COORDINATION

- Creation of economic surplus and efficient functioning of the society also involves coordination of involved parties.
- Here are some fundamental examples:
  - Use of clock time to coordinate schedules, meetings, events, etc.
  - Traffic rules (such as which side of the road to drive on) to streamline traffic and organize it in a cost-efficient way.
  - Use of common language in communication.
- Unlike in cooperation games, in coordination games the interests of the players are not torn between socially optimal and privately optimal actions. Rather, they are interested in taking the same action (coming to a meeting at the same time, driving on the same side of the road, speaking the same language). The issue is which action to coordinate on.
  - Example: meeting in New York City at noon. Where?
- Sometimes, though, there may be a conflict between the involved parties since coordination on one action may be better for one subset of them, whereas coordination on another action may be better for another subset of them.
- Consider the following three examples of a 2×2 coordination games:
  - **Traffic Game** (coordination game *without a payoff-dominant equilibrium*)

Driver 1\Driver 2	Drive on the left	Drive on the right
Drive on the left	$(1,1)$	$(-1,-1)$
Drive on the right	$(-1,-1)$	$(1,1)$

    This game has two pure strategy Nash equilibria and one mixed-strategy Nash equilibrium. Examples of applicability:
    * Choice of NEW technological standards.
  - **Minimum Effort Game** (coordination game *with payoff-ranked equilibria*): there are n players, each expending an effort level of $e_i \in [0, \overline{e}]$. The payoffs are given by
    $$\pi(e_i, e_{-i}) = a \min\{e_i, e_{-i}\} - ce_i + b$$
    with $a > c > 0$. In this game, any common effort level $e_i = e \in [0, \overline{e}]$ for all i is a Nash equilibrium. The higher the e is, the higher the payoffs are. Here a is the return to coordination, c is the private cost of effort and b is some base level of payoff. Examples of applicability:
    * A production process with Leontieff technology (it takes exactly one of each kind of component produced by different people/production units to assemble the final product). This technology is extremely sensitive to bottlenecks.
    * **Animal spirits** in macroeconomics (due to Keynes): reinterpret effort as investment. It only pays off to invest if others do so as well. Otherwise there will be insufficient demand in the future and the private investment will not pay off (although the Minimum Effort Game is quite an extreme representation of this phenomenon).

– **Battle of the Sexes** (coordination game with *payoff conflict*)

Man\Woman	Football	Opera
Football	$(2,1)$	$(0,0)$
Opera	$(0,0)$	$(1,2)$

This game has two pure strategy Nash equilibria and one mixed-strategy Nash equilibrium. Examples of applicability:

* Which language should be the international language?
* Whose technical standards (e.g. measures and weights) should be applied internationally?

Van Huyck, Battalio and Beil (1990)

- The authors experimentally implement the **Minimum Effort Game** with $e_i \in \{1,2,3,4,5,6,7\}$ in two versions (payoffs in \$):

  – Version A: $a = 0.2, c = 0.1, b = 0.6$ (rounds 1-10, 16-20, the latter labeled as A')

  – Version B: $a = 0.1, c = 0, b = 0.6$ (rounds 11-15)

- There were 14 to 16 players in each game. Groups are fixed and minimum effort choices are announced at the end of each round.

- Note that in A, choosing a high effort level may be motivated by coordination on a *payoff-dominant equilibrium*. On the other hand, however, putting up high effort is also risky, and hence supplying the lowest possible effort is *risk-dominant*. To illustrate, supplying $e_i = 1$ leads to a payoff of $a - c + b$ for sure. Supplying $e_i = 7$ leads to a payoff of $a \min\{e_{-i}\} - 7c + b$. If the expected value of $\min\{e_{-i}\}$ is high enough, then supplying $e_i = 7$ may lead to a higher expected payoff, but at the cost of this payoff being risky. Also note that if there is a fraction of players who choose their effort level according to some exogenously given distribution, as represented by their e_j's being i.i.d. draws from this distribution, then the expected value of $\min\{e_{-i}\}$ decreases with the size of the group that is trying to coordinate, and hence even the players who would otherwise strive to coordinate give up.

- Note that since effort is costless in version B, choosing $e_i = 7$ is a weakly dominant strategy for each player, eliminating the coordination problem.

- The standard theory ignores risk dominance and only pays attention to payoff dominance. According to this criterion, among all 7 possible Nash equilibria, it predicts that the payoff-dominant one will prevail with every player choosing $e_i = 7$.

- Here are the results:

- We observe that:

  1. In Treatment A, there is a lot of coordination failure and it gets worse over time, with play tending toward the "security equilibrium" of minimum effort. Hence playing the payoff-dominant action seems too "risky" to many subjects and they often fly to "security."
  2. In Treatment B, in most experiments there is a coordination on the payoff-dominant equilibrium.

TABLE 2—EXPERIMENTAL RESULTS FOR TREATMENT *A*

	Period									
	1	2	3	4	5	6	7	8	9	10
Experiment 1										
No. of 7's	8	1	1	0	0	0	0	0	0	1
No. of 6's	3	2	1	0	0	0	0	0	0	0
No. of 5's	2	3	2	1	0	0	1	0	0	0
No. of 4's	1	6	5	4	1	1	1	0	0	0
No. of 3's	1	2	5	5	4	1	1	1	0	1
No. of 2's	1	2	2	4	8	7	8	6	4	1
No. of 1's	0	0	0	2	3	7	5	9	12	13
Minimum	2	2	2	1	1	1	1	1	1	1
Experiment 2										
No. of 7's	4	0	1	0	0	0	0	0	0	1
No. of 6's	1	0	1	0	0	1	0	0	0	0
No. of 5's	3	3	2	1	0	0	1	1	0	1
No. of 4's	4	6	2	3	3	0	0	0	0	0
No. of 3's	1	4	2	5	0	1	1	0	1	0
No. of 2's	3	2	6	5	5	9	3	4	3	1
No. of 1's	0	1	2	2	8	5	11	11	12	13
Minimum	2	1	1	1	1	1	1	1	1	1
Experiment 3										
No. of 7's	4	4	1	0	1	1	1	0	0	2
No. of 6's	2	0	2	0	0	0	0	0	0	0
No. of 5's	5	6	1	1	1	0	0	0	0	0
No. of 4's	3	3	2	1	2	1	0	0	0	1
No. of 3's	0	0	7	6	0	2	3	0	0	0
No. of 2's	0	1	1	4	5	3	6	3	2	2
No. of 1's	0	0	0	2	5	7	4	11	12	9
Minimum	4	2	2	1	1	1	1	1	1	1
Experiment 4										
No. of 7's	6	0	1	1	0	0	1	0	0	0
No. of 6's	0	6	2	0	0	1	0	0	0	0
No. of 5's	8	5	5	5	0	1	0	0	0	0
No. of 4's	1	1	4	6	7	1	2	1	1	0
No. of 3's	0	2	3	2	4	3	2	2	1	0
No. of 2's	0	1	0	0	2	3	7	4	2	2
No. of 1's	0	0	0	1	2	6	3	8	11	13
Minimum	4	2	3	1	1	1	1	1	1	1

3. But this does not induce coordination in the subsequent Treatment A', in which subjects again coordinate on the security equilibrium.

- In some experiments the authors also add Version C with only two players matched in fixed pairs for 5 rounds or randomly rematched into pairs for 5 rounds.
  - With fixed pairs, most pairs coordinate on the payoff-dominant equilibrium. This suggests that ability to coordinate is quite sensitive to group size as suggested above: the larger the group, the harder it gets to coordinate.
  - With rematched pairs, there is no longer coordination on the payoff-dominant equilibrium. Most effort choices are in the middle of the range.

TABLE 3—EXPERIMENTAL RESULTS FOR TREATMENT *B* AND TREATMENT *A′*

	Treatment *B*					Treatment *A′*				
	11	12	13	14	15	16	17	18	19	20
Experiment 2										
No. of 7's	13	15	16	16	16	8	2	0	0	0
No. of 6's	1	0	0	0	0	0	0	0	0	0
No. of 5's	0	1	0	0	0	1	0	0	0	0
No. of 4's	1	0	0	0	0	1	2	0	0	0
No. of 3's	1	0	0	0	0	1	1	1	1	0
No. of 2's	0	0	0	0	0	3	3	4	2	0
No. of 1's	0	0	0	0	0	2	8	11	13	16
Minimum	3	5	7*	7*	7*	1	1	1	1	1*
Experiment 3										
No. of 7's	13	13	12	13	14	6	2	2	1	1
No. of 6's	0	0	1	1	0	1	0	0	0	0
No. of 5's	0	0	1	0	0	0	2	1	0	0
No. of 4's	1	0	0	0	0	1	0	0	0	1
No. of 3's	0	1	0	0	0	0	0	0	0	0
No. of 2's	0	0	0	0	0	2	4	2	3	0
No. of 1's	0	0	0	0	0	4	6	9	10	12
Minimum	4	3	5	6	7*	1	1	1	1	1
Experiment 4										
No. of 7's	12	13	14	14	15	3	1	0	0	0
No. of 6's	0	0	0	0	0	0	0	0	0	0
No. of 5's	1	0	0	1	0	0	0	0	0	0
No. of 4's	0	1	1	0	0	2	0	0	0	0
No. of 3's	0	1	0	0	0	2	0	0	0	0
No. of 2's	0	0	0	0	0	2	1	2	0	0
No. of 1's	2	0	0	0	0	6	13	13	15	15
Minimum	1	3	4	5	7*	1	1	1	1*	1*
Experiment 5										
No. of 7's	13	13	15	15	15	1	0	0	0	0
No. of 6's	0	0	0	0	0	0	0	0	0	0
No. of 5's	1	1	0	0	0	0	0	0	0	0
No. of 4's	1	1	0	0	0	0	0	0	0	0
No. of 3's	0	0	0	0	0	1	1	0	0	0
No. of 2's	0	0	0	0	0	3	4	2	2	3
No. of 1's	1	1	1	1	1	11	11	14	14	13
Minimum	1	1	1	1	1	1	1	1	1	1
Experiment 6										
No. of 7's	13	13	12	12	13	2	2	2	2	2
No. of 6's	0	1	1	1	0	0	0	0	0	0
No. of 5's	0	1	1	0	1	0	0	0	0	0
No. of 4's	1	0	1	1	0	1	0	0	0	0
No. of 3's	0	1	0	1	0	1	0	0	0	0
No. of 2's	1	0	0	0	1	5	6	7	6	5
No. of 1's	1	0	1	1	1	7	8	7	8	9
Minimum	1	3	1	1	1	1	1	1	1	1
Experiment 7										
No. of 7's	12	14	13	13	14	3	4	2	2	2
No. of 6's	0	0	1	0	0	0	0	0	0	0
No. of 5's	0	0	0	0	0	1	0	0	0	0
No. of 4's	1	0	0	0	0	2	0	0	0	0
No. of 3's	0	0	0	1	0	2	0	0	0	0
No. of 2's	0	0	0	0	0	2	4	2	2	1
No. of 1's	1	0	0	0	0	4	6	10	10	11
Minimum	1	7*	6	3	7*	1	1	1	1	1

* – Denotes a mutual best-response outcome.

Goeree and Holt (2005)

- The authors investigate the sensitivity of coordination to such changes in the effort cost parameter c that do not change the set of equilibria or their Pareto ranking. In this game, $a = 1$, $b = 0$ and $e_i \in [110, 170]$. There is a low-cost treatment with $c = 1/4$ and the high-cost treatment with $c = 3/4$.
- Each session utilizes 10 subjects and they play for 10 periods with random rematching.
- Result:

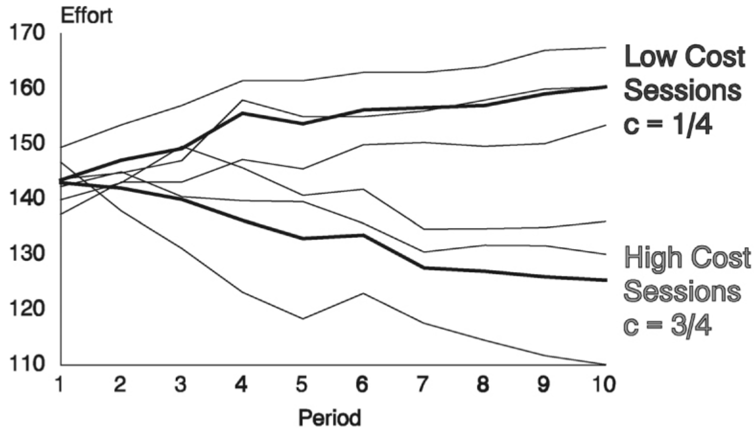

Fig. 1. A coordination game: average effort decisions by period. *Key*: Fine lines are session averages. are averages across all sessions in a treatment.

- Clearly, the higher the cost of effort is, the less effort there is, even though the set of Nash equilibria is unchanged.

Guide to Further Reading

- **Cooper, DeJong, Forsythe and Ross (1990)** wonder whether, in multiple-Pareto-ranked-equilibira coordination games subjects end up playing a Nash equilibrium and whether they end up picking the Pareto-dominant one. They find that Nash equilibrium predicts behavior quite accurately, but coordination on the Pareto-dominant equilibrium is far from being prevalent. They argue that this may be due to the presence of cooperative, but dominated strategies.
- **Van Huyck, Battalio and Beil (1991)** analyze equilibrium selection when systematically varying the presence of payoff-dominance and security in average opinion games. Equilibrium selection does respond to these treatments as expected. If both payoff-dominance and security concerns are present, history (median effort at the beginning of play) play the role of equilibrium selection devices.
- **Van Huyck, Battalio and Beil (1993)** think in a direction of forward induction. They show that if subjects buy the right to participate in an asset market, they end up coordinating on a payoff-sominant equilibrium. On the other hand, if they are endowed with the participation right, they do not coordinate on the payoff-sominant equilibrium.
- **Schotter and Sopher (2003)** investigate creation and evolution of conventions of behavior in intergenerational games. In this game, a sequence of non-overlapping generations of players play a stage game of Battle of Sexes (coordination with payoff conflict) for a finite number of periods and are then replaced by other agents who

continue the game in their role for an identical length of time. Players in generation t can offer advice to their successors in generation $t+1$, and the payoff of the former positively depends on the payoff of the latter. The authors find that word-of-mouth social learning (from “parents” to “children”), as opposed to simple observation of history, can be a strong force in the creation of social conventions (coordination on a particular equilibrium in battle of Sexes).

- **Weber (2006)** wonders how it is possible that large groups seem to have a trouble coordinating in the lab (see, for example, Van Huyck at al., 1990), yet large organizations seem to exist and coordinate themselves efficiently in the real world. The author presents experiments that show that, even though efficient coordination does not occur in groups that start off large, efficiently coordinated large groups can be “grown.” By starting with small groups that find it easier to coordinate, one can add entrants—who are aware of the group's history—to create efficiently coordinated large groups.

- **Cooper, DeJong, Forsythe and Ross (1989, 1992)** experimentally analyze the effect of pre-play communication in coordination games. They consider three types of games: a symmetric Battle of the Sexes game, Stag Hunt Game and a Stag Hunt game with an additional cooperative, but dominated, strategy. They also condiser three different types of communication: one-way, one-round; two-way, one-round; two-way, three rounds. In the Battle of the Sexes game, one-way communication is most effective in resolving the coordination problem, followed by two-way repeated communication. Two-way communication with one round helps somewhat, but comparatively less than the other ways of communication. In the Stag Hunt game, two-way coordination increases the play of the Pareto dominant equilibrium, whereas one-way communication does not. In the Stag Hunt game with a cooperative strategy, one-way communication increases the incidence of Pareto-dominant equilibrium play, whereas two-way communicaiton does not.

- **Blume and Ortmann (2007)** show that costless pre-play communication in order-statistic games facilitates coordination on the payoff-dominant equilibrium.

- **Riedl, Rohde and Strobel (2011a, 2011b)** analyze how coordination on the payoff-dominant equilibrium in the Weakest Link and Stag Hunt games is affected by endogenous selection of fellow players (“neighbors”). In the Stag Hunt game, one has to take the same action against all the opponents. In both games, action needs to be taken before the structure of the network is observed. They consider either one-way or two-way proposal versions of link formation. Previous actions of all the other players are observed. Ability to choose/exclude neighbors results in a very significant increase in the incidence of Pareto dominant equilibrium.