Journal of Physical Education and Sport ® (JPES), Vol. 24 (issue 7), Art 194 pp. 1743 - 1749, July 2024
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

The Alligator game: effects of bodily stake on decision-making

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Published online: July 31, 2024
Accepted for publication : July 15, 2024
DOI:10.7752/jpes.2024.07194

Abstract:
Experimental game theory explores decisions-making intelligence in simulated laboratory scenarios that engage participants' imagination. However, do choices differ when subjects face real-life situations? and decisions when subjects are exposed to the real life? Hence, the objective of this study was to determine the effect of physical involvement on decision-making. Therefore, this study aimed to assess the impact of physical engagement on decision-making. Fifty-eight athletes competed in a paradoxical motor game, the Alligator Game, conducted underwater in a swimming pool. Depending on whether they broke the surface before or after a line 15 meters from the wall, they won a certain number of points according to a matrix known to them. During the confrontation, the players were either row-players or column-players (depending on their choice in the matrix). Depending on what type of player they've chosen, they had tactics to maximize their number of points won. They could, if they wanted to stay in static apnea (like an alligator), to see the decision taken by their opponents in order to choose the best move. Participants also played this game beforehand in the locker room (what would they do theoretically if they were confronted to this situation?). Statistical analyses of the 174 water confrontations showed that (i) alligator players did not consistently apply the best tactic (Nash's equilibria), (ii) the best players did not play as they had announced in theory. The best free divers maximized their earnings by forcing the decisions of the other players. In conclusion, decisions made were, above all, subordinated by the person's ability to put them into place: "without technique, no tactics".
Key Words: **Decision-making, Motor game, Game theory, Aquatic apnea, Sports science students, Bodily stake**

Introduction:

The success of the game theory comes from its multiple fields of investigation: military, political, economic, species evolution, etc. The human and social sciences have also widely exploited the potential of this mathematical theory of interactive decision-making (Binmore, 2008; Shubik, 1982). Confronting by computer a dozen strategies over 200 moves, Axelrod (Axelrod, 1997) showed that the "vivre et laisser vivre" (tit-for-tat) from (Rapoport, 2012) is the best way to act within the Prisoner's dilemma (Tucker, 1983). Axelrod presented this dilemma as the archetype for many social situations including the trench warfare of World War I. In the evolutionary theory, (Dawkins, 1976) Dawkins went so far as to claim that the repeated game of "Hawk *vs.* Dove" (Aradhye et al., 2017) was the most important discovery of Darwin's work (Darwin, 1859). Dawkins explained how dominated species survive in a stable manner (*i.e.,* evolutionarily stable strategy) amidst dominant species. "Nice Guys Finish First" was Dawkins' title, going against the grain of current ethological knowledge.

In the last few years, studies in experimental game theory (Crawford, 2002) have readjusted the focus by introducing variables that were more subjective to the game's resolution. The effects of norm conformity (Harsanyi, 1975; Moffitt, 2017), group context (Burns et al., 2017), in-group reputation (Obayashi, 2018; Ren et al., 2018; Roddie, 2019), emotions perceived on the faces of other players (Eckel & Wilson, 2003), affects mobilized in the social decision-making (Sanfey, 2007), but also the effects of gender (Schwartz-Shea, 2002) and age (Sutter & Kocher, 2007), introduce a finer granularity to the analysis.

However, the physical involvement has very rarely been considered (Parlebas, 2005) and when it was the case, the engaged motricity was close to that of esports (Braun et al., 2009). This is nonsensical for games that lead to years in prison (The Nash's *Prisoner's Dilemma*), affect life expectancy (*Chicken run game*; (Xia, 2018)) or lead to the disappearance of a species (*Hawk vs. Dove;* Aradhye et al., 2017). In many common human interactions, decision-making can be disturbed by the presence of bodily stakes. A stake is what is bet at the start of the game play (*i.e.,* in sport or a game) or a situation (*i.e.,* for other everyday personal and professional contexts) – voluntary or not – that which one tries not to lose. In actuarial mathematics (*e.g,* used as a basis for insurance calculations), the risk is the stake multiplied by its probability of occurrence (Said, 2016).

Aquatic apnea presents a recognized physical stake (Ganchar et al., 2018; Ildikó et al., 2017; Monteiro et al., 2021; Muth et al., 2005). It is part of such sports where mastery allows the acquisition of a skill-set favorable to personal safety against the risk of drowning (McCool et al., 2008; Scurati et al., 2019; Stallman et

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al., 2017). During a pre-experiment at their university, eighteen sports science students (students in physical education) were asked to achieve their maximum distance underwater. Except for a few, the swimmers did not exceed 20 meters (m) and most surfaced around 15 m. The measurement of their oxygen (O_2) saturation rate – 10 seconds before and 10 seconds after the apnea – revealed that these young people had only used up 5% (*SD* = 2.3) of their O_2 reserves during their underwater trajectory compared to 40% for a confirmed freediver. Hence, students were not lucid on their dynamic possibilities of action in immersion and their body's involvement in the activity disrupts perceptions. These results corroborated with previous results obtained in 373 physical education students in dynamic apnea pool challenges (Moran et al., 2012). However, can mastering dynamic apnea can improve the rationality choices taken when faced with incertitude?

In this context, the present study aimed at determining the effect of physical involvement on decision-making during a dynamic apnea game: the Alligator game. The main hypothesis is that motor intelligence (the correctness of choices made in motor action) is subordinated to the bodily stake. The secondary hypotheses are: (i) the ways of playing are discordant according to whether there is a bodily stake (play out of the water *vs.* play underwater in apnea); (ii) when the objective risk is better understood – by expert freediver – decisions are more rational; (iii) when it is less understood – by beginner freediver – decisions in the water are more absurd.

Material & methods

Procedure

Swimmers competed round by round in the swimming pool. They had swum in pair, each in a 2.5 meters (m) wide corridor. Placed at the bottom of the water, an object represents the 15 m line from the starting wall. Fins on the feet, all swimmers left at the same time on a signal (Figure 1). They could only move underwater. Depending on whether they emerged before or after the 15m line, they won points according to a matrix (Figure 2) known to them. The game was repeated 6 times. The players alternatively played row-player or column-player (according to the matrix). The number of turns was not precised to them.

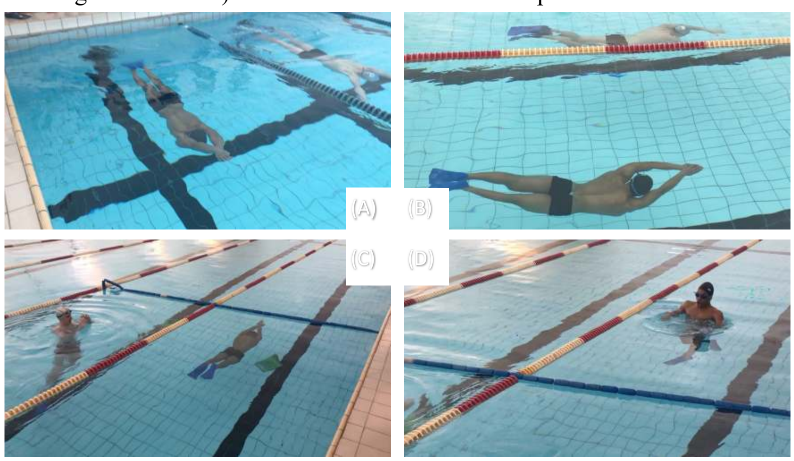

Fig. 1. The *Alligator game*. Photo (A): game on. On the left is the player 1 (row-player). To the right is the player 2 (column-player). Photo (B): during the first 15 meters. Photo (C): decision-making. Photo (D): unveiling of the game. The row-player went up after 15 m and got 4 points. The player 2 broke the surface before the 15m line (C) and got 2 points.

Attribution of points during the dynamic apnea game:

1/ If the both swimmers surface before the 15m line (Figure 2, M=(1,1)): the row-player gets 2 points and the column-player gets 3 points.

2/ If row-player swims >15m apnea whilst the column-player surfaces before the 15m (Figure 2, M= (2,1)), their scores are improved: +4 points for the row-player and +2 points for the column-player.

3/ If both swimmers surface after the 15m (Figure 2, M= (2,2)), the row-player gets 1 point and the column-players gets the best score possible (*i.e.,* 4 points).

4/ If row-player swims <15m apnea, whilst column-player swims >15m apnea (Figure 2, M= (1,2)), the row-player gets 3 points and the column-player gets 1 point.

		Column-player	
	Matrix	< 15m Apnea	> 15m Apnea
Row-player	< 15m Apnea	M(1,1) = (2,3)	M(1,2) = (3,1)
	> 15m Apnea	M(2,1) = (4,2)	M(2,2) = (1,4)

Fig. 2. Payoffs associated for the tactic chosen. The first number in each parenthesis corresponds to the payoff of the row-player, the second to the payoff of the column-player. The matrix is unsymmetrical. With each combination, one of the two players is unsatisfied. We owe this dilemma type matrix or paradoxical game to the mathematician Marc Barbut (Barbut, 1968).

If freedivers were logical virtual players, they would foremost avoid the worst-case scenario. The tactic of "lesser evil", called *Maximin* by Von Neumann and Morgenstern (von Neumann & Morgenstern, 1944) is, for the two swimmers, $Max(+1, +2) = +2$. This allows the player to escape the worst score: +1. The combination of both *Maximin* tactics leads to the following play: α = ('<15m apnea', '<15m apnea') = (+2, +3). This strategy is not balanced, and the row-player would gain to change tactics if the column-player maintains his surfacing before the 15 m. The *Minimax*, on the other hand, is defined by the minimum of maximum satisfaction; it is given by $Min(+3, +4) = +3$. Simultaneous search of this *Minimax* also finishes with α = (+2, +3). In this game, prudent behavior is neither satisfying nor balanced.

As a true vicious circle, the Alligator game does not offer a Nash Equilibrium (Nash, 1950) in pure strategy. As the game is repeated, there is necessarily an equilibrium in mixed strategy. Let p, the probability of playing '<15m apnea' and $(1 – p)$ that of playing '<15m apnea' for the column-player. So, the expected (E) returns of the row-player if they play '<15m apnea' is $E_{<15m} = 2p + 3(1 – p) = 3 – p$. And their expected returns if '>15m apnea' is $E_{>15m} = 4p + 1(1 – p) = 3p + 1$. To play for a break-even, $E_{<15m} = E_{>15m}$, otherwise put $3p + 1 = 3 – p$; it occurs that $p = ½$ and so $E_{<15m} = E_{>15m} = +2.5$ points in favor of the row-player. Similarly, if q is the probability that the row-player surfaces before the 15 m and $(1 – q)$ the probability that they pass it, the break-even occurs with $q = ½$ to obtain a score of +2.5 points for the column-player.

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

Study participants

The quasi-experimental procedure conformed with the declaration of Helsinki and had been approved by the institutional review board of the Paris Cité university. The 58 subjects gave informed consent to participate. The swimmers who participated to the experimentation were all male and the mean age were 18.8 (SD = 0.6) years old. They were sports sciences (*i.e.,* UFR STAPS) students from the university. The measurements were taken at the beginning of the university year; the students did not know each other. Of similar and average competitive swimming ability (they could all swim a 400 m in front crawl between 7'30 and 9 minutes), they were all able to swim 15 m underwater equipped with flippers.

Measurements

The data were analyzed according to a base of 5 indicators that generated 12 active variables. These were analyzed using Percentage of Maximum Deviation from independence (PMD) developed by Cibois (Cibois, 1982, 2006). This statistical technique is close to the "Chi2 maximum" percentage but differs in the following points: (i) the values of the independence deviations are not squared – to distinguish from the other variables with positive ties, and (ii) the deviations are not reduced by their independence values – to avoid that the sample size influences the attraction strength between variables. The *PMD* generates a Factorial Analysis *TRI2* – a kind of factor analysis, where the variables with the strongest contribution factor are linked in pairs (by a full line) on the vector plane. A logistic regression completes the analysis by cross-examining the explanatory factors.

Alligator gameplay in locker-room

The players started the game by answering a questionnaire that also revealed the matrix (Figure 2): "What tactic out of the following two would you play if the game was repeated several times against different opponents that you do not know? Answer only by giving a probability of playing one tactic rather than another." Even if it means the same, the questionnaire expected an answer depending on whether they were a row-player or a column-player. We could then compare the strategies chosen without bodily risk to those chosen once in action. When the choice made in the locker-room was confirmed in the swimming pool (if the deviation was not more than 1/3 (33.34%) between what it was said and what was done) it referred to the *theorical concordance* (TCONC). Otherwise, the choice made referred to the *theorical conflict* (TCONF).

Alligator gameplay in the swimming pool

The 58 swimmers each played 6 times against different randomly selected opponents. In order to avoid observations that could influence the player's future gameplay, when players were not called to play Alligator Game, they were occupied with numerous swimming exercises in a different pool, visually cut-off from the experiment. During these swimming exercises, the maximum dynamic apnea distance was tested for each swimmer. We coded *Limited Apnea* (LA) for those who swam underwater from 0 to a maximum of 20 m with flippers. We code *Apnea Comfort* (AC) for those who swam more than 20 m but less than 25 m. We code *Apnea Perform* (AP) for the swimmers abled to break the surface after 25 m of underwater swim.

Order of surfacing

Even though the game was described as "simultaneous", observations showed that *in situ*, swimmers never surfaced at exactly the same time. There were those who surfaced first (coded S1) and those who surfaced second (coded S2). This factor, specific to motor performance, was likely to interfere with game resolution.

Good and bad scores

With a balanced result, the swimmers could expect on average +2.5 points. We considered bad score (BS), scores lower than this average (lower limit of 1); and good score (GS) those that were over or equal to it (higher limit of +4).

Rationality of motricity strategy

If swimmers resurfaced before 15m line two, three or four times out of six, considering the relative proximity to the balanced strategy (1 out of 2 time), they were arbitrarily coded *Nashian Play* (NP). If they resurfaced five or six times out of six before the 15 m, they were *Maximin Play* (MP) in reference to the aforementioned theory of Maximin (which calls for a player to surface 6 times out of 6 before the 15 m: by alternating row-player and column-players, we note than the expected gain is $E_{MAXIMIN} = (3*2 + 3*3)/6 = +2.5$ points, equal to that given by Nash). To finish, if they resurfaced five or six times after the 15m, we classified these swimmers as *Irrational Play* (IP) to indicate that they were playing with fire, risking the worst score (+1) in the hope for the best (+4).

Results

The percentages of maximum deviation between performance in the Alligator game and choices of freedivers

The Figure 3 presents the significant (>10%) and positive PMD. The bad scores obtained during Alligator Game (BS) were correlated with surfacing before the adversary (S1, 86.2%) and to playing the "lesser evil" as described by Von Neumann (MP, 46.2%). Precision must be assured so that the percentages given here did not correspond to the total percentage of players (N = 58), but to the maximum deviation from the independence of the players, equally shared across 4 other variables. The good scores (GS) were strongly tied to the quality of dynamic apnea (AP, 100%) as well as to playing second (S2, 86.2%). Playing contrary to game theory recommendations (IP) allowed players to often obtain 2.5 points or more on each turn (GS, 45.5%).

PAYOFF1 = BS					
	S1	MP	TCONC	LA	AC
	86.2	46.2	36.8	33.3	31.0
PAYOFF2 = GS					
	AP	S1	IP	TCONF	NP
	100.0	86.2	45.5	36.8	33.3
STRATEGY1 = MP					
	S1	BS	LA	TCONC	
	46.2	46.2	39.6	29.6	
STRATEGY2 = NP					
	S2	GS	AP	TCONF	
	33.3	33.3	21.6	17.5	
STRATEGY3 = IR					
	GS	S2	AC	AP	
	45.5	45.5	27.3	16.1	
APNEA1 = LA					
	S1	MP	BS		
	46.7	39.6	33.3		
APNEA2 = AC					
	TCONC	BS	IP	S1	
	47.4	31.0	27.3	17.2	
APNEA3 = AP					
	GS	S2	TCONF	NP	IP
	100.0	85.7	46.9	21.6	16.1

Fig. 3. Percentages of maximum deviation. Ties interlinking variables (those chosen or experienced by the same players). BS= Bad Score; GS= Good Score; MP= Maximin Play; NP= Nashian Play; IR=IP= Irrational Play; LA=Limited Apnea; AC= Apnea Comfort; AP= Apnea Perform; S1= Surface First; S2= Surface Second; TCONC=Theoretical Concordance; TCONF= Theoretical Conflict.

The principal components of performance in the Alligator game

The first three factors – as a principal component – of the factorial analysis: *TRI*2 (Cibois, 1982) carries 92.2% of the information. The links between the variables were strong. The first factor (F1, 74.7%) opposed – on the left of the plan (Figure 4) – swimmers obtaining good scores (GS) and surfacing second (S2) to swimmers obtaining less than +2.5 points per turn, so a bad score (BS) and surfacing first (S1) – on the right of the plan. The second factor (F2) had a lower explanatory contribution (11.6%) and opposed– at the top of the plan – the TCONF swimmers with a low level of dynamic apnea (LA) to the TCONC swimmers with a correct level of apnea (AC) – at the bottom of the plan. Of weak contribution (5.9%), the third factor (F3) opposed – towards the front – the Nash rational players, meaning those that played 2 to 4 times out of 6 before the 15 m (NP) to the prudent players, those that surfaced 5 or 6 times out of 6 before the 15m line (MP) – towards the back.

Multiple linkages between variables can be seen in Figure 4. The lines link two-by-two of the variables chosen by the same participants. They sometimes associated variables of strong contribution to F1 – as *Good Score* (GS) and *Surfacing Second* (S2) – to other inexistent elements in the construction of F1 – such as *Apnea Perform* (AP). Two poles emerged from our analysis: the players succeeding at the left of the plane, and the players in failure to the right.

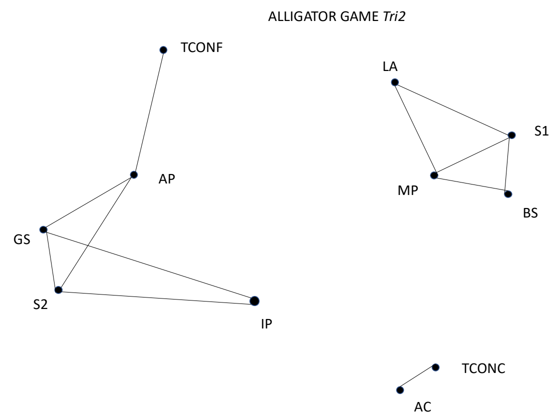

Fig. 4. Factorial analysis of principal components (*TRI2*). Two by two sorting of the variables**.** The conjunctions between active variables are marked by a line. BS= Bad Score; GS= Good Score; MP= Maximin Play; NP= Nashian Play; IR=IP= Irrational Play; LA= Limited Apnea; AC= Apnea Comfort; AP= Apnea Perform; S1= Surface First; S2= Surface Second; TCONC=Theoretical Concordance; TCONF= Theoretical Conflict.

Correlation between scores obtained in the Alligator game and apnea capacities and technic

Having limited apnea capacities (LA) influenced the variable *Good Score* (GS) at -74.2%: students who were uncomfortable underwater were unable to obtain good score in the Alligator game ($p < .01$). In contrast, the fact that a player *Surface First* (S1) did not explain – on its own – the *Bad Score* (BS).

Discussion

The main hypothesis of this paper was that motor decisions were subordinated by bodily stake. The ways of playing in motor action often diverges with the ways of playing by questionnaire. The *PMD* and *TRI2* even tended to reveal that freedivers who better succeeded in the swimming pool were those who were in conflict with their choices on the paper. Very often, in game theory, once the questions are asked and the decisions made, the game is over – even before it has begun (Aumann & Brandenburger, 1995). In motor action, which is more emotionally involving, once the problem is presented, the decision to be made is indexed against the participant's ability to put it into action (Colman, 2003; Eckel & Wilson, 2003; Roddie, 2019). In the present study, it was observed that some freedivers who rushed to the 15m line out of fear of lacking oxygen (even though their O_2 saturation levels indicate that they were using less than 10% of their maximum apnea reserves) and surfaced before or after without worrying about the other players' tactic. This corresponds to the lowest level of motricity intelligence in the context of this game. Thus, it seems that freediver students having lower apnea capacities take more absurd decisions in water and do not clearly understand the risk of the game.

The students more at ease in apnea acted as true alligators by becoming immobile below the surface before the 15m line, waiting to see how their opponents will play. Most of the time, they surfaced second, once their startled 'prey' had been neutralized. Depending on where the prey emerged, it was more interesting for the alligators to surface <15 m or >15 m ("<" meaning "before"; ">": "after") depending on whether they were a row-player or a column-player. To win, the row-alligator had always to choose a different tactic of the column-player (if column-player surfaces <15 m, row-alligator maximizes their win by >15 m; if column-player surfaces >15 m, row-alligator maximizes their win by <15 m). Thus, the row-alligators can guarantee themselves 3 or 4 points (*Ealligator* = +3.5 points) whilst the column-players would either obtain 1 or 2 points (*Eother* = +1.5). Logically, considering the matrix, the column-alligators must always choose a tactic equivalent to the row-player (if row-player surfaces <15 m, *Alligator* performs <15 m; if row-player surfaces >15 m, *Alligator* performs >15 m). As such, the alligators can always guarantee +3 or +4 (*Alligator* = +3.5) whilst line-players will only obtain +1 or +2 (*Other* = +1.5). Thus, it seems that freediver students having good apnea capacities take more intelligent decisions in water, clearly understand the risk of the game, and obtained great scores.

However, in rare cases, the lucidity of the *alligators* allowed them to decode the blindness of the other player and they surfaced first, having the certainty of having won (Burns et al., 2017). This explains why the good scores are primarily obtained by the swimmers associated with the variable's "comfort" or "performance" in apnea, more than those who played second rather than first. When two *alligators* confront each other, they both remained at the bottom of the pool. The game lasted a long while and we timed static apnea of over one minute, until the weaker of the two finished by giving up, leaving the second the possibility to make the more rational choice. Why do these results question a decision theory that systematically ignores the presence of a bodily stake? We can imagine a game without bodily stake using the same logic as the *Alligator game*. We can imagine experimenting with numerous factors (age, sex, reputation, etc.). But in the case of bodily involvement, the decisions are subordinated (a) by the various physical actions possible: 'I decide depending on what I know how to do', (b) by the decoding of the physical capacities of other players: 'I act according to what I believe the other can do' and, (c) by knowing my own physical capacities: 'I know I'm able (or not) to stay a bit longer in apnea'. These aspects are often ignored in games without bodily stake or even within the ill-named *esports* (Braun et al., 2009). It is easy to remain level-headed or keep a presence of mind when using screens. But the study of decision-making cannot be subtracted from the thought process associated with a physical and immediate bodily risk (Parlebas, 2005). As such, motor games (traditional games and sports) can reveal themselves to be the best laboratory for studying human conduct (Pic et al., 2020).

Conclusions

The analysis of the Alligator Game reveals significant insights into the interplay between physical abilities and decision-making. The study identifies two distinct groups of players: those who succeeded by deviating from their theoretical strategies and those who adhered to theoretical predictions but performed poorly. The findings highlight that the best players adapted their strategies in real-time, using their superior apnea skills to outmaneuver opponents. This adaptation transformed the game from a simultaneous to a sequential one, providing a strategic advantage. These players demonstrated a deeper understanding of the game's physical demands, allowing them to make more rational decisions and achieve higher scores.

Conversely, players with lower apnea skills who followed theoretical strategies without adaptation tended to perform worse. This suggests that theoretical knowledge alone is insufficient when physical stakes are involved. The ability to execute strategies effectively in a physical context is crucial, and a lack of such ability leads to irrational decision-making. The implications of these results extend beyond the scope of the game. They suggest that in real-world scenarios involving physical stakes, decision-making is closely tied to an individual's physical capabilities. This has significant theoretical and practical implications, particularly in fields such as sports, military, and any area where physical performance plays a critical role.

In conclusion, the study confirms that motor skills and bodily stakes are integral to rational decision-making in physical contexts. Future research should further explore this relationship, considering other variables such as emotional and psychological factors, to develop a more comprehensive understanding of decision-making under physical constraints.

The findings underscore the importance of integrating physical training with decision-making processes, particularly in high-stakes environments. By enhancing physical capabilities, individuals can improve their decision-making accuracy and overall performance in both theoretical and practical domains.

Conflicts of interest - There is no conflict of interest.

References:

Aradhye, A., Altman, E., & El-Azouzi, R. (2017). A Multitype Hawk and Dove Game. In L. Duan, A. Sanjab, H. Li, X. Chen, D. Materassi, & R. Elazouzi (Éds.), *Game Theory for Networks* (p. 16-28). Springer International Publishing. https://doi.org/10.1007/978-3-319-67540-4_2

Aumann, R., & Brandenburger, A. (1995). Epistemic Conditions for Nash Equilibrium. *Econometrica*, *63*(5), 1161-1180. https://doi.org/10.2307/2171725

Axelrod, R. (1997). The Complexity of Cooperation : Agent-Based Models of Competition and Collaboration. In *The Complexity of Cooperation*. Princeton University Press. https://doi.org/10.1515/9781400822300

Barbut, M. (1968). Jeux et mathématiques. Jeux qui ne sont pas de pur hasard. In R. Caillois, *Jeux et sports* (p. 836-864). Gallimard.

Binmore, K. (2008). Rational Decisions. In *Rational Decisions*. Princeton University Press. https://doi.org/10.1515/9781400833092

Braun, D. A., Ortega, P. A., & Wolpert, D. M. (2009). Nash Equilibria in Multi-Agent Motor Interactions. *PLOS Computational Biology*, *5*(8), e1000468. https://doi.org/10.1371/journal.pcbi.1000468

Burns, T. R., Roszkowska, E., Corte, U., & Machado Des Johansson, N. (2017). Linking Group Theory to Social Science Game Theory : Interaction Grammars, Group Subcultures and Games for Comparative Analysis. *Social Sciences*, *6*(3), Article 3. https://doi.org/10.3390/socsci6030107

Cibois, P. (1982). Tri-Deux : Une Méthode Post-Factorielle De Dépouillement D'enquête. *L'Année sociologique (1940/1948-)*, *32*, 61-80.

Cibois, P. (2006, novembre). *Principe de l'analyse factorielle*. https://cibois.pagesperso-orange.fr/PrincipeAnalyseFactorielle.pdf

Colman, A. M. (2003). Cooperation, psychological game theory, and limitations of rationality in social interaction. *Behavioral and Brain Sciences*, *26*(2), 139-153. https://doi.org/10.1017/S0140525X03000050

Crawford, V. P. (2002). Introduction to Experimental Game Theory. *Journal of Economic Theory*, *104*(1), 1-15. https://doi.org/10.1006/jeth.2001.2909

Darwin, C. (1859). *On the Origin of Species*. https://doi.org/10.4324/9780203509104

Dawkins, R. (1976). *The Selfish Gene*. Oxford University Press. https://doi.org/10.4324/9781912281251

Eckel, C. C., & Wilson, R. K. (2003). The Human Face of Game Theory : Trust and Reciprocity in Sequential Games. In E. Ostrom & J. Walker, *Trust and reciprocity : Interdisciplinary lessons from experimental research.* (Russel Sage Foundation, p. 245-274). https://papers.ssrn.com/abstract=1843493

Ganchar, O., Terentieva, N., & Ganchar, I. (2018). Swimming skill assessment based on swimmers` achievements at the XVII World Aquatics Championship in Budapest-2017. *Journal of Physical Education and Sport*, *18*(02), 725-730. https://doi.org/DOI:10.7752/jpes.2018.02106

Harsanyi, J. C. (1975). Can the Maximin Principle Serve as a Basis for Morality? A Critique of John Rawls's Theory. *American Political Science Review*, *69*(2), 594-606. https://doi.org/10.2307/1959090

Ildikó, V., József, K., Ladislav, B., L'ubomíra, B., & Matús, P. (2017). Results of a five-year test program to develop the swimming skills and physical abilities of freshman pedagogy students in Nitra. *Journal of Physical Education and Sport*, *17*(03), 1089-1094.

McCool, J., Moran, K., Ameratunga, S., & Robinson, E. (2008). New Zealand beachgoers' swimming behaviours, swimming abilities, and perception of drowning risk. *International Journal of Aquatic Research and Education*, *2*(1). https://doi.org/10.25035/ijare.02.01.02

Moffitt, S. D. (2017). *A Mathematics of Morality For Utopian Economics*.

Monteiro, Nelli, G., Araújo, Dias, N., Mazzardo, Tatiane, Francisco, Soares, P., Ribas, Schelyne, Aburachid, & Campos, L. M. (2021). Practice schedule analysis and pedagogical feedback in swimming classes. *Journal of Physical Education and Sport*, *21*(3), 1950-1957. https://doi.org/DOI:10.7752/jpes.2021.s3248

Moran, K., Stallman, R., Kjendlie, P.-L., Dahl, D., Blitvich, J., Petrass, L., McElroy, G., Goya, T., Teramoto, K., Matsui, A., & Shimongata, S. (2012). Can You swim? An Exploration of Measuring Real and Perceived Water Competency. *International Journal of Aquatic Research and Education*, *6*(2). https://doi.org/10.25035/ijare.06.02.04

Muth, C.-M., Ehrmann, U., & Radermacher, P. (2005). Physiological and Clinical Aspects of Apnea Diving. *Clinics in Chest Medicine*, *26*(3), 381-394. https://doi.org/10.1016/j.ccm.2005.05.007

Nash, J. F. (1950). Equilibrium points in n-person games. *Proceedings of the National Academy of Sciences*, *36*(1), 48-49. https://doi.org/10.1073/pnas.36.1.48

Obayashi, S. (2018). Self-organizing collective action : Group dynamics by collective reputation. *The Journal of Mathematical Sociology*, *42*(4), 205-221. https://doi.org/10.1080/0022250X.2017.1371148

Parlebas, P. (2005). Modélisation dans les jeux et les sports. *Mathématiques et Sciences Humaines. Mathematics and Social Sciences*, *170*, Article 170. https://doi.org/10.4000/msh.2968

Pic, M., Navarro-Adelantado, V., & Jonsson, G. K. (2020). Gender Differences in Strategic Behavior in a Triadic Persecution Motor Game Identified Through an Observational Methodology. *Frontiers in Psychology*, *11*. https://www.frontiersin.org/articles/10.3389/fpsyg.2020.00109

Rapoport, A. (2012). *Game Theory as a Theory of Conflict Resolution* (Vol. 2). Springer Science & Business Media.

Ren, Y., Wang, G., Yu, L., Shi, B., Hu, W., & Wang, Z. (2018). Rigorous or tolerant : The effect of different reputation attitudes in complex networks. *Future Generation Computer Systems*, *83*, 476-484. https://doi.org/10.1016/j.future.2017.09.006

Roddie, C. (2019). Reputation and gossip in game theory. In F. Giardini & R. Wittek, *The Oxford Handbook of Gossip and Reputation* (p. 214-229). Oxford University Press.

Said, K. (2016). *Mesures de risque multivariées et applications en science actuarielle*. Université Claude Bernard Lyon 1.

Sanfey, A. G. (2007). Social Decision-Making : Insights from Game Theory and Neuroscience. *Science*, *318*(5850), 598-602. https://doi.org/10.1126/science.1142996

Schwartz-Shea, P. (2002). Theorizing Gender for Experimental Game Theory : Experiments with "Sex Status" and "Merit Status" in an Asymmetric Game. *Sex Roles*, *47*(7), 301-319. https://doi.org/10.1023/A:1021474929976

Scurati, R., Michielon, G., Signorini, G., & Invernizzi, P. L. (2019). Towards a Safe Aquatic Literacy : Teaching the breaststroke swimming with mobile devices' support. A preliminary study. *Journal of Physical Education and Sport*, *19*(5), 1999-2004. https://doi.org/DOI:10.7752/jpes.2019.s5298

Shubik, M. (1982). *Game Theory in the Social Sciences : Concepts and Solutions*. MIT Press.

Stallman, R., Moran, K., Quan, L., & Langendorfer, S. (2017). From Swimming Skill to Water Competence : Towards a More Inclusive Drowning Prevention Future. *International Journal of Aquatic Research and Education*, *10*(2). https://doi.org/10.25035/ijare.10.02.03

Sutter, M., & Kocher, M. G. (2007). Trust and trustworthiness across different age groups. *Games and Economic Behavior*, *59*(2), 364-382. https://doi.org/10.1016/j.geb.2006.07.006

Tucker, A. W. (1983). A two-person dilemma : The prisoner's dilemma. *The Two-Year College Mathematics Journal*, *14*(3), 228-232. https://doi.org/10.2307/3027092

von Neumann, J., & Morgenstern, O. (1944). *Theory of Games and Economic Behavior*. Princeton University Press. https://doi.org/10.1515/9781400829460

Xia, X. (2018). Adaptive Traffic Signal Coordinated Timing Decision for Adjacent Intersections with Chicken Game. In T. Kováčiková, Ľ. Buzna, G. Pourhashem, G. Lugano, Y. Cornet, & N. Lugano (Éds.), *Intelligent Transport Systems – From Research and Development to the Market Uptake* (p. 239-251). Springer International Publishing. https://doi.org/10.1007/978-3-319-93710-6_25