

**Corrections and updates for first printing of  
Osborne and Rubinstein's "A Course in Game Theory"  
(MIT Press, 1994)**

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**Corrections**

<i>Page, Line</i>	<i>Correction</i>
xiii, 4	Solutions to the exercises are now available at <a href="https://www.economics.utoronto.ca/osborne/cgt/">https://www.economics.utoronto.ca/osborne/cgt/</a> .
xiii, -4	Replace "that" with "than".
xv	Martin J. Osborne's email address is now <a href="mailto:martin.osborne@utoronto.ca">martin.osborne@utoronto.ca</a> and his mailing address is Department of Economics, University of Toronto, 150 St. George Street, Toronto, Canada, M5S 3G7.
xv	Ariel Rubinstein's email address is now <a href="mailto:rariel@tauex.tau.ac.il">rariel@tauex.tau.ac.il</a> , his website is <a href="https://arielrubinstein.tau.ac.il">https://arielrubinstein.tau.ac.il</a> , and his second address is Department of Economics, New York University, New York, NY 10003, USA.
xv	The authors now maintain a web site for the book: <a href="https://www.economics.utoronto.ca/osborne/cgt/">https://www.economics.utoronto.ca/osborne/cgt/</a> .
6	Zermelo did not define the algorithm discussed in the second paragraph; the references to him should be deleted.
7, -13	Insert "nonempty" before "disjoint".
13	In the caption of Figure 13.1, replace "strategies" by "actions".
19, 2	After "density function" add: " $f$ on $[0, 1]$ with $f(x) > 0$ for all $x \in [0, 1]$ "
23, 11	Replace " $A_2$ " with " $A_1$ ".
23, 14	Replace the sentence "Note that ..." with "Note that by part (c), the players' Nash equilibrium strategies may be found by solving the problems $\max_x \min_y u_1(x, y)$ and $\max_y \min_x u_2(x, y)$ ."
30	Add, at the start of line 5, "The result in Exercise 20.4 is due to Nash (1951)."

- 32 Replace the first two sentences of the paragraph above (32.2) with: “Note that each function  $U_i$  is multilinear. That is, for any mixed strategy profile  $\alpha$ , any mixed strategies  $\beta_i$  and  $\gamma_i$  of player  $i$ , and any number  $\lambda \in [0, 1]$ , we have  $U_i(\alpha_{-i}, \lambda\beta_i + (1-\lambda)\gamma_i) = \lambda U_i(\alpha_{-i}, \beta_i) + (1-\lambda)U_i(\alpha_{-i}, \gamma_i)$ .”
- 35 In the fourth line of the caption of Figure 35.1 replace “indicated” with “indicate”.
- 36 The argument suggested for Exercise 36.3 is correct, but there is a simpler argument. Delete the paragraph preceding the exercise and replace the exercise with the following.  
“Show the following mathematical result, which we use in Exercise 64.2. For any two compact convex subsets  $X$  and  $Y$  of  $\mathbb{R}^k$  there exist  $x^* \in X$  and  $y^* \in Y$  such that  $x^* \cdot y \leq x^* \cdot y^* \leq x \cdot y^*$  for all  $x \in X$  and  $y \in Y$ . (You can prove this result either by appealing to the existence of a Nash equilibrium in a strategic game (Proposition 20.3), or by the following elementary argument (which avoids the implicit use of Kakutani’s fixed point theorem). Let  $(x^k)$  and  $(y^k)$  be sequences dense in  $X$  and  $Y$  respectively, and for each positive integer  $n$  consider the strictly competitive game in which each player has  $n$  actions and the payoff function of player 1 is given by  $u_1(i, j) = x^i \cdot y^j$ ; use Propositions 33.1 and 22.2.)”
- 40, 6 Replace  $((\frac{1}{3}, \frac{2}{3}), (\frac{2}{3}, \frac{1}{3}))$  with  $((\frac{2}{3}, \frac{1}{3}), (\frac{1}{3}, \frac{2}{3}))$ .
- 42 In line 3 of Exercise 42.1 replace “distribution” with “distributed”.
- 42, -4 The  $\epsilon_1(x, b_2)$  near the end of the line should be  $\epsilon_2(x, b_2)$ .
- 45, 7 Replace “he” with “she”.
- 50, -2 Replace “ $0 \leq \gamma \leq 1$ ” with “ $0 < \gamma \leq 1$ ”.
- 55, -10 Replace “ $\mu_3^2(A)$ ” with “ $\mu_3^2(B)$ ”.
- 56, -9 Replace “the following exercises” with “Exercises 56.4 and 56.5”.
- 60, 22 Replace “player 1” with “player  $i$ ”.
- 60, 23 Replace “ $U_i(a_{-i}, a_i^*)$ ” with “ $u_i(a_{-i}, a_i^*)$ ”.
- 62, 2 Delete second “that”.
- 64, -9 Replace the third sentence of the Notes with the following. “Versions of the procedure of iterated elimination of dominated strategies were first studied in detail by Gale (1953) and Luce and Raiffa (1957, pp. 108–109, 173); the formulation that we give is due to Moulin (1979).”
- 68, -2 Add “infinite” before “decimal”. (A number has a unique infinite decimal expansion.)
- 90, -20 Replace “If the length of every history is finite” with “If the longest history is finite”.
- 96 The Nash equilibrium  $((2, 0), nny)$  (resulting in the division  $(0, 0)$ ) is missing in Example 96.1.
- 97 In the display in Definition 97.2 replace  $\succsim_i$  with  $\succsim_i|_h$ .

- 98 In the display in Lemma 98.2 replace  $\succsim_i$  with  $\succsim_i|_h$ .
- 99, 3 Replace “the longest” with “a longest”.
- 99, 4 Replace  $\Gamma(h^*)$  with  $\Gamma(h', h^*)$  on this line and on lines 6, 8, and 10.
- 99, 5 Replace  $s^*|_{h'}$  with  $s_i^*|_{h'}$ .
- 99, 9 Replace  $s_i^*|_{h^*}$  with  $s_i^*|_{(h', h^*)}$ .
- 100, 7–8 Delete “(a result first proved by Zermelo (1913))”.
- 100, 9 The official version of chess is not finite, because a player has the *option* of declaring a draw once a position is repeated three times. Our argument applies to the version of chess in which a draw is automatic in this case.
- 104, –9, –8 Replace “she” with “he”.
- 107 Replace the first clause of the sentence starting on line 8 with “Player  $P(C(t))$  prefers  $S(t+3)$  to  $S(t+1)$  to  $S(t+2)$  for  $t \leq T-3$ ”.
- 108 On the fifth line of Exercise 108.1 insert “strategic form of the” before “modification”.
- 108, –2 Delete “only”.
- 109, –5 Replace “equilibria” with “equilibrium”.
- 114, –2 Replace “Kuhn (1953)” with “Kuhn (1950, 1953)”.
- 115, 2 Replace “Kuhn (1953)” with “Kuhn (1950, 1953)”.
- 122 Add to A3 the requirement that the Pareto frontier of  $X$  be connected.
- 123 In the first display  $(M_i(G_i))$  replace “a SPE” with “an SPE”.
- 123 Replace the second sentence of the proof of Step 1 with “By A3 and the continuity of the preference relations, the domain of  $\phi$  is an interval and  $\phi$  is continuous, one-to-one, and decreasing.”
- 129, –6 After “histories” add “in which no agreement is reached”.
- 131, 3 Omit “the”.
- 131, 4 Change the parenthetical clause to read “(in which he makes the same proposal whenever he is the proposer, uses the same rule to accept proposals whenever he is the first responder, and uses the same rule to accept proposals whenever he is the second responder)”.
- 137 Replace the first point of the itemization in Definition 137.1 by
- $H = \{\emptyset\} \cup (\cup_{t=1}^{\infty} A^t) \cup A^{\infty}$  (where  $\emptyset$  is the initial history and  $A^{\infty}$  is the set of infinite sequences  $(a^t)_{t=1}^{\infty}$  of action profiles in  $G$ )
- and in the third point replace “the set  $A^{\infty}$  of infinite sequences  $(a^t)_{t=0}^{\infty}$  of action profiles in  $G$ ” by “ $A^{\infty}$ ”. Remove the period at the end of the display in the third point.
- 137, –5 Change the summation to  $\sum_{t=1}^{\infty} \delta^{t-1}(v_i^t - w_i^t)$ .
- 137, –3 Change the summation to  $\sum_{t=1}^{\infty} \delta^{t-1}v_i^t$ .
- 138, 1 Remove  $\lim_{T \rightarrow \infty}$ .
- 138, 1 (except printings 1–3) Change upper limit of sum from  $T$  to  $\infty$ .
- 138, 9 Replace  $t$  with  $T$  (twice).

- 143, –6 Replace “A payoff profile  $w$  in  $G$ ” with “A feasible payoff profile  $w$  of  $G$ ”.
- 143, –6 In printings 4 and later replace “A payoff profile  $w$ ” with “A feasible payoff profile  $w$  of  $G$ ”. (Note that, according to our definitions, a feasible payoff profile may not be a payoff profile.)
- 144 In Proposition 144.1, replace “an enforceable payoff profile of  $G$ ” with “an enforceable convex combination of payoff profiles of  $G$ ”. [The coefficients in the convex combination are not necessarily rational.]
- 145, 2 Replace line with: “where  $\beta_a$  for each  $a \in A$  is an integer and  $\gamma = \sum_{a \in A} \beta_a$ , and let  $(a^t)$  be the cycling”
- 145, 6 Insert “other than  $i$ ” before “deviated”.
- 145 The statement of Proposition 145.2 is correct, but is improved by changing the second sentence to read: “For all  $\varepsilon > 0$  there exists  $\underline{\delta} < 1$  such that for all  $\delta > \underline{\delta}$  there exists a payoff profile  $w'$  of  $G$  for which  $|w' - w| < \varepsilon$  and  $w'$  is a Nash equilibrium payoff profile of the  $\delta$ -discounted infinitely repeated game of  $G$ .”
- 152, 11 Change “it” to “if”.
- 156, 3 Replace the sentence starting “Consider” and the following sentence with “Consider a strategy  $\hat{s}_i$  of player  $i$  that differs from  $s_i$  only in that after the history  $(a^1, \dots, a^{t-1})$  it chooses  $a_i$ , and after any longer history  $h$  it chooses an action that, given the profile  $s_{-i}(h)$  of actions planned by the other players after the history  $h$ , yields at least  $i$ ’s minmax payoff. The outcome of  $(s_{-i}, \hat{s}_i)$  is a terminal history  $\hat{a}$  that is identical to  $a$  through period  $t - 1$ ;  $u_i(\hat{a}^t) > u_i(a^t)$  and  $u_i(\hat{a}^r) \geq u_i(a^r)$  for  $r \geq t + 1$ .”
- 156, –17 After “of the game, so that” add: “if for each player the constituent game has a Nash equilibrium in which that player’s payoff exceeds his minmax payoff then”.
- 159–160 The sketch of the proof of Proposition 160.1 is flawed. It has been replaced. (The text has been rewritten, moving the result to page 159, where it appears as Proposition 159.1.)
- 160 Replace the second sentence of the Notes with “Perfect folk theorems for the limit of means criterion were established by Aumann and Shapley and by Rubinstein in the mid 1970’s; see Aumann and Shapley (1994) and Rubinstein (1994).”
- 171, –3 Change  $\ell \leq t^*$  to  $\ell < t^*$ .
- 182, –6 Modify line to read “bility theorem (for a proof of which see, for example, Sen (1986)).)”
- 185, 5 After the colon modify the text to read: “for example, if  $\gamma = 2$ ,  $|N| = 2$ , and  $\theta_i = 1$  for both players then the associated game has also, in addition to  $(1, 1)$ , inefficient equilibria (e.g.  $(0, 0)$ )”.
- 185, 13 The 1 should be 0.

- 189 The second sentence of the second paragraph is correct, but may be misleading. Replace it with the following. “If there are at least three alternatives and  $\mathcal{P}$  is the set of all preference profiles then *no* monotonic choice *function* has no veto power.”
- 200, –17 Delete “by a player”.
- 200, –11 Replace “after the history  $h$ ” with “after the history  $h$  if  $P(h) \in N$  and chance if  $P(h) = c$ .”
- 201 Replace the paragraph starting on line –2 with: “Note that Definition 200.1 extends our definition of an extensive game with perfect information and chance moves (see Section 6.3.1) in the sense that the extensive game with perfect information and chance moves  $\langle N, H, P, f_c, (\succsim_i)_{i \in N} \rangle$  may naturally be identified with the extensive game  $\langle N, H, P, f_c, (\mathcal{I}_i)_{i \in N}, (\succsim_i)_{i \in N} \rangle$  in which every member of the information partition of every player is a singleton.”
- 207, –1 Replace  $A(h)$  with  $A(I_i)$ . ( $A(h)$  is not incorrect, but may be confusing.)
- 208, 1 Replace through the period with: “suppose that  $\{(h', a): h' \in I_i\}$  is an information set of player  $i$ .”
- 209, 2 After “recall” add “in which no information set contains both a history  $h$  and a subhistory of  $h$ ”.
- 209, –7 Replace  $\ell$  with  $r$ .
- 212 In Figure 212.1 replace –2, 2 with 2, –2 at the right-hand side of the top and middle games and replace –1, 1 with 1, –1 in the bottom game.
- 215, 5 Replace “the sets of actions” with “the sequences of actions”.
- 216, –6 Replace the mathematical expression with  $p^2 \cdot 0 + p \cdot (1 - p) \cdot 1 + (1 - p) \cdot 0 = p(1 - p)$ .
- 217, –2 Replace “Kuhn (1953)” with “Kuhn (1950, 1953)”.
- 218, 3 Replace “Kuhn (1953)” with “Kuhn (1950, 1953)”.
- 221, –2  $L$  at the end of the line should be  $R$ .
- 226, 1 Replace from the start of the line to the end of the sentence with “equilibrium since the associated assessment violates sequential rationality at player 2’s (singleton) information set.”
- 226, 5 Replace  $\beta_2^\varepsilon(C)(c) = 1 - 2\varepsilon$  with  $\beta_2^\varepsilon(C)(d) = 2\varepsilon/(1 - \varepsilon)$ .
- 229 In the fifth line of Exercise 229.1, replace “two” with “three”.
- 229 In the sixth line of Exercise 229.1, replace “ $S$ ” with “ $s$ ”.
- 236, 7 Replace the sentence starting “The following example ...” with: “The following example shows, however, that there are games in which no perfect Bayesian equilibrium satisfies the requirement: in all perfect Bayesian equilibria of the game we describe, a player who at some point assigns probability zero to some history later assigns positive probability to this history.”

- 236, -8 Replace line with “player 2 chooses  $X$  with probability at least  $\frac{4}{5}$  at his information set  $I^2$  (otherwise”
- 237 After “0.” on line 9 of Exercise 237.1, add “Take the set of possible offers to be finite, including 2 and 5.”
- 238, -12 Replace “Thus” at the end of the line and the following two lines with “Since  $\theta_1^H > \theta_1^L$ , a separating equilibrium always exists; the messages  $e^L = 0$  and”
- 241, -8 Delete “if”.
- 244, -9 Replace “one unit” with “two units”.
- 244, -8 Replace “two units” with “one unit”.
- 244, -7 Replace “type” with “breakfast”.
- 245 Replace the payoffs at the top of Figure 245.1 with  $(2, 1)$ ,  $(0, 0)$ ,  $(3, 0)$  [unchanged],  $(1, 1)$  and replace those at the bottom with  $(3, 1)$  [unchanged],  $(1, 0)$ ,  $(2, 0)$ ,  $(0, 1)$ .
- 245, -14 Replace “she obtains 1” with “she obtains 2”.
- 252 At the end of Example 252.1 the perturbed strategy of player 3 should be  $\sigma_3^\varepsilon(R) = \sigma_3(R)$  if  $\sigma_3(R) < 1$ , and  $\sigma_3^\varepsilon(R) = 1 - \varepsilon$  if  $\sigma_3(R) = 1$ .
- 260 After “for all coalitions  $S$  and  $T$ ” on the last line add “, where  $v(\emptyset) = 0$ ”.
- 261 In Exercise 261.1b, insert “nonnegative” before “feasible payoff profiles”.
- 263 On line 12, insert “for all  $S \in \mathcal{C}$ ” before “by the left-hand inequality”, and replace the last sentence of this paragraph with “Thus  $x(N) = v(N)$ , so that the payoff profile  $x$  is in the core.”
- 269, -13 After “we have” add: “ $p^*x_i^* \leq p^*\omega_i$  and”.
- 270, 4 Replace the sentence starting “A standard result” with “A standard result in economic theory is that an exchange economy in which every agent’s preference relation is increasing has a competitive equilibrium (see, for example, Arrow and Hahn (1971, Theorem 5 on p. 119)<sup>1</sup>).” and replace the last sentence of the footnote with “Note that every agent is resource related (in the sense of Arrow and Hahn) to every other agent if every agent’s preference relation is increasing.”
- 274 Add, between lines 7 and 8, the following paragraph. “Now, for every agent  $i$  we have  $x_i - \omega_i + \varepsilon \in Q$  for every  $\varepsilon > 0$ , so that  $p(x_i - \omega_i + \varepsilon) \geq 0$ . Taking  $\varepsilon$  small, we conclude that  $px_i \geq p\omega_i$  for all  $i$ . But  $x$  is an allocation, so  $px_i = p\omega_i$  for all  $i$ .”
- 274, -4 Replace “Shubik (1969)” with “Shubik (1969a)”.
- 275, 13 Replace “from Moulin (1986, p. 237)” with “from Shapley and Shubik (1969b)”.
- 281, -2 Replace “member” with “members”.
- 287, 7 Replace  $\geq$  at end of line with  $\leq$ .

- 289      Replace the last sentence with the following two sentences. “Consider a zerosum homogeneous weighted majority game  $\langle N, v \rangle$  in which  $w_i = 0$  for every player  $i$  who does not belong to any minimal winning coalition. Show that the nucleolus of  $\langle N, v \rangle$  consists of the imputation  $x$  defined by  $x_i = w_i/w(N)$  for all  $i \in N$ .”
- 296, 5    After “active players” add “, initially  $N$ ,”.
- 305, –4   Replace  $F(X, D, \succsim_1, \succsim_2)$  with  $F(X, D, \succsim_2, \succsim_1)$ .
- 307, 7–8   Replace  $\succsim'_1, \succsim_2$  with  $\succsim'_i, \succsim_j$  (twice).
- 307, 15   Replace  $p \cdot x \succsim_j x^*$  with  $p \cdot x \succ_j x^*$ .
- 312      Delete the suggested steps in Exercise 312.2. (The problem is easier to solve without the steps.)
- 327      Replace “Recherche” with “Recherche” on line –10.
- 335, 3    Replace “[85]” with “[84]”.
- 336, 3    Replace “[115]” with “[114]”.
- 337, 16   Replace “Shapley, L. S., and M. Shubik (1969)” with “Shapley, L. S., and M. Shubik (1969a)”.
- 339      Delete reference to Zermelo (1913).
- 344      Entry for “Dominant action” should be Exercise 18.3.

## Additional References

The modifications on pages 114, 115, 217, and 218 require the following additional reference.

Kuhn, H. W. (1950), “Extensive Games”, *Proceedings of the National Academy of Sciences of the United States of America* **36**, 570–576. [114, 115, 217, 218]

The modifications on pages 64 and 275 require the following additional references.

Gale, D. (1953), “A Theory of  $N$ -Person Games with Perfect Information”, *Proceedings of the National Academy of Sciences of the United States of America* **39**, 496–501. [64]

Shapley, L. S., and M. Shubik (1969b), “On the Core of an Economic System with Externalities”, *American Economic Review* **59**, 678–684. [275]

## Updates

Abreu, Dutta, and Smith (1993) is now

- Abreu, D., P. K. Dutta, and L. Smith (1994), “The Folk Theorem for Repeated Games: A NEU Condition”, *Econometrica* **62**, 939–948.
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- Aumann, R. J., and A. Brandenburger (1995), “Epistemic Conditions for Nash Equilibrium”, *Econometrica* **63**, 1161–1180.
- Aumann and Shapley (1976) is now
- Aumann, R. J., and L. S. Shapley (1994), “Long-Term Competition—A Game-Theoretic Analysis”, pp. 1–15 in *Essays in Game Theory* (N. Megiddo, ed.), New York: Springer-Verlag.
- Battigalli (1993) is now
- Battigalli, P. (1996), “Strategic Independence and Perfect Bayesian Equilibria”, *Journal of Economic Theory*, **70**, 201–234.
- Brams and Taylor (1992) is now
- Brams, S. J., and A. D. Taylor (1994), “Divide the Dollar: Three Solutions and Extensions”, *Theory and Decision* **37**, 211–231.
- Elmes and Reny (1992) is now
- Elmes, S. and P. J. Reny (1994), “On the Strategic Equivalence of Extensive Form Games”, *Journal of Economic Theory* **62**, 1–23.
- Geanakoplos (1993) is now
- Geanakoplos, J. (1994), “Common Knowledge”, pp. 1437–1496 in *Handbook of Game Theory*, Vol. 2 (R. J. Aumann and S. Hart, eds.), Amsterdam: North-Holland.
- Glazer and Perry (1992) is now
- Glazer, J. and M. Perry (1996), “Virtual Implementation in Backwards Induction”, *Games and Economic Behavior* **15**, 27–32.
- Hart and Mas-Colell (1992) is now
- Hart, S. and A. Mas-Colell (1996), “Bargaining and Value”, *Econometrica* **64**, 357–380.
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- Hendon, E., H. J. Jacobsen, and B. Sloth (1996), “The One-Shot-Deviation Principle for Sequential Rationality” *Games and Economic Behavior* **12**, 274–282.
- Kohlberg and Reny (1993) is now
- Kohlberg, E., and P. J. Reny (1997), “Independence on Relative Probability Spaces and Consistent Assessments in Game Trees”, *Journal of Economic Theory* **75**, 280–313.
- Krishna and Serrano (1993) is now
- Krishna, V. and R. Serrano (1995), “Perfect Equilibria of a Model of N-Person Noncooperative Bargaining”, *International Journal of Game Theory* **24**, 259–272.
- Mertens (1992) is now
- Mertens, J.-F. (1995), “Two Examples of Strategic Equilibrium”, *Games and Economic Behavior* **8**, 378–388.
- Rubinstein (1977) is now
- Rubinstein, A. (1994), “Equilibrium in Supergames”, pp. 17–27 in *Essays in Game Theory* (N. Megiddo, ed.), New York: Springer-Verlag.
- Rubinstein (1992) is now
- Rubinstein, A. (1995), “On the interpretation of two theoretical models of bargaining”, pp. 120–130 in *Barriers to Conflict Resolution* (K. J. Arrow, R. H. Mnookin, L. Ross, A. Tversky, and R. B. Wilson, eds.), New York: Norton.
- Rubinstein and Wolinsky (1990) is now
- Rubinstein, A. and A. Wolinsky (1994), “Rationalizable Conjectural Equilibrium: Between Nash and Rationalizability”, *Games and Economic Behavior* **6**, 299–311.
- Shaked (1987) is now
- Shaked, A. (1994), “Opting Out: Bazaars versus ‘Hi Tech’ Markets”, *Investigaciones Económicas* **18**, 421–432.
- Thompson (1952) is reprinted in *Classics in Game Theory* (H. W. Kuhn, ed.), Princeton University Press, 1997, pp. 36–45.