alone. The game being repeated, there necessarily exists a balance issued from a
 134 mixed strategy. If p , the probability of playing <15M APNEA and $(1 - p)$ that of playing
 135 >15M APNEA for the column-swimmer. So, the expected returns of the line-swimmer if they
 136 play <15M APNEA is $E <15M = 2p + 3(1 - p) = 3 - p$. And their expected returns if >15M
 137 APNEA is $E >15M = 4p + 1(1 - p) = 3p + 1$. To play for a break-even, $E <15M = E >15M$,
 138 otherwise put $3p + 1 = 3 - p$; it occurs that $p = \frac{1}{2}$ and so $E <15M = E >15M = +2.5$ points in
 139 favor of the line-swimmer. Similarly, if q is the probability that the line-swimmer surfaces
 140 before the 15m and $(1 - q)$ the probability that they pass it, the break-even occurs with $q = \frac{1}{2}$
 141 to obtain a score of +2.5 points for the column-swimmer.

142 If the players behave as programmed machines in order to win the game – having neither
 143 apnea problems, nor problems decrypting the matrix – they would surface before the 15m line
 144 one time out of two.

145 2.2 Participants

146 The quasi-experimental procedure conformed with the declaration of Helsinki and had been
 147 approved by the Institutional review board of the Paris Descartes Sorbonne University. The
 148 58 subjects gave informed consent to participate.

149 Of male sex and of 18.8 years of age ($SD = 0.6$), the swimmers are from the *Faculté des*
150 *Sciences et du Sport (STAPS)* (Science and Sports faculty) of the university. They are first
151 year undergraduate students. The measurements were taken at the beginning of the university
152 year; the students did not know each other. Of similar and average competitive swimming
153 ability (they can all swim a 400m in front crawl between 7'30 and 9 minutes), they are all
154 able to swim 15m underwater equipped with flippers.

155 **2.3 Measurements**

156 The data is analyzed according to a base of 5 indicators (that will be explained in a later
157 section: 2.3.1, 2.3.2) that generates 12 active variables. These are analyzed using *PMD*
158 (Percentage of Maximum Deviation from Independence) developed by Cibois (2006). This
159 statistical technique is close to the “Chi2 maximum” percentage but differs in the following
160 points: (i) deviation from independence values are not squared – so as to differentiate from
161 other variables with positive ties, and (ii) the deviations are not reduced by their independence
162 values – in order to avoid that the sample size influences the attraction strength between
163 variables. The *PMD* generates a Factorial Analysis *TRI2*, where the variables with the
164 strongest contribution factor join in pairs (by a full line) on the vectorial plane. A logistical
165 regression completes the analysis by cross-examining the explanatory factors.

166 **2.3.1 Alligator game-play in locker-room**

167 The players start by answering a questionnaire that also reveals the matrix (Figure 2): “What
168 tactic out of the following two would you play if the game was repeated multiple times
169 against different adversaries that you did not know? Answer only by providing a probability
170 of playing one tactic over another.” Even if it means exactly the same thing, the questionnaire
171 expects a reply depending on if they are a line-player or a column-player. We can then
172 compare the strategies chosen without bodily risk to those chosen once in action. We shall
173 talk of THEOCONCORDANCE when the choice made in the locker-room is confirmed in the
174 swimming pool (arbitrarily: if there is not a deviance of more than 1/3 (33.34%) between
175 what is said and what is done). In the opposite case, we shall mention THEOCONFLICT.

176 **2.3.2 Alligator game-play in the swimming pool**

177 The 58 swimmers each play 6 times against adversaries chosen at random. In order to avoid
178 observations that could influence the player’s future game-play, when players are not called to
179 play Alligator game they are occupied with numerous swimming exercises in a different
180 swimming area, visually isolated from the experiment. During these swimming exercises, we
181 test, for each individual, the maximum distance they can cover in dynamic apnea. We code
182 LIMITEDAPNEA for those who swim underwater for a maximum of 20m with flippers. We
183 code APNEACOMFORT for those who can stay underwater for 25m. We code
184 APNEAPERFORM for the swimmers who only surface after 25m.

185 **2.3.3 Order of surfacing**

186 Even though the game is described as “simultaneous”, observations show that *in situ*, the
187 swimmers never surface at exactly the same time. There are those that play first (coded as
188 ACTINGFIRST) and those that surface second (coded ACTINGSECOND). This factor,
189 specific to motor performance, is likely to interfere with game resolution.

190 **2.3.4 Good and bad scores**

191 With a balanced result, the swimmers can expect on average +2.5 points. We consider
 192 BADSCORE, scores lower than this average (lower limit of 0); and GOODSCORE those than
 193 are over or equal to it (higher limit of +4).

194 2.3.5 Rationality of motricity strategy

195 If the swimmers surface before the 15m line two, three or four times out of six, taking into
 196 account the relative proximity to the balanced strategy (1 time out of 2), they are arbitrarily
 197 coded NASHIANPLAY. If they surface five or six times out of six before the 15m, they are
 198 MAXIMINPLAY in reference to the theory of Maximin aforementioned (which calls for a
 199 player to surface 6 times out of 6 before the 15m: by alternating line-player and column-
 200 player, we note that the expected gain is $E_{MAXIMIN} = (3*2 + 3*3)/6 = +2.5$ points, equal to
 201 that given by Nash). To finish, if they surface five or six times after the 15m line, we classify
 202 these swimmers as IRRATIONNALPLAY to indicate that they are playing with fire, risking
 203 the worst score (+1) in the hope for the best (+4).

204 3 Results

205 3.1 PMD

206 Figure 3 presents the significant (>10%) and positive PMDs. The bad scores obtained during
 207 Alligator Game (BADSCORE) are correlated with surfacing before the adversary
 208 (ACTINGFIRST, 86.2%) and to playing the “lesser evil” as described by Von Neumann
 209 (MAXIMINPLAY, 46.2%). Precision must be assured so that the percentages given here do
 210 not correspond to the total percentage of players (N = 58), but to the maximum deviation from
 211 independence of the players, equally shared across 4 other variables. The good scores
 212 (GOODSCORE) are strongly tied to the quality of dynamic apnea (APNEAPERFORM,
 213 100%) as well as to playing second (ACTINGSECOND, 86.2%). Playing contrary to Game
 214 Theory recommendations (IRRATIONNALPLAY) allows players to often obtain 2.5 points
 215 or more on each turn (GOODSCORE, 45.5%). This result questions the sub-hypothesis (i).

216 **Figure 3. PMD.** Ties interlinking the variables (those chosen or experienced by the same
 217 players).

PAY1 = BADSCORE				
ACTINGFIRS	MAXIMINPLA	THEOCONCOR	LIMITEDAPN	APNEACOMFO
86.2	46.2	36.8	33.3	31.0
PAY2 = GOODSCORE				
APNEAPERFO	ACTINGSECO	IRRATIONAL	THEOCONFLI	NASHIANPLA
100.0	86.2	45.5	36.8	33.3
STR1 = MAXIMINPLAY				
ACTINGFIRS	BADSCORE	LIMITEDAPN	THEOCONCOR	
46.2	46.2	39.6	29.6	
STR2 = NASHIANPLAY				
ACTINGSECO	GOODSCORE	APNEAPERFO	THEOCONFLI	
33.3	33.3	21.6	17.5	
STR3 = IRRATIONNALPLAY				
GOODSCORE	ACTINGSECO	APNEACOMFO	APNEAPERFO	
45.5	45.5	27.3	16.1	
APN1 = LIMITEDAPNEA				
ACTINGFIRS	MAXIMINPLA	BADSCORE		
46.7	39.6	33.3		
APN2 = APNEACOMFORT				
THEOCONCOR	BADSCORE	IRRATIONAL	ACTINGFIRS	
47.4	31.0	27.3	17.2	
APN3 = APNEAPERFORM				
GOODSCORE	ACTINGSECO	THEOCONFLI	NASHIANPLA	IRRATIONAL
100.0	85.7	46.9	21.6	16.1

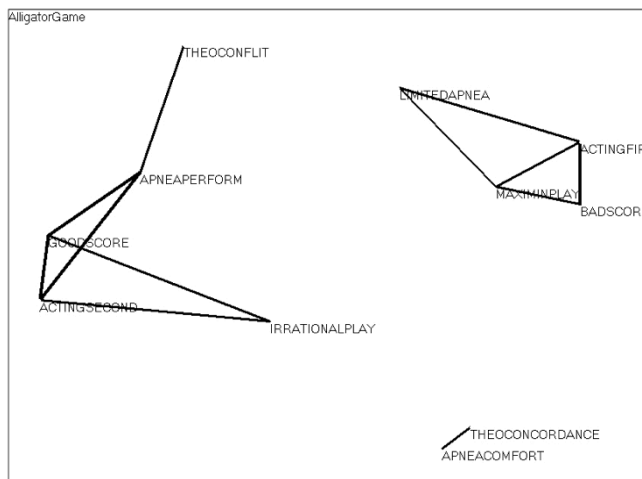
218

219 **3.2 TRI2**

220 The first three factors – as a principal component – of the factorial analysis: *TRI2* (Cibois,
 221 1982) carries 92.2% of the information. The links between the variables are strong. The first
 222 factor (F1, 74.7%) opposes – to the left of the plane (Figure 4) – the swimmers obtaining the
 223 good scores (GOODSCORE) and surfacing second (ACTINGSECOND) to the swimmers
 224 obtaining less than +2.5 points per turn (BADSCORE) and playing first (ACTINGFIRST) –
 225 to the right of the plane. Of lesser explicative contribution (11.6%), the second factor (F2)
 226 opposes – at the top of the plane – the swimmers weakest in dynamic apnea
 227 (LIMITEDAPNEA) that did not play when in the pool as they said they would when out of
 228 the pool (THEOCONFLICT) to the swimmers having a correct level of apnea
 229 (APNEACORRECT) who execute in the pool what they had announced in the questionnaire
 230 (THEOCONCORDANCE) – at the bottom of the plane. Of weak contribution (5.9%), the
 231 third factor (F3) opposes – towards the front – the Nash rational players, meaning those that
 232 play 2 to 4 times out of 6 before the 15m (NASHIANPLAY) to the cautious players, those
 233 that surface 5 or 6 times out of 6 before the 15m line (MAXIMINPLAY) – towards the rear.

234 Multiple chaining elements are visible in Figure 4. (lines linking two-by-two the variables
 235 chosen by the same participants). They sometimes associate variables of strong contribution
 236 to F1 – as GOODSCORE and ACTINGSECOND – to other inexistent elements in the
 237 construction of F1 – such as APNEAFORM. The robustness of the link between these three
 238 variables interests sub-hypothesis (ii) and (iii).

239 **Figure 4. Factorial analysis of principal components (TRI2).** Two by two sorting of the
 240 variables. The conjunctions between active variables are marked by a line. Two poles emerge:
 241 the players succeeding at the left of the plane, and the players in failure to the right.



242

243 **3.3 Logistical regression**

244 Does success within the Alligator Game depend more than anything on the act of playing
 245 second – once you have seen what the other player is doing – or the dynamic apnea capacity
 246 of the participants – which allows the player to concentrate exclusively on the resolution of
 247 the game? Thus, the variable to explain, by means of Logistical regression, is GOODSCORE.
 248 Let us use the baseline situation: APNEACOMFORT and ACTINGSECOND. The estimated
 249 proportion is 83.3% of the total sum. For each of the other variables, we can calculate the
 250 marginal effects. Having limited apnea capacities (LIMITEDAPNEA) acts on the variable
 251 GOODSCORE at -74.2%: students ill at ease under water make themselves incapable of

252 obtaining good scores within the game ($p < .01$). In contrast, despite what could be interpreted
253 in *PMD* and *TRI2*, the fact that a player acts first (ACTINGFIRST) does not explain – on its
254 own – the BADSCORE. Contrary to logistical regression, *PMD* and *TRI2* are not “all is equal
255 elsewhere” techniques. It is due to the chaining effect that GOODSCORE finds itself linked
256 in the factorial plane (Figure 4) to ACTING SECOND and APNEAPERFORM. If the
257 swimmers fail to obtain good scores, it is not due to the fact that they played first but more
258 due to their poor free-diving skills. And because they are weak in dynamic apnea, they have a
259 tendency to surface first and often before the 15m line (MAXIMINPLAY).

260 4 Discussion

261 The main hypothesis of this paper was that motricity decisions were subordinated by bodily
262 stake. The manner of playing within mobile action often diverges with the manner of playing
263 by questionnaire (sub-hypothesis (i)). The *PMD* and *TRI2* tend to even reveal that those who
264 better succeeded in the swimming pool were those that were in conflict with their choices on
265 paper. Very often, in Game Theory, once the questions are asked and the decisions made, the
266 game is over – even before it has started (Aumann and Brandenburger, 2016). In mobile
267 action, which is more emotionally involving, once the problem is presented, the decision to be
268 made is indexed against the participant’s ability to put it into action (Colman, 2003; Eckel and
269 Wilson, 2003; Roddie, 2019). We have thus observed that some swimmers rush to the 15m
270 line out of fear of lacking oxygen (even though their O_2 saturation levels indicate that they are
271 using less than 10% of their maximum apnea reserves) and surface before or after without
272 worrying about the other players tactic. This corresponds to the lowest level of motricity
273 intelligence in the context of this game (sub-hypothesis (iii)).

274 Those more at ease in apnea act as true alligators by becoming immobile below the surface
275 well before the 15m line, waiting to see how their adversary will play (sub-hypothesis (ii)).
276 Most of the time, they surfaced second, once their startled ‘prey’ had been neutralized.
277 Depending on where the prey emerged, it was more interesting for the alligators to surface
278 $<15m$ or $>15m$ (“ $<$ ” meaning “before”; “ $>$ ”: “after”) depending on whether they were a line-
279 player or a column-player. In order to win, the line-alligators had to always chose a tactic
280 different to the column-player (if column surfaces $<15m$, *Alligator* maximizes their win by
281 $>15m$; if column surfaces $>15m$, *Alligator* maximizes their win by $<15m$). Thus, the alligators
282 can guarantee themselves +3 or +4 ($E_{alligator} = +3.5$ points) whilst the column-players would
283 either obtain +1 or +2 ($E_{other} = +1.5$).

284 Logically, taking into account the matrix, the column-alligators must always choose a tactic
285 equivalent to the line-player (if line surfaces $<15m$, *Alligator* performs $<15m$; if line surfaces
286 $>15m$, *Alligator* performs $>15m$). As such, the alligators can always guarantee +3 or +4
287 ($E_{alligator} = +3.5$) whilst line-players will only obtain +1 or +2 ($E_{other} = +1.5$).

288 But sometimes, in rare cases, the lucidity of the *Alligators* allowed them to decode the
289 blindness of the other player and they surface first, having the certainty of having won (Burns
290 et al., 2017). This explains why the good scores are primarily obtained by the swimmers
291 associated with the variables “comfort” or “performance” in apnea, more than those who play
292 second rather than first. When two *Alligators* confront each other, they both remained at the
293 bottom of the pool. The game lasted a long while and we timed static apnea of over 1 minute,
294 until the weaker of the two finished by giving up, leaving the second the possibility to make
295 the more rational choice.

296 Why do these results question a Decision Theory that systematically ignores the presence of a
297 bodily stake? We can imagine a game without bodily stake using the same logic as the
298 *Alligator game*. We can imagine experimenting with numerous factors (age, sex, reputation
299 etc.). But in the case of bodily involvement, the decisions are subordinated (a) by the various
300 physical actions possible: “I decide depending on what I know how to do”, and (b) by the
301 decoding of the physical capacities of other players: “I act according to what I believe the
302 other can do”. These aspects are often ignored in games without bodily stake or even within
303 the ill-named *e-sports* (Braun et al., 2009). It is easy to remain level-headed or keep a
304 presence of mind when using screens. But the study of decision making cannot be subtracted
305 from the thought-process associated with a physical and immediate bodily risk (Parlebas,
306 2005). As such, motor-games (traditional games and sports) can reveal themselves to be the
307 best laboratory for studying human conduct (Pic et al., 2020).

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