



A theory and dynamic model of dyadic interaction: Concerns, appraisals, and contagiousness in a developmental context [☆]

Henderien W. Steenbeek ^{*}, Paul L.C. van Geert

Department of Clinical and Developmental Psychology, University of Groningen, Grote Kruisstraat 211, 9712 TS, Groningen, The Netherlands

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Abstract

A theory of the dynamics of dyadic interaction is presented, based on the concepts of “concern” (i.e., intentions, goals, and interests), “appraisal” and “contagiousness”. Differences between children who participate in a specific interaction are linked to differences in social competence and social power. An overview is given of the social psychological underpinnings of these concepts and of their developmental trajectories. The theory is transformed into a mathematical, dynamic systems model of dyadic interaction. The model describes the time evolution of an “involvement” variable, which is defined as “the number of actions of an individual that are explicitly aimed at the interaction partner”. In order to illustrate the veracity and applicability of the mathematical model, an empirical study is described that applies the model to a dyadic play situation in children of different sociometric statuses. Most of the predictions generated by the model are verified. The conclusion addresses, among others, the use of dynamic systems models in the study of social development and a number of applied issues. A final point concerns the necessity of coupling models of short-term dynamics, such as the one presented in the current article, with models of long-term dynamics, i.e., of developmental change.

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^{*} Corresponding author.

E-mail address: H.W.Steenbeek@rug.nl (H.W. Steenbeek).

Introduction

To entertain pleasurable and prosocial interactions with other people is a main concern of psychologically healthy people, irrespective of age. There exists a wide range of social interactions that are of great importance to psychological well-being and that are neither as intensive and deep as the interaction with persons to whom we feel deeply attached, nor as shallow, neutral and casual as interactions with relative strangers that we occasionally meet. Social interaction implies change over the short-term of a concrete interaction and over the long-term of development across childhood and adolescence (e.g., short- and long-term change in the intensity, quality, and nature of the interaction). How can this change be explained? Children, for instance, learn and practice interaction skills (the long-term change) during concrete peer interactions (the short-term change). These skills help them to establish pleasurable interactions with others that are of crucial importance for their social, cognitive, and emotional development (Harris, 1995; Hartup & Laursen, 1999; Kindermann, 2003; Ladd, 1989; Lease, Musgrove, & Axelrod, 2002; Reis, Collins, & Berscheid, 2000; Rubin, Bukowski, Parker, & Damon, 1998). In the course of childhood, children develop an increasing concern to interact with peers, and specific peers in particular (Adler & Adler, 1998; Parker & Gottman, 1989). That is, in terms of interaction preference, some peers occupy a higher social position in a group. This position is commonly referred to by the term “sociometric status”. This sociometric status is attributed to the child by members of the group (Coie, Dodge, & Kupersmidt, 1990). Interaction patterns and sociometric status are related. For instance, children who develop social skills that lead to less adequate interaction patterns run the risk of receiving a rejected sociometric status in the class (Asher & Coie, 1990).

An extensive body of literature exists that, in addition to presenting all sorts of nuances, basically reports an association between adequate and emotionally positive interaction patterns with high social status on the one hand, and less or inadequate and emotionally negative interaction patterns with rejected status on the other hand (Asher, 1983; Asher & Parker, 1989; Black & Hazen, 1990; Black & Logan, 1995; Cirino & Beck, 1991; Denham, McKinley, & Couchoud, 1990; Eisenberg & Fabes, 1995; Eisenberg et al., 1993; Gottman, Gonso, & Rasmussen, 1975; Hazen & Black, 1989; Hubbard, 2001; Markell & Asher, 1984; Masters & Furman, 1981; Miller & Olson, 2000; Newcomb, Bukowski, & Pattee, 1993; Rose-Krasnor, 1997; Rubin et al., 1998).

Although the studies from the above-mentioned literature are certainly relevant, there are nevertheless two comments that can be made. The first comment is that these studies implicitly treat interaction skills as abilities of the children themselves, and not as abilities that emerge in the interaction of the child with its environmental context. In their study of skills of emotion regulation, Gottman, Guralnick, Wilson, Swanson, and Murray (1997) posit that what is missing in many studies is a focus on “a variety of settings provided in the child’s peer world as sources of the development of (emotion regulation) abilities” (p. 423). The authors proceed by remarking that “children may not be able to select these settings, . . . and so it may be incumbent upon researchers to uncover the inherent variability in these settings that affect a child’s ability to . . . regulate affect” (p. 423). A similar remark holds for the child’s ability to display particular interaction skills. An important question that results from this viewpoint concerns the variability in peer settings and its effect on the actual interaction skills of children.

A second comment, which is related to the first, is that the aforementioned studies imply an explanatory model that does not explicitly reckon with the actual, real-time processes of interaction. These processes are formed by a mutual action–reaction of the partners, which serves as co-regulated causes of the course and outcome of the iterative real-time interaction process (Fogel, 1993). This point is connected with an important theoretical issue in developmental psychology that we already hinted at, namely the relation between short-term processes (social interaction) and long-term processes (development of relations, social skills, and statuses). We believe that the understanding of the long-term process of development is served by the availability of a model of the short-term processes that these long-term phenomena directly relate to. This model must have the potential to show how short-term events affect the long-term process and vice versa. A model of a short-term process of social interaction must explicitly account for context properties and the reasons for context-specific variation, while nevertheless maintaining a level of generality that allows it to incorporate a great variety of contexts. By doing so, it should allow for considerably more refined, context-specific predictions than those that result from a straightforward generalization of the findings in the literature.

In this article, we present a short-term process model of dyadic interaction, describing interaction as a self-organizing process which is shaped by the iterative interplay between the participants. Note that we confine ourselves to psychological processes within individuals, to individual behavior and to the resulting dyadic interaction between individuals. These elements can be conceived of as the basis of all kinds of interaction processes (see Hinde's model of social complexity, Hinde, 1997a, 1997b). The model focuses on a crucial action category of the individual, for which we have chosen the term "involvement". It refers to a person's actions that are aimed at interacting with another person. If such involvement actions are adequately reciprocated by the other person, "real", coherent interaction results. Involvement is defined as a macroscopic variable that aggregates over instrumental behaviors, for instance a child approaching his interaction partner verbally or non-verbally, and over approach-related emotional expressions, such as smiles and laughter.

In the current article, we view the reciprocal interaction as a result of the involvement that individuals introduce in the dyadic contact. Thus, we use the term "involvement" as a term referring to an individual's social approach actions, and "interaction" as a term that refers to the reciprocal coupling of such individual actions. Our aim is to develop this model with regard to children in the age range of primary school, which is when the social skills and preference for specific interaction partners become increasingly important.

First, in this article we will argue that the "involvement" of a child emerges from the confluence of various dynamic forces, the description of which has been drawn from the social psychological literature on dyadic or direct interaction. One such force consists of the participating children's continuous appraisals of the interactions they have with the interaction partner. These appraisals relate to concerns, interests or preferences. A second force consists of the automatic and largely unconscious tendency to bridge the difference between one's own actions and the actions of the social interaction partner, which amounts to a form of imitation. Models that focus on such dynamic forces and on how they drive the course of interaction processes, are, almost by definition, dynamic systems models. In the broad sense, a dynamic system can be defined as "... a means of describing how one state develops into another state over the course of time" (Weisstein, 1999, p. 501; see Howe & Lewis, 2005; Van Geert & Steenbeek, 2005; for a more general account related

to development). In the present article, the states at issue are states of interaction, for instance specified by the intensity of a participant's "involvement" at a particular moment in time. A dynamic systems model thus aims at explaining how one "involvement" state changes into a successive state, and how the "involvement" of one participant influences the "involvement" of another.

A recent special issue of *Developmental Review* is entirely devoted to providing overviews of dynamic systems approaches in the field of developmental psychology, with a considerable number of articles addressing social interaction and emotion (Camras & Witherington, 2005; Granic, 2005; Howe & Lewis, 2005; Lewis, 2005; Martin, Fabes, Hanish, & Hollenstein, 2005; Nowak, Vallacher, & Zochowski, 2005; Smith, 2005; Van Geert & Steenbeek, 2005). Finally, it should be noted that within the field of developmental psychology, dynamic systems theory varies between a relatively straightforward application of the elementary definition mentioned above (see for instance Van Geert, 1991, 1994, 1998) to a specific theory of embodied action (Smith, 2005; Thelen & Smith, 1994; see Lewis, 2000; for a discussion).

Second, we will argue that the interaction process is a multi-component system, in which the components 'goal-directedness', 'appraisal', and 'contagiousness' of the interaction partners determine the course of the process in an intertwining way. In addition, the participants' social competence and social power form the most important differential components in the process, due to which differences in interaction processes emerge. Practically speaking, there is hardly any other way to actually understand this intertwining of factors across time than by modeling it in the form of a dynamic, iterative process. As noted earlier, such modeling also provides a good method for generating context-specific, detailed predictions of the properties of a particular type of interaction process.

The model resembles existing dynamic systems models of dyadic interaction (Buder, 1991; Felmlee & Greenberg, 1999; Gottman et al., 1997, Gottman, Murray, Swanson, Tyson, & Swanson, 2002; Nowak et al., 2005; Olthof, Kunnen, & Boom, 2000). For instance, the model of emotion regulation in free play groups of Gottman et al. (1997) takes the form of a system of coupled equations that describe the transformation of the relevant variables over time. In a similar vein, our model uses coupled equations to describe the course of the involvement of the interaction participants. What our model aims to add to the existing models is its explicit combination of appraisal theory on the one hand and recent social psychological theories on the other hand, using components such as concerns, appraisals, and contagiousness.

This article consists of the following parts. First, we present an overview of a theory of dynamic forces and components as announced earlier in this introduction. Second, this theory will then be used to formulate a dynamic model of dyadic interaction, which is cast in the mathematical form of coupled dynamic equations. Third, we illustrate and test the theory and the mathematical model by means of an empirical study, demonstrating how the model can be applied to a concrete interaction process. The empirical example focuses on potential differences in "involvement" related to different sociometric statuses of six to seven year-old children who participate in a dyadic interaction with a classmate during play. The model prediction, corroborated by our empirical findings, is that in this particular play situation, lower-status children will show more involvement than higher-status children, i.e., more action directed towards the other child and more positive expressions. Note that this prediction and the corresponding result differs from findings in the literature (see beginning of this introductory section) that popular children will show more actions

and expressions than rejected children. There is no reason to doubt the literature on this point, but, in line with our first critical remark, it should be cautioned that this conclusion is based on a variety of social contexts and situations and does not in itself tell us how sociometric status interferes in establishing a particular form of involvement with another child in a concrete situation. Finally, in the conclusion we come back to the general issue of why a model of short-term processes is a necessary supplement to a long-term, developmental model.

A general theory of social interaction in a developmental context

The theory that we wish to propose is strongly reminiscent of control theory, framed in the context of dynamic developmental systems and applied to social interaction in particular. Control theory refers to self-regulating purposeful systems that aim at realizing or maintaining a particular desired state (for general accounts, see Carver & Scheier, 1990, 2002; and Powers, 2005; for the original phrasing of this type of theory). In this particular case, the “desired state” refers to satisfactory social interaction, the evaluation of which relies heavily on emotions and emotional appraisals (Carver & Scheier, 1990; Frijda, 1986; Scherer, 1999). The principles that we shall discuss are highly general, but assumed to be essential to any dynamic control system, including young children who wish to establish and maintain a pleasurable short-term dyadic interaction with a particular peer, in a particular context. In each of the forthcoming sections, we will first discuss a particular general principle and then specify its developmental origins.

Goal orientation and intentionality

Goal orientation and intentionality as general principles of (social) behavior

Social behavior is intentional, i.e., aimed at the realization or pursuit of goals or intentions (Austin & Vancouver, 1996; Carver & Scheier, 1990; Powers, 2005). These goals can differ in level of temporal extension and generality (Carver, 1996; Vallacher & Wegner, 2000). From a more general, system-theoretic point of view, goals are equilibrium states, i.e., states of minimal potential energy. Once a system reaches its goal state, its impetus or tendency to change becomes theoretically zero (Ashby, 1966). In the colloquial sense, goals or intentions are often viewed as a person’s deliberate, conscious anticipatory representations of a goal state. However, many if not most of people’s goals or intentions are more or less automatic and immediate, i.e., largely unconscious. They emerge under the control of the context, in the sense that “the environment itself activates and puts the goal into motion” (Bargh & Chartrand, 1999; p. 468; see also Austin & Vancouver, 1996; Bargh & Ferguson, 2000). Goals are co-constructed in the interplay between an organism with specific “effectivities” (skills, habits, possibilities...) and a context with specific “affordances” (Shaw, 2001). Goals self-organize in the context and are macroscopic parameters that play a fundamental causal role in action and behavior (Gibbs & Van Orden, 2003; Juarrero, 2000; Kappas, 2002).

Goal orientation and intentionality in a social-developmental context

According to Piaget and in general the constructivist theorists, children develop an understanding of the goal-directedness of their actions, during the first year of life (Beilin & Fireman, 2000; Flavell, 1999; Piaget, 1936). An understanding of other people as

intentional agents develops roughly around the age of one year (Tomasello, 1995; Tomasello & Rakoczy, 2003; Woodward, Sommerville, & Guajardo, 2001), with precursors of understanding of other people's goal-directed action occurring as early as 6–9 months of age (Gergely & Csibra, 2003; Király, Jovanovic, Prinz, Aschersleben, & Gergely, 2003; Meltzoff, 1995; Woodward, 1998; Woodward, 1999). As a consequence, the intentions of other people are more or less automatically incorporated in the intentional actions of the child himself, which is witnessed by early phenomena such as joint attention and the emulation of other people's goals. It is important to note that this understanding of intentionality is a property of the action itself, and does not require explicit, conscious representations of the goals to be achieved (see for instance Roberts & Lee, 2002).

The question as to which goals children pursue and how this relates to their social interactions can be answered in terms of a general ethological theory that puts the individual's acquisition of resources (ranging from food to interaction with socially attractive partners) in a central place. Hawley's resource theory (1999), for instance, describes how children's general strategies for obtaining resources will develop in the context of an evolving social structure, where differences in social dominance among children evolve naturally. This theoretical approach is related to empirical studies in peer social interaction that stress the importance of basic goals or motivations for explaining social behavior of children in interaction (Brown, Odom, & Holcombe, 1996; Crick & Dodge, 1994; Erdley & Asher, 1996; Mize & Ladd, 1990; Packer & Scott, 1992; Rabiner & Gordon, 1992; Renshaw & Asher, 1983). What the resource theory and the empirical studies show is that even in young children the pursuit of goals is closely related to the structure of the child's peer group and in particular to emerging differences in dominance of the group members. The resource-oriented literature focuses on the concept of social power, which is closely related, but not similar, to the earlier-mentioned notion of sociometric status (for instance, high-power children tend to be attractive interaction partners, which corresponds with the sociometric notion of popularity; Hawley, 1999; Sebanc, Pierce, Cheatham, & Gunnar, 2003).

In addition to the social and basic aspects of intentionality and goal-pursuit, the cognitive means for planning intentional action and the ability to monitor the expected rewards of an action develop rapidly after the age of 3–4 years. The literature on this issue is extensive, covering the development of executive functions as part of the intentional action system (Eenshuistra, Weidema, & Hommel, 2004; Zelazo, Müller, Frye, & Marcovitch, 2003a, Zelazo, Müller, Frye, & Marcovitch, 2003b) and the development of the ability to delay immediate gratification in function of a more distant goal (Eenshuistra et al., 2004; Metcalfe & Mischel, 1999; Mischel & Mischel, 1983; Mischel, Shoda, & Rodriguez, 1989).

The evaluative aspect of goal orientation: Appraisal and the pleasure dimension

Appraisal as a general principle

Goals represent interests, or, as Frijda (1986) calls them, concerns. The concern aspect of intentions and goals implies that organisms automatically evaluate situations in function of their goals, i.e., as either being good or bad. According to the old but still influential theory of Arnold (1961), emotions play a central role. They are immediate evaluations of the value of a situation with regard to the person's goals. Such immediate evaluations that prepare for further action are also called "appraisals" (Frijda, 1986; Scherer, 1999).

Although in the literature the notion of “appraisal” often bears a heavy cognitive burden, we use it to specify any automatic evaluation associated with an action potential. Appraisals have a neurophysiological underpinning (Ledoux, 1996; Sugrue, Corrado, & Newsome, 2004). In addition, it is likely that appraisal refers to a general evaluative dimension of pleasure versus displeasure. Pleasure is conceived of as a biologically fundamental dimension of emotions, which has important potential for action (Cabanac, 2002; Johnston, 2003; Panksepp, 2000). The pleasure dimension is also a central component of Russell’s (2003) notion of core affect. Whereas pleasure is a dimension of core affect in general, joy is a specific emotional appraisal in a situation of pleasure-maximization such as in dyadic interaction among children, including play (Roseman, Wiest, & Swartz, 1994; Roseman & Evdokas, 2004).

Appraisal in a social-developmental context

The system of emotional appraisal of the value of contexts and events is a biologically fundamental system and is already functional at a very early age (Camras et al., 2002; Messinger, 2002), independent of the fact that emotions continue to develop until late in childhood (Denham, 1998; Saarni, 2000). The ability to understand the relation between an other person’s emotional expressions and that person’s goals and actions is already developed at the end of the first year (Montague & Walker-Andrews, 2001; Phillips, Wellman, & Spelke, 2002). Thus, from a very early age on, emotional appraisal is not just an automatic individual expression of evaluation, but a socially transparent signal of one’s own or an interaction partner’s evaluation of the situation in function of the participants’ goals. Appraisals through emotional expressions constitute a social and interactional system as early as infancy. Infants appreciate the emotional appraisals of interaction partners and incorporate them into their own intentional actions and emotional appraisals (Trocken, 1989). In the context of social interaction, the pursuit of social goals and the associated emotional expressions of appraisals are closely related to the child’s developing ability to regulate emotional expressions, in an attempt to establish positively evaluated and coherent interactions with others. This ability begins to develop at an early age and shows a major improvement around ages 4–5 (Grolnick, Bridges, & Connell, 1996; Mischel & Mischel, 1983; Mischel et al., 1989; Murphy & Eisenberg, 2002; Shipman, Zeman, & Stegall, 2001).

Social interaction as a goal

General aspects of social interaction as a goal

Establishing a satisfactory, pleasurable interaction is an important goal or concern in itself (Austin & Vancouver, 1996). Interactions differ in the nature of the actions involved, which depend on the roles or functions of the participants. Interactions also differ in term of intensity or frequency. Thus, given a particular role or type of relationship, people will have differential concerns for interaction, i.e., they will prefer some people over others and thus will act in an attempt to satisfy their concerns for more intensive and/or frequent interaction with some people in comparison to others.

As we already stated in the first lines of the Introduction section, the present article focuses on discussing goals concerning social interaction to interactions that are of a mutually positive nature and that, at least in intention, are aimed at being agreeable for all participants. More or less irrespective of age, people can also have negative interaction

concerns, aimed at hurting, harming or suppressing others. For instance, some children can have a high concern for bullying others. We will address the issue of negative concerns and its relation to the general model presented in the current article, in the Discussion section.

The developmental context of social interaction as a goal

There exists a wealth of developmental literature about the issue of social interaction as a goal. This literature focuses on the nature of the roles or functions of the interaction partner and documents the emerging differences in interaction concerns in an indirect way. To begin with, the extensive literature on attachment (Ainsworth, 1979; Bowlby, 1969, 1973, 1980) demonstrates that babies develop a strong differentiation in their proximity and interaction concerns with other persons, which take the form of strong attachments to particular adults. The well-known attachment types demonstrate, in fact, that differences in the strength of the proximity and interaction concern and differences in the way the positive and negative appraisals are expressed emerge already at an early age. These early attachment characteristics continue to develop and differentiate (see also Bartholomew & Horowitz, 1991; for a generalization to later development).

Of central concern is the differentiation on the level of peer relationships. By the age of four to five years, children have developed a pattern of differential proximity and interaction concerns, dividing their social network into various roles related to the intensity of these concerns. The issue of sociometric status deals with the fact that children have different and evolving concerns for interaction: strong concerns define popularity and weak to negative (avoidance) concerns define rejected status of peers (Martin et al., 2005; Rubin et al., 1998). The concept of social power that features in resource-oriented models is related to popularity, in that high-power individuals tend to be highly valued and preferred partners for interaction (Hawley, 1999). Finally, if preferences are relatively durable, symmetric, strong, and person-oriented, we will call them friendships.

There is a host of factors that co-determine children's preferences for certain interaction partners over others. An important factor is the "match", i.e., similarity between the interaction partners, in terms of shared communicative resources (interesting data about this factor come from research on social play in hearing-impaired children; Lederberg, 1991; Minnett, Clark, & Wilson, 1994; Nangle, Erdley, Zeff, Stanchfield, & Gold, 2004), shared knowledge of play events (Meckley, 1994), shared motor skills (Smyth & Anderson, 2000), and gender match (Blatchford, Baines, & Pellegrini, 2003).

Preference for social play as a particular form of pleasurable social interaction increases with age (more precisely with developmental level; Barnes, 1971; Goncu, 1993; Kopp, Baker, & Brown, 1992; Parten, 1932; Lyytinen, 1991; Rubin, 1977). It depends on various factors (for examples of relevant factors, see Belle, 1989; Benenson, 1993; Cheah, Nelson, & Rubin, 2001; Cho & Jang, 1995; Morris, Messer, & Gross, 1995; Ramsey, 1995; Saracho, 1995, 1996; Schneider & Daniels, 1992; Shin, 1997). In children between 5 and 8, the preference for and ability to engage in social play is well consolidated (Goncu, 1993; Lyytinen, 1991; Rubin, 1977).

An important aspect of satisfactory positive interaction in children, i.e., interaction that satisfies the interaction concerns (for instance during social play) is reciprocal involvement. It is the major characteristic of positive interaction between children, and is expressed by the level of mutual responsiveness (Fogel, 1993; Hinde, 1997a, 1997b; Russell, Pettit, & Mize, 1998; Van Egeren, Barratt, & Roach, 2001). Reciprocity refers to the

interdependency aspect in interaction (Rubin et al., 1998; Linam, 1998).¹ The ability to engage in coherent peer interaction, i.e., interaction with a sufficient level of reciprocity in the participants' actions is already developed in toddlers (see Ross, Conant, Cheyne, & Alevizos, 1992; Rubin et al., 1998).

Contagiousness of social behavior

General aspects of contagiousness and imitation

Social behavior is also deeply affected by a non-intentional component, namely the tendency of people in social interaction to automatically copy or mimic the behavior of the other person, relatively regardless of their own immediate intentions or goals. Note that this factor should be distinguished from the aspect of reciprocity, which is a central feature of true interaction. The following is an example to clarify the distinction: in a conversation, participants both ask questions and give answers, which is primarily an expression of reciprocity. However, if one participant begins to talk rapidly because of the rapid speaking of the other participant, it is likely that this is a matter of contagiousness and imitation.

Evidence for the tendency to mimic or imitate, and thus for the contagiousness of other people's behavior, comes from research on behavior contagion (Levy & Nail, 1993; Nail, MacDonald, & Levy, 2000; Wheeler, 1966) and mood contagion (Neumann & Strack, 2000). Research on the "chameleon effect" shows that people tend to show an automatic mimicry of other persons in a group, relating to facial expressions and behaviors (Chartrand & Bargh, 1999). The phenomenon of imitation in a social context is an important theme in current social psychological research (Ferguson & Bargh, 2004).

Although unintentional, imitation based on the contagiousness of another person's behavior can be highly functional. In the social realm, it can be related to cohesion between group members and it is assumed that it contributes to effective behavior co-ordination among members of a group (Chartrand & Bargh, 1999). However, in some circumstances mimicry can also be dysfunctional, i.e., against the goal of at least one of the interaction partners. For instance, if one interaction partner shows a high amount of solitary action, the mimicry or contagion principle implies that the other person will tend to imitate at least some of the solitary action and thus that the level of interaction is reduced, eventually in spite of one person's intention to establish a high level of reciprocity.

Developmental aspects of contagiousness and imitation

Although the contagion effects have been studied primarily in adults, there is ample evidence of imitation in infants and young children. The first source of evidence is biological (it is not primarily human-developmental, but has important consequences for development). For instance, biologically and evolutionary inspired research on the direct coupling between perception (of another person's behavior) and one's own action, has shown that various forms of social imitation are important for survival (Preston & de Waal, 2002).

¹ To avoid misunderstanding, it should be noted that in the literature, reciprocity is often given a social-cognitive meaning, i.e., the child's understanding of mutuality and reciprocity as a principle of social exchange, for instance in friendships (see for instance Laursen & Hartup, 2002). In the present article, however, we define reciprocity explicitly on the action or behavioral level, i.e., as coherence of interaction.

Neurophysiological research has demonstrated the existence of “copying neurons” in the brains of social species (see Rizzolatti & Craighero, 2004), which are assumed to play important developmental roles, for instance in the development of social cognition (Gallese, Keysers, & Rizzolatti, 2004).

The second source of evidence lies in the research on the tendency of babies and infants to imitate the behavior of other people (Callaghan, Rochat, & MacGillivray, 2004; Carpenter, Call, & Tomasello, 2005; Gergely, Bekkering, & Király, 2002; Meltzoff, 1988; Meltzoff & Moore, 1983; Thompson & Russell, 2004).

The third source of evidence comes from the literature on social learning and modeling, primarily in children (see for instance Bandura & Walters, 1977). During childhood, imitation tends to decrease with age, and is more likely to occur with models who have positive emotional properties (e.g., who are kind), are similar to the imitator (e.g., same gender) and have social power or are socially desirable (see for instance Abramovitch & Grusec, 1978; Bandura & Bussey, 2004; Bandura, Ross, & Ross, 1963; Bussey & Bandura, 1984; Bussey & Bandura, 1999; Gottfried & Gottfried, 1974; Grusec & Abramovitch, 1982; Grusec, 1992; Rushton, 1975).

Note that the contagiousness of behavior is not confined to mere, “dumb” imitation. In a developmental context, for instance, evidence has been collected of the complexity of “imitation”, ranging from direct mimicry to goal emulation, thus suggesting that the contagiousness of behavior extends to relatively “abstract” aspects of the imitated behaviors (see for instance Call & Carpenter, 2002; Thompson & Russell, 2004).

Differential aspects of the components of the general interaction model

The general model of social interaction describes features that are supposed to be present in all interactions and are thus common to all individuals. However, people differ in the extent to which a certain aspect or component applies to a specific interaction. For instance, some persons may imitate others more easily, or some persons are more easily imitated than others. There are also within-person differences, for instance in the nature of the concerns of a single individual across development. We refer to these within- and between-person differences as differential aspects of the general action model, in line with the traditional meaning of “differential” (as in “differential psychology”). With regard to the properties of interaction in general, a myriad of ways exists in which people and contexts may differ. However, in view of our theoretical emphasis on the realization of goals in a social context, we have chosen to focus on two basic dimensions along which individuals may vary, namely their competence to achieve their goals and their power to do so. These differential components will serve to explain differences in the general components of interaction (i.e., how do they affect people’s social goals, preferences, and contagiousness).

Social competence

Social skills can be defined as “discrete, learned behaviors exhibited by an individual for the purpose of performing a task” (Sheridan & Walker, 1999). The nature of those skills defines the level of social competence of an individual, i.e., the individual’s effectiveness in social interaction (Rose-Krasnor, 1997). Rubin et al. (1998) define social competence as “the ability to achieve personal goals in social interaction while simultaneously maintaining positive relationships with others over time and across situations” (p. 645). That is, social competence implies the ability to achieve a balance between one’s own goals and

those of others (Hawley, 2002). However, social competence in the sense of social effectiveness is not necessarily, or always, prosocial and can be coercive as well, depending on the goal to be achieved in the group (see Hawley, 1999; Hawley, Little, & Pasupathi, 2002; on social strategies and competence in grade three through six). Roughly by middle childhood, most children have developed a repertoire of social skills for achieving their goals in the peer network (Hawley et al., 2002; Mayeux & Cillessen, 2003). The nature and level of a child's social competence depend, among others, on the child's social history, including parental influences and influences from siblings and peers (Denham et al., 2001; Stormshak, Bellanti, & Bierman, 1996; Swick & Hassell, 1990).

In a developmental context, social competence shows an overall increase for most children, with individual differences tending to remain stable over relatively short time periods (Lafreniere & Dumas, 1996). Of particular interest for the present article is the relationship between social competence and the sociometric status of a child. A general finding is that the sociometric status of a child is an adequate reflection of the child's social competence, i.e., the level of sociometric status is positively related to the level of social competence (Hazen & Black, 1984; Simeo-Munson, 2000). Thus, in their interaction with others, higher-status (e.g., popular) children are more socially effective, i.e., more socially competent than lower-status (e.g., rejected) children. Popular children are more effective in achieving the social goal of establishing a satisfactory relationship with others than rejected children.

Social influence, power and dominance

A second differential component is social influence and the related construct of social power. In social psychology in particular, the social influence and social power of members of various groups, including dyads, have been thoroughly investigated (Forsyth, 1990). Power is defined by Lewin (in Bruins, 1999, p. 8) as “the possibility of inducing force on someone else, or, more formally, as the maximum force person A can induce on person B divided by the maximum resistance that B can offer”. Influence and power are related, in the sense that “influence is kinetic power, just as power is potential influence” (French & Raven, 1959, p. 152).

In one of the key papers on social power, French and Raven (1959) have distinguished six types of power, one of which is the so-called referent power (see also Raven, 1992). Referent power is related to being “the best liked member of the group”; i.e., having a popular status. In a dyadic situation, a difference in referent power will influence the interaction between the participants (Snyder & Kiviniemi, 2001), resulting from the different motivations of the participants. Copeland (1994) found that low-power individuals (for instance, a child with a rejected or average status who interacts with a child with a popular status) are particularly motivated “to get along with the other person” (see also Dépret & Fiske, 1999). They show behavior that “ensures a smooth interaction by trying to fit in, to be responsive, and be generally accommodating to one's partner” (Snyder & Kiviniemi, 2001, p. 145).

In a developmental context, differences in a child's power to realize one's goals in a social context are closely related to the development of social dominance, i.e., the ability to have control over social and material resources (Charlesworth, 1996; Hawley & Little, 1999; Hawley, 2002; Nepl & Murray, 1997; Pettit, Bakshi, Dodge, & Coie, 1990; Strayer, Chapeskie, & Strayer, 1978; Strayer & Strayer, 1978). Social dominance is related to social preference: socially dominant children—in the sense of being in control of resources—are valuable interaction partners and are preferred by their peers over others (Hawley, 1999).

They enjoy a high social status, which is a well-established phenomenon by the age of middle childhood (Lease et al., 2002; Pettit et al., 1990). On the other hand, high social status is a valuable and scarce resource in itself, since it is defined by the preference of many other children to interact with a particular (and thus popular) child. Hence, the popular child is the one who, in principle, is in control over the interactions that other children wish to have with him or her. In summary, power and status are different concepts, but their properties in terms of their effects on social interaction, overlap to a great extent.

Social power is positively related to the contagiousness of behavior: children tend to imitate socially powerful persons, including peers, more than children without or with less social power (Abramovitch & Grusec, 1978; Bandura & Bussey, 2004; Bandura et al., 1963; Bussey & Bandura, 1984; Bussey & Bandura, 1999; Eisenberg-Berg & Geisheker, 1979; Gottfried & Gottfried, 1974; Rushton, 1975). Thus, in their interactions with others, lower-status children—given their motivation to get along with their high(er)-status interaction partner, will more easily imitate their interaction partner than the other way round.

A dynamic systems model of involvement during dyadic interaction²

The dynamic model, which will be expressed in the form of coupled mathematical equations, consists of two parts. The first one is based on the principles of appraisal maximization and refers to the person's own behavior and the behavior of the interaction partner; the second one is based on the principles of behavioral contagion.

A mathematical formulation of the dynamics of appraisal maximization

The main variable of the model is “involvement”, defined as the proportion of involvement behavior over the total behavior, including the non-involvement behavior. The idea is that an interaction situation is always a mixture of involvement and non-involvement, i.e., a mixture of actions directed towards the other person and actions not directed towards the other.

The change in involvement I is given by the expression

$$I_{t+1} = f(I_t) \quad (1)$$

The equation says that the value of variable I at time $t+1$ is an—as yet undefined—function f of the value of the variable I at time t (the “1” accompanying the time reference can be an interval of any length, but must be chosen in accordance with the properties of the dynamics it describes). The equation defines an iterative sequence, which describes a process in time

$$I_{t+1} = f(I_t), I_{t+2} = f(I_{t+1}), I_{t+3} = f(I_{t+2}), I_{t+4} = f(I_{t+3}), \dots \quad (2)$$

Interaction amounts to a process of choice. In general, choice implies alternatives. In interaction, the choice is between involvement, i.e., actions that are directed towards the other child or person (I -actions) and actions that are not directed towards the other child, i.e., that are solitary, without sharing the activity with the interaction partner (non- I actions). Both types of actions are assumed to lead to appraisals. For instance, interaction with the

² The model has been implemented in the form of an Excel file which can be obtained from the authors at H.W.Steenbeek@rug.nl or vangeert@inn.nl; it can also be downloaded from the authors' websites at <http://www.gmw.rug.nl/~model/> or <http://www.inn.nl/~vangeert/research.htm>.

other child is pleasurable, but solitary actions are pleasurable too. It is likely that the average pleasure (average appraisal) drawn from these activities over some fixed period of time is likely to be different (for instance, in a play situation, depending on the nature of the toys provided, playing with the other child may be more fun than playing alone, although the play event itself will show a succession of playing-together and playing-alone episodes).

The pleasure or appraisal drawn from a particular activity is comparable to a “reward” brought about by that activity (in that a reward is a positively appraised effect of an activity or event). Such choice behavior answers to the learning-theoretical law of effect (Staddon & Cerutti, 2003), and more particularly to the Matching Law (Baum & Davison, 2004; Gallistel & Gibbon, 2000; Herrnstein & Prelec, 1991; Heth, 1992; Sugrue et al., 2004; McDowell, 1988). The Matching Law holds that the proportional distribution of behaviors (e.g., how much involvement behavior over non-involvement behavior) will evolve towards a value that reflects the reinforcements provided by these behaviors (e.g., how pleasurable, on average, is involvement over how pleasurable is, on average, non-involvement). The Matching Law explains the emergence of what in dynamic systems terms is called a specific attractor state (see Dishion, Spracklen, Andrews, & Patterson, 1996, 2002; Fogel, 1993; Granic, 2000; Martin et al., 2005; Nowak et al., 2005; for an application in the field of social interaction). In the case of interaction, the attractor state is basically the stable proportion of *I*- over non-*I* activities over a certain amount of time, for instance, the time covered by a dyadic play interaction.

Of particular importance for the current model is the fraction

$$\Delta A / \Delta I \tag{3}$$

which represents the change in appraisal (ΔA) corresponding with a change in the *I*-variable (ΔI). More precisely, an increase in involvement actions, i.e., trying to establish more approaches, leads to a change—and increase or eventually decrease—in appraisal, depending on the current effect of those actions. As long as ΔA for some ΔI remains positive, ΔI will, metaphorically speaking, run up its slope (the amount of involvement will tend to increase). Sometime along the slope, i.e., for some proportional value of involvement behavior, ΔA must become 0 or negative. For this to occur, it suffices that, with some probability, the immediate appraisal (ΔA) for a non-*I* choice is greater than the immediate appraisal of an *I*-choice. The tendency to make a choice for a behavior that, at the current moment promises to give more reward or pleasure, is called melioration (Herrnstein & Prelec, 1991). Melioration is a robust phenomenon, and it is very likely that it applies to appraisals arising from such highly variable activities as interaction with another person, where the choice is between actions that are or that are not directed towards the other person. Thus, the proportion of involvement behaviors over non-involvement actions will tend to stabilize at a level that guarantees maximal immediate reward, i.e., maximal immediate positive appraisal. This stabilizing level is the preferred level of involvement, which we will denote by the letter *P*.

It is important to note that people do not need to have an explicit, advance representation of this preferred level. From a dynamic systems point of view, *P* emerges from the organism’s attempts to locally maximize reward, pleasure or appraisal. The preferred level emerges as a relatively stable attractor state that reflects the properties of the person-in-the-environment, i.e., the current play partner and the current play context. *P* is a soft-assembled property, in the terminology of Thelen and Smith (1994).

Since the P -term describes a fundamental macroscopic property of the play context, namely the child's emergent preferred I -level, it can be incorporated into the equation that describes the change in I over time. It is likely that the increase in appraisal will proportionally diminish as I approaches its equilibrium level P (as I approaches P , the probability of experiencing an increase in I that causes an increase in A grows smaller). Hence, a simple way to describe the change in I is by the following equation

$$\Delta I / \Delta t = a(P - I_t) \quad (4)$$

The a -parameter specifies how fast the preferred level can be achieved. The value of the parameter depends, at least partly, on the child's social competence and on the other child's power.

The child can change his own I -actions (e.g., increase the number of approach actions directed towards the other child), but the appraisal depends to a great extent on whether this I -action results in real interaction, i.e., on the reciprocity of the actions (i.e., situations where an involvement act such as smiling to the other child is responded to by a comparable act of the other child, such as smiling back).

Let us use the term I for the involvement level of the child and Y for the involvement level of the interaction partner. If, by way of example, $I > Y$, reciprocity (the proportion of reciprocal actions) can never exceed the smallest of the two values, i.e., it will depend on Y . Thus, the child's appraisal (under this condition) will also depend on Y . To put it differently, achieving the preferred level depends on the child's own involvement (I) as well as on the interaction partner's involvement (Y). The child can directly influence his own I -level (increase it, for instance). However, the child can only indirectly influence the play partner's involvement level, Y . This influence occurs by definition through actions addressed toward the play partner, i.e., by I -behavior. Thus, if the other child shows little initiative towards real interaction, one way to try to change this in the direction of more pleasurable interaction is by showing more initiatives towards the other. Hence, Eq. (5) can be extended in the following way

$$\Delta I / \Delta t = a(P - I_t) + b(P - Y_t) \quad (5)$$

The b -parameter determines to which extent the difference between the preferred interaction level and the other child's involvement behavior affects the current child's behavior. Its value depends, as with the a -parameter, on aspects such as the child's social competence and the other child's power.

In dyadic interaction, the basic principles that hold for one agent (the child) also hold for the other (the interaction partner). Thus, the more complete form of the dynamic system equation for appraisal maximization is the following set of coupled equations

$$\begin{aligned} \Delta I / \Delta t &= a(P_I - I_t) + b(P_I - Y_t) \\ \Delta Y / \Delta t &= c(P_Y - Y_t) + d(P_Y - I_t) \end{aligned} \quad (6)$$

A mathematical formulation of behavioral contagion

Our theoretical model claims that behavior is contagious, i.e., that people have a tendency to imitate their interaction partner's behavior. Consequently, if in an interaction situation the partner shows a relatively high proportion of solitary activities, the child will imitatively tend to increase his own solitary activity level towards a closer match with

the interaction partner. It is important to note that this imitative tendency is in addition to the first tendency, namely the tendency to increase one's appraisal by attempting to reach a level of best liked interaction. Hence, part of the change in I (and Y) is directly dependent on the Y -level, respectively, I -level, of the respective interaction partner. Thus

$$\begin{aligned}\Delta I/\Delta t &= e(Y_t - I_t) \\ \Delta Y/\Delta t &= f(I_t - Y_t)\end{aligned}\quad (7)$$

The e - and f -parameters specify how fast the child adapts to the behavior of the interaction partner (and vice versa). We have argued that e and f will depend, among others, on the imitated person's social power (for instance, with e being greater than f if the interaction partner has high social power).

Under the simplifying assumption that all components affecting the change in I and Y linearly contribute to the overall change, the complete model is the following set of coupled equations

$$\begin{aligned}\Delta I/\Delta t &= a(P_I - I_t) + b(P_I - Y_t) + e(Y_t - I_t) \\ \Delta Y/\Delta t &= c(P_Y - Y_t) + d(P_Y - I_t) + f(I_t - Y_t)\end{aligned}\quad (8)$$

For terminological conventions, the first equation refers to the "child", the second equation refers to the interaction partner.

Accounting for differences in social influence and social competence in the mathematical model

In order to model the dyadic interaction between children of different power, the differential components social competence and social power are specified in the form of different values for the model parameters (a to h ; note that g and h will be introduced later), and values for the preferred levels P_I and P_Y .

Interacting with a higher-power child will allow for a higher level of appraisal than interacting with a lower-power child. That is, the level of I at which ΔA stabilizes is higher for interactions with higher-power than for interactions with lower-power children. For instance, if in a situation of dyadic play the child has higher-power and the play partner has lower-power, $P_Y > P_I$ (with a similar logic applied to other dyadic combinations).

Second, we have seen that children with higher social power have a stronger "contagious" effect on others than children of lower-status. For instance, in a play situation children are more likely to take over the behavior of higher-power than of lower-power playmates. The strength of the imitative effect is governed by the parameters e and f . Thus, if the higher-power child plays with a lower-power play partner, $f > e$.

Third, social competence implies the ability to achieve more by doing less, which implies, among others, the ability to act if the action is effective and refrain from action if it is not. The effect of adapting one's I -level (i.e., ΔI and ΔY) in relation to one's preferred level depends on the actual difference between the P , I , and Y levels and can sometimes be ineffective or counter-productive. Table 1 specifies the conditions under which action is effective or ineffective. The effect can be calculated by determining whether the action at issue is likely to bring the interaction closer to the preferred level or not, which depends on the relative levels of the I , P , and Y values.

The more a child is socially competent, the more effective, on average, the child's social actions will be. In the mathematical model, we will define differences in effectiveness as

Table 1
The effectiveness of children in different conditions, as presented in the model

Component	$\Delta I = (P - I)$				$\Delta I = (P - Y)$			
	$I > P > Y$	$I = Y > P$	$P > I = P$	$Y > P > I$	$I > P > Y$	$I = Y > P$	$P > I = Y$	$Y > P > I$
Effect on I	↓ I	↓ I	↑ I	↑ I	↑ I	↓ I	↑ I	↓ I
Effect on Y	↓ Y	↓ Y	↑ Y	↑ Y	↑ Y	↓ Y	↑ Y	↓ Y
Effect on R	↓ R	↓ R	↑ R	↑ R	↑ R	↓ R	↑ R	↓ R
Changing the involvement level is	Ineffective	Effective	Effective	Effective	Effective	Undecided	Effective	Ineffective

Note. (a) *I*, involvement actions of the child; *Y*, involvement actions of the play partner; *P*, preferred level of involvement; *R*, level of reciprocity of the dyad; effective, closer to the preferred level of involvement; ineffective, farther from the preferred level of involvement. (b) The table can be read as follows (we give an example based on the first column): if *I* is greater than *P*, and *P* is greater than *Y*, the adaptation on the basis of the difference between *P* and *I* leads to a decrease in the *I* level, and consequently also to a decrease in the *Y* level through the contagiousness component. The resulting effect on the reciprocity will be that reciprocity, which is already under the preferred level, decreases further. This action is ineffective. (c) Remember that the effect of the two components ($P - I$ and $P - Y$) occurs at the same time, which implies that the summed result depends on their relative magnitude.

differences in the probability that an ineffective or counter-productive action is performed (as defined by the set of possibilities in Table 3). Thus, children who are more socially competent are less likely to show ineffective involvement actions. Less socially competent children are more likely to do so, and are thus more likely to show an excess of interaction attempts that are not always responded to in a reciprocal way. The probabilities that an involvement action is effective (thus avoiding ineffective action) are *g* for the child and *h* for the play partner. For instance, a socially competent child could be attributed a *g* of 0.9, which means that social action will not be effective in only 10% of the cases.

$$\frac{\Delta I}{\Delta t} = \left\{ \begin{array}{l} \text{if } g \text{ then } \left\{ \begin{array}{l} \text{if } I > P_1 > Y \text{ then } 0 \\ \text{else } a \cdot (P_1 - I) \end{array} \right\} \\ \text{else } a \cdot (P_1 - I) \end{array} \right\} + \left\{ \begin{array}{l} \text{if } g \text{ then } \left\{ \begin{array}{l} \text{if } Y > P_1 \text{ then } 0 \\ \text{else } c \cdot (P_1 - Y) \end{array} \right\} \\ \text{else } c \cdot (P_1 - Y) \end{array} \right\} + e \cdot (Y - I)$$

$$\frac{\Delta Y}{\Delta t} = \left\{ \begin{array}{l} \text{if } h \text{ then } \left\{ \begin{array}{l} \text{if } Y > P_Y > I \text{ then } 0 \\ \text{else } b \cdot (P_Y - Y) \end{array} \right\} \\ \text{else } b \cdot (P_Y - Y) \end{array} \right\} + \left\{ \begin{array}{l} \text{if } h \text{ then } \left\{ \begin{array}{l} \text{if } Y > P_Y \text{ then } 0 \\ \text{else } d \cdot (P_Y - I) \end{array} \right\} \\ \text{else } d \cdot (P_Y - I) \end{array} \right\} + f \cdot (I - Y) \tag{9}$$

This (indeed somewhat forbidding) equation should be read as follows (focusing on the upper part): the change in *I* ($\Delta I/\Delta t$) depends on three components, two of which depend on if-then conditions. For instance, if condition *g* holds, then the first part of the equation will evaluate to 0 if the condition $I > P_1 > I$ holds, and to *a* · ($P_1 - I$) if the $I > P_1 > I$ condition does not hold. Condition *g* (and *h*, for that matter), is implemented as follows: for each step of the model a random number between 0 and 1 is drawn from a uniform distribution. If the random number is smaller than 0.9 (or *g*), action takes place only if it is effective (see effectiveness conditions in Eq. (10)). If the number is greater than 0.9 (or *g*) action takes place irrespective of whether it is effective or not.

From involvement to reciprocal action: The interaction model

Actual Interaction implies that the involvement actions of one person are reciprocated by those of the other person, and vice versa. Probabilistically speaking, the chance that an involvement action of one person is reciprocated by an involvement action of the other person is a function f of the involvement levels of the interacting persons

$$R = f(I, Y) \quad (10)$$

The probability that an involvement action will be reciprocated by the interaction partner will vary between 0 and a maximum value. The minimum of 0 corresponds with a situation in which none of the involvement actions of one person are reciprocated by the other, and vice versa. This is a condition that is very unlikely to occur in normal interaction. Maximum reciprocity occurs when all involvement actions of one person are reciprocated by an involvement action of the other, and vice versa. This condition requires that $I = Y$, and thus that $R = I = Y$. If $I \neq Y$, R is equal to the smallest of the two (in this case, all actions of one are reciprocated by those of the other person, but not the other way around).

In the preceding section, we related social competence to the ability to make an adequate choice between effective and ineffective social actions. At this point, we may invoke a second aspect of social competence, namely the ability to elicit higher responsiveness to one's own actions from the interaction partner. Hence, Eq. (10) can be rewritten as follows

$$R = r * I * Y \quad (11)$$

for r a reciprocity parameter which, for simplicity, is linearly dependent on the levels of social competence of the interaction partners. For convenience, r is set equal to 1 for average social competence and is allowed to vary within a range that results in the minimum and maximum values as stated above. Finally, r can also be estimated empirically by taking the proportion of reciprocal action (interaction) over the product of I and Y .

Summary and prospects

In the preceding sections, we have described the theoretical components of approach-oriented, positively valued social interaction in a dyadic context. Based on these components, we have inferred a dynamic model of dyadic interaction. The model describes the time evolution of involvement behavior in each participant, based on the simultaneous and continuous evaluation of three components, namely a self-appraisal component (“how far apart are my current level and my preferred level of involvement”), an other-appraisal component (“how far apart are the other person's level and my preferred level of involvement”) and an imitation-eliciting self-other comparison (“how far apart are my and your level of involvement”). From a developmental point of view, the basic components are already established at an early age. The differential aspects—differences between persons in their ability to establish their preferred levels of interaction—relate to social competence and social power. These differences develop throughout childhood, and throughout the entire life span, for that matter.

The theory and the associated dynamic model can be used for building specific models of interaction, i.e., models of specific participants and in specific contexts. We will give an example of how this can be done in the next section.

An illustration of the theory and the dynamic model: Dyadic play in children with different sociometric statuses

In the current section, we will illustrate the theory and associated dynamic model by means of an empirical example, namely a study of a 10-min dyadic play session between children of different sociometric status. In this study, we have used sociometric status as an operationalization of social power and social competence, in line with Hawley's model (Hawley, 1999). We have seen that status, power, and competence are positively related.

Hypotheses and predictions

The differences in the model's parameter values associated with different sociometric statuses, which were discussed in the preceding section, are specified in the form of ranges of values corresponding with the types of dyads studied. The ranges are chosen in accordance with the theoretical principles discussed in the preceding sections. For instance, in accordance with the principle that social preference depends on social power, children with higher social power have lower preference for children with lower social power, and vice versa. The exact values of the parameters have no meaning in themselves: what matters is the numerical relationship between the parameters (compare for instance the differences in the magnitudes of social influence in popular versus average and versus rejected children in Table 2).

For each set of parameters (a , b , c , etc.), the equations yield an attractor state (a stable value of I and Y , and the corresponding level of expected reciprocal action R). The range of all possible combinations of parameter values that (hypothetically) characterize a particular status group, results in a particular distribution of such attractor states. For each type of dyad, 10,000 combinations representative of the dyad's parameter space were calculated. The distributions imply specific predictions about differences between children, play partners, and dyads of different sociometric status.

Predictions about the children

On the basis of the theoretical distributions as produced by our model (see Fig. 1a and b), we expect the popular child to display significantly less involvement than the rejected child (difference generated by the model is 1.7 SD). Second, the model distribution shows that in the popular child the proportion of reciprocal action over the total amount of involvement action is considerably greater than in the rejected child (model difference is 1.5 SD).

With regard to the first prediction, it can be objected that, since the rejected child has a higher involvement preference than the popular child in this particular situation, the prediction of higher involvement is tautological. However, this objection is not warranted: the effect of the P_I parameter can easily be counteracted by the contagiousness parameter e (see Eqs. (8) and (9)).

Play partners

The distributions of involvement levels of the play partners shows that partners of rejected children have a higher I -level than partners of popular children, but also that the difference is smaller than those found for the children. The predicted model difference is 0.44 SD (Fig. 1c). Fig. 1d implies that in play partners of rejected children, the proportion of reciprocal action over the total amount of involvement action is greater than in

Table 2

The model's parameter values for children of different sociometric status in interaction with play partners of average status

Type of dyad		Minimum	Maximum
<i>Popular dyad</i>			
Popular child			
<i>P</i>	Preferred involvement level	0.3	0.5
<i>C</i>	Influence from other person	0.05	0.1
<i>A</i>	Adaptation parameter		0.05
<i>E</i>	Effectiveness norm	0.9	1
Average play partner			
<i>P</i>	Preferred involvement level	0.7	0.9
<i>C</i>	Influence from other person	0.3	0.4
<i>A</i>	Adaptation parameter		0.05
<i>E</i>	Effectiveness norm	0.4	0.6
Dyad			
<i>R</i>	Reciprocity parameter		1.25
<i>Rejected dyad</i>			
Rejected child			
<i>P</i>	Preferred involvement level	0.7	0.9
<i>C</i>	Influence from other person	0.1	0.3
<i>A</i>	Adaptation parameter		0.05
<i>E</i>	Effectiveness norm	0	0.1
Average play partner			
<i>P</i>	Preferred involvement level	0.3	0.5
<i>C</i>	Influence from other person	0.1	0.3
<i>A</i>	Adaptation parameter		0.05
<i>E</i>	Effectiveness norm	0.4	0.6
Dyad			
<i>R</i>	Reciprocity parameter		1

Note. (a) *P*, preferred involvement level; *C*, contagiousness other; *A*, adaptation parameter, corresponds with the parameters *a*, *b*, *c*, and *d* in Eq. (10); *E*, effectiveness norm, the probability that the most effective action will be performed. (b) The parameter values have been chosen in such a way that they optimally differentiate the three status groups, based on the theory explained in the article. For instance, a popular child playing with an average play partner has a relatively low preferred involvement level (with a minimum of 0.3 and a maximum of 0.5, the average preferred level amounts to 40% of the play time devoted to playing together). The popular child has a strong influence on the play partner (see influence from other person, under average play partner), whereas the play partner has only a minor effect on the popular child (see the parameter Influence from other person, under popular child). Finally, the popular child is highly effective (an effectiveness norm between 0.9 and 1, which implies that an effective decision is taken in 95% of the time on average). (c) Note that the contagiousness only differs for the popular dyad, in the sense that the influence of the popular child on the play partner is always higher than the influence of the play partner on the popular child.

play partners of popular children. The predicted difference is 0.62 *SD*, which is again smaller than the differences predicted for the children.

Dyads

At the dyad level, the criterion is not involvement, but actual reciprocity in the interaction. The model predicts that the “popular” dyad (consisting of a popular child and his average play partner) will show less total reciprocity than the rejected dyad (consisting of a rejected child and his average play partner) (see Fig. 1e). Note that this prediction

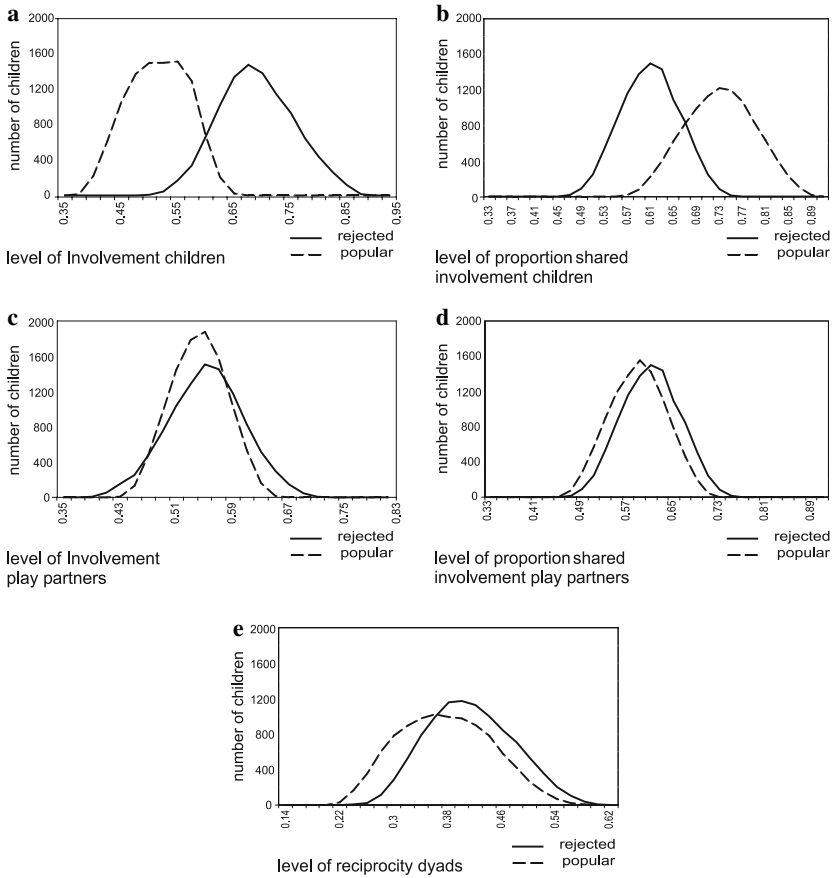


Fig. 1. The predictions about (a) the level of involvement in the children; (b) the level of proportion shared involvement in the children; (c) the level of involvement of the play partners; (d) the level of proportion shared involvement of the play partners; (e) the level of reciprocity in the dyads.

runs against the expectation that one is likely to form on the basis of the existing literature. This expectation is that the dyad consisting of a popular and an average child will show more reciprocity than a dyad consisting of a rejected and average child, due to the social interaction competence attributed to the popular child in comparison with the rejected one. The predicted is $0.54 SD$, which is smaller than the differences predicted for the popular and rejected children separately.

Method

Participants

Grade 1 pupils with mean age of 6.5 years, with an upper limit of 8.8 years and a lower limit of 5.8 years participated in this empirical study. They were recruited from three different schools for regular primary education in a small town in The Netherlands. One school was a school with a special, additional focus on children from immigrant families. In one group most of the children were in grade 1, but a few children were still in kindergarten.

From this group of 83 children (47 boys and 36 girls), 24 children were selected on the basis of their sociometric status, which had to be either popular, rejected or average (see the Procedure section). For each of the 24 children, a play partner of average status was selected from the original group. The dyads were composed in such a way that animosity as well as more intense friendship relations were avoided. Each dyad consisted of two same-sex children (12 female dyads and 12 male dyads). There were 13 “rejected” dyads (11 female dyads and 2 male dyads), 14 “popular” dyads (5 female dyads and 9 male dyads), and 14 “average” dyads (6 female dyads and 8 male dyads). There is an overrepresentation of girls in the rejected group of dyads. However, there is no statistically significant gender difference in the two most important variables (the p -values are 0.86 and 0.58 for the expression measures of child and partner, 0.94 and 0.25 for the action measures, respectively). Thus, gender does not need to be taken into account as an additional explanatory variable.

The empirical study was done in collaboration with the University of Utrecht, and the design is based on [Gerrits \(2004\)](#).

Procedure

Determining sociometric status. The sociometric status of the participants was determined by means of a rating test ([Asher, Singleton, & Tinsley, 1979](#)). The test presents the child with a photograph of each child in the class (in randomized order) and contains a frequency measure and a quality measure. In the frequency measure the question ‘How often do you play with this particular child?’ was posed. The answers formed a three-point scale ranging from ‘never’, ‘sometimes’ to ‘often’. The quality measure consisted of the question ‘Do you like to play with this particular child?’. Possible answers were ‘no’, ‘indifferent’, and ‘yes’. The answers were coded by means of the two-dimensional ratings-method for the determination of sociometric status Ssrat ([Maassen, Akkermans, & Van der Linden, 1996](#); [Maassen, Steenbeek, & van Geert, 2004](#)). The ratings over the three measurements and two versions were combined to determine the dominant status of the child. Children who received less than four times the same status were excluded from the analysis. Of the 24 dyads (48 children), 24 children received six times the same status, 17 children received five times the same status and 7 children four times.

Videotaping dyads of children. The situation under study is a relatively free, adult-initiated dyadic play situation, the implicit goal of which is to establish a pleasurable situation. The dyads were videotaped during a 10-min play session, which took place in a separate room in the school. Four sets of toys that are relatively well-known to the children (Tarzan figures, kitchen toys, Playmobil toys, and Lego toys) were placed on the table in a standardized manner. The only instruction was to play together with the toys on the table. After giving the instruction, the researcher left the room, leaving the children alone with the toys and the camera. After 10 min, the researcher came back and the play session was ended.

This procedure was repeated two times, with intervals of approximately one and a half month. In principle the second and third round were selected for coding. Due to practical limitations, only 17 dyads were coded twice and 7 dyads were coded once. This resulted in a total of 41 coded interactions. The small sample sizes are explained by the fact that popular and rejected children form a small minority of the total number of children in the class. Moreover, the analysis of interaction in real time is very labor-intensive. The

statistical problems with lack of independence when some dyads are coded twice can be avoided by the use of permutation tests and similar simulation methods (see the Section on Statistical analyses).

Coding and data reduction

The recordings were coded with the computerized system Observer 4.0 pro (Noldus information technology, 1999). Changes in expressiveness and responsiveness of each videotaped child separately were coded every one-tenth of a second (event sampling). We based our coding system on an original coding system by De Koeper (2001). To determine the inter-observer reliability between the observers, we used a non-parametric permutation test (see the section on Statistical analysis for more information about permutation techniques; see also Van Geert & van Dijk, 2003). The reliability was determined before the coding was started, and can be considered adequate, in terms of percentage agreement (.8 for actions, $p = .01$, .81 for expressions, $p = .01$)

Observed variables

Remember that the involvement variable contains emotional expression as well as instrumental action. The emotional expression of each child was coded on a scale ranging from very negative (−4) to + 5 (very positive), representing the intensity of the expression. Categories −4 to −2 represented negative expressions, −1 to +1 neutral expressions, and +2 to +5 positive expressions. The one-dimensional coding is consistent with models of emotion that describe one underlying (dis)pleasure dimension (see the Theoretical section).

The instrumental action was coded with the help of three overt variables: verbal turn, non-verbal turn, and focus. Verbal turn refers to verbal utterances; non-verbal turn to non-verbal actions, and focus involves the direction of gaze of the children. These partial variables can either be present or absent. In addition, verbal and non-verbal turns can be contiguous (reciprocating the action of the play partner) or initial. On the basis of these partial variables, every 1/10-s a child is coded as displaying involvement behavior or non-involvement behavior. If the child displays neither a verbal turn, nor a non-verbal turn, nor a focus, the child is supposed to display non-involvement. Otherwise the child is coded as displaying involvement.

Operational variables

In order to derive as much information as possible from both observed variables, they were transformed into operational variables. The operational variables describe various aspects of the observed actions and emotional expressions, both on the individual and on the dyadic level (see Table 3). On the individual level (child or play partner), we distinguish two types of involvement actions, namely an instrumental-type of involvement action divided into ‘directedness’ and ‘proportion shared directedness’, and two emotion-related variables called ‘positive expressions’, and ‘proportion shared positive expressions’. The ‘proportion shared’ refers in both cases to the fraction of reciprocal action or reciprocal expression over a child’s total involvement action or expression. On the dyadic level, we specify the amount of reciprocity by means of an action-related involvement variable, namely ‘coherence dyad’, and one emotion-related involvement variable ‘shared positive emotional expression dyad’. For a description of these variables, see Table 3.

Table 3

Operational variables corresponding with involvement (of the child or play partner), and reciprocity (of the dyad) such as derived from the empirical data

	Variables	Description
Child or play partner involvement	Directedness	Proportion of actions ('playing together') directed towards the other child over the total of all actions (both 'playing together' and 'playing alone')
	Proportion shared directedness	Proportion of 'directed' actions of this child accompanied by a 'directed' action of the other child
	Positive expressions	Proportion of total average intensity of positive expressions
	Proportion shared positive	Proportion of positive expressions of this child accompanied by a positive expression of the other child
Dyad reciprocity	Coherence dyad	Proportion of time that both children reciprocally direct their actions towards the other child ('playing together') over the total time of the play session
	Shared positive dyad ^a	Proportion of shared positive expressions over the total number of expressions. This variable can be read as a measure for "reciprocity of positive expressions"

Note. (a) Concerning variable 'shared positive dyad': (1) a high level of shared positive expression does not necessarily imply a high level of positive expressions per se. (b) Besides these above-mentioned operational variables more variables were tested, in most cases representing minor variations in measured values, for instance the variable positive expression, in which positive was calculated as ranging from intensity 1–5 (instead of 2–5). They were mostly used as a check for the utility of the eventually chosen variables; see the second section of Conclusion.

Expectations regarding the operational variables

The hypotheses derived from our mathematical model can be directly translated into expectations regarding the set of operational variables about expression and action described above. We do not expect to find differences that are numerically similar to those predicted by the model (an elementary model like the current one cannot be expected to accomplish such similarity). However, what we do expect to find is qualitative similarity, namely differences that are of the same rank order as those predicted by the model. Thus, given the predictions of the model, our qualitative expectations are as follows. The popular child will show less directedness towards the other child (in terms of observed variable: less 'directedness') than the rejected child; less intense positive emotional expressions (in observed variable: less 'positive expression'). On the other hand, the popular child will show more effectively distributed involvement actions (in observed variable: more 'proportion shared directedness') and more effectively distributed positive expressions (in observed variable: more 'proportion shared positive'). In line with the model predictions, we expect that the differences will be greater than those found for the partners and the dyad (we define a great difference as one that is bigger than 1 *SD*).

With regard to the play partner, we expect more directedness and positive expressions in the play partner of the rejected child than in the play partner of the popular child. We also expect more proportion shared directedness and more proportion shared positive in

the play partner of the rejected than in the play partner of the popular child. Consistent with the model prediction, we expect the differences between play partners to be small ($<0.5 SD$) for the directedness and positive expression, and moderate (around $0.6 SD$) for the ‘proportion shared’ aspects (the criteria for “small” and “moderate” have been arbitrarily chosen, see the Results section for further discussion).

The hypothesis for dyads is that popular dyads will show less involvement than the rejected dyads, displayed in less reciprocity (in observed variable: less ‘coherence dyads’) and less shared positive expressions (in observed variable: less ‘shared positive dyad’). Consistent with the model prediction, we expect a small to moderate difference (about $0.5 SD$) between the dyads (i.e., smaller than those between the popular and the rejected child in the dyad but bigger than those found with the play partners).

In Table 4, all expectations are summarized.

Finally, it should be noted that the hypotheses are not completely independent of one another (for instance, the “shared” variables are proportions of the child variables). On the other hand, close inspection of the data shows that there is sufficient possibility of variation to allow for a fair testing of the hypotheses (in the sense that it is not so that if one hypothesis is verified—or falsified—all others are verified or falsified too).

Statistical analyses, null hypothesis, and permutation test

In this section, we describe a number of issues regarding statistical methods, comparison of differences, goodness-of-fit of the model, and the use of p -values that are related to our small sample size and the (partial) lack of independence in our data.

In view of our small sample, we applied a non-parametric permutation test (see Good, 1999; Manly, 1997; Todman & Dugard, 2001) for each operational variable and for the totality of model predictions. This test is based on the null hypothesis that there exists no statistical difference between children and dyads from different status groups. Thus, according to this null hypothesis idea, there exists only one underlying distribution instead of distinct distributions for each of the status groups. We define a “dyad set” as the set of values of all variables for any particular dyad (e.g., the “popular” dyad, consisting of a popular and an average status child). Thus according to the null hypothesis, the

Table 4

Expectations about children, play partners, and dyads, expressed in operational variables

		Variables	Direction	Effect size
Actions	Child	Directedness	Popular < rejected	Great
		Proportion shared directedness	Popular > rejected	Great
	Play partner	Directedness	Popular < rejected	Small
		Proportion shared directedness	Popular < rejected	Moderate
	Dyad	Coherence	Popular < rejected	Small/moderate
	Positive expressions	Child	Positive expression	Popular < rejected
Proportion shared positive			Popular > rejected	Great
Play partner		Positive expression	Popular < rejected	Small
		Proportion shared positive	Popular < rejected	Moderate
Dyad		Shared positive expression	Popular < rejected	Small/moderate

Note. (a) < means that the expectation is that this child (play partner, or dyad) yields a lower value on this variable than the child (play partner, or dyad) of the other status group; magnitudes of expected differences (great, moderate, and small) are based on the effect size predicted by the model (great means $>1 SD$, moderate is around $0.6 SD$ and small is around $0.4 SD$).

assignment of a particular dyad set to a particular status group is in fact completely arbitrary. This null hypothesis is tested by randomly permuting the dyad sets over the three statuses. For each random permutation, we calculate the difference between the averages of the “rejected versus” the “popular dyads”. The number of times that the random permutation produces a difference that is as big or bigger than the observed difference is counted and divided by the number of times the random permutation has been carried out (in principle 5000 times). The result of this division is an estimation of the exact p -value (i.e., the p -value based on the particular distribution of the observed data).

In addition to providing reliable p -values for small samples, the permutation method also allows us to calculate p -values for samples with uncommon properties. In our sample, for instance, some dyads are represented twice in the sample (i.e., by two interactions, observed with an interval of about 1 1/2 months).

In order to compare differences between variables, these differences must be standardized by dividing them by the standard deviation of each variable separately (since the variables differ considerably in terms of distributional characteristics).

The goodness-of-fit of the model will be calculated by means of a χ and a χ^2 -function, defined, respectively, as the sum of absolute differences and the sum of squared differences between the predicted and the observed values (standardized by dividing by the standard deviation). The value of χ and χ^2 obtained from the data can be compared with the distributions of χ and χ^2 based on the random permutation test, in order to determine the p -values. The use of χ in addition to the more common χ^2 is justified by the fact that χ provides an intuitively simple distance measure between the model and the data, with a probability distribution generated by the random permutation method.

Consistent with recommendations from discussions in the statistical literature regarding the meaning of p -values (Cohen, 1994), we present the p -values of the distinct variables “as is”. Their meaning depends on the expectation at issue. For instance, if there is a variable for which we expect a relatively small difference between the popular and rejected dyads, and such relatively small difference in the expected direction is indeed found, the corresponding p -value will be most likely in the order of 0.2–0.25, given the relatively small number of dyads present in our sample. This p -value is consistent with the predicted effect and should thus not lead to a rejection of the hypothesis in question.

Results

Overall pattern

The χ and χ^2 values are 7.6, $p = 0.006$ and 8.6, $p = 0.001$, respectively (average χ and χ^2 values of the null hypothesis model are 10.8 and 15.8, respectively). These p -values support the conclusion that the model provides a better description of the pattern of observations than a null hypothesis model based on the assumption that popular and rejected children, play partners, and dyads are similar.

The effect sizes for all variables (children, partner, and dyad) found in the data are within a narrower range than those predicted by the model. The effect sizes are 0.6, 0.54, 0.51, 0.5, 0.5, 0.4, 0.37, 0.34, 0.23, and 0, respectively. We divided these 10 values into three groups, in which a ‘great’ effect size means greater than 0.5 SD , a ‘moderate’ effect size is between 0.4 and 0.5, and a ‘small’ effect size is smaller than 0.4 SD . Overall, the predictions regarding the effect sizes are confirmed in the sense that the rank order of the found effect sizes matches that of the predicted effect sizes.

Children

First, we will review the differences in averages of the operational variables between the group of rejected and popular children, see Table 5 for an overview of all the results. Results of the average children (in the “average” dyads) are not reported, because analyses reveal that in all cases but one the mean scores of the “average” dyads lie in between the mean scores of the “popular” and “rejected” group, with one exception, in which the difference is not statistically significant.

Consistent with the model prediction, the popular child directs his behavior less often towards the play partner than does the rejected child. The difference is “great” (‘directedness’ variable; the difference is 0.6 *SD*, $p = 0.06$). Also consistent with the model prediction, the popular child shows on average less intensity in its positive expressions than does the rejected child (the difference is again “great”, 0.51 *SD*; $p = 0.1$).

Regarding the effectiveness of the actions and expressions, i.e., the reciprocity of instrumental actions and emotional expressions, Table 5 shows that if the popular child directs his behavior towards the other child, this action is not more often shared with the play partner than if the rejected child shows a directed action (‘proportion shared directedness’ $SD = 0.00$, $p = 0.5$). This finding is inconsistent with the model prediction. However, the model prediction is confirmed if the second criterion of involvement, namely positive emotional expressions, is taken into account. If the popular child shows a positive expression, this expression is more often shared with the play partner than if the rejected child shows a positive expression (‘proportion shared positive’; the difference is 0.54 *SD*, $p = 0.08$). The magnitude of the effect size is consistent with the prediction (great, $>0.5 SD$). Thus, the postulated greater effectiveness of the popular child is confirmed on the level of emotional communication, but not the level of the instrumental actions.

Play partners

Consistent with the model prediction, we found that the levels of directedness and positive emotional expressions of the popular child’s play partner were lower than those of the

Table 5
Results regarding differences between popular and rejected children, play partners, and dyads

		Variables	<i>SD</i>	<i>P</i>	Confirmation	
					Direction	Effect size
Actions	Child	Directedness	−0.6	0.06	+	+
		Proportion shared directedness	0	0.5	−	−
	Play partner	Directedness	−0.23	0.27	+	+
		Proportion shared directedness	−0.5	0.09	+	+
Dyad	Coherence	−0.4	0.14	+	+	
Positive expressions	Child	Positive expression	−0.51	0.1	+	+
		Proportion shared positive	0.54	0.08	+	+
	Play partner	Positive expression	−0.34	0.2	+	+
		Proportion shared positive	0.5	0.1	−	−
	Dyad	Shared positive expression	−0.37	0.19	+	+

Note. (a) The variables have been standardized and centered, which implies that they have a standard deviation of 1 and a mean of 0. For instance, a difference of −0.6 *SD* with a *p*-value of 0.06 means that popular children scored 0.6 *SD* less on this variable than rejected children, with a *p*-value of 0.06. (b) Confirmation is expressed in both direction, and in effect size.

rejected child's play partner ('directedness', 0.23 *SD*, $p = 0.27$; 'positive expression', 0.34 *SD*, $p = 0.2$). As expected, the differences were "small" (< 0.4 *SD*). Also consistent with the prediction, we found that the proportion of shared directedness was higher in the rejected child's play partner than in the play partner of the popular child (0.5 *SD*, $p = 0.09$). Again, the magnitude of the effect size is consistent with our prediction, namely 'moderate' ($0.4 < 0.5$ *SD*).

Contrary to the expectation is the finding that the popular child's play partner shows a higher proportion of shared positive emotional expressions than the rejected child's play partner ($SD = 0.5$, $p = 0.1$). This finding suggests that the popular dyad as a whole is more effective on the emotional expression level in particular, most likely due to the presence of the popular child.

Dyads

Consistent with the model prediction, the "popular" dyad shows less coherence than the "rejected dyad" (0.4 *SD*; $p = 0.14$). Also consistent with the model prediction, the "popular" dyad expresses on average less shared positive expressions (the difference is 0.37 *SD*, $p = 0.19$). The magnitudes of these differences is also consistent with the prediction (0.4 or smaller *SD*).

Discussion

The main goal of this article was to present a theory of the short-term dynamics of social interaction in children and to use that theory to formulate a dynamic systems model, put in a mathematical form, that implements the "bare essentials" of the underlying theory. The theory and model integrate aspects such as social-interaction intentions (concerns), contagiousness of behavior, social competence, and social power. The empirical application to dyadic play between children of different sociometric statuses served several functions: to illustrate by which steps the general model can be applied to specific situations, to illustrate the way predictions can be generated from the model, and finally, to demonstrate the potential validity of the model vis-à-vis empirical data. We shall first discuss the validity of the model in view of the empirical data, which, needless to say, serve as an illustration and do not pretend to be a comprehensive empirical test.

Conclusions from the empirical data

First, a calculation of the goodness-of-fit of the model as a whole convincingly shows that the model predicts the pattern of differences and similarities between rejected and popular dyads considerably better than a null-hypothesis model.

Second, to summarize the presentation of the separate variables presented in the Results section, 8 of the 10 predictions were confirmed. Given the nature of the data, confirmation depends on whether the direction of the difference between popular and rejected dyads was according to prediction, whether the magnitude of the observed difference matched the rank order of expected differences and finally, whether the p -value calculated for each of the variables supported the predicted difference.

The eight variables that are consistent with our predictions, described the following pattern of distinctions and similarities between rejected and popular dyads. To begin with, rejected children show a different behavioral pattern than expected on the basis of what

is reported in the mainstream of the existing literature, which predicts low levels of positive expressions and directedness. We found significantly higher levels of positive expressions and directedness for rejected than for popular children. In view of their smaller proportion of shared positive emotional expressions, it can be speculated that rejected children are inclined to show an overflow of positive expressions, in the sense that they show many positive expressions that are not reflected by reactions of the play partner. It is likely that this overflow is a consequence of their hypothesized high preference for involvement, in this particular context of playing with a child of a higher-status. The overflow is also an indicator of their relative lack of effectiveness, in the sense that much of their effort in terms of emotional expression is not shared. Note, however, that the rejected children do not differ from the popular children in terms of shared directedness. That is, their sharing of instrumental (verbal and non-verbal) actions with the play partner is equal to the popular child's sharing of such actions with the popular child's play partner.

We found popular children to display less positive expression and less directedness, as a consequence of their hypothesized lower preference for involvement, in this specific context of playing with a child of a lower-status. However, the positive expressions they do show are more often accompanied by a positive expression of the play partner. Thus, considering positive expressions the interaction suggests a better intersubjective framework. In addition, popular children are effective in their interaction, in the sense that they invest less effort and nevertheless generate proportionally high levels of effort in the play partner. In order to check this interpretation, we counted the play partner's verbal and non-verbal initiation actions and found that they were considerably more frequent than that of the popular child ($p = 0.09$). Our model explains this observation by assuming that popular children are able to make a good distinction between situations in which action is effective or not.

With regard to the play partner, we confirmed the expectation that his or her level of involvement would be drawn towards the preferred level of involvement of the rejected and popular child, respectively, and thus that play partners of rejected children would show more involvement than those of popular children. We also expected this to occur with the proportional measures. This expectation was confirmed with directedness (instrumental reciprocity) but not with positive expressions, where the difference was opposite to expected. The fact that the play partner of the rejected child shows greater instrumental reciprocity than the play partner of the popular child can possibly be understood as an effect of the rejected child's apparently greater effort to establish interaction, based on his preference for a more intensive interaction with the play partner.

A final point of consideration regards the expressions of negative emotions. Our theoretical decision not to examine negative expressions was supported by our ad hoc observation that they occur with very low frequency and, moreover, that there exist no differences between status groups. There is an interesting exception for one variable, which shows that if play partners of rejected children showed a negative expression, they were more intensely negative than if play partners of popular children showed a negative emotion.

In summary, our empirical data generally support the predictions of the dynamic model. The data were collected from a dyadic play interaction between children of different sociometric status. Although, this particular interaction situation encompasses the various components distinguished in the theoretical and dynamic model, it is only one particular situation to which the model is applicable. Moreover, as an illustration, the current

situation has further limitations, in that for instance only a few of the possible combinations of sociometric statuses in dyads were tested (although the tested combinations implemented the type of differences in social power and competence that our model considers important). It is clear that more and also more elaborate empirical studies are needed in order to show to what extent the predictions made by the model can be empirically corroborated.

It is necessary to remark that the differential components we used to study context dependency, i.e., the social competence-component and social power-component, are postulates that we employed to generate predictions from our model. However, they were not directly measured in the popular, average, and rejected children that were distinguished on the basis of our sociometric test. Future research must look for ways to observe social competence (effectiveness) and social power directly.

Predictions based on process models and relation with previous findings

An important point of consideration is the discrepancy between findings from earlier studies (see the Introduction section) and our own study concerning differences in behavior of rejected and popular status groups. The difference, in our view, can be explained by the fact that we used a process model to make predictions. Predictions based on a process—i.e., dynamic—model that applies to a specific situation can easily differ from predictions based on “static” models (a particularly illuminating example is discussed in Musher-Eizenman, Nesselroade, & Schmitz, 2002). Static models describe statistical associations between variables over groups, for instance the association between sociometric status and emotional expressions during interaction within a group of 5–7-year-olds (see Howe & Lewis, 2005; Van Geert & Steenbeek, 2005; for a discussion of static versus dynamic models). They are often based on data from questionnaires or the observation of diverse interaction situations. The dynamic model generates predictions based on a model of the temporal trajectory of the process of interaction in specific contexts. Thus, the predictions apply to these contexts, and not necessarily to others. Dynamic models derive their generalizability from the extent to which they can be adapted to many different situations by changing the model’s parameter values.

It is likely that the difference in the predictions, and the fact that predictions based on our process model are confirmed can, first, be explained by the specific play situation that our research setting entails. In our setting, the children are explicitly asked to play with the other child and are monitored by adults. This situation is different from a free play situation in the daily life of children. Possibly, rejected children in particular do not often get the chance to play with a higher-status child, in a one-to-one situation that is explicitly sanctioned by an adult (see Gottman et al., 1997). Our process model predicts that, given this opportunity, they will show many positive expressions and direct many actions towards the other child. The fact that they behave in this way in this particular situation does not exclude another fact, which is described by the literature discussed earlier, namely that their overall daily experience might be one of predominantly negative emotions and little interaction. A challenge for our process model is to try to explain why spontaneous interactions with other children are infrequent and often negatively loaded.

A second possible explanation for the difference between our findings and those reported in the majority of the earlier studies, is that the strength of the effects of the social competence-component and the social power-component possibly depends on the situation in

which the interaction takes place. In our research setting, i.e., in an adult-controlled play situation, the social power-component probably has more influence on the behavior of the children than the social competence-component. In this context, the rejected child can for a longer period attempt to show more involvement behavior, because the play partner has less opportunity to reject the child by (actually physically) withdrawing from the play interaction. This context is in contrast with free play situations, where children seek their own play partners and eventually reject others, and in which the social competence is likely to play a significant role in initiating and maintaining interactions, given the play partner's freedom to quit if the interaction is not sufficiently satisfying.

Applied consequences

Our approach provides an alternative for the literature that stresses negative characteristics of rejected children, for instance their aggressive or withdrawn behavior. It provides a more balanced image of the rejected child, which puts forwards the (potential) high preference for involvement of the child and the high amount of effort that the child invests in trying to establish interaction, in situations where it is given the opportunity to achieve his or her social interests and preferences.

A practical consequence of the above remarks is that it is important for teachers and counselors to bring rejected children in social situations in which they can realize their social goals more easily, in which positive interaction occurs, and in which they have control over resources. These are situations that are likely to heighten the competence and the social power of these children, and thus, counteract the vicious circle in which rejected children often are entrapped.

From an assessment point of view, we think it is important to consider the extent to which the child's behavior is sensitive to various types of contexts. Instead of merely diagnosing particular children as having poor social competence and a rejected status, it is more interesting to look for particular contexts which will help the child interact positively and realize his concerns, (e.g., a cooperative learning situation with just one other child) and thus help the child develop his competence and possibly improve his social status. A further diagnostic implication is that children are in fact characterized by a range of possible interaction forms that are co-determined by the extent to which they can realize their goals (concerns) or control resources. This emphasizes the use of repeated testing and observation in different contexts, aimed at trying to understand the child's interaction dynamics, i.e., trying to understand what it is that drives a child's actions.

Dynamic systems thinking in developmental theory building: Reflections on the current study and suggestions for further research

In the Introduction section, we made two remarks about the majority of existing developmental studies on social interaction. The first remark concerned the role of the context. In our dynamic systems model, the involvement actions of one participant form the context for the involvement actions of the other participant, and vice versa. In this sense, the context is not a static given, but something that evolves over the course of, and is created by, the interaction process itself. The model further specifies various contexts in the form of specific parameter values, and thus allows for variability in the peer context.

The second remark contained a plea for dynamic, process-oriented explanations of interaction. Our dynamic systems model took the form of a system of coupled differential equations. The underlying model aims at specifying the minimal set of theoretical components that we think are fundamental to any dyadic interaction process. This minimal set is intended to explain what we see as a fundamental property of interaction, namely the emergence of a (temporary and context-specific) attractor for the level or amount of involvement of the participants in the interaction. This attractor is a relatively “high-level” property of an ongoing interaction process, which must be sampled by observing the interaction process over a certain amount of time (e.g., the duration of a play interaction between children). For this reason, the current dynamic model is particularly suited for studying concatenated aspects of interaction, such as average involvement emerging after some initiation time. In short, the main empirical use of the model lies in predicting distributions of such average properties for various sorts of dyads.

The study of lower-level properties of interaction—for instance the fluctuations in interaction over the course of minutes or less—requires a more detailed dynamic model, which, however, should be based on the same general principles or components as those described in the current article. An example is the current authors’ agent model of dyadic interaction, which can be used for the prediction of group-based averages and distributions, as well as prediction of the actual course of an interaction process, including its fluctuations and patterns over the course of a single interaction episode (see Steenbeek, 2006; Steenbeek & van Geert, 2005; Van Geert & Steenbeek, 2005).

A further consideration concerns the applicability of the current model to interactions other than dyadic play situations. Application to other contexts requires that the interaction parameters are specified in terms of differential interaction concerns, social competence, and social power. An example of an important dyadic context is that of parent–child interactions, where in addition to the vertical nature of parent–child relationships also horizontal qualities of interaction can be investigated (see Russell et al., 1998). Another example is that of situations in which the goals and appraisals of the participants are not symmetrically positive. A characteristic example is bullying, in which the bully’s involvement actions towards the victim are intended to do the victim harm. In this case, the victim’s eventual willingness to undergo the bullying cannot be an example of mere imitation (in which case the victim should imitate the bullying). The victim’s being gravitated towards the bully’s activities, against the victim’s preference, interests, and concerns, is nevertheless described by the contagiousness-component of the mathematical model, which thus obtains a wider applicability than imitation per se. In addition, the bully’s social competence can act as a parameter enhancing the unpleasantness of the interaction for the victim. This could easily be implemented in the model by setting the other-appraisal terms (the c and d parameters, see Eq. (10)) to negative values.

Note also that the model confines itself to describing the time evolution of the involvement attractor once the interaction partner has been selected. Thus, in order to broaden its applicability, the model should be complemented by an interaction-partner selection model. It is highly likely that interaction-directed intentions (concerns and preferences), social power and competence will be crucial to any dynamic model of interaction-partner selection. At present, the model does not contain a stop- or escape-parameter, determining whether and when a child will step out of the interaction if the child’s concerns are not realized in a satisfactory way.

Taking the dyadic interaction as a building block, the model can also be extended to account for interactions between multiple players, in which networks of interaction emerge. In this way, a link could be made to the extensive literature about social network research (Van Rossem & Vermande, 2004).

A characteristic feature of the dynamic systems approach is that it focuses on both short-term and long-term processes, and attempts to describe the link between the two (for an example of long-term dynamics in social development, see Kunnen and Bosma's model of meaning making, Kunnen & Bosma, 2000). In the current article, we have confined ourselves to presenting a model of the short-term dynamics of social interactions. The developmental point of view, however, requires that this short-term model is complemented by one that focuses on the long-term processes (for a discussion of the link between short- and long-term dynamics in the agent model of social interaction, see Van Geert & Steenbeek, 2005). This long-term model must specify how properties of the short-term interaction—basically the participants' experiences with social interaction—modify the parameters that govern the short-term process (e.g., the preference, social-competence, and social-power related parameters) and by doing so, change the pattern of interaction itself over the long run.

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