Journal of Mathematical Sociology, 35:1–25, 2011

ISSN: 0022-250X print/1545-5874 online
DOI: 10.1080/0022250X.2010.532263

Introduction

Micro-Macro Links and Microfoundations in Sociology

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Using Coleman's well-known scheme as an anchor, we review key features of explanations of social phenomena that employ micro-macro models. Some antecedents of micro-macro models and of Coleman's scheme as well as some paradigmatic examples of micro-macro links are sketched. We then discuss micro-level assumptions in micro-macro explanations and the robustness of macro-level implications to variations in micro-level assumptions. We conclude with an overview of some recent developments in micro-macro modeling and of the contributions to the special issue.

Keywords: agent-based modeling, analytical sociology, microfoundations, micro-macro link, rational choice, simulation

We acknowledge financial support for Raub by the Netherlands Organization for Scientific Research (NWO) under grant 400-09-159 for the project "The Feasibility of Cooperation under Various Sanctioning Institutions" and for Buskens by Utrecht University for the High Potential-program "Dynamics of Cooperation, Networks, and Institutions."

We are grateful to the contributors for their cooperation in making this special issue possible, including their patience in revising articles and timely submission of revisions. Also, we would like to acknowledge the help of quite some anonymous referees and the support of Phil Bonacich, the *JMS* editor.

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1. INTRODUCTION

Establishing micro-macro links to explain social macro-level phenomena as a result of the behavior of individual actors is a core aim of model building in sociology. Schelling's models of segregation, published in the very first volume of *The Journal of Mathematical Sociology* (*JMS*; Schelling, 1971, see also his *Micromotives and Macrobehavior,* 1978, that has become a "modern classic"), have become a paradigm for micro-macro links (see also Sakoda's closely related model in the same 1971 *JMS* volume). Schelling's models show that the macro-level phenomenon "extreme residential segregation by ethnicity" can emerge when individuals living in integrated neighborhoods are satisfied if at least 50% of their neighbors are of their own ethnicity but move if they are part of the minority. Many subsequent contributions in *JMS* have been implicitly or explicitly concerned with micro-macro issues as well. Examples include Coleman's (1972) model of social exchange and work on opinion dynamics such as Friedkin and Johnsen (1990).

In this introductory chapter to the *JMS* special issue on micro-macro links and the dependence of macro-level outcomes on micro-level assumptions, we start by reviewing key features of explanations of social phenomena that employ micro-macro links. We refer to such explanations as micro-macro explanations or micro-macro models. We organize our discussion around Coleman's well-known scheme, which is the standard tool for representing micro-macro models. Next, we highlight some antecedents of micro-macro modeling in sociology and of Coleman's scheme. A sketch of some paradigmatic examples of micro-macro links follows. We then turn to micro-level assumptions, focusing on a major issue, namely, the robustness of macro-level implications to variations in micro-level assumptions. We conclude with an overview of some recent developments in micro-macro modeling and of the contributions to the special issue.

2. MICRO-MACRO LINKS: COLEMAN'S SCHEME

Much formal modeling of micro-macro links in sociology has roots in a family of research programs that conceive of sociology as a problem- and theory-guided discipline, with theory construction aiming at the explanation of social phenomena (see Section 3). Explanations involve deductive arguments or variants of such arguments. Thus, theory construction involves more than specifying sets of hypotheses. Theory construction also comprises specifying assumptions, including but not restricted to hypotheses, as well as specifying implications of these assumptions. Due to the focus on implications, analytical rigor is an ingredient of these programs. Implications should include testable implications: empirical content in the sense of testability (at least "in principle") is a criterion for appraising sociological theories. Likewise, empirical tests of implications are a core aim and empirical corroboration is a criterion for appraising theories in addition to testability. Thus, the integration of theory construction and empirical research becomes an aim, too.

Coleman (1987a, 1990) provided a stylized scheme that has become a standard way of representing micro-macro links. In his scheme, depicted in Figure 1, nodes A and D represent propositions describing macro-conditions and macro-outcomes, respectively. Arrow 4 represents propositions about an empirical regularity at the macro-level, for example, an association between macro-conditions and macro-outcomes. The macro-outcomes D and the empirical regularity 4 represent explananda. Node B represents (descriptions of) micro-conditions, that is, independent variables in assumptions about regularities of individual behavior or, more ambitiously, in a theory of individual behavior. Arrow 1 represents assumptions on how social conditions affect these variables. For example, social conditions such as networks and institutions as well as prices can be conceived as opportunities or, conversely, constraints that affect the feasible alternatives between which actors can choose. Social conditions likewise shape the incentives associated with various feasible alternatives and shape actors' information. Various labels have been suggested for such assumptions on macro-to-micro relations. Here, we follow Lindenberg (1981; Wippler and Lindenberg, 1987) and label them "bridge assumptions." Node C represents micro-outcomes, that is, descriptions of individual behavior. Assumptions about regularities of individual behavior or a theory of individual behavior are represented by arrow 2. Thus, arrow 2 represents a micro-theory. Finally, arrow 3 represents assumptions on how actors' behavior generates macro-outcomes. Again following Lindenberg (1977; Wippler and Lindenberg,

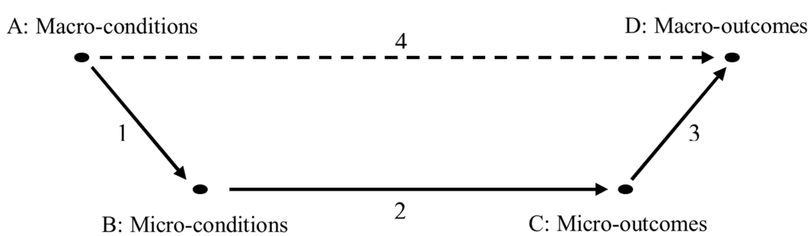

FIGURE 1 Coleman's scheme.

1987) we use "transformation rules" as a label for such assumptions on micro-to-macro relations. It is evident from the scheme that the explananda, that is, descriptions of macro-outcomes (D) or macro-regularities (4), follow from an explanans comprising assumptions on individual behavior (2), macro-conditions (A), and bridge assumptions (1) and transformation rules (3).

To make things more concrete, consider a simplified example that Coleman (1987a, pp. 160–163; 1990, pp. 203–215, pp. 912–925) uses: escape panics as a case of collective behavior. Imagine a crowded theater in which a fire alarm goes off, with limited time for the visitors to leave the theater. Node A represents a description of this situation in the theater. Node B represents assumptions on the available alternatives for those in the theater such as "dashing" versus "orderly moving to the exit" as well as assumptions on the actors' incentives for choosing one of the alternatives. Node C represents a description of the actors' actual choices between their behavioral alternatives. The macro-outcome represented by node D is then "panic" or "collective exit of the theater in an orderly fashion." Arrow 1 could then represent the bridge assumption that under the macro-conditions represented by node A the actors are involved in a situation that resembles a Prisoner's Dilemma (PD) with "dashing to the exit" as a dominant strategy for each actor. In Coleman's account, arrow 2 represents rational choice theory and more specifically the assumption of equilibrium behavior in the sense of noncooperative game theory. Thus, concerning the micro-outcomes represented by node C, the assumptions summarized so far imply that each actor will choose the dominant strategy and will dash to the exit. Arrow 3 is then conceived as a transformation rule specifying that the macro-outcome "panic" ensues from dashing behavior of the actors. Hence, our assumptions jointly imply the macro-outcome "panic" as well as a macro-level regularity that a fire alarm in a crowded theater produces a panic (see Brown, 1965, for a similar account and Helbing, Farkas, and Vicsek, 2000, for an alternative micro-macro model of escape panics).

Some additional remarks on Coleman's scheme are useful. First, note how the labels "macro" and "micro" are used. In Coleman's terminology, "macro" refers to social systems such as a family, a city, a business firm, a school, or a society (Coleman 1986a, p. 346), whereas "micro" refers to individuals.[1] Hence, in terms of the number of actors involved, "macro" may refer not only to large but also to small social systems. The system might be a network involving a sizeable number

[1]There are also well-known examples of micro-macro models with *corporate* actors (Coleman, 1990, Parts III and IV) on the micro-level.

of actors. The macro-conditions might then be network characteristics such as density and transitivity, and the macro-outcomes might be Pareto efficiency or Pareto suboptimality resulting from economic or social exchange between the actors involved in the network. Or the system might be a dyad consisting of two actors. For example, the interdependence structure of a two-person Prisoner's Dilemma is a macro-condition, and results of individual behavior in the Prisoner's Dilemma such as Pareto efficiency or Pareto suboptimality are cases of macro-outcomes.

Second, one might wish to inquire into the methodological status of the various assumptions in Coleman's scheme. In particular, what is the status of the arrows 1–4 in the scheme? A detailed discussion is beyond the scope of this introduction (see Opp's contribution in this special issue for further discussion and references), but it seems quite clear that the arrows should be conceived broadly. Arrow 4 represents assumptions about empirical regularities on the macro-level, including associations between macro-level variables, rather than general causal laws, let alone empirically corroborated causal laws. Conversely, arrow 2 represents assumptions on regularities of individual behavior and perhaps a general theory of behavior. Concerning bridge assumptions represented by arrow 1 and transformation rules represented by arrow 3, they may include empirical assumptions as well as analytical statements such as definitions.

Third, "micro-macro link" is ambiguous from the perspective of Coleman's scheme. In a narrow sense, "micro-macro link" can refer exclusively to arrow 3. In a broader sense, "micro-macro link" can refer to explaining macro-outcomes (node D) or macro-regularities (arrow 4) using assumptions on individual behavior (arrow 2), macro-conditions (node A), as well as bridge assumptions (arrow 1) and transformation rules (arrow 3). We use "micro-macro link" in this broader sense. Hence, we avoid cumbersome terminology like "macro-micro-macro link" and systematically refer to assumptions represented by arrow 3 as "transformation rules."

What are key features of explanations of macro-phenomena that employ modeling micro-macro links? Without claiming that our list is complete, we mention five features. First, Coleman's scheme clearly indicates that such explanations focus on macro-phenomena as explananda and try to highlight macro-conditions rather than exclusively micro-conditions as part of the explanation.[2]

[2]Thus, such explanations follow the minimal program of sociology that has been set forth already by Durkheim (1895/1982) in his *Rules of Sociological Method*.

Second, while aiming at the explanation of macro-outcomes or macro-regularities, the theoretical core of the explanation involves micro-level assumptions, together with bridge assumptions and transformation rules. Various arguments have been provided why using the micro-level in the explanation of macro-phenomena is preferable to an approach that tries to provide explanations exclusively in terms of macro-assumptions (see Coleman, 1990, pp. 3–5). For example, Coleman (1990, pp. 3–4) and Wippler and Lindenberg (1987, p. 138) reason that, compared to assumptions on macro-level regularities, assumptions on regularities of individual behavior are less subject to changing boundary conditions that affect whether or not these assumptions apply in a given situation: human nature is relatively stable in the sense that actors behave similarly under the same conditions, while associations between macro-conditions and macro-outcomes are less stable.

Third, explanations according to Coleman's scheme follow simple principles of model building. Model building faces the tradeoff between on the one hand simplifying assumptions that preserve tractability and analytical power allowing for the derivation of implications, including testable implications, at the cost of being less realistic and, on the other hand, more complex and realistic assumptions that make it more difficult to derive implications. Thus, it makes sense to start with a model that is as simple as possible, making simplifying assumptions explicit. Subsequently, one can introduce more complex assumptions in a stepwise fashion when simplifying assumptions turn out to be problematic because, for example, implications are highly dependent on such assumptions rather than being robust or because implications fare badly in the light of empirical evidence. This procedure is known as the method of decreasing abstraction (Lindenberg, 1992).

Consider once again Coleman's example of a fire alarm in a crowded theater. Our simple rational choice model represents the situation as a Prisoner's Dilemma and implies panic as a macro-outcome. Accounting for the observation that a panic is sometimes avoided, one can then refine the model. Coleman considers a more complex model with node A also representing assumptions on features in the theater that facilitate or hinder communication and coordination between those in the theater. Such a feature could be the presence of actors on the stage who are visible to everyone in the theater and can thus more easily coordinate collective behavior. Under such conditions, the behavioral alternatives represented by node B may not only include "dashing" versus "orderly moving to the exit" but also the option to make one's own behavior conditional on the behavior of others or, in Coleman's terminology, "transfer of control." The bridge assumptions of such a model would then specify conditions such that "transferring control" becomes a feasible and attractive strategy in addition to "dashing" and "orderly moving." The more complex model can then account for the avoidance of a panic and can also yield implications on who is more likely to dash than others. For example, the more complex model may imply that the highly visible actors are less likely to run than those less observed by others.

The principle of sufficient complexity (Lindenberg, 2001) complements the method of decreasing abstraction by requiring that even the simplest model assumptions should be complex enough such that the phenomenon to be explained can be described rather than being assumed away. In the collective behavior case, this requires among other things that the model at least includes explicit assumptions on strategic interdependency between the actors, thus implying that whether or not an actor can reach the exit depends not only on his or her own behavior but also on the behavior of other actors.

Fourth, micro-macro models typically try to employ comparatively simple micro-level assumptions while simultaneously trying to incorporate more complex assumptions on macro-conditions as well as specifying the transformation rules as carefully as possible (see Coleman, 1987b, for a succinct statement). The motivation seems to be threefold. Micro-macro models aim at explanations of macro-outcomes and at incorporating macro-conditions in the explanation rather than at explaining individual behavior as such. Hence, it seems reasonable to allow for complexity of macro-assumptions. Furthermore, since deriving macro-implications from micro-assumptions as well as bridge assumptions and transformation rules is often a nontrivial task, it seems advisable to keep the micro-assumptions simple with an eye on tractability of the model. Finally, Coleman argues that the careful specification of transformation rules is not only a core task of sociology but also that sociological explanations are often deficient precisely with respect to the transformation rules. Hence, Coleman assumes that investments in improving transformation rules will be more beneficial for theory development in sociology than improving micro-assumptions.[3] It seems straightforward to motivate careful specification of bridge-assumptions in a similar way.

[3]Note the similarity with Coleman's earlier arguments for "synthetic theories" in his *Introduction to Mathematical Sociology* (1964, p. 34ff; see also p. 516ff). In fact, synthetic theories can be conceived as transformation rules in micro-macro models: "it is characteristic of many of these theories that they begin with postulates on the individual level and end with deductions on the group level" (Coleman, 1964, p. 41).

Finally, macro-outcomes are typically the result of interdependence between actors, such as interdependencies in the game-theoretic sense that the outcomes of an actor's behavior depend not only on own choices and possibly chance events but also on the behavior of other actors. Moreover, due to interdependence, macro-outcomes are often unintended consequences of individual behavior: the very fact that outcomes depend also on the behavior of others means that the intentions an actor pursues need not coincide with the outcomes of the actor's behavior.

It should be added that Coleman's scheme provides a highly stylized and simplified representation of full-fledged micro-macro models, leaving complex issues implicit. The nodes and arrows summarize possibly numerous and rather different kinds of assumptions. Also, model building involves not only the careful specification of assumptions but crucially involves deriving implications from assumptions.

3. ANTECEDENTS OF MICRO-MACRO MODELS AND OF COLEMAN'S SCHEME

Micro-macro models have roots that can be traced back to the Scottish Moralists of the 18th century (Hume, Adam Smith, Ferguson; see Schneider, 1967). For example, the Scottish Moralists focused on explaining macro-phenomena, using assumptions on human nature and pushing the idea that macro-phenomena are often unintended results of individual behavior in situations with interdependence between actors. Smith's "invisible hand" is a well-known metaphor for unintended consequences of individual behavior in market contexts, whereas, for example, Ferguson tried to account for the emergence and dynamics of norms and institutions as an unintended result of the behavior of interdependent actors. The research program of the Scottish Moralists advocates the methodological unity of the social sciences. It is thus not surprising that core ideas of this program have been influential and that micro-macro models are used throughout the social sciences that focus on explaining macro-phenomena. Similarly, key ideas underlying micro-macro models can be identified in various strands of methodological individualism that derives from Scottish moral philosophy (see the reader O'Neill, 1973, and the overview Udehn, 2001). Research programs in economics, including neoclassical economics, but also, for example, the new institutional economics and evolutionary economics as well as applications of game theory in economics, have contributed to the development of micro-macro models and employ such models (see a microeconomics textbook such as Mas-Colell, Whinston, and Green, 1995).

Social exchange theory (Homans, 1958; Blau, 1964) is commonly (e.g., Coleman, 1986b) seen as the pioneer of micro-macro models in modern sociology, at least for small groups and teams in formal organizations. Other modern work in sociology that pioneered micro-macro models is less known, while its contributions to micro-macro models and to the understanding of micro-macro modeling are substantial. In Europe, the structural-individualistic research program, sometimes labeled "explanatory sociology," developed since roughly the 1970s. This program, pushed by authors such as Albert, Boudon, Opp, Hummell, Lindenberg, Wippler, Esser, and others, developed the methodological foundations and tools for micro-macro models in much detail, provided theoretical studies involving micro-macro modeling, and induced empirical research (Wippler, 1978, provides a succinct summary of the program; see Raub and Voss, 1981, for a more detailed overview). For example, Lindenberg (1977, 1981; Wippler and Lindenberg, 1987) and Hummell and Opp (1971; see also Opp, 1979) developed the methodological tools needed for micro-macro modeling, including the use of micro-assumptions as well as bridge assumptions and transformation rules in such models. Ziegler (1972) and Hummell (1973) clarified the use of formal modeling in establishing micro-macro links. Seminal theoretical studies and many examples of applications of the program can be found, for example, in Boudon (1974, 1977, 1979).

We conclude this brief overview of related research programs by pointing out that micro-macro models likewise resemble middle-range theories in the sense of Merton (1968). As Hedström and Udehn (2009) have shown, paradigmatic examples of middle-range theories à la Merton, such as his analyses of unanticipated consequences, self-fulfilling prophecies, and the Matthew effect, typically comprise explanations of macro-phenomena in terms of macro-to-micro links represented by bridge assumptions, micro-assumptions about behavioral regularities, and micro-to-macro links through transformation rules.

While Coleman's scheme has meanwhile become a standard way of representing micro-macro links, it is worth noting that the scheme itself has several predecessors. In fact, the scheme already appears in McClelland (1961, p. 47). Quite some time before Coleman pushed the idea, Lindenberg (1977; see also Wippler and Lindenberg, 1987) had developed a scheme for explaining macro-phenomena comprising exactly the components of Coleman's scheme, albeit organized in a somewhat different way, namely, adapting the Hempel-Oppenheim model (Hempel, 1965) of explanations (see Fig. 2). To facilitate comparison, we have indicated explicitly where the various elements

Propositions on individuals
(micro-assumptions; arrow 2)
Bridge assumptions (arrow 1)
Initial conditions
- Macro-conditions (node A)
- Micro-conditions (node B)

Individual effects
(micro-outcomes; node C)

→

Transformation rules
(arrow 3)
Additional boundary
conditions
Individual effects
(micro-outcomes; node C)

Collective effects
(macro-outcomes; node D)

FIGURE 2 Lindenberg's scheme (including references to the nodes and arrows in Coleman's scheme).

(nodes and arrows) from Coleman's scheme are located in Lindenberg's version. Note that the horizontal lines indicate that the proposition below (the explanandum) is implied by the assumptions above (the explanans). The scheme indicates that micro-macro models involve two steps. In the first step, micro-outcomes ("individual effects") are explained using a micro-theory together with initial conditions comprising assumptions on macro- as well as micro-conditions and bridge assumptions. In the second step, macro-outcomes ("collective effects") are derived from a set of assumptions that include the micro-outcomes from the first step, possibly additional boundary conditions, and the transformation rules. Hernes (1976, p. 518) and Boudon (1979, ch. 5) offer schemes representing micro-macro links in similar ways. Boudon makes it clear that to account for processes over time, one needs an extension of Coleman's scheme. More precisely, one could conceive of the macro-outcomes (node D) as the "initial" node of a further micro-macro link and so forth, leading to a sequence of "connected" schemes, similar to Figure 1, that account for the development of a social process over a number of periods 1, 2... Such an extended version of the scheme also indicates how micro-macro models can endogenize the macro-conditions of a micro-macro model.

4. SOME PARADIGMATIC EXAMPLES OF MICRO-MACRO MODELS

We now briefly highlight some paradigmatic examples of micro-macro models. The various features of micro-macro models are reflected in these examples, including the focus on explaining macro-outcomes rather than micro-outcomes, the focus on macro-conditions, the use of relatively simple micro-assumptions, careful specification of bridge assumptions and transformation rules, and the explanation of macro-outcomes as an unintended result of the behavior of interdependent actors.

4.1. The Perfect Market Model in Neoclassical Economics

While Coleman was clearly aware that sociologists typically do *not* study perfect markets, he considered the perfect market model as an exemplary case of establishing micro-macro links (Coleman, 1987a, pp. 157–158). The characteristics of a perfect market are the relevant macro-conditions. Given rational behavior of actors, unintended macro-outcomes of individual exchange behavior can be derived such as the existence of an equilibrium with a set of equilibrium prices for the goods and an equilibrium distribution of goods among actors as well as Pareto-optimality of the equilibrium. It is an exemplary case because it is nonobvious that the macro-outcomes are in fact implied by the model assumptions. The perfect market model shows that proving theorems, that is, showing that certain consequences follow from assumptions, is a core ingredient of model building.

4.2. Production of Collective Goods

Olson's (1965) theory of collective goods is an often cited example of a micro-macro model. It is a useful example in at least two respects. First, it can be used as a nontrivial example for the use of bridge assumptions in micro-macro models. After all, core assumptions of Olson's theory are on how the macro-condition "group size" affects the costs and benefits of individual contributions. Similarly, Olson's theory comprises bridge assumptions that specify how the macro-condition "existence of selective incentives" modifies these costs and benefits. Second, the theory reveals the importance of transformation rules in micro-macro models. Using a rational choice model as the micro-theory, one can derive micro-outcomes in the sense of individual contributions (or individual noncontribution) to the collective good and can study how individual contributions vary with macro-conditions such as group size and the availability of selective incentives. Subsequently, however, further assumptions are required, namely transformation rules that specify how the production of the collective good depends on individual contributions and further conditions. Depending on context and application, such transformation rules may be simple rules of aggregating the individual contributions. This may be the case, for example, in a laboratory experiment on public goods production. In other cases, however, the transformation rules can be considerably more complex. For example, "individual contribution" may mean "becoming a member of an organization (such as a trade union) that engages in producing the collective good." The transformation rule would then have to specify how collective good production depends not only on individual contributions but also on various further conditions such as whether the collective good can exclusively be provided by the organization, how the success of the organization depends on the number of members, and so forth.

4.3. Schelling's Models of Segregation

These models show how extreme residential segregation can arise as a macro-outcome from macro-conditions that include an initially integrated situation (see Schelling, 1971, 1978, ch. 4). Fascinating features of the models include that extreme segregation can arise without preferences of actors (or households as corporate actors) for living in segregated neighborhoods. "Mild" assumptions on individual preferences and behavior suffice. For a context with two groups, each comprising 50% of the population, it suffices to assume, for example, that actors are content and do not move if at least 50% of their neighbors belong to their own ethnicity. They move only if they are in the minority in their own neighborhood. If they move, they move to a nearby neighborhood that is consistent with their threshold for being content. Under this assumption actors may actually prefer to live in integrated rather than segregated neighborhoods. Also, extreme residential segregation can arise as macro-outcome without assuming macro-conditions such as discrimination on the housing market that would evidently favor segregation. Residential segregation arises in these models since actors are interdependent through the macro-condition "neighborhood composition." Thus, assuming an almost perfectly integrated situation, there are very few actors who move initially. However, these moves set a process in motion by changing the neighborhood composition in their original as well as in their new neighborhood, thus inducing moves of other actors and so forth. Hence, macro-level segregation arises as an unintended result of uncoordinated moves of actors on the micro-level and can be a result that is worse for almost every actor than an integrated situation. In terms of Coleman's scheme, the dynamic nature of Schelling's models is noteworthy: segregation develops in a number of "rounds," with moves of actors in each of those rounds. Almost perfect integration is a macro-condition (node A) in round 1 and the segregation-level that emerges as a macro-outcome (node D) through the actors' moves in a given round is a macro-condition in the next round.

4.4. Network Formation

The study of the emergence of social networks has a long tradition in *JMS* with three special issues edited by Doreian and Stokman in 1996, 2001, and 2003, and is meanwhile attracting much interest by economists (see Dutta and Jackson, 2003, and the textbook Jackson, 2008). In network formation models, networks and their characteristics are not conceived as exogenous fixed structures but rather result endogenously from the behavior of actors who establish, maintain, or delete links with others. Macro-conditions include opportunities to establish relations such as meeting places of actors. Bridge assumptions include assumptions on how networks create value for actors; for example, network positions with more structural holes may be more worthwhile than other network positions (Burt, 1992; Buskens and Van de Rijt, 2008). The assumptions at the micro-level often assume bounded rationality, namely, myopic best-response behavior, which implies that actors change relations if that is immediately beneficial, but they do not take subsequent changes of relations by other actors or by themselves into account. Macro-outcomes in such models can be, for example, (in)equality of outcomes or inefficiency and Pareto suboptimality of the emerging network (Dogan, van Assen, van de Rijt, and Buskens, 2009). Again, these are unintended consequences of interdependent action. Often, the macro-outcomes depend strongly on specifications of bridge assumptions and transformation rules. For example, the choice-set of an actor, whether actors can only change one relation at a time or more relations simultaneously, can affect macro-outcomes. Likewise, the ordering in which actors can make their choices, whether they can change relations simultaneously or only sequentially, can affect macro-outcomes.

5. MICROFOUNDATIONS

A comprehensive discussion of alternative micro-theories that are used in different micro-macro models is beyond the scope of this introduction. We rather highlight some key issues by focusing on microfoundations in another paradigmatic example of micro-macro models, namely, models of cooperation in social dilemmas (see Buskens and Raub, 2010, for an overview of research on social dilemmas; for broad overviews of alternative micro-models and micro-assumptions in various fields, see Camerer, 2003; Loewenstein, 2007; Lindenberg, 2001). While much of the discussion generalizes to other social dilemmas as well, we focus on the well-known Prisoner's Dilemma (PD) as depicted in Figure 3 and assume that the payoffs T, R, P, and S are material outcomes for the two actors such as own money or own points that

		Actor 2	
		Cooperation	Defection
Actor 1	Cooperation	*R*,*R*	*S*,*T*
	Defection	*T*,*S*	*P*,*P*

FIGURE 3 The Prisoner's Dilemma ($T > R > P > S$).

will be converted into money at the end of an experiment. In terms of Coleman's scheme, important macro-conditions are, for instance, that the actors cannot enter binding agreements and commitments, and that it is a one-shot rather than a repeated game.

Rational choice theory and more precisely game theory (see Rasmusen, 2007, for a textbook) can be used as a microfoundation for studying social dilemmas such as the PD. Rational choice theory and game theory can be seen as specifications of the idea of incentive-driven and goal-directed behavior. In terms of Coleman's scheme, arrow 2 then represents the assumption of equilibrium behavior (roughly, each actor maximizes own utility, given the other actor's strategy). Applications of rational choice theory require the use of additional assumptions over and above the assumptions of utility maximization or equilibrium behavior. More precisely, substantive assumptions are needed that specify, for example, the actors' feasible alternatives, their preferences, and their information. In other words, one needs to specify the assumptions represented by node B in Coleman's scheme. For the PD, some of these assumptions, such as the feasible alternatives, namely, cooperation and defection, are already represented in Figure 3. In a standard rational choice model for the PD, one also assumes that the actors are exclusively self-regarding in the sense of being only interested in maximizing own payoffs (i.e., a selfishness assumption of the type "utility = own money") and that they have complete information about the game, including information about the other actor's preferences. Then, the payoffs in Figure 3 can be interpreted as utilities for the actors, and Figure 3 represents the normal form of the game. Under our assumptions, defection is a dominant strategy for each of the actors and equilibrium behavior thus implies mutual defection as the micro-outcome. Also, Figure 3 reveals that defection by both actors implies Pareto suboptimality as a macro-outcome.[4]

[4]Our example of the PD indicates that bridge-assumptions characterizing the interdependency between the actors as well as the transformation rule linking individual behavior with macro-outcomes such as Pareto efficiency or, respectively, Pareto suboptimality are implicit in the normal form of the game. A more elaborate description of a game that likewise comprises bridge assumptions and transformation rules implicitly is the tree-like extensive form.

The standard rational choice micro-model is parsimonious. This facilitates keeping micro-macro models of social dilemmas tractable when they become more complex (see Wippler and Lindenberg, 1987; Coleman, 1987b, 1990, p. 19). For example, one may wish to replace the macro-condition "one-shot interaction" by more complex macro-assumptions on various forms of "embeddedness" (Granovetter, 1985) of the PD, such as repeated interactions between the two actors. In a still more complex model, the two actors are part of a network: each actors is also involved in interactions with third parties and actors receive information on how their partners behave in interactions with third parties. The parsimony of a standard rational choice micro-model then allows for deriving implications from these more complex micro-macro models on when and how embeddedness induces cooperation rather than defection in a social dilemma like the PD and implications on Pareto efficient macro-outcomes. An important feature is that, due to embeddedness, cooperation can be a result of entirely self-regarding rational actors who follow principles of reciprocity in the sense of tit for tat-like behavior. Thus, these models also show that Becker's (1976) well-known rule can be fruitful to use simple assumptions on actors' preferences and to focus on effects of macro-conditions when applying rational choice theory rather than making assumptions on preferences more complex.

Parsimony such as in standard rational choice models can come at the cost of lack in empirical accuracy. For example, many empirical regularities in experiments on social dilemmas, including the PD, are hardly consistent with rational and self-regarding behavior. This refers specifically to much cooperative behavior in one-shot social dilemmas (see Camerer, 2003, for a review). Empirical regularities from many other contexts, including contexts with as well as without strategic interdependencies between actors, are likewise hard to reconcile with rational and self-regarding behavior (see Camerer, 2003, for such regularities in strategic situations and Kahneman and Tversky, 2000, for an overview of the extensive work on "anomalies" in situations without interdependence between actors).

Various reactions are conceivable, given such findings. One such reaction (see Harsanyi, 1976, chs. 6 and 7; 1977, chs. 1 and 2) is that although rational choice models may yield empirically problematic conclusions, it is useful to employ them for establishing a "benchmark" so that empirically observed refutations become themselves explananda for more refined models. Another argument (e.g., Goldthorpe, 2000) is that errors in predicting individual behavior with a rational choice micro-model will cancel out on the macro-level. Finally, Becker (1976, ch. 8) has developed the argument that typical macro-outcomes of micro-macro models are robust to replacing the rational choice micro-model by alternative micro-models. Coleman (1987b; 1990, p. 19) argues in a similar direction and suggests that replacing simple rational choice assumptions by more complex micro-theories would undermine the tractability of the micro-macro model in the sense that it becomes unfeasible to derive implications for macro-outcomes at all, certainly so when complex bridge assumptions and transformation rules are involved in the model.

Such arguments are meanwhile far from undisputed. Experimental work on social dilemmas shows that not only micro- but also macro-outcomes such as contribution levels in public good games that model collective action problems are often hard to explain as a result of rational and self-regarding behavior, indicating that the "errors cancel out"-argument might be problematic (for reviews, see Camerer, 2003; Camerer and Fehr, 2004; Ledyard, 1995). Theoretical work has established for various contexts, certainly so for contexts with interdependency between actors, that idiosyncratic deviations from the micro-predictions of a rational choice model need not cancel out on the macro-level, that macro-level implications need not be robust relative to variations in micro-level assumptions, and that alternatives to standard rational choice assumptions do yield new implications for macro-outcomes (see Akerlof and Yellen, 1987; Frey and Eichenberger, 1994; Fehr and Gintis, 2007). A simple example for repeated social dilemmas, including the PD, is that, assuming equilibrium behavior, actors' risk preferences affect their behavior and consequently the macro-outcome (Raub and Snijders, 1997; Van Assen, 1998). Hence, micro and macro implications of a rational choice model for cooperation in a repeated social dilemma are not robust to merely varying assumptions on risk preferences.

It is thus not surprising that alternative micro-theories have been developed and are being used in models of cooperation in social dilemmas as well as in many other micro-macro models. Many of these alternatives preserve the idea of incentive-guided and goal-directed behavior. One can then roughly distinguish two kinds of alternatives to standard rational choice micro-models. First, one can retain rational choice assumptions such as the assumption of Nash equilibrium behavior but replace standard additional assumptions such as the assumption of self-regarding behavior. Influential examples are models that assume inequity aversion or similar motives as elements of actor's utility functions as well as heterogeneity between actors with respect to the strength of such motives (see Fehr and Schmidt, 2006; Fehr and Gintis, 2007, for systematic surveys). The important feature is that these models have implications for micro- as well as macro-outcomes in very different contexts and that they imply that behavior strongly depends on macro-conditions. More precisely, these models imply much cooperative behavior in many social dilemmas but seemingly selfish behavior in market contexts. While these models are less parsimonious than standard rational choice micro-models, tractability and testability is preserved.

Second, there are micro-models that replace the rationality assumptions themselves and use alternative decision rules and behavioral heuristics, often modeling "bounded rationality." Such micro-models include, for example, a variety of models assuming myopic behavior, backward-looking learning models, and evolutionary models (see Macy and Flache, 2009, for an overview and further references). They are also used as microfoundations for models of cooperation in social dilemmas. For example, Macy and Flache (2002) employ a learning model for the analysis of conditions for cooperation, whereas Trivers (1971) and Axelrod (1984) provide well-known variants of evolutionary models of cooperation. Note that such micro-level assumptions are sometimes integrated in micro-macro models that allow for analytical equilibrium solutions. Often however, these micro-level assumptions are incorporated in models that rely on computational simulation models.

It is still an open question whether, in what respects or under what conditions such alternative micro-models should be seen as better alternatives to standard rational choice models and how broadly they can be applied. Also, note that the introduction of alternative micro-theories in micro-macro models leaves the question open how much priority should be given to empirical tests and to empirical corroboration of micro-assumptions when the focus is on macro-outcomes. It seems to be reasonable to consider modifying microfoundations at least when actors' behavior deviates systematically from the behavior implied by the micro-theory and when deviations from the implications of the micro-theory have strong implications for macro-outcomes.

6. SOME RECENT DEVELOPMENTS

Our selective overview has largely focused on contributions of "modern classics" to key features of micro-macro models, including microfoundations of such models. We conclude with some pointers to recent developments that appear to be fruitful.

In a series of publications, Hedström (2005; Hedström and Bearman, 2009; Hedström and Ylikoski, 2010) has advocated the research program of analytical sociology (see Diekmann, 2010; Opp, 2007, for critical discussions). Analytical sociology "seeks to explain complex social processes by carefully dissecting them and bringing into focus their most important constituent components. The approach focuses on traditional sociological concerns but uses explanatory strategies more often found in analytical philosophy and behavioral economics. It is an approach that seeks precise, abstract, realistic and action-based explanations for various social phenomena" (Hedström, 2005, p. 1). Many features of micro-macro modeling fit well with such a program. The approaches we reviewed can even be seen as variants of a broad analytical sociology program. However, Hedström likewise ties analytical sociology to what he labels "mechanism-based explanation" and to his "DBO theory" (desires, beliefs, and opportunities) of action. Hedström accentuates the differences between mechanism-based explanations and deductive arguments, let alone deductive-nomological explanations in Hempel's sense. Also, while it is tempting to conceive of DBO theory as a useful umbrella term for micro-theories that rely on the idea of incentive-driven and goal-directed behavior, Hedström (2005, p. 41) seemingly sees rational choice theories and learning theories as alternatives rather than special cases of DBO theory. It thus remains to be seen if and in what sense analytical sociology will contribute to spelling out and expanding the common core of research on micro-macro problems in sociology.

Fruitful applications of other micro-models than rational choice theory are used in roughly two kinds of micro-macro models (see Macy and Flache, 2009, for a useful overview). First, there are micro-macro models that succeed in combining assumptions on alternative decision rules and behavioral heuristics with equilibrium models that allow for an analytical approach. Such models include applications of evolutionary game theory, learning models, stochastic evolutionary models, and applications of models from physics to social dynamics. Analytical tractability induces a strong need for various simplifying assumptions also in these classes of models. Second, agent-based computational models have been developed and meanwhile figure prominently in micro-macro modeling (Macy and Flache, 2009, is a concise introduction to agent-based computational models; Sawyer, 2003, discusses the link with micro-macro models; Epstein, 2006, provides a manifesto).[5] These models rely on simulation methods rather than on analytical solutions, allowing for much more flexibility with respect to incorporating ever more assumptions and parameters in the model. Thus, there is a tradeoff between making a

[5]As outlined in Hegselmann and Flache (1998), Schelling's models of segregation can be seen as a "classic" of agent-based modeling.

micro-macro model more realistic and simultaneously hampering the understanding of how and why such a model generates certain macro-outcomes. Also, while the sometimes used slogan "computational experiments" may suggest otherwise, it is useful to keep in mind that agent-based computational models are theoretical models. Such models may be useful for deriving testable implications on macro-outcomes, but they should not be conflated with empirical research.

A further development is toward more integration of micro-macro modeling with empirical research. Interestingly, Coleman (see his programmatic statement 1986b) argued already in an early phase that micro-macro models based on rational choice assumptions might contribute to a better integration of theory and empirical research in sociology. However, while Coleman has contributed much to empirical research in very diverse fields as well as to the methodology of empirical research, it is hard to deny that his theoretical and his empirical work developed quite independent from each other, without systematic mutual influence (see Heckman and Neal, 1996). Micro-macro modeling based on the rational choice approach has been criticized for its week links with empirical research (Green and Shapiro, 1994), but this situation has changed. For example, Goldthorpe's (2000) arguments for a sociological alliance involving quantitative analysis of large-scale data sets and rational action theory has been influential and seems to have encouraged quite some work by theorists as well as empirical researchers aimed at reducing the gap between micro-macro models based on rational choice assumptions on the one hand and empirical research in sociology on the other (see Blossfeld and Prein, 1998, for an example). In fact, Wittek, Snijders, and Nee (in press) is aimed at taking stock of this development. We tend to believe that such an emerging alliance has contributed to more acceptance of micro-macro modeling in sociology in general and certainly in the scientific community of empirical researchers (see also various contributions in Hedström and Bearman, 2009, for indications in this direction). While Goldthorpe advocated the use of survey research, another approach that contributes to a merger of micro-macro models and empirical research is the use of experiments, such as in behavioral game theory (see Camerer, 2003; Fehr and Gintis, 2007). Other important contributions involve the development of statistical models that facilitate better integration of theoretical micro-macro models and empirical research by integrating core assumptions of micro-models into the statistical model itself. Good examples of this are statistical models for the co-evolution of networks and behavior (e.g., Snijders, 2001).

7. OVERVIEW OF THE SPECIAL ISSUE

The contributions in this special issue, we believe, reflect key features of micro-macro modeling in sociology as well as recent progress in this field. The special issue starts with three contributions that employ equilibrium analysis and analytical solutions. Two articles rely on rational choice micro-models. Gächter and Thöni address micro-macro models of voluntary cooperation. They show how macro- and micro-conditions jointly affect individual behavior and macro-outcomes such as market wages and contribution levels to public goods. Specifically, they show how assumptions on purely self-regarding behavior can be avoided without endangering empirical testability: a rather parsimonious extension of the assumption of self-regarding behavior provides predictive power for a large set of macro-outcomes. Also, in the tradition of behavioral game theory, they show how laboratory experiments can fruitfully be used for empirical research in this field.

Micro-macro models often assume that actors are homogeneous. Using a rational choice micro-model, Yamaguchi studies how predictions for macro-outcomes change if we assume that the population of actors is heterogeneous rather than homogeneous. He assumes heterogeneity in the sense of differences among actors in their costs and benefits associated with choices they make. In terms of Coleman's scheme, he employs complex bridge assumptions: the same macro-conditions put different constraints on different actors or shape their preferences differently.

Van de Rijt likewise employs equilibrium analysis to study balance ("a friend of a friend is a friend") in networks with changing sentiments between actors. Other than Gächter and Thöni as well as Yamaguchi, he studies different assumptions about the actors' rationality in the micro-model. He shows that whether or not imbalance in networks of relations can persist as the macro-outcome depends strongly on the micro-model.

The special issue then proceeds with three contributions that employ agent-based computational models. Fossett provides a large collection of simulations that extend Schelling's models of segregation in several dimensions. Macro-conditions in his model include the presence of three rather than two ethnic groups, different status groups, and housing units in different qualities. In addition to micro-assumptions on preferences of actors concerning the ethnic composition of their neighborhood, Fossett includes actors' preferences concerning the status of a neighborhood as well as the quality of housing units. His model thus also requires new bridge assumptions on how the additional macro-conditions provide opportunities and constraints for the actors. Fossett also extends the macro-outcomes considered by adding analyses of, for example, the centrality of the different ethnic groups as a result of the actors' housing choices.

Flache and Macy study the effects of combining changing social networks with changing micro-conditions on macro-outcomes related to cultural polarization. They show that bridging ties promote cultural diffusion and integration if there is only "positive" influence; that is, actors assimilate with and feel attracted to similar others, but that the effect reverses to differentiation in case of "negative" influence, that is, actors differentiate from others who are dissimilar. This study illustrates that the empirical applicability of a micro-macro model requires correct assumptions on macro-conditions and micro-conditions or one needs to assure that the macro-outcomes of the model are robust to changes in such conditions.

Helbing, Yu, and Rauhut offer a model for the co-evolution of social environments and cooperation. Thus, they contribute to a quickly growing literature on the co-evolution of networks and behavior that extends pure network formation models (see Roca, Sanchez, and Cuesta, in press, for a related *JMS*-contribution). They analyze the interplay of two elements of the micro-macro model, namely, the condition that actors can change their neighbors by moving to another neighborhood and the micro-assumption that actors imitate successful others. They show that neither imitating successful others nor moving to a more attractive neighborhood without adapting behavior is on its own sufficient to foster cooperation. However, when actors can move to attractive neighborhoods and in addition imitate successful neighbors, cooperation is likely to emerge.

Finally, Opp's contribution provides a detailed discussion of remaining open theoretical and methodological problems of micro-macro models that are based on rational choice assumptions. He also proposes solutions to some of those problems and offers suggestions for how some of these proposals can be used in further research.

REFERENCES

Akerlof, G. A. & Yellen, J. L. (1987). Rational models of irrational behavior. *American Economic Review*, *77*, 137–142.

Axelrod, R. (1984). *The Evolution of Cooperation*. New York, NY: Basic Books.

Becker, G. S. (1976). *The Economic Approach to Human Behavior*. Chicago, IL: University of Chicago Press.

Blau, P. M. (1964). *Exchange and Power in Social Life*. New York, NY: Wiley.

Blossfeld, H.-P. & Prein, G. (Eds.). (1998). *Rational Choice Theory and Large-Scale Data Analysis*. Boulder, CO: Westview.

Boudon, R. (1974). *Education, Opportunity, and Social Inequality*. New York, NY: Wiley.

Boudon, R. (1977). *Effets pervers et ordre social* [*The Unintended Consequences of Social Action*]. Paris, France: PUF.
Boudon, R. (1979). *La logique du social* [*The Logic of Social Action*]. Paris, France: Hachette.
Brown, R. (1965). *Social Psychology*. New York, NY: Free Press.
Burt, R. S. (1992). *Structural Holes: The Social Structure of Competition*. Cambridge, MA: Harvard University Press.
Buskens, V. & Raub, W. (2010). Rational choice research on social dilemmas: embeddedness effects on trust, forthcoming. In R. Wittek, T. A. B. Snijders, & V. Nee (Eds.), *Handbook of Rational Choice Social Research*.
Buskens, V. & van de Rijt, A. (2008). Dynamics of networks if everyone strives for structural holes. *American Journal of Sociology*, *114*, 371–407.
Camerer, C. F. (2003). *Behavioral Game Theory: Experiments in Strategic Interaction*. New York, NY: Russell Sage.
Camerer, C. F. & Fehr, E. (2004). Measuring social norms and preferences using experimental games: a guide for social scientists. In J. Henrich, R. Boyd, S. Bowles, C. F. Camerer, E. Fehr, & H. Gintis (Eds.), *Foundations of Human Sociality: Experimental and Ethnographic Evidence from 15 Small-Scale Societies*, (pp. 55–95). Oxford, UK: Oxford University Press.
Coleman, J. S. (1964). *Introduction to Mathematical Sociology*. New York, NY: Free Press.
Coleman, J. S. (1972). Systems of social exchange. *The Journal of Mathematical Sociology*, *2*, 145–163.
Coleman, J. S. (1986a). Micro foundations and macrosocial theory. In S. Lindenberg, J. S. Coleman, & S. Nowak (Eds.), *Approaches to Social Theory* (pp. 345–363). New York, NY: Russell Sage.
Coleman, J. S. (1986b). Social theory, social research, and a theory of action. *American Journal of Sociology*, *91*, 1309–1335.
Coleman, J. S. (1987a). Microfoundations and macrosocial behavior. In J. C. Alexander, B. Giesen, R. Münch, & N. J. Smelser (Eds.), *The Micro-Macro Link* (pp. 153–173). Berkeley, CA: University of California Press.
Coleman, J. S. (1987b). Psychological structure and social structure in economic models. In R. M. Hogarth & M. Reder (Eds.), *Rational Choice. The Contrast Between Economics and Psychology* (pp. 181–185). Chicago, IL: University of Chicago Press.
Coleman, J. S. (1990). *Foundations of Social Theory*. Cambridge, MA: Belknap Press of Harvard University Press.
Diekmann, A. (2010). Analytische Soziologie und Rational Choice [Analytical sociology and rational choice]. In T. Kron & T. Grund (Eds.), *Die Analytische Soziologie in der Diskussion*. Wiesbaden, Germany: VS-Verlag.
Dogan, G., van Assen, M. A. L. M., van de Rijt, A., & Buskens, V. (2009). The stability of exchange networks. *Social Networks*, *31*, 118–125.
Durkheim, E. (1982). *The Rules of Sociological Method*. Houndmills, UK: Macmillan. (Original work published 1895)
Dutta, B. & Jackson, M. O. (Eds.). (2003). *Networks and Groups. Models of Strategic Formation*. Berlin, Germany: Springer.
Epstein, J. (2006). *Generative Social Science. Studies in Agent-based Computational Modeling*. Princeton, NJ: Princeton University Press.
Fehr, E. & Gintis, H. (2007). Human motivation and social cooperation: Experimental and analytical foundations. *Annual Review of Sociology*, *33*, 43–64.
Fehr, E. & Schmidt, K. M. (2006). The economics of fairness, reciprocity and altruism – experimental evidence and new theories. In S.-C. Kolm & J. M. Ythier (Eds.),

Handbook of the Economics of Giving, Altruism and Reciprocity (pp. 615–691). Amsterdam, The Netherlands: Elsevier.

Frey, B. S. & Eichenberger, R. (1994). Economic incentives transform psychological anomalies. *Journal of Economic Behavior & Organization*, *23*, 215–234.

Friedkin, N. E. & Johnsen, E. C. (1990). Social influence and opinions. *The Journal of Mathematical Sociology*, *15*, 193–206.

Goldthorpe, J. (2000). The quantitative analysis of large-scale data sets and rational action theory: for a sociological alliance. In J. Goldthorpe (Ed.), *On Sociology* (pp. 94–114). Oxford, UK: Oxford University Press.

Granovetter, M. (1985). Economic action and social structure. The problem of embeddedness. *American Journal of Sociology*, *91*, 481–510.

Green, D. P. & Shapiro, I. (1994). *Pathologies of Rational Choice Theory*. New Haven, CT: Yale University Press.

Harsanyi, J. C. (1976). *Essays on Ethics, Social Behavior, and Scientific Explanation*. Dordrecht, The Netherlands: Reidel.

Harsanyi, J. C. (1977). *Rational Behavior and Bargaining Equilibrium in Games and Social Situations*. Cambridge, UK: Cambridge University Press.

Heckman, J. J. & Neal, D. (1996). Coleman's contribution to education: theory, research styles and empirical research. In J. Clark (Ed.), *James S. Coleman* (pp. 81–102). London, UK: Falmer Press.

Hedström, P. (2005). *Dissecting the Social: On the Principles of Analytical Sociology*. Cambridge, UK: Cambridge University Press.

Hedström, P. & Bearman, P. (Eds.). (2009). *The Oxford Handbook of Analytical Sociology*. Oxford, UK: Oxford University Press.

Hedström, P. & Udehn, L. (2009). Analytical sociology and theories of the middle range. In P. Hedström & P. Bearman (Eds.), *The Oxford Handbook of Analytical Sociology* (pp. 25–47). Oxford, UK: Oxford University Press.

Hedström, P. & Ylikoski, P. (2010). Causal mechanisms in the social sciences. *Annual Review of Sociology*, *36*, 49–67.

Hegselmann, R. & Flache, A. (1998). Understanding complex social dynamics: a plea for cellular automata based modeling. *Journal of Artificial Societies and Social Simulation*, *1*(3). Retrieved from http://www.soc.surrey.ac.uk/JASSS/1/3/1.html

Helbing, D., Farkas, I., & Vicsek, T. (2000). Simulating dynamical features of escape panic. *Nature*, *407*, 487–490.

Hempel, C. G. (1965). *Aspects of Scientific Explanation*. New York, NY: Free Press.

Hernes, G. (1976). Structural change in social processes. *American Journal of Sociology*, *82*, 513–547.

Homans, G. C. (1958). Social behavior as exchange. *American Journal of Sociology*, *65*, 597–606.

Hummell, H. J. (1973). Methodologischer Individualismus, Struktureffekte und Systemkonsequenzen [Methodological individualism: structural effects, and system-level consequences]. In K.-D. Opp & H. J. Hummell (Eds.), *Probleme der Erklärung sozialer Prozesse II: Soziales Verhalten und soziale Systeme* (pp. 61–134). Frankfurt a.M., Germany: Athenäum.

Hummell, H. J. & Opp, K.-D. (1971). *Die Reduzierbarkeit von Soziologie auf Psychologie* [*The Reducibility of Sociology to Pschology*]. Braunschweig, Germany: Vieweg.

Jackson, M. O. (2008). *Social and Economic Networks*. Princeton, NJ: Princeton University Press.

Kahneman, D. & Tversky, A. (Eds.). (2000). *Choices, Values and Frames*. Cambridge, UK: Cambridge University Press.

Ledyard, J. O. (1995). Public goods: a survey of experimental research. In J. H. Kagel & A. E. Roth (Eds.), *The Handbook of Experimental Economics* (pp. 111–194). Princeton, NJ: Princeton University Press.

Lindenberg, S. (1977). Individuelle Effekte, kollektive Phänomene und das Problem der Transformation [Individual effects, collective phenomena, and the problem of transformation]. In K. Eichner & W. Habermehl (Eds.), *Probleme der Erklärung sozialen Verhaltens* (pp. 46–84). Meisenheim a.G., Germany: Hain.

Lindenberg, S. (1981). Erklärung als Modellbau [Explanation as model building]. In W. Schulte (Ed.), *Soziologie in der Gesellschaft* (pp. 20–35). Bremen, Germany: Zentraldruckerei der Universität.

Lindenberg, S. (1992). The method of decreasing abstraction. In J. S. Coleman & T. J. Fararo (Eds.), *Rational Choice Theory. Advocacy and Critique* (pp. 3–20). Newbury Park, CA: Sage.

Lindenberg, S. (2001). Social rationality versus rational egoism. In J. Turner (Ed.), *Handbook of Sociological Theory* (pp. 635–668). New York, NY: Kluwer.

Loewenstein, G. (2007). *Exotic Preferences*. Oxford, UK: Oxford University Press.

Macy, M. W. & Flache, A. (2002). Learning dynamics in social dilemmas. *Proceedings of the National Academy of Sciences USA*, *99*, 7229–7236.

Macy, M. W. & Flache, A. (2009). Social dynamics from the bottom up: agent-based models of social interaction. In P. Hedström & P. Bearman (Eds.), *The Oxford Handbook of Analytical Sociology* (pp. 245–268). Oxford, UK: Oxford University Press.

Mas-Colell, A., Whinston, M. D., & Green, J. R. (1995). *Microeconomic Theory*. New York, NY: Oxford University Press.

McClelland, D. C. (1961). *The Achieving Society*. New York, NY: Free Press.

Merton, R. K. (1968). *Social Theory and Social Structure* (Enlarged ed.). New York, NY: Free Press.

Olson, M. (1965). *The Logic of Collective Action* (2nd ed.). Cambridge, MA: Harvard University Press.

O'Neill, J. (Ed.). (1973). *Modes of Individualism and Collectivism*. London, UK: Heinemann.

Opp, K.-D. (1979). *Individualistische Sozialwissenschaft* [*Individualism in Social Science*]. Stuttgart, Germany: Enke.

Opp, K.-D. (2007). Review essay on Hedström 2005. *European Sociological Review*, *23*, 115–122.

Rasmusen, E. (2007). *Games and Information: An Introduction to Game Theory* (4th ed.). Oxford, UK: Blackwell.

Raub, W. & Snijders, C. (1997). Gains, losses, and cooperation in social dilemmas and collective action: the effects of risk preferences. *The Journal of Mathematical Sociology*, *22*, 263–302.

Raub, W. & Voss, T. (1981). *Individuelles Handeln und gesellschaftliche Folgen* [*Individual Action and Social Consequences*]. Darmstadt, Germany: Luchterhand.

Roca, C. P., Sanchez, A., & Cuesta, J. A. (in press). Individual strategy update and emergence of cooperation in social networks. *The Journal of Mathematical Sociology*.

Sakoda, J. M. (1971). The checkerboard model of social interaction. *The Journal of Mathematical Sociology*, *1*, 119–132.

Sawyer, R. K. (2003). Artificial societies: Multiagent systems and the micro-macro link in sociological theory. *Sociological Methods and Research*, *31*, 325–363.

Schelling, T. C. (1971). Dynamic models of segregation. *The Journal of Mathematical Sociology*, *1*, 143–186.

Schelling, T. C. (1978). *Micromotives and Macrobehavior*. New York, NY: Norton.
Schneider, L. (Ed.). (1967). *The Scottish Moralists on Human Nature and Society*. Chicago, IL: Phoenix.
Snijders, T. A. B. (2001). The statistical evaluation of social network dynamics. *Sociological Methodology*, *31*, 361–395.
Trivers, R. (1971). The evolution of reciprocal altruism. *Quarterly Review of Biology*, *46*, 35–57.
Udehn, L. (2001). *Methodological Individualism*. London, UK: Routledge.
Van Assen, M. A. L. M. (1998). Effects of individual decision theory assumptions on predictions of cooperation in social dilemmas. *The Journal of Mathematical Sociology*, *23*, 143–153.
Wippler, R. (1978). The structural-individualistic approach in Dutch sociology: toward an explanatory social science. *Netherlands Journal of Sociology*, *14*, 135–155.
Wippler, R. & Lindenberg, S. (1987). Collective phenomena and rational choice. In J. C. Alexander, B. Giesen, R. Münch, & N. J. Smelser (Eds.), *The Micro-Macro Link* (pp. 135–152). Berkeley, CA: University of California Press.
Wittek, R., Snijders, T. A. B., & Nee, V. (in press). *Handbook of Rational Choice Social Research*.
Ziegler, R. (1972). *Theorie und Modell* [*Theory and Model*]. München, Germany: Oldenbourg.