MICRO-MACRO MODELS IN SOCIOLOGY: ANTECEDENTS OF COLEMAN'S DIAGRAM[*]

Werner Raub[a] & Thomas Voss[b]

[a] Department of Sociology/ICS, Utrecht University, Netherlands, w.raub@uu.nl
[b] Department of Sociology, Leipzig University, Germany, voss@sozio.uni-leipzig.de

Version May 4, 2016

Prepared for
Ben Jann & Wojtek Przepiorka (eds.),
Social Dilemmas, Institutions and the Evolution of Cooperation. Festschrift for Andreas Diekmann,
Berlin: De Gruyter 2017

[*] Support for Raub was provided by NWO (PIONIER-program "The Management of Matches"; grants S 96–168 and PGS 50–370). Raub acknowledges the hospitality of Nuffield College, University of Oxford.

MICRO-MACRO MODELS IN SOCIOLOGY: ANTECEDENTS OF COLEMAN'S DIAGRAM

Abstract

In sociology, Coleman's diagram (the "Coleman-boat" or "Coleman's bathtub") has become the standard way of representing micro-macro links. Coleman's work on micro-macro links and his diagram have several "predecessors". Many of these are due to European sociologists and appeared, roughly, in the period 1970–1980, quite some years ahead of Coleman's contributions. Much of this work, while often seminal, has been hardly noticed outside Europe and is meanwhile largely forgotten. Moreover, it has been typically published in languages like German, Dutch, and French that are not easily accessible to sociologists who tend to focus on scholarly literature in English, if only because of lack of command of other languages. We present a brief overview of some of the relevant work.

Introduction

Coleman's diagram for depicting micro-macro models (Figure 1) is arguably among his best known contributions to sociology and certainly so to social theory. It seemingly appeared first of all in a journal that is not easily available (Coleman 1984) and a bit later in some of his better known programmatic publications in the second half of the 1980s (Coleman 1986a: 347, 1986b: 1322, 1987a: passim, with 1987a a variant of his 1984 paper).[1] The diagram gained prominence in Chapter 1 of his magnum opus *Foundations of Social Theory* (Coleman 1990). The underlying theoretical approach took shape earlier in two strands of his work, namely, his exchange model and theory of collective decisions (see 1964a for his early work in this field, 1973 and 1990 for comprehensive treatments) on the one hand and on the other, as we shall see, in his contributions to mathematical sociology (in particular Coleman 1964b).

The diagram reflects the "logic" of "purposive action explanations" (Coleman 1986b, 1990: Chapter 1) of social phenomena, including purposive action explanations that use rigorous rationality assumptions like employed in Coleman's formal theory of social exchange and collective decisions or in much of economics and in the "economic approach to human behavior" (e.g., Becker 1976). Work on social dilemmas, institutions, and cooperation often exemplifies the same spirit, including work on such topics based on game-theoretic tools. More generally, the diagram represents approaches to the explanation of social phenomena that focus on micro-macro links, irrespective of whether or not purposive action assumptions are used. These are approaches related to "methodological individualism" (Coleman 1986b, 1990: Chapter 1; see Udehn 2001 for an overview). Hence, more recent approaches such as behavioral and experimental game theory (Camerer 2003), "analytical sociology" (Hedström 2005), agent-based computational modeling (e.g., Macy and Flache 2009), and "sociology as a population science" trying to explain aggregate-level regularities (Goldthorpe 2016) likewise refer to Coleman's diagram or employ roughly the same logic of explanation. The diagram is meanwhile influential also in other social sciences such as demography (see Billari 2015 for a perspective similar to Goldthorpe 2016).

While his diagram has meanwhile become the more or less standard exposition of micro-macro models, there are various "predecessors", mostly developed by European sociologists, that appeared quite some time – five to fifteen years or more – earlier, roughly in the 1970s and the early 1980s. Somewhat unfortunately, if only from the perspective of

[1] The bibliography of Coleman's works in Clark (1996), albeit somewhat incomplete, is useful for a search. We screened the bibliography, checked various "suspect publications," and Coleman (1984) seems to be the earliest "hit".

getting priority and originality issues right, these predecessors are by now largely forgotten. From the perspective of the history and sociology of science, this is not surprising. It is an illustration of a regularity known as Stigler's law of eponymy: "No scientific discovery is named after its original discoverer" (Stigler 1999: 277; see also Merton 1973 who, also according to Stigler himself, may claim priority with respect to Stigler's law). In our case, this may be due to the success of Coleman's diagram, deriving from its simplicity and intuitive appeal. It may likewise result from the fact that Coleman, while aware of at least some of these predecessors, declined to refer to them. Finally, the original literature is often not in English, with few, if any, English translations.

Our paper aims primarily, though not exclusively, at "history of ideas." We provide an overview of some predecessors, highlighting relations with Coleman's diagram. We embed this in brief sketches of some intellectual background for these predecessors and some comments on ramifications for formal model building and empirical research in sociology. With good reason, the approach to sociological and social science theory that is the focus of this contribution is quite opposed to conceiving of social theory as a kind of history of ideas, i.e., opposed to social theory as a series of chapters on the ideas of "great sociologists and their lesser contemporaries." What is more, and again understandably, engaging in social theory in the sense of developing testable explanations of social phenomena is typically preferred to spending much time and effort on history of ideas (see Merton's 1957: 4 distinction between "systematics" and "history of sociological theory" and his preference for focusing on the former). Still, every now and then it seems useful to straighten out the development of ideas, certainly so when it comes to seminal ideas that have been overlooked or forgotten. We do *not* aim at contributing to recently revived discussions on methodological individualism and related approaches which by and large refer to ontological ideas inspired by work in the philosophy of mind or focus on concepts of causality implied by Coleman's diagram (e.g., List and Spiekermann 2013, Little 2012; see Voss 2016 for a discussion of some of these issues). We start with an overview of Coleman's diagram and its main features, including an example that highlights the logic of explanations in line with the diagram. We then turn to micro-macro models before Coleman. Subsequently, we briefly discuss how micro-macro models are related to formal model building and offer some comments on theoretical models and empirical research. Concluding remarks follow.

1. Coleman's micro-macro model

In his diagram,[2] "macro" refers, in Coleman's terminology, to social systems such as a family, a city, a business firm, a school, or a society (Coleman 1986a: 346), whereas "micro" refers to individuals.[3] The macro-level thus refers to collective phenomena that are described by concepts referring to properties of social systems, such as the size of a group. In terms of the number of actors involved, "macro" may refer not only to large but also to small social systems such as a dyad, a triad, or a small group. The micro-level refers to properties of individuals, such as their preferences, their information, or behavior. Hence, the distinction "micro" versus "macro" corresponds to the distinction "individual" versus "collective".

[Figure 1 about here.]

Nodes A and D represent propositions describing macro-conditions and, respectively, macro-outcomes. Arrow 4 represents propositions about an empirical regularity at the macro-level,

[2] For our sketch, see Raub, Buskens and Van Assen (2011).
[3] There are also well-known examples of micro-macro models with *corporate* actors (Coleman, 1990: Part III and IV) on the micro-level.

say, an association between macro-conditions and macro-outcomes. Macro-outcomes denoted by Node D as well as empirical regularities denoted by Arrow 4 represent explananda at the macro-level. Node B represents propositions describing micro-conditions. These propositions thus refer to "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 or institutions but also 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. We follow Lindenberg (1981, Wippler and Lindenberg 1987) and label them "bridge assumptions." Node C represents micro-outcomes and the explanandum on the micro-level, namely, 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 1987), we use "transformation rules" as a label for such assumptions on micro-to-macro relations. It is evident from the diagram that the explanandum at the micro-level, descriptions of individual behavior, follows from an explanans comprising assumptions on individual behavior (Node B, Arrow 2), macro-conditions (Node A), and bridge assumptions (Arrow 1). The explananda at the macro-level, i.e., descriptions of macro-outcomes (Node D) and macro-regularities (Arrow 4), follow from an explanans comprising assumptions on individual behavior (Node B, Arrow 2), macro-conditions (Node A), as well as bridge assumptions (Arrow 1) and transformation rules (Arrow 3). The diagram clearly indicates that sociological explanations focus on macro-phenomena as explananda and try to highlight macro-conditions rather than exclusively micro-conditions as part of the explanation. Thus, such explanations follow the "minimal program of sociology" (Lindenberg 1977) that has been set forth already by Durkheim in his *Rules of Sociological Method*: social facts should be causally explained by social facts.

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

Consider a paradigmatic example of a micro-macro problem, namely, the production of collective goods and the empirical regularity at the macro-level that group size is often negatively related to the production of collective goods (Olson 1971). The core feature of a collective good is that, once available, actors who did not contribute to its production cannot be excluded from its consumption. This induces the free rider problem: when the costs of an individual contribution are high compared to the marginal effects of such a contribution on individual benefits from the good, actors face incentives not to contribute. Assume now that there are no "selective incentives" such that additional individual benefits do depend on individual contributions to the production of the collective good. Then, Olson argued, collective good production will depend on group size in the sense that large groups with a common interest of group members concerning the production of the collective good will typically suffer from less than optimal production of the good. However, the relation between group size and collective good production at the macro-level should not be considered as a

simple macro-law. Rather, this relation depends on a number of specific conditions such as the absence of selective incentives, the production function for the collective good, and others (see, e.g., Sandler 1992). Diekmann's (1985) Volunteer's Dilemma (VOD) is a formal model of a set of conditions that imply the group size effect.

The bystander intervention and diffusion of responsibility problem (Darley and Latané 1968) is Diekmann's (1985) example of a social situation for which VOD is a reasonable model. This is a situation with actors witnessing an accident or a crime. Everybody would feel relieved if at least one actor would help the victim by, for example, calling the police. However, providing help is costly and each actor might be inclined to abstain from helping, hoping that someone else will help. VOD captures these features in a non-cooperative game with N actors.[4] In a non-cooperative game, intuitively speaking, actors are unable to incur binding and enforceable agreements or unilateral commitments with respect to certain behaviors. More specifically, in the VOD, actors are unable to incur binding and enforceable agreements or commitments to contribute to the production of the collective good (such as calling the police). Actors have binary choices. They decide simultaneously and independently whether or not to contribute to the collective good: each actor, when choosing, is not informed about the choices of the other actors. The good is costly and will be provided if at least one actor – a "volunteer" – decides to contribute. Contributions by more than one actor are feasible and then each actor pays the full costs of providing the good but contributions of more than one actor do not further improve the utility level of any actor. A core feature of VOD is that the costs K of contributing to the collective good are *smaller* than the gains U from the good. The matrix in Figure 2 summarizes the normal form of the game, with rows representing an actor's strategies, namely, to contribute (CONTR) or not to contribute (DON'T), columns indicating the number of other actors who contribute, and cells representing an actor's payoffs as a function of his[5] own strategy and the number of other actors who contribute.

[Figure 2 about here.]

In terms of Coleman's diagram (see Figure 3 for an illustration), both being a non-cooperative game and group size N are macro-conditions represented by Node A in the diagram. The macro-outcome of interest, represented by Node D, is the probability P that the collective good will be provided. Arrow 4 now represents the relation between group size and the probability that the collective good will be provided. Node B represents the micro-conditions (a) that each actor can choose between CONTR and DON'T, (b) actors' information, namely, that actors, when choosing, are not aware of the other actors' choices,[6] and (c) actors' preferences as represented by their payoffs. Note that the normal form of the game includes bridge assumptions (Arrow 1) on macro-micro transitions. Namely, the normal form includes a specification of how an actor's payoff depends on own choices as well as those of all other actors – that is, the normal form specifies the structure of actors' interdependence.

Game-theoretic rationality assumptions such as the assumption of equilibrium behavior are micro-level assumptions represented by Arrow 2 in Coleman's diagram. In an equilibrium, each actor's strategy maximizes own payoffs, given the strategies of the other players. VOD has N equilibria in pure strategies. These are the strategy combinations with

[4] See, e.g., Heifetz (2012) for details on game-theoretic concepts and assumptions and for a discussion of Diekmann's VOD (Heifetz 2012: 211–214).

[5] Throughout, we use "he" and "his" to facilitate readability and without intending any gender-bias.

[6] Strictly speaking, we would have to specify the extensive form, including the game tree, rather than only the normal form of VOD, to make its information structure explicit.

exactly one volunteer choosing CONTR with probability 1, while all other actors choose DON'T with probability 1. In each of these equilibria, the collective good is provided with certainty. However, the equilibria involve a bargaining problem, since each actor prefers the equilibria with another actor as the volunteer to the equilibrium where he himself is the volunteer. Moreover, while the game is symmetric, the *N* equilibria in pure strategies require that actors do not choose the same strategies. It is a natural assumption that rational actors play a symmetric equilibrium in the sense of choosing the same strategies in a symmetric game. It can be shown that VOD has a unique symmetric equilibrium in mixed strategies such that each actor chooses CONTR with probability $p^* = 1 - (\frac{K}{U})^{\frac{1}{N-1}} < 1$. From a game-theoretic perspective, the symmetric equilibrium in mixed strategies is a plausible candidate for the "solution" of VOD. Thus, *p** is represented by Node C in the diagram. Under the assumption of game-theoretic rationality, a testable implication on how group size affects micro-outcomes thus follows: the individual probability to contribute to the collective good declines with increasing group size *N*. Moreover, the individual probability to contribute to the collective good approaches zero for very large groups, since $\lim_{N\to\infty}\left[1-(\frac{K}{U})^{\frac{1}{N-1}}\right]=0$.

The individual probability *p** has to be distinguished from the macro-outcome, namely, the probability *P* that the collective good will be provided, represented by Node D in Coleman's diagram. One can see that the normal form of the game likewise includes a transformation rule represented by Arrow 3 in Coleman's diagram. This is so because the normal form specifies how the probability that the collective good is provided depends on each actor's individual behavior. More specifically, the normal form implies that the collective good is provided if and only if at least one actor chooses CONTR. How, then, will group size affect the probability that the collective good is provided? In VOD, group size affects collective good provision through two different mechanisms. First, since it is sufficient for the good to be provided that one single actor is willing to bear the costs and since all actors are willing to bear the costs with positive probability in the symmetric mixed equilibrium, there is a positive effect of increasing group size since the number of actors increases who may decide to contribute. Second, and conversely, there is a negative effect of increasing group size, since each actor's individual probability *p** to contribute decreases with increasing *N*. What is the total effect? For the symmetric mixed equilibrium, the probability that the collective good will be provided, i.e., that there is at least one volunteer, can be shown to be $P^* = 1 - (\frac{K}{U})^{\frac{N}{N-1}}$. Obviously, $P^* < 1$ so that production of the collective good may fail. Moreover, as can be seen from *P**, the negative effect of increasing group size on collective good production outweighs its positive effect. Hence, a testable implication, represented by Arrow 4 in Coleman's diagram, follows for how group size affects macro-outcomes: the probability that the collective good is provided decreases with increasing *N*. Moreover, since $\lim_{N\to\infty}\left[1-(\frac{K}{U})^{\frac{N}{N-1}}\right]=1-\frac{K}{U}$, the probability of collective good provision approaches $1-\frac{K}{U}$ for increasing *N*.

[Figure 3 about here.]

Some additional remarks on Coleman's diagram are useful and can be illuminated by the VOD example. First, Coleman argued for employing comparatively simple micro-level

assumptions, while simultaneously incorporating 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 exclusively explaining individual behavior as such. Hence, it seems reasonable to allow for complexity of macro-assumptions. Accordingly, the core issue in the analysis of VOD is not the individual probability to contribute, but rather the probability of collective good production at the macro-level and how that probability depends on group size as a macro-condition. Furthermore, since deriving macro-implications from micro-assumptions as well as bridge assumptions and transformation rules is often a non-trivial task, it seems advisable to keep the micro-assumptions simple with an eye on tractability of the model. In the VOD example, the analysis of model implications becomes feasible through employing the micro-assumption of equilibrium behavior, the most simple and basic rationality assumption for non-cooperative games. Finally, Coleman argues that the careful specification of transformation rules is not only a core task of sociology but that sociological explanations are also 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. It seems straightforward to motivate careful specification of bridge-assumptions in a similar way. Considering the VOD example, note that it is precisely the explicit specification of the normal form of the game that allows for clearly linking macro- and micro-level since the normal form comprises the relevant bridge assumptions and transformation rules.

Second, VOD also highlights that 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 and vice versa. 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. For example, given the incentive structure of VOD, actors do prefer the production of the collective good to the outcome such that the good is not produced, while individually rational equilibrium behavior does not exclude that the good will not be produced and may even imply a high probability of such a macro-outcome. Notice that the outcome due to individual rationality is suboptimal in the Pareto sense: in the symmetric mixed equilibrium each actor receives an expected payoff $U - K$ whereas in any asymmetric equilibrium of pure strategies the volunteer gets $U - K$, while $N - 1$ actors receive payoff U.

Finally, it should be added that Coleman's diagram provides a highly stylized and simplified representation of full-fledged micro-macro models, leaving many issues implicit. As the VOD example shows, the nodes and arrows of the diagram summarize possibly numerous and complex assumptions. As the VOD example likewise shows, model building involves not only the careful specification of assumptions but crucially involves deriving implications from assumptions. We will return to this issue below.

2. Micro-macro models before Coleman

2.1 McClelland's reconstruction of Weber's argument on Protestantism and the emergence of capitalism

While we do not – and quite obviously cannot – claim to have identified all predecessors of Coleman's diagram, it seems quite likely that the very first version of the diagram is due to

McClelland (1961: 47) in his classic study on *The Achieving Society*. McClelland used his version to summarize his reconstruction of Weber's analysis of the relation between Protestantism and the growth of capitalist economic organization. This is exactly one of Coleman's paradigmatic examples that he used repeatedly when discussing his diagram. Panel a in Figure 4 presents McClelland's version of the diagram, Panel b is Coleman's (1984, 1987a: 155 and 1990: 8; see 1986b: 1322 for a slightly different variant). In the four works mentioned, Coleman does not refer to McClelland (note, too, that we are not the first to highlight McClelland's contribution in this context, see e.g. Brüderl 2004: 175, Diekmann and Voss 2004, and Opp 2009: 33, 2011: 211).[7]

[Figure 4 about here.]

2.2 Structural individualism in European sociology

McClelland's diagram reflects his focus on how Weber's macro-level relation between Protestantism and modern capitalism depends on how Protestantism affects micro-level phenomena and processes that in turn affect the development of capitalism: "a psychological means by which the historical development described by Weber may have come about" (McClelland 1961: 47). McClelland studied specifically how achievement motivation at the micro-level is related to economic growth at the macro-level. He did not aim at developing a broader sociological research program that systematically attempts to explain macro-level phenomena using micro-macro models. Such a broader family of programs, sometimes labeled "structural individualism" (Opp 1978; Wippler 1978) or "explanatory sociology" (Wippler 1985), developed in the 1970s, with seminal contributions by European sociologists, mainly in Germany, the Netherlands, and to some degree in France. Various predecessors of Coleman's diagram emerged in this context.

The common core of structural individualism is to conceive of sociology as a problem- and theory-guided discipline, with theory construction aiming at the explanation of social phenomena, including well-established empirical regularities. Explanations involve deductive arguments or variants of such arguments. Therefore, theory construction involves more than specifying sets of hypotheses. Rather, theory construction comprises specifying assumptions, including but not exclusively hypotheses, as well as specifying implications of these assumptions. Due to the focus on implications, analytical rigor is an ingredient of structural individualism. Implications should include *testable* implications and 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 is an aim, too. The affinity with a meta-theoretical approach such as Popper's (1934, 1963) and Lakatos' (1970) is evident. Indeed, Albert, who had been influential in advocating Popper's philosophy of science in Germany (Albert 1968) and in advocating Popperian principles also for social science theory formation and empirical research, contributed in important ways to the methodological foundations of structural individualism (e.g., Albert 1967, 1977).

More substantively, and in line with micro-macro models à la Coleman, structural individualism aims at the explanation of social phenomena at the macro-level by employing hypotheses on individual behavior as well as assumptions on how macro-level phenomena affect individual behavior and the macro-outcomes of individual behavior. Vanberg (1975)

[7] The philosopher Wright (1971: 137) used a diagram similar to Coleman's in his study on "explanation" and "understanding" in history and the social sciences. Since Wright's approach differs quite a bit from the program of causal explanations underlying Coleman's diagram, we omit a more detailed discussion.

and Bohnen (1975) provided detailed studies on the roots of structural individualism in the work of the Scottish Moralists of the 18th century (Hume, Adam Smith, Ferguson), the Austrian School of economics (including Menger, Schumpeter, Mises, and Hayek), the work of Max Weber, and various strands of methodological individualism (including Popper, Watkins, and Agassi; see also the reader O'Neill 1973 and the overview Udehn 2001). Social exchange theory (Homans 1958, Blau 1964) and behavioral sociology (Homans 1961, 1974) influenced the development of structural individualism in various ways. Core features of structural individualism are an interdisciplinary orientation and a focus on the methodological unity of the social sciences: this includes the use of theoretical tools that had originally been developed in other disciplines such as the use of various psychological theories or, somewhat later, rational choice assumptions, including game-theoretic modeling, as micro-theories represented by Arrow 2 in Coleman's diagram. It also includes a keen eye on and import of insights from approaches in other social science disciplines that are based on similar methodological and theoretical principles such as economics and applications of the rational choice approach in political science. Boudon, Esser, Hummell, Lindenberg, Opp, Wippler, and Ziegler were key contributors. They provided numerous theoretical studies involving micro-macro modeling and induced empirical research (see Wippler 1978 and 1985 for concise summaries, Raub and Voss 1981 for a more detailed overview, and Diekmann and Voss 2016 for a recent discussion).

2.3 Micro-macro models in structural individualism

2.3.1 Hummell and Opp: reducing sociological to psychological theories

Early variants of structural individualism in the tradition of behavioral sociology focused on the application of psychological theories and hypotheses in sociological explanations (e.g., Hummell 1969; Opp 1972). This led to the provocative thesis "that sociology is reducible to psychology" (Hummell and Opp 1968: 206; see Hummell and Opp 1971 for a detailed presentation; Opp 2009: 27–30 provides a personal account of the development and the reception of the reducibility thesis; for the standard explication of the concept of "reduction of a theory T_j to a theory T_i", see Nagel 1961: Chapter 11). Hummell and Opp intended to show that psychological hypotheses allow for the derivation of sociological hypotheses, including the derivation of modified and improved versions of sociological hypotheses. A detailed discussion of the thesis that sociology is reducible to psychology is beyond the scope of this paper (see Raub and Voss 1981: Chapter 2 for an overview and a critical analysis). However, Hummell and Opp (1971: 15) introduce the diagram in Figure 5 to clarify their argument.

[Figure 5 about here.]

In this diagram, T_P denotes, a psychological theory, namely, a hypothesis comprising an independent variable *V* and a dependent variable *N* that refer to properties of individuals (*V* refers to the allocation of rewards, *N* to norm conforming behavior). The arrow indicates that *V* has a positive effect on *N*. T_S denotes a sociological theory, with *Kh* and *Kf* variables referring to properties of collectives (*Kh* refers to group cohesion, *Kf* to group conformity) and the arrow indicating that *Kh* has a positive effect on *Kf*. Finally, *C I* and *C II* are coordination rules, considered as definitions of *Kh* and *Kf* in terms of *V* and *N*, respectively. Clearly, then, the diagram is an upside down variant of Coleman's diagram. Note, that T_S is reducible to T_P in the sense that T_S is implied by T_P, *C I*, and *C II*.

2.3.2 Lindenberg's model for the explanation of collective effects

In a series of articles that appeared in the 1970s, Lindenberg developed a model for explaining macro-phenomena comprising exactly the components of Coleman's diagram, albeit organized in a somewhat different way, namely, adapting the Hempel-Oppenheim model (Hempel 1965) of explanations (the major source is Lindenberg 1977; see also Lindenberg 1976 and Lindenberg and Wippler 1978). Figure 6 depicts Lindenberg's model of of the logic of individualistic explanations. To facilitate comparison, we slightly expand his diagram by adding explicitly where the various elements (nodes and arrows) from Coleman's diagram 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 model shows 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.

[Figure 6 about here.]

Subsequent work analyzed various features of Lindenberg's model in more detail and contributed to clarifying characteristics of micro-macro models (see Opp 1979, Lindenberg 1981, Raub 1984: Part I, Wippler and Lindenberg 1987, and later Lindenberg 1992, 2001, Esser 1993; see Raub et al. 2011, Opp 2009, 2011, 2014 and Voss 2016 for recent discussions).[8] First, the status of various assumptions in Lindenberg's model (and of the corresponding assumptions in Coleman's) has been scrutinized. It is quite clear that the propositions on individuals in Lindenberg's model and assumptions represented by Arrow 2 in Coleman's comprise assumptions on regularities of individual behavior and perhaps indeed a general theory of behavior. For example, in Diekmann's VOD, these propositions include the assumption of Nash equilibrium behavior, the core assumption of game-theoretic rationality. Likewise, it is clear that collective effects in the sense of regularities at the macro-level (Arrow 4 in Coleman's diagram) should not be conceived as macro-laws, let alone deterministic laws. Goldthorpe (2016: 7) refers to them as "aggregate-level regularities of a probabilistic kind." The group size effect for collective good production is a standard example of a regularity at the macro-level that should not be conceived as a deterministic law but as a regularity that depends on various sets of conditions such as those spelled out in the VOD. Bridge assumptions and transformation rules may include empirical assumptions as well as definitions and analytical statements (for more detailed discussion, see Lindenberg 1977, 1981, Lindenberg and Wippler 1978, Opp 1979, Raub and Voss 1981; Opp 2011 and 2014 provides a more recent account). In the VOD example, the bridge assumptions and transformation rules implied by the normal form of the game could be considered empirical assumptions that are more or less approximately true in "real life" social situations or, respectively, can be implemented in experimental tests of implications of the VOD model. Notice that the transformation rules in the VOD comprise definitions ("The collective good is provided if at least one member of the group chooses CONTR") and analytical statements ("If N actors independently choose CONTR with probability p^*, then P^* will be the probability that at least one actor chooses CONTR").

[8] One of the reviewers of this paper claims that the overview and analysis Raub and Voss (1981) became a "crystallization point for further discussions of the micro-macro link in Europe" and required us to mention this.

While aiming at the explanation of macro-phenomena, the theoretical core of micro-macro 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. For example, Wippler and Lindenberg (1987: 138) submit (see Coleman 1990: 3–4 for a similar point) that, compared to assumptions on macro-level regularities, assumptions on regularities of individual behavior, including assumptions on purposive 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, micro-macro explanations follow common 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, see also Wippler and Lindenberg 1987). For example, the VOD employs the simplifying assumptions of a symmetric game. More complex versions of VOD allow for individual heterogeneity with respect to costs of and gains from contributions (Diekmann 1993, Weesie 1993).

Fourth, the principle of sufficient complexity (Lindenberg 2001) complements the method of decreasing abstraction by requiring that model assumptions, while as simple as possible, should be complex enough such that the phenomenon to be explained can be described rather than being assumed away. In the case of our VOD example, 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.

According to Opp (2009: 28, 2014: 160–162), Lindenberg's model for the explanation of collective phenomena is in fact equivalent to the Hummell and Opp-diagram for reducing sociological to psychological theories, only employing a different terminology. It is neither feasible nor necessary to discuss this issue here in detail. We can well imagine that Hummell and Opp indeed aimed at a model such as Lindenberg's. Still, apart from various mostly technical issues related to the concept of theory reduction, a basic problem remains (see Raub and Voss 1981: Chapter 2 for more detailed discussion). Namely, according to standard accounts such as Nagel's (and others mentioned in Hummell and Opp 1971), "reduction of a theory T_j to a theory T_i" requires that *both* the reducing theory – in their case: psychology and more generally a theory at the micro-level of behavior – *and* the reduced theory – sociology or a theory at the macro-level – are *mature* general theories, satisfying various kinds of adequacy criteria for such theories, including precision, a system of propositions with testable implications (empirical content), and indeed empirical corroboration. However, a core motivation for using micro-macro models in sociology is precisely that there are no such mature theories at the macro-level of social systems (and that mature theories are something quite different from macro-level regularities). Lindenberg's model, like Coleman's, has the advantage that it does not presuppose the availability of such sociological theories and rather

aims at micro-macro explanations of explananda other than mature macro-level theories. Nagel's (1961: Chapter 11) and others' paradigm example of theory reduction is the reduction of thermodynamics to statistical mechanics and it seems hard to figure out a mature theory like thermodynamics in (macro-) sociology. Lindenberg's model seems more consistent with a modest but realistic view of theory construction in sociology that is close to Merton's (1957) middle-range theories (see also Hedström and Udehn 2009) in the sense that much of such theory construction aims at explanations of well-specified macro-outcomes, including macro-regularities, while the use of similar micro-theories in various micro-macro models that address quite different phenomena at the macro-level allows for a common theoretical core and coherence of such models as well as cumulative growth of knowledge (see also Diekmann and Voss 2004: 20).

2.3.3 Boudon and Hernes: diagrams representing social processes

While most of structural individualism has been developed in the 1970s and 1980s in Germany and the Netherlands, important contributions in France have been due to Boudon. For example, his meanwhile classic study on inequality of educational and social opportunity (Boudon 1974) is one of the very first detailed applications of the structural individualistic approach to core problems of sociology. A collection of essays (Boudon 1977) and a textbook (Boudon 1979) offer, in particular, numerous "case studies" of contributions from classical sociology and "modern classics" showing that these can be systematically reconstructed, made precise, and improved as micro-macro models (an instructive example is his analysis of the "logic of relative frustration" in Boudon 1977: Chapter 5; see Berger and Diekmann 2015 for an overview of related literature and an experimental test).

In his textbook, Boudon (1979: Chapters 5 and 6) discusses different types of processes of social change and introduces a diagram (1979: 148, 153) that can be used to represent such processes. Figure 7 is a slightly simplified version of his diagram. To highlight the similarities with Coleman's micro-macro model, we again add where the nodes and arrows from Coleman's model are located in Boudon's. Note, too, that Boudon's emphasis on social processes is the reason that he includes "feedback effects" (Boudon 1979: 149, 151) from "outputs" (Coleman's macro-outcomes) to the "environment" (Coleman's macro-conditions) as well as to the "system of interaction" (Coleman's micro-level). Roughly, Coleman's diagram could be extended to more explicitly represent processes over a number of periods 1, 2,… by considering a sequence of diagrams like in Figure 1 such that macro-outcomes (Node D) are macro-conditions (Node A) of a subsequent macro-micro-macro sequence.

[Figure 7 about here.]

Boudon (1979: 167, note 12) mentions that his diagram has been inspired by somewhat earlier work of Hernes' (1976). Hernes (1976: 518) provides another micro-macro diagram, reproduced in Figure 8, with explicit references to the elements of Coleman's diagram again added.

[Figure 8 about here.]

2.3.4 Diekmann's reconstruction of Merton's theory of anomie

In his PhD thesis on dynamic models of social processes, Diekmann (1980: Chapter III.1) provided a dynamic version of Merton's theory of anomie. He distinguished between a

macro- and a micro-version of the theory and argued that both versions could be "integrated" (Diekmann 1980: 72) by connecting the variables on both levels through empirical as well as analytical relations (definitions). He summarized his reconstruction with the diagram depicted in Figure 9, clearly another predecessor of Coleman's model for micro-macro links.

[Figure 9 about here.]

3. Formal model building and empirical research

We presented heuristic devices that, due to their simplicity, "hide" that full-fledged micro-macro models typically comprise a sizeable number of possibly complex assumptions and that the core issue of model building is precisely to identify implications of those assumptions for micro- and, more particularly, macro-outcomes, including macro-regularities. Also, it has been argued that deriving macro-implications from micro-assumptions as well as bridge assumptions and transformation rules that link micro- and macro-levels can be a non-trivial task. Therefore, formal building or at least the formalization of certain assumptions of micro-macro models can be helpful. An early version of this argument can be found already in Coleman's *Introduction to Mathematical Sociology* and more specifically in his discussion of "synthetic theories" (Coleman 1964b: Chapters 1.4 and 18). The major aim of synthetic theories is to identify the consequences of a set of assumptions and more precisely to identify consequences on the macro-level for a set of assumptions on the micro-level: "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 1964b: 41).

In structural individualism, authors like Ziegler (1972) and Hummell (1973) have elaborated the rationale for formal micro-macro models. They argue that formal theoretical models not only allow, for example, to identify assumptions that are actually used in deriving certain conclusions and that all too often remain implicit in purely informal accounts. Based on detailed "case studies" with careful and systematic formal reconstructions of micro-macro models, their core claim is, rather, that formal model building is often a necessary condition to be at all able to derive macro-consequences from micro-assumptions. The title of Hummell's study refers to "methodological individualism, structural effects, and consequences for social systems", aptly summarizing Coleman's diagram, with "methodological individualism" quite obviously related to Arrow 2, "structural effects" related to bridge assumptions (Arrow 1), and "consequences for social systems" related to transformation rules (Arrow 3). This title clearly indicates the core idea that formal model building is precisely useful for making sure that micro-macro models allow for deriving implications on the macro-level, often including at first sight counterintuitive implications. Hummell's (1973: 66) remark that, from the perspective of methodological individualism, sociology should not be equated with (social) psychology but rather with "social psychology plus mathematics" is provocative and invites misunderstandings (as Hummell acknowledges) but sharply conveys the core idea, provided one conceives of "social psychology" broadly enough so that it includes a broad range of theories of individual behavior on the micro-level, thus not exclusively theories commonly associated with psychology as a discipline, and if it likewise includes assumptions on social conditions and interdependencies between actors.

The issue that deriving macro-implications from micro-assumptions is often a demanding task and a key element of serious micro-macro modeling is related to the idea of keeping micro-assumptions as simple as possible (see Section 1) and can justify, at least as long as conflicts with other aims of theory construction can be avoided, to use micro-assumptions that readily allow for formal model building and thus facilitate the derivation of consequences at the macro-level. This has been seen (e.g., Coleman 1987b) as a good reason

for using rigorous and parsimonious rational choice assumptions on the micro-level. At the same time, then, the issue of empirical adequacy of such assumptions emerges, certainly in light of quite some empirical evidence, including empirical regularities from many experimental studies, that are hard to reconcile with standard rational choice models. One can then try to argue, for example, that empirically more adequate micro-level assumptions than standard rational choice assumptions will not yield relevant new macro-level implications or one can try to develop alternative and empirically better corroborated micro-level assumptions that likewise do allow for deriving relevant macro-implications (see Raub et al. 2011: 15–17 for further discussion and references; note that influential developments in structural individualism since the 1980s include attempts to develop alternative micro-level theories for micro-macro models such as Esser's 1996 framing model and Lindenberg's 2001 theory of social rationality).[9]

Coleman sometimes (e.g., 1986b) argued that micro-macro models can contribute to a better integration of theory and empirical research in sociology. His own contributions to empirical research in very diverse fields of sociology as well as to the methodology of empirical research and statistical modeling are outstanding but it has been observed (e.g., Heckman and Neal 1996) that much of his theoretical and his empirical work developed without systematic mutual influence. In principle, formal model building, rather than hampering empirical research (see, for example, Green and Shapiro 1994 for arguments that formal model building using rational choice assumptions has been associated with weak links between theory and empirical research), should be helpful in improving the integration of theoretical micro-macro models and empirical research in sociology. This is possible precisely due to the fact that such integration requires that propositions on macro-level phenomena do follow from micro-level assumptions and that formal model building often helps or is even necessary to establish macro-level implications of micro-level assumptions. This applies to the situation where one starts with a micro-macro model and derives new testable macro-implications. It applies as well to the case Goldthorpe (2000, 2016; see also Billari 2015) envisages in his arguments for a sociological alliance between quantitative analysis of large-scale data sets and theoretical micro-macro models, namely, systematic empirical research has established a macro-outcome or a macro-regularity and one subsequently shows that such macro-phenomena can be explained using a micro-macro model. In fact, progress is being made in better integrating micro-macro models and mainstream empirical research (see Wittek, Snijders and Nee 2013 as well as various contributions in Hedström and Bearman 2009 for indications in this direction).

4. Conclusion

It is beyond doubt that Coleman was aware of structural individualism in European sociology and was also aware of at least some of the predecessors of his diagram, certainly Lindenberg's model. Over a long period, he had frequent and regular contacts – lectures, conferences, workshops, and otherwise – with leading figures pushing structural individualism in Europe. To mention just two examples, one of his programmatic papers (Coleman 1986a) appeared in a volume that he co-edited with Lindenberg (Lindenberg, Coleman and Nowak 1986), based on a conference at the University of Chicago in 1983 (note that one of the discussions included in the volume, the discussion of Coleman's own conference contribution, includes an exchange between Lindenberg and Coleman, with

[9] Diekmann's VOD is an example for cases showing that alternative micro-level assumptions, i.e., alternatives to the assumption of Nash equilibrium behavior, do yield new macro-implications (see already Diekmann 1985 and more recently Tutić 2014). Note that this implies that in the VOD the group size effect on the macro-level is *not* "microrealization robust" in the sense of List and Spiekermann (2013).

Lindenberg explicitly mentioning the "problem of transformation", Lindenberg et al. 1996: 364). Another programmatic paper (Coleman 1987a) appeared in a volume based on a 1984 conference, likewise comprising a programmatic paper by Wippler and Lindenberg (1987) on Lindenberg's model.[10] It is beyond doubt, too, that Coleman respected theoretical and empirical work that was being done in structural individualism. In fact, he referred to that work (see, e.g., references in *Foundations of Social Theory*). Why, then, as far as we know, did he never refer to the predecessors of his diagram? Coleman's most specific suggestion we could spot that there have been such predecessors is a casual remark, without any reference, in one of his programmatic papers (Coleman 1986b: 1321): "This micro-macro problem is sometimes called by European sociologists the problem of transformation." Why?

Answers to these questions are necessarily speculative. We guess that Coleman knew better than others the difference between a heuristic device and a full-fledged model that includes an explicit set of assumptions together with theorems spelling out the assumptions' implications (not to forget the proofs of such theorems). He was thus well aware of the fact that his diagram, just like its predecessors, was a heuristic and didactic tool, not more, and was not a micro-macro model as such. Why, thus, pay explicit attention to predecessors? Still, a reference every now and then might have been useful. And, we believe, putting Coleman's diagram in some perspective is worth the effort, if only because of its later prominence that might have come as somewhat of a surprise for Coleman himself.

Postscript

Andreas Diekmann has made important contributions to micro-macro modelling and structural individualism. This includes his own predecessor of Coleman's diagram, about four years ahead of Coleman's version. It of course includes his influential textbooks (Diekmann 2007, 2013) that help to train students so that they can do rigorous sociology rather than produce "teutonischer Tiefsinn" devoid of empirical content or empirical research that lacks sound theory. He has contributed thorough theoretical work, often in the form of micro-macro modelling and including formal model building (the VOD model is a fine and meanwhile classic example) and careful empirical studies employing observational as well as experimental designs and data. Both his theoretical and his empirical work cover a broad range of very different fields in sociology. Moreover, we owe him seminal contributions to methods of empirical research and statistical modelling. In all these respects, a certain similarity with Coleman's work cannot be overlooked. Perhaps more so than Coleman, he has likewise succeeded in contributing to the *integration* of systematic theory construction, empirical research and statistical modelling, building on foundations that have been laid by Coleman but also building on seminal ideas for such an integration put forward in an early phase of structural individualism by European authors such as Opp, Hummell, and Ziegler, to mention only those leading proponents of structural individualism who might have influenced him most in the formative phase of his academic career.

[10] Lindenberg (personal communication January 30, 2016) remembers discussions with Coleman on the Lindenberg 1977-paper and on McClelland's diagram at a number of conferences in Germany and the Netherlands in 1980 and 1981. He also remembers Coleman's interest in the topic. Barbera (2006: 44n15) provides a related account. Seemingly through informal channels and personal communication, some European sociologists became aware of the story: Abell (1996) mentions the "Coleman-Lindenberg diagram," although without reference to Lindenberg (1977) or other papers by Lindenberg that comprise his model. See also Manzo (2007: n14) for remarks on the diagrams and references to Barbera (2006). Manzo (personal communication) knew of the background through his mentor Boudon.

References

Abell, Peter. 1996. “Sociological theory and rational choice theory.” Pp. 223–244 in *The Blackwell Companion to Social Theory*, edited by Bryan S. Turner. Oxford: Blackwell.

Albert, Hans. 1967. *Marktsoziologie und Entscheidungslogik [The Sociology of Markets and the Logic of Decision]*. Neuwied: Luchterhand.

Albert, Hans. 1968. *Traktat über kritische Vernunft [Tract on Critical Reason]*. Tübingen: Mohr.

Albert, Hans. 1977. “Individuelles Handeln und soziale Steuerung. Die ökonomische Tradition und ihr Erkenntnisprogramm [Individual action and social steering. The economic tradition and its research program].” Pp. 177–225 in *Handlungstheorien – interdisziplinär IV: Sozialwissenschaftliche Handlungstheorien und spezielle systemwissenschaftliche Ansätze*, edited by Hans Lenk. München: Fink.

Alexander, Jeffrey C., Bernhard Giesen, Richard Münch, and Neil J. Smelser, eds. 1987. *The Micro-Macro Link*. Berkeley, CA: University of California Press.

Barbera, Filippo. 2006. “A star is born? The authors, principles and objectives of analytical sociology.” *Revista de Sociologia* 80: 31–50.

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

Berger, Joël, and Andreas Diekmann. 2015. “The logic of relative frustration: Boudon’s competition model and experimental evidence.” *European Sociological Review* 31(6): 725–737.

Billari, Francesco C. 2015. “Integrating macro- and micro-level approaches in the explanation of population change.” *Population Studies* 69(S1): S11–S20.

Blau, Peter M. 1964. *Exchange and Power in Social Life*. New York: Wiley.

Bohnen, Alfred. 1975. *Individualismus und Gesellschaftstheorie [Individualism and Social Theory]*. Tübingen: Mohr.

Boudon, Raymond. 1974. *Education, Opportunity, and Social Inequality*. New York: Wiley.

Boudon, Raymond. 1977. *Effets pervers et ordre social*. Paris: PUF. English translation: *The Unintended Consequences of Social Action*. London: Macmillan 1982.

Boudon, Raymond. 1979. *La logique du social*. Paris: Hachette. English translation: *The Logic of Social Action*. London: Routledge 1981.

Brüderl, Josef. 2004. “Die Überprüfung von Rational-Choice-Modellen mit Umfragedaten [Testing Rational Choice models with survey data].” Pp. 163–180 in *Rational-Choice-Theorie in den Sozialwissenschaften. Anwendungen und Probleme. Rolf Ziegler zu Ehren*, edited by Andreas Diekmann and Thomas Voss. München: Oldenbourg.

Camerer, Colin F. 2003. *Behavioral Game Theory. Experiments in Strategic Interaction*. New York: Russell Sage.

Clark, Jon, ed. 1996. *James S. Coleman*. London: Falmer Press.

Coleman, James S. 1964a. “Collective decisions.” *Sociological Inquiry* 34(Spring): 166–181.

Coleman, James S. 1964b. *Introduction to Mathematical Sociology*. New York: Free Press.

Coleman, James S. 1973. *The Mathematics of Collective Decisions*. London: Heinemann.

Coleman, James S. 1984. “Micro foundations and macrosocial behavior.” *Angewandte Sozialforschung* 12(1/2): 25–37.

Coleman, James S. 1986a. “Micro foundations and macrosocial theory.” Pp. 345–363 in *Approaches to Social Theory*, edited by Siegwart Lindenberg, James S. Coleman, and Stefan Nowak. New York: Russell Sage.

Coleman, James S. 1986b. “Social theory, social research, and a theory of action.” *American Journal of Sociology* 91(6): 1309–1335.

Coleman, James S. 1987a. “Microfoundations and macrosocial behavior.” Pp. 153–73 in *The Micro-Macro Link*, edited by Jeffrey C. Alexander, Bernhard Giesen, Richard Münch, and Neil J. Smelser. Berkeley, CA: University of California Press.

Coleman, James S. 1987b. “Psychological structure and social structure in economic models.” Pp. 181–185 in *Rational Choice. The Contrast between Economics and Psychology*, edited by Robin M. Hogarth and Melvin W. Reder. Chicago, IL: University of Chicago Press.

Coleman, James S. 1990. *Foundations of Social Theory*. Cambridge, MA: Belknap Press of Harvard University Press.

Darley, John M., and Bibb Latané. 1968. “Bystander intervention in emergencies: Diffusion of responsibility.” *Journal of Personality and Social Psychology* 8(4): 377–383.

Diekmann, Andreas. 1980. *Dynamische Modelle sozialer Prozesse [Dynamic Models of Social Processes]*. München: Oldenbourg.

Diekmann, Andreas. 1985. “Volunteer’s dilemma.” *Journal of Conflict Resolution* 29(4): 605–610.

Diekmann, Andreas. 1993. “Cooperation in an asymmetric volunteer’s dilemma game. Theory and experimental evidence.” *International Journal of Game Theory* 22: 75–85.

Diekmann, Andreas. 2007. *Empirische Sozialforschung. Grundlagen, Methoden, Anwendungen [Empirical Social Research. Foundations, Methods, Applications]*. 23rd and 7th enlarged ed., Reinbek: Rowohlt (1st ed. 1995).

Diekmann, Andreas. 2013. *Spieltheorie. Einführung, Beispiele, Experimente [Game Theory. Introduction, Examples, Experiments]*. 3rd ed., Reinbek: Rowohlt (1st ed. 2009).

Diekmann, Andreas, and Thomas Voss. 2004. “Die Theorie rationalen Handelns. Stand und Perspektiven [The theory of rational action. State of the art and perspectives].” Pp. 13–29 in *Rational Choice Theorie in den Sozialwissenschaften. Probleme und Perspektiven. Rolf Ziegler zu Ehren*, edited by Andreas Diekmann and Thomas Voss. München: Oldenbourg.

Diekmann, Andreas, and Thomas Voss. 2016. “Rational Choice-Rezeption in der deutschsprachigen Soziologie [Rational Choice in sociology in Germany, Austria, and Switserland].” Forthcoming in *Handbuch Geschichte der deutschsprachigen Soziologie*, edited by Stephan Moebius and Andrea Ploder. Wiesbaden: Springer.

Esser, Hartmut. 1993. *Soziologie: Allgemeine Grundlagen [Sociology: General Foundations]*. Frankfurt a.M.: Campus.

Esser, Hartmut. 1996. “Die Definition der Situation [The definition of the situation].” *Kölner Zeitschrift für Soziologie und Sozialpsychologie* 48(1): 1–34.

Goldthorpe, John. 2000. “The quantitative analysis of large-scale data sets and rational action theory: for a sociological alliance.” Pp. 94–114 in John Goldthorpe, *On Sociology*. Oxford: Oxford University Press.

Goldthorpe, John. 2016. *Sociology as a Population Science*. Cambridge: Cambridge University Press.

Green, Donald P., and I. Shapiro. 1994. *Pathologies of Rational Choice Theory*. New Haven, CN: Yale University Press.

Heckman, James J., and Derek Neal. 1996. “Coleman’s contribution to education: Theory, research styles and empirical research.” Pp. 81–102 in *James S. Coleman*, edited by Jon Clark. London: Falmer Press.

Hedström, Peter. 2005. *Dissecting the Social. On the Principles of Analytical Sociology*. Cambridge: Cambridge University Press.

Hedström, Peter, and Peter Bearman, eds. 2009. *The Oxford Handbook of Analytical Sociology*. Oxford: Oxford University Press.

Hedström, Peter, and Lars Udehn. 2009. “Analytical sociology and theories of the middle range.” Pp. 25–47 in *The Oxford Handbook of Analytical Sociology*, edited by Peter Hedström and Peter Bearman Oxford: Oxford University Press.
Heifetz, Aviad. 2012. *Game Theory: Interactive Strategies in Economics and Management*. Cambridge: Cambridge University Press.
Hempel, Carl G. 1965. *Aspects of Scientific Explanation*. New York: Free Press.
Hernes, Gudmund. 1976. “Structural change in social processes.” *American Journal of Sociology* 82(3): 513–547.
Homans, George C. 1958. “Social behavior as exchange.” *American Journal of Sociology* 63(6): 597–606.
Homans, George C. 1961. *Social Behavior. Its Elementary Forms*. New York: Harcourt.
Homans, George C. 1974. *Social Behavior. Its Elementary Forms*. Rev. ed., New York: Harcourt.
Hummell, Hans J. 1969. “Psychologische Ansätze zu einer Theorie sozialen Verhaltens [Psychological approaches to a theory of social behavior].” Pp. 157–277 in *Handbuch der empirischen Sozialforschung*, Vol. II, edited by René König. Stuttgart: Enke.
Hummell, Hans J. 1973. “Methodologischer Individualismus, Struktureffekte und Systemkonsequenzen [Methodological individualism, structural effects, and system level consequences].” Pp. 61–134 in *Probleme der Erklärung sozialer Prozesse II: Soziales Verhalten und soziale Systeme*, edited by Karl-Dieter Opp and Hans J. Hummell. Frankfurt a.M.: Athenäum.
Hummell, Hans J., and Karl-Dieter Opp. 1968. “Sociology without sociology. The reduction of sociology to psychology: A program, a test, and the theoretical relevance.” *Inquiry* 11: 205–226.
Hummell, Hans J., and Karl-Dieter Opp (1971). *Die Reduzierbarkeit von Soziologie auf Psychologie. Eine These, ihr Test und ihre theoretische Bedeutung [The Reducibility of Sociology to Psychology. A Thesis, Its Test, and Its Theoretical Relevance]*. Braunschweig: Vieweg.
Lakatos, Imre. 1970. “Falsification and the Methodology of Scientific Research Programmes.” Pp. 91–196 in *Criticism and the Growth of Knowledge*, edited by Imre Lakatos and Alan Musgrave. Cambridge: Cambridge University Press.
Lindenberg, Siegwart. 1976. “De struktuur van theorieën van collectieve verschijnselen [The structure of theories of collective phenomena].” Pp. 1–20 in *Gedrag en struktuur*, edited by Wil Aarts, Siegwart Lindenberg, and Reinhard Wippler. Rotterdam: Universitaire Pers Rotterdam.
Lindenberg, Siegwart. 1977. “Individuelle Effekte, kollektive Phänomene und das Problem der Transformation [Individual effects, collective phenomena, and the problem of transformation].” Pp. 46–84 in *Probleme der Erklärung sozialen Verhaltens*, edited by Klaus Eichner and Werner Habermehl. Meisenheim a.G.: Hain.
Lindenberg, Siegwart. 1981. “Erklärung als Modellbau [Explanation as model building].” Pp. 20–35 in *Soziologie in der Gesellschaft*, edited by Werner Schulte. Bremen: Zentraldruckerei der Universität.
Lindenberg, Siegwart. 1992. “The method of decreasing abstraction.” Pp. 3–20 in *Rational Choice Theory. Advocacy and Critique*, edited by James S. Coleman and Thomas J. Fararo. Newbury Park, CA: Sage.
Lindenberg, Siegwart. 2001. “Social rationality versus rational egoism.” Pp. 635–668 in *Handbook of Sociological Theory*, edited by Jonathan H. Turner. New York: Kluwer.
Lindenberg, Siegwart, James S. Coleman, and Stefan Nowak. 1986. *Approaches to Social Theory*. New York: Russell Sage.

Lindenberg, Siegwart, and Reinhard Wippler. 1978. “Theorienvergleich: Elemente der Rekonstruktion [Comparing theories: Elements for reconstruction].” Pp. 219–231 in *Theorienvergleich in den Sozialwissenschaften*, edited by Karl-Otto Hondrich and Joachim Matthes. Darmstadt: Luchterhand.

List, Christian, and Kai Spiekermann. 2013. “Methodological individualism and holism in political science: A reconciliation.” *American Political Science Review* 107(4): 629–643.

Little, Daniel. 2012. “Explanatory autonomy and Coleman’s boat.” *Theoria* 74: 137–151.

Macy, Michael W., and Andreas Flache. 2009. “Social dynamics from the bottom up. Agent-based models of social interaction.” Pp. 245–268 in *The Oxford Handbook of Analytical Sociology*, edited by Peter Hedström and Peter Bearman. Oxford: Oxford University Press.

Manzo, Gianluca. 2007. “Progrès et ‘urgence’ de la modélisation en sociologie. du concept de ‘modèle générateur’ et de sa mise en Œuvre.” *L’Année Sociologique* 57(1): 13–61. English translation “The progress and ‘urgency’ of modeling in sociology. The concept of ‘generative model’ and its implementation” available on the journal’s website.

McClelland, David C. 1961. *The Achieving Society*. New York: Free Press.

Merton, Robert K. 1957. *Social Theory and Social Structure*. Revised and enlarged ed., Glencoe, IL: Free Press.

Merton, Robert K. 1973. *The Sociology of Science*. Chicago, IL: University of Chicago Press.

Nagel, Ernest. 1961. *The Structure of Science*, London: Routledge.

Olson, Mancur. 1971. *The Logic of Collective Action*. 2nd ed., Cambridge, MA: Harvard University Press.

O’Neill, John, ed. 1973. *Modes of Individualism and Collectivism*. London: Heinemann.

Opp, Karl-Dieter. 1972. *Verhaltenstheoretische Soziologie [Behavioral Sociology]*. Reinbek: Rowohlt.

Opp, Karl-Dieter. 1978. *Theorie sozialer Krisen [Theory of Social Crises]*. Hamburg: Hoffmann & Campe.

Opp, Karl-Dieter. 1979. *Individualistische Sozialwissenschaft [Individualistic Social Science]*. Stuttgart: Enke.

Opp, Karl-Dieter. 2009. “Modeling micro-macro relationships: Problems and solutions.” *Journal of Mathematical Sociology* 35(1–3): 209–234.

Opp, Karl-Dieter. 2011. “Das individualistische Erklärungsprogramm in der Soziologie. Entwicklung, Stand und Probleme [The individualistic research program in sociology. Development, present state, and problems].” *Zeitschrift für Soziologie* 38(1): 26–47.

Opp, Karl-Dieter. 2014. “Das Aggregationsproblem bei Mikro-Makro-Erklärungen [The problem of aggregation in micro-macro explanations].” *Kölner Zeitschrift für Soziologie und Sozialpsychologie* 66(Supplement): 155–188.

Popper, Karl. 1934. *Logik der Forschung*. 5th ed. Tübingen: Mohr. English translation: *The Logic of Scientific Discovery*. London: Routledge 1992.

Popper, Karl. 1963. *Conjectures and Refutations*. London: Routledge.

Raub, Werner. 1984. *Rationale Akteure, institutionelle Regelungen und Interdependenzen [Rational Actors, Institutional Rules, and Interdependencies]*. Frankfurt a.M: Lang.

Raub, Werner, Vincent Buskens, and Marcel A.L.M. van Assen. 2011. “Micro-macro links and microfoundations in sociology.” *Journal of Mathematical Sociology* 35(1–3): 1–25.

Raub, Werner, and Thomas Voss. 1981. *Individuelles Handeln und gesellschaftliche Folgen [Individual Actions and Societal Level Implications]*. Darmstadt: Luchterhand.

Sandler, Todd. 1992. *Collective Action*. Ann Arbor, MI: University of Michigan Press.

Stigler, Stephen M. 1999. “Stigler’s Law of Eponymy.” Pp. 277–290 in: *Statistics on the Table*. Cambridge, MA: Harvard University Press.

Tutić, Andreas. 2014. “Procedurally rational volunteers.” *Journal of Mathematical Sociology* 38(3): 219–232.
Udehn, Lars. 2001. *Methodological Individualism*. London: Routledge.
Vanberg, Viktor. 1975. *Die zwei Soziologien. Individualismus und Kollektivismus in der Sozialtheorie [The Two Sociologies. Individualism and Collectivism in Social Theory]*. Tübingen: Mohr.
Voss, Thomas. 2016. “Methodologischer Individualismus: Reduktion oder Direkterklärung? [Methodological individualism: Reduction or explanation?]” Forthcoming in *Reduktionismus und Soziologie*, edited by Gerhard Wagner and Kai Müller.
Weesie, Jeroen. 1993. “Asymmetry and timing in the Volunteer’s Dilemma.” *Journal of Conflict Resolution* 37(3): 569–590.
Wippler, Reinhard. 1978. “The structural-individualistic approach in Dutch sociology: Toward an explanatory social science.” *Netherlands Journal of Sociology* 14(2): 135–155.
Wippler, Reinhard. 1985. “Explanatory sociology: The development of a theoretically oriented research programme.” *Netherlands Journal of Sociology* 21(2): 63–74.
Wippler, Reinhard, and Siegwart Lindenberg. 1987. “Collective phenomena and rational choice.” Pp. 135–152 in *The Micro-Macro Link*, edited by Jeffrey C. Alexander, Bernhard Giesen, Richard Münch, and Neil J. Smelser. Berkeley, CA: University of California Press.
Wittek, Rafael, Tom A.B. Snijders, and Victor Nee, eds. 2013. *Handbook of Rational Choice Social Research*. Stanford, CA: Stanford University Press.
Wright, Georg Henrik von. 1971. *Explanation and Understanding*. London: Routledge.
Ziegler, Rolf. 1972. *Theorie und Modell [Theory and Model]*. München: Oldenbourg.

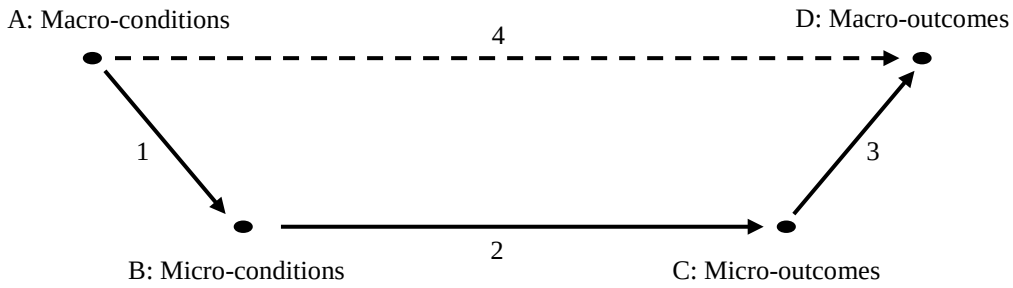


Figure 1 Coleman's diagram.

	Number of other actors choosing CONTR				
	0	1	2	…	$N-1$
CONTR	$U-K$	$U-K$	$U-K$	…	$U-K$
DON'T	0	U	U	…	U

Figure 2 Diekmann's (1985) Volunteer's Dilemma ($U > K > 0$; $N \geq 2$).

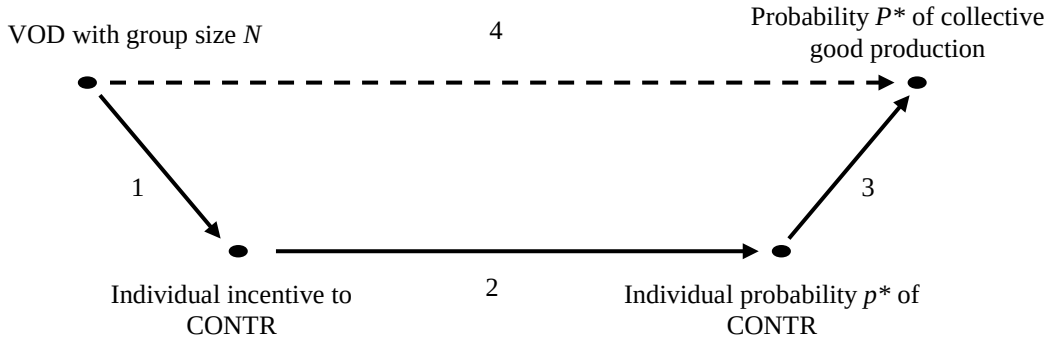
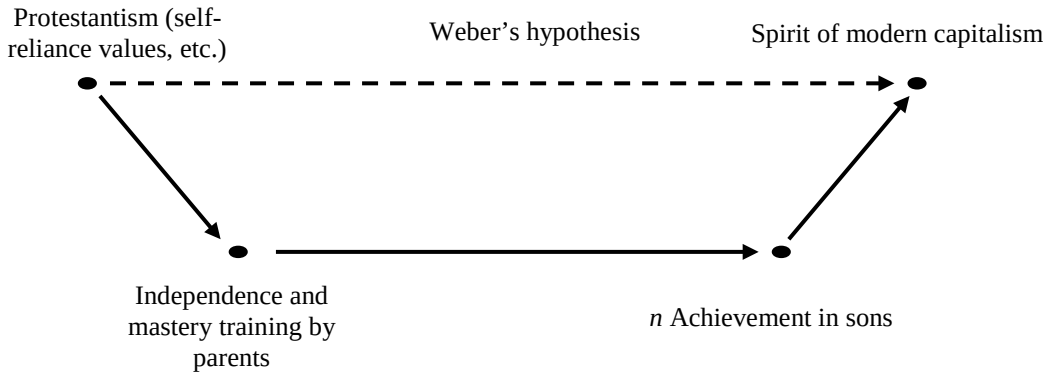
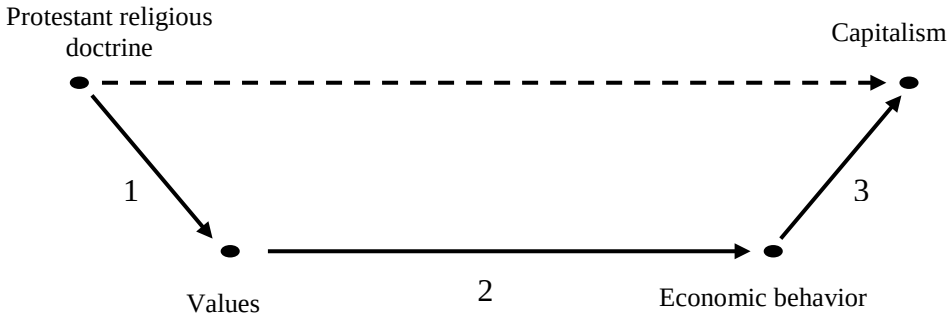


Figure 3 Micro-macro diagram for Diekmann's Volunteer's Dilemma.



Panel a McClelland's (1961: 47) diagram.



Panel b Coleman's (1990: 8) version.

Figure 4 Micro-macro diagrams for Weber's thesis.

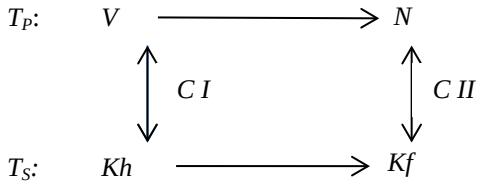


Figure 5 Opp and Hummell's (1971: 15) diagram.

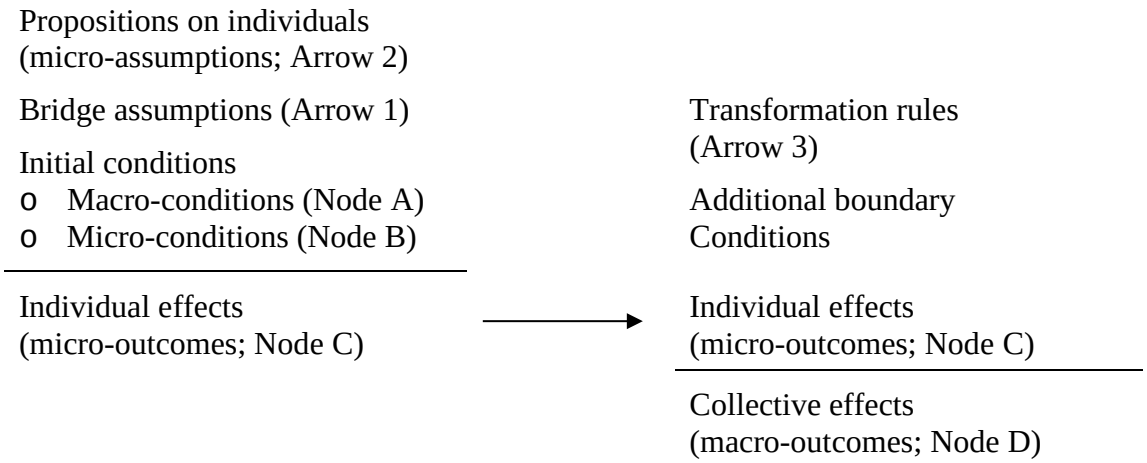


Figure 6 Lindenberg's (1976, 1977) model (including references to the related nodes and arrows in Coleman's diagram).

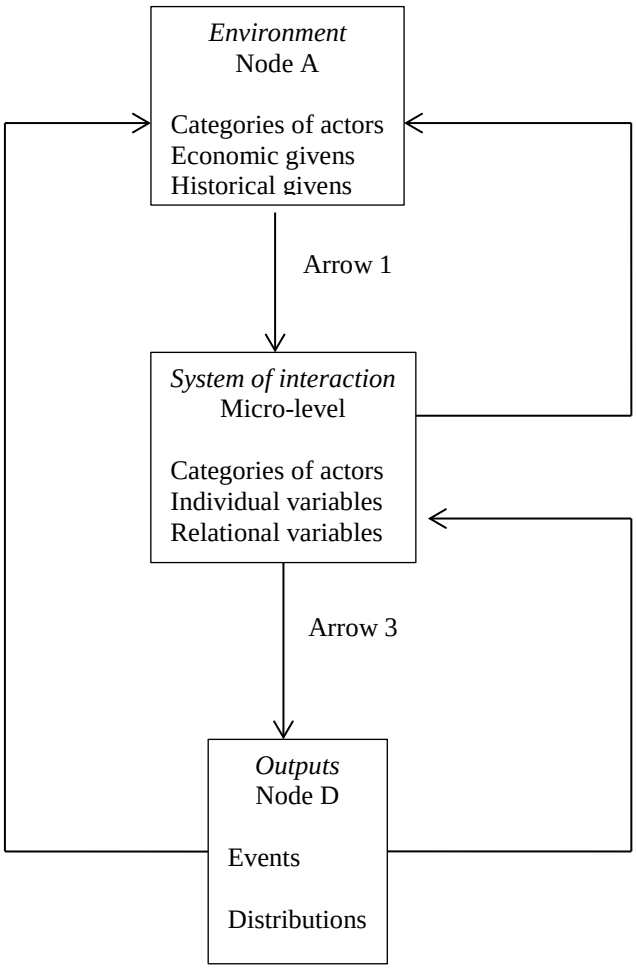


Figure 7 Boudon's (1979: 148, 1981: 95) diagram for social processes (including references to related elements in Coleman's diagram).

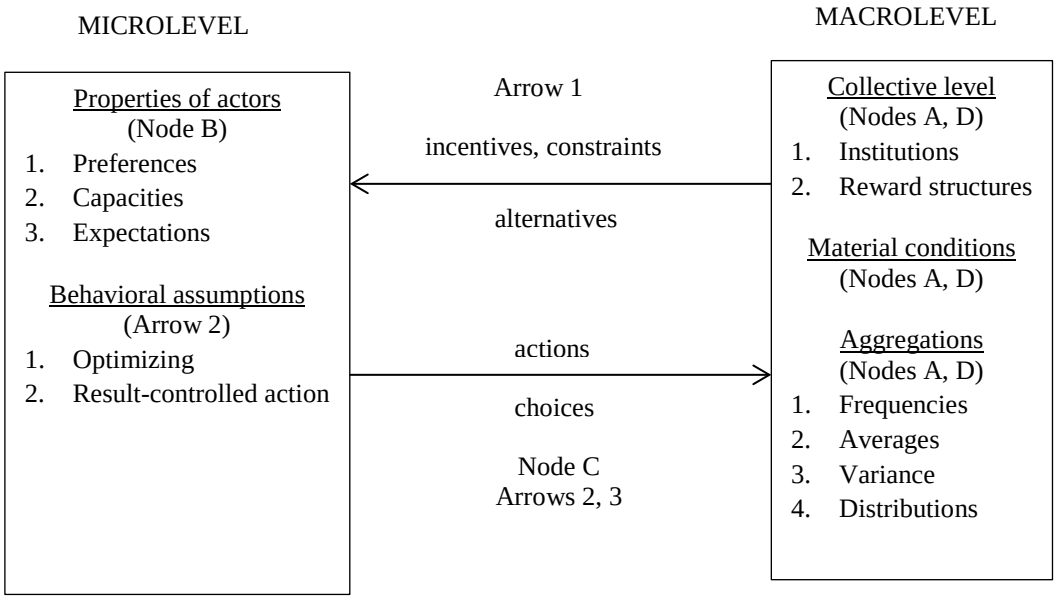
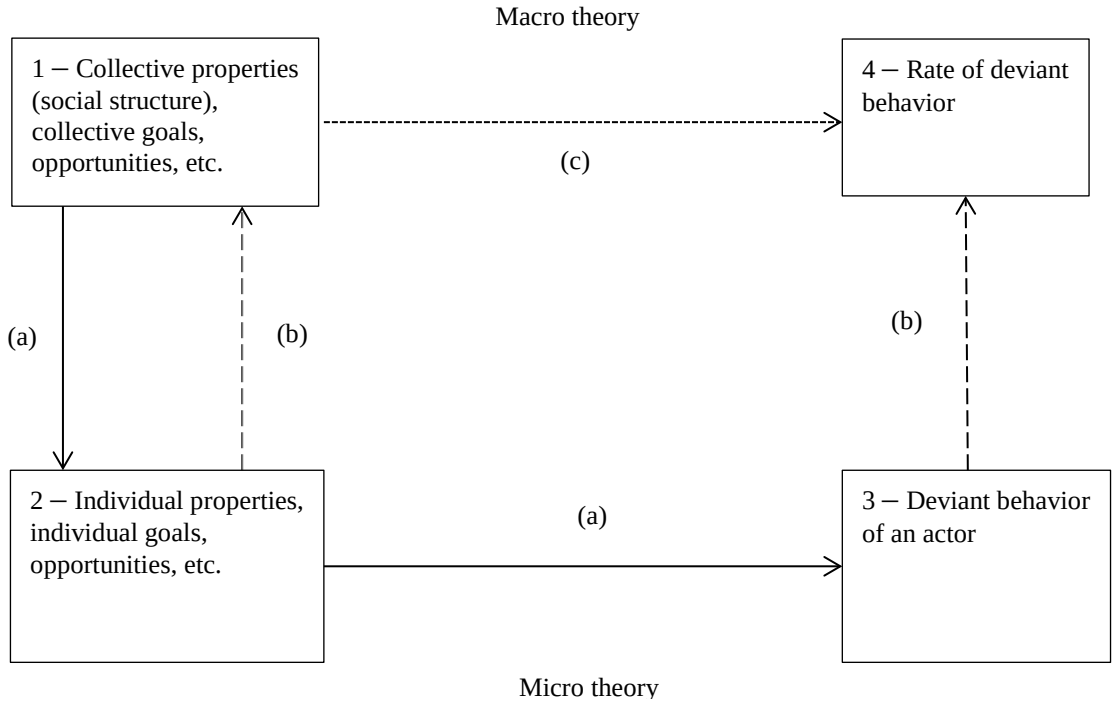


Figure 8 Hernes' (1976: 518) diagram for the relation between micro and macro-level (including references to related elements in Coleman's diagram).



(a): empirical relation; (b) aggregation (analytical relation); (c) indirect empirical relation

Figure 9 Diekmann's (1980: 73) reconstruction of Merton's theory of anomie.