

ORIGINAL RESEARCH REPORT

Prediction of Group Performance: The Interplay of Individual Performance, Interpersonal Attraction, and Interpersonal Behavior

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On the basis of the input-process-output model, the present research examined how individual performance, interpersonal attraction, and interpersonal behavior affect group performance in a problem-solving task. 164 participants were assigned to 41 groups, each consisting of four same-sex members. Participants completed a measure of interpersonal attraction and individually solved the established moon-landing task. Afterwards, all group members worked together to find a common solution for this task. Four interpersonal behaviors were recorded on video while the group interacted (cooperative, communicative, coordinative, and conflict behavior). Two main findings emerged: First, on average, groups performed better than the individuals did alone. Second, individual performance, interpersonal attraction, and directly observed interpersonal behaviors were independent predictors of group performance. Furthermore, we found indications that interpersonal behavior might play a mediating role here. The results and their implications are discussed.

Keywords: group performance; individual performance; interpersonal attraction; interpersonal behavior

Humans work together in almost all areas of everyday life. In the context of academic performance, for example, from the beginning of elementary school, students learn how to work together effectively in groups. Later in their educations, students work in learning groups to achieve their academic goals (e.g., to pass exams). And finally, in a professional context, colleagues form project teams, production groups, or departments where individuals can work together more efficiently for various purposes (e.g., to build a house, perform surgery, publish a research article). Furthermore, in almost all areas of everyday life, groups often make it easier for people to achieve their goals.

Because a great deal of work and many human activities are accomplished in groups, research on small groups has focused on investigating the processes and factors that explain and improve group performance (Bell & Kozlowski, 2012; Kozlowski & Ilgen, 2006). Important determinants of group performance are the performances of the individual group members (Devine & Philips, 2001). That is, high-performing individuals are able to enhance the performance of the group with their abilities. A further important determinant of group performance is the interpersonal attraction between the group members: The more group members evaluate each other positively,

the better a group's performance is (see, e.g., the meta-analysis by Beal, Cohen, Burke, & McLendon, 2003). However, to date, the mechanisms through which both individual performance and interpersonal attraction lead to improved group performance have yet to be investigated.

With the present study, we aimed to fill this gap by examining the influence of *both* individual performance and interpersonal attraction on group performance and by investigating possible mediating processes. Participants worked individually and in groups on an established rational problem (i.e., the moon-landing task). We also assessed their attraction to the other group members, and we assessed four interpersonal behaviors (cooperation, communication, coordination, and conflict) while the group interacted. This allowed us to investigate the role of actual interpersonal behavior in explaining the relations between individual performance, interpersonal attraction, and group performance.

A Conceptual Framework for the Prediction of Group Performance

The conceptual approach that guided our research was the *input-process-output model* (Hackman, 1987; McGrath, 1964), which describes important variables that influence group performance (see **Figure 1**). The *input variables* are characteristics of the group members and the situation, both of which exist *before* the group interaction takes place. Inputs can consist of, for example, the average age of a group, cultural diversity, or gender ratio. In the

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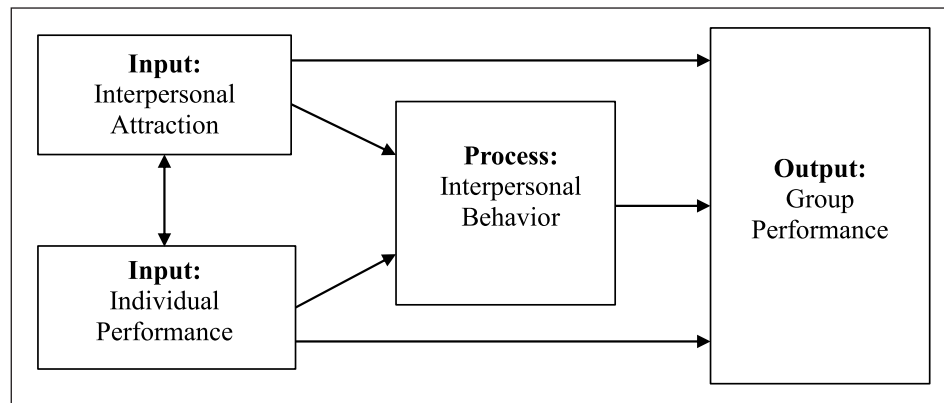


Figure 1: General overview of the investigated variables modeled according to the input-process-output model (Hackman, 1987; McGrath, 1964).

present study, we focused on individual performance and interpersonal attraction between the group members before the group interaction as the input variables that would be most likely to predict group performance (e.g., Beal et al., 2003; Devine & Philips, 2001). The *process variables* describe all processes that determine how the group members interact and behave together (see McGrath, 1964). These interaction processes are affected by the input variables but are also shaped by internal processes during the interaction. We expected that the interpersonal behaviors that could be observed by the other group members (see Furr, 2009) would mediate how interpersonal attraction and individual performance lead to group performance. For example, cooperative behaviors such as mutual adjustments and the integration of activities for task management should be affected by interpersonal attraction as well as individual performance, and this in turn should influence group performance. Finally, group performance as the *output variable* should be determined by the input variables (i.e., individual performance and interpersonal attraction) as well as the process variables (i.e., interpersonal behaviors). In general, group performances can be assessed in different ways (e.g., productivity, efficacy, satisfaction). In the present study, we measured group performance as the correctness of the result of a problem-solving task.

The input-process-output model can be extended to additionally include relevant dynamic components such as time and feedback loops, and interactions between the components of the model can also be added (e.g., Arrow, Poole, Henry, Wheelan, & Moreland, 2004; Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Pavitt, 2014; Rosen, & Pronovost, 2014). However, all conceptualizations are in agreement about the main idea of the primary model, which is also the key idea of the theoretical framework of this study: There are inputs that trigger processes within the group and that result in group outcomes. Next, we present findings on the input variables and process variables that we hypothesized would be found to be predictors of group performance.

Individual performance as a predictor of group performance

Devine and Philips (2001) summarized the results of several meta-analyses that investigated the role of

individual performance in predicting group performance. They examined which operationalization of individual performance had the greatest impact on group performance: (a) the individual performance of the best group member, (b) the individual performance of the worst group member, (c) the mean of the individual performances of all group members, or (d) the standard deviation of the individual performances of the group members. They concluded, “to predict how well a team will perform, it appears more valuable to know the mean level of cognitive ability of members than the score of the highest or lowest scoring individual” (p. 523). The standard deviation of the group members’ individual performance did not predict group performance. Note that the statements made by Devine and Philips (2001) referred exclusively to the influence of individual performance on group performance. In other group contexts, there are important psychological constructs (e.g., leader membership exchange) for which the mean of the individuals’ values on the construct is not sufficient for investigating group outcomes (see, e.g., Martin, Thomas, Legood, & Dello Russo, 2018; Yu, Matta, & Cornfield, 2018).

Devine and Philips’ (2001) results suggest that the average level of individual performance within the group should be the best predictor of most group tasks. Nevertheless, it is important to consider the conceptualization of the task before considering the conceptualization of relevant variables (i.e., which aspect of individual performance should be the best predictor of group performance). Accordingly, for tasks in which the group members and subtasks are interrelated and influence each other, it can be assumed that the mean of individual performances is better at predicting group performance than the performances of particular individuals in the group would be (e.g., discussing problems with uncertainty about the right solution). In tasks for which the focus is on the best or worst member, these best or worst individuals should have the greatest impact on the group outcome (e.g.: When a group is asked to solve a problem containing eureka-type questions and the best member has solved the problem, the whole group automatically succeeds. In contrast, when climbing a mountain as a group, the group can only be as fast as the slowest group member). Accordingly, for the problem-solving task used in the present study (in which subtasks

are interrelated), we assume that the mean level of individual performance in the group should be the most appropriate predictor.

H1: Mean individual performance will predict group performance.

Interpersonal attraction as a predictor of group performance

Previous research has repeatedly shown that, on average, people in groups outperform individuals (Wittenbaum, Hollingshead, & Botero, 2004). Thus, other determinants that improve group performance beyond the level of individual performance must exist. Interpersonal attraction, for example, could be a potential factor that incrementally predicts group performance. Interpersonal attraction is an important facet of group cohesion according to the theoretical definitions put forth by Festinger (1950), who defined group cohesion as a combination of three components: group pride, task commitment, and interpersonal attraction. Montoya and Horton (2014) defined interpersonal attraction as one person's spontaneous positive or negative evaluation of another person. In fact, a number of meta-analyses have shown that interpersonal attraction between group members is a significantly positive predictor of group performance (e.g., Beal et al., 2003; Castaño, Watts, & Teklab, 2013; Chung, Lount, Park, & Park, 2017). Furthermore, in applied psychology, cohesion, the superordinate construct of interpersonal attraction (see Festinger, 1950), has often been found to increase so that group performance can be enhanced (Casey-Campbell & Martens, 2009). In line with this evidence, we expected that interpersonal attraction would be a significant predictor of group performance.

H2: Interpersonal attraction will predict group performance.

Four interpersonal behaviors as processes in the prediction of group performance

Although individual performance and interpersonal attraction are linked to group performance, researchers have not yet determined how the positive impact of these variables on group performance is conveyed. In the input-process-output model, interpersonal behavior between group members is proposed to be a mediator of the effect of individual performance and interpersonal attraction on group performance. Here, we want to focus on four interpersonal behaviors related to cooperation, communication, coordination, and relationship conflict that are assumed to be important observable process mechanisms that influence group performance (see Devine & Philips, 2001; Kozlowski & Bell, 2003; Kozlowski & Bell, 2006; Kozlowski & Ilgen, 2006).

Kozlowski and Bell (2003) equated cooperation with collaboration (i.e., the willful contribution of group members to successfully working on an interdependent group task). Furthermore, while communication was defined as a way to enable interactions within groups by being the "lens" of information exchange, coordination describes activities that are required to

manage several interdependent aspects of a group task. Finally, relationship conflict was described as a process that underlies divergence in groups. Whereas relationship conflict is detrimental to group performance, cooperation, communication, and coordination enhance group performance in different ways. Coordination, to begin with, involves and focuses on a temporal component and the management of, for example, mutual adjustments, the effective integration of activities in task management, or the resolving of obscurities. All of these components are not essential parts of cooperation where more interpersonal aspects such as team orientation, trust, support, and compromises while working together are addressed. Finally, although communicative behavior enables cooperation and coordination, it also refers to contact between group members that enables the exchange of all (spoken) information.

In order for these four interpersonal behaviors to function as process variables in the input-process-output model, they must be related to all input variables and also to the group performance outcome. Therefore, we first describe theoretical considerations and empirical evidence for the relations between the four behaviors and individual performance, and then we report the relations between the four interpersonal behaviors and interpersonal attraction and finally with group performance.

When individuals are motivated to positively affect their group's performance, they have to convey their individual knowledge to their group through interpersonal behaviors, and they must interact with the other group members. Thus, individual performance should be related to the four aforementioned interpersonal behaviors. Interestingly, the only study that investigated individual performance and behavior found no such association (LePine & van Dyne, 2001). However, a problem with this previous study is that behavior was measured in a virtual context. Interactions via computer messages may differ from actual interpersonal behavior in real life. Therefore, we expected that individual performance would predict interpersonal behavior in face-to-face interactions.

H3a: Individual performance will predict the four interpersonal behaviors coordination, communication, cooperation, and conflict.

In addition, we also propose that high interpersonal attraction between group members should lead to performance-enhancing interpersonal behaviors that in turn should have a positive effect on group performance. With regard to cooperation, to begin with, teams with higher interpersonal attraction have been found to cooperate more when they work together on a task than teams with lower interpersonal attraction (Casey-Campbell & Martens, 2009). Furthermore, a recent meta-analysis found that cooperation was also positively correlated with group efficacy (Beal et al., 2003). Moreover, in a medical context, standardized tools have been developed to organize and optimize cooperation between and within teams, and these tools have been found to be successful at increasing performance (Leonard, Graham, & Bonacum, 2004; Sexton, Thomas, & Helmreich, 2000).

Concerning communication, research has shown that communicative behavior is related to both interpersonal attraction (Berscheid & Walster, 1969; Chung et al., 2017) and group outcomes (Kozlowski & Bell, 2003; Marlow, Lacerenza, Paoletti, Burke, & Salas, 2018). We propose that interpersonal attraction should increase communicative behavior and hence the amount of knowledge that is shared across group members. The amount of shared information should then have a positive impact on the group's performance (van Woerkom & Sanders, 2010; Larson, 2010). Moreover, mistakes in communication should lead to failure in achieving group goals (Kozlowski & Ilgen, 2006).

Furthermore, there should be a positive relation between the interpersonal attraction of group members and interpersonal coordination. Groups with higher interpersonal attraction should coordinate their group activities better than groups with lower interpersonal attraction, and this better coordination should serve to increase the performance of the group (Cartwright, 1968; Davis, 1969; Vicaria & Dickens, 2016). Coordination as a central behavioral process in group work has been found to have a positive impact on creative thinking (Ashton-James & Chartrand, 2009) and field-dependent thinking (van Baaren, Horgan, Chartrand, & Dijkmans, 2004) as well.

A main reason for why groups fail to achieve their aims is relationship conflict (Janss, Rispen, Segers, & Jehn, 2012; Manata, 2016). Three meta-analyses have demonstrated that relationship conflict between group members has a negative impact on group performance (DeDreu & Weingart, 2003; DeWit, Greer, & Jehn, 2012; O'Neill, Allen, & Hastings, 2013). Furthermore, relationship conflict has been found to lead to less information sharing (Chung et al., 2017), and results have hinted that interpersonal attraction could have an important influence on the connection between relationship conflict and group performance (DeWit et al., 2012).

Thus, altogether, we hypothesized:

H3b: Interpersonal attraction will predict the four interpersonal behaviors coordination, communication, cooperation, and conflict.

H4: The four interpersonal behaviors coordination, communication, cooperation, and conflict will predict group performance.

As we noted from Hypothesis 1 to Hypothesis 4, previous studies have provided empirical evidence for important features of the input-process-output model. That is, (a) individual performance as well as interpersonal attraction should predict group performance (H1 and H2), (b) individual performance as well as interpersonal attraction should predict interpersonal behaviors (H3a and H3b), and (c) interpersonal behaviors should predict group performance (H4). On the basis of these findings, we propose that interpersonal behaviors should mediate the relations between the input variables (i.e., individual performance and interpersonal attraction) and the output variable (i.e., group performance). To our knowledge,

previous research has not yet investigated the mediating role of interpersonal behaviors. Nevertheless, on the basis of theoretical considerations on the input-process-output model and on the findings presented above, we thus hypothesized:

H5: The four directly observed interpersonal behaviors coordination, communication, cooperation, and conflict will mediate the correlation between individual performance or interpersonal attraction and group performance, respectively.

The Present Research

We conducted the present study to investigate whether and how group performance could be predicted by individual performance and interpersonal attraction, and whether and how directly observed interpersonal behaviors mediate the relations between these variables on the theoretical basis of the input-process-output model. Our study extends previous research because we went beyond examining the relations between the relevant variables in isolation (e.g., Chung et al., 2017; Casey-Campbell & Martens, 2009; LePine & van Dyne, 2001; DeDreu & Weingart, 2003; Hackmann, 2002; Kozlowski & Bell, 2003). Rather, we considered all of the theoretically important variables in one study. This was important to do because it allowed us to control for the effect of the other variables when examining the relation between two specific variables.

Another extension of our study is that we did not assess interpersonal behavior via questionnaire data, but we measured behavior directly (Furr, 2009; Back & Egloff, 2009). As far as we know, no prior studies directly tested observed interpersonal behaviors as mediators of the link between individual performance/interpersonal attraction and group performance. Another noteworthy feature of our study is that we categorized participants into same-sex groups, and that we used a zero-acquaintance design.¹ By doing so, we attempted to minimize the probability that possible confounders would influence the interpersonal attraction evaluations (e.g., heterosexual attraction, heterosexual flirting behavior, acquaintance, familiarity). Because the group members did not know each other before the study, all groups began their interactions in the first stage of group formation according to Tuckman (1965).

Moreover, the zero-acquaintance setting and the chronological order of the measures in our design allowed us to examine how both individual performance and interpersonal attraction affected group performance (and not the other way around).² Furthermore, research has shown that ratings of interpersonal attraction (e.g., Indik, 1965; Slater, 1958) and group performance (Mullen & Baumeister, 1987; Mullen & Copper, 1994; Mullen, Johnson & Drake, 1987) decrease with increasing group size. We therefore decided to assess groups with an invariable group size of four participants. Finally, tasks and interactions have been classified in various ways in the literature (e.g., Steiner, 1972; McGrath, 1984). These

taxonomies have been useful for many areas of group research, but few have been relevant for investigating interpersonal attraction in groups (Beal et al., 2003). However, task interdependence was found to be a highly relevant aspect of group interactions in investigations of interpersonal attraction and group performance (Gully, Devine, & Whitney, 1995). Thus, in the present study, we focused on the prediction of group performance in a task with high interdependence (i.e., group members had to interact with each other).

Level of Analysis

When group performance is investigated as an outcome, it is important to identify the appropriate level of analysis. In general, because predictors affecting group performance refer to the result of various forces and processes acting on the group level, it seems appropriate to conceptualize the constructs of interest at the group level. This idea is also in line with the analytical approach used in earlier group performance research (see, e.g., Beal et al., 2003; Gully et al., 1995). This approach also provides compelling evidence that the relation between group performance and interpersonal attraction (or group cohesion; see below) tends to be stronger when the data are analyzed at the group level. Accordingly, we examined the relations between the variables of the input-process-output model at the group level.

More specifically, group performance and the four interpersonal behaviors were directly measured at the group level. Because interpersonal attraction and individual performance cannot be measured directly at the group level, both kinds of variables were first measured at the individual level and then aggregated to the group level (see, e.g., Mathieu, Kukenberger, D'Innocenzo, & Reilly, 2015). Thus, to predict group performance, we computed a mean level of individual performance and a mean level of interpersonal attraction for each group. We believe that these average values are valid indicators of the processes that occur on the group level: The average of interpersonal attraction, for example, reflects the amount of liking or social bonds in the group. Furthermore, the average of the individual performances provides a measure of the performance capacity of the group.

When the means of individual performance (or interpersonal attraction) are high or low, the composition of the group is relatively clear. The members of these groups consistently solved the task very well or not very well (evaluated each other positively or not), respectively. When the means of individual performance (or interpersonal attraction) are in the middle of the range, the composition of the group is ambiguous. It could be the case that (a) each of the group members solved the task well on average (evaluated each other positively on average), or (b) two members solved the problem task very well and two members solved the problem task very poorly (two members evaluated each other very positively and two members evaluated each other very negatively). Of course, other combinations are possible for explaining the group composition of a mid-scale mean of individual performance (or interpersonal attraction).

In either case, we expect that groups differ in their level of mean individual performance and mean interpersonal attraction. In our study, we aimed to examine how these group differences affect subsequent group performance in a problem-solving task.

Method

Participants

One hundred sixty-four unacquainted participants (92 women) participated in exchange for monetary compensation (20 €). Participants were German students from different fields of study and were 24.64 years old on average ($SD = 3.44$, $Min = 20$, $Max = 38$). Participants belonged to 41 same-sex groups, each consisting of four group members.

Procedure

After arriving, participants provided written informed consent. Then they were photographed in a standardized position with a neutral facial expression to create photographs for the ratings of interpersonal attraction. Next, participants were asked to stand in front of the group and briefly introduce themselves by providing information about their first name, family name, place of origin, field of study, semester, interests, and leisure activities. The duration of self-introductions was 30s. Then, participants were seated at personal computers in separate cubicles to rate each group member on interpersonal attraction. Thereafter, participants were escorted to the observation room where they first individually solved the "Lost on the Moon" problem (Robins & Beer, 2001). Afterwards, the group was asked to solve the moon problem together and to find a common solution. The time limit was 10 min for individuals and 20 min for groups. The allotted time limit for the discussion was sufficient: Group discussions lasted an average of 14 min 51s ($SD = 4$ min 15s). During the group task, interpersonal behaviors were recorded with video cameras.

Measure of Interpersonal Attraction

There are established questionnaires that can be used to measure interpersonal attraction as a global measure (example item: "The members of my team feel close to each other"; Mathieu, 1991). We decided to assess interpersonal attraction with a round-robin design (Back & Kenny, 2010; Kenny, 1994) because this allowed us to disentangle different components that are considered in interpersonal attraction judgments (see below). That is, each participant was asked to evaluate each of his or her group members on positive adjectives, and each participant was also evaluated by each of the other group members (Nestler, Grimm, & Schönbrodt, 2015). To make their ratings, participants were presented a picture of each group member's face, along with four questions: "How *likeable* do you find this person?"; "How *honest* do you find this person?"; "How *sincere* do you find this person?"; and "How *cheerful* do you find this person?" The four adjective ratings were made on a 6-point Likert scale ranging from 1 (*not at all*) to 6 (*very much*). The internal consistency of this four-item measure was $\alpha = .82$.

Note that participants were instructed to use the photo only to identify the group members. In other words, participants were asked to rate the impression they had formed of the group member at the introductory session and not any impressions that might be suggested by the photo itself.

We used the social relations model (SRM; Kenny, 1994) to analyze the round robin data. In the SRM, each interpersonal judgment consists of a perceiver effect (e.g., how much a person likes the other group members on average), a target effect (e.g., how much a person is liked by the other group members), and a relationship effect (e.g., how much person *i* uniquely likes person *j*). Here, we used the target effects of interpersonal attraction ratings at the group level to examine our research questions. To accomplish this, we first aggregated the four judgments that referred to one dyadic evaluation. Then, we used the R package 'TripleR' (Schönbrodt, Back & Schmukle, 2016) to extract the SRM effects of interpersonal attraction for each group member. These values were then averaged per group to obtain a mean value of interpersonal attraction per group. The reliability of the target effects was .64.

Our measure of interpersonal attraction has several advantages over the established global questionnaires. Typically, participants do not like or dislike each of their group members to the same extent. Hence, when they are asked global questions (example item: "The members of my team feel close to each other"; Mathieu, 1991), participants can generate only one general interpersonal attraction evaluation of the entire group. With our measure, a participant's evaluation of each specific group member's interpersonal attraction is less abstract and should thus be easier to rate.

Measures of Individual and Group Performance

Individual and group performances were obtained with the established rational problem-solving task *Lost on the Moon* (Robins & Beer, 2001). In this task, participants were told that they were members of a space crew that had crash-landed on the moon and needed to get back to their mothership, which was 200 miles away. The participants had to rank a list of 15 items with respect to the importance of each item for the crew's survival. First, each group member worked on the task alone. Afterwards, the group solved the task together and had to achieve a group consensus on the rankings.

Conceptually, the moon landing task is an interdependent rational (i.e., a correct solution to the task exists) multiple-stage problem, where various ideas and information have to be arranged in proper relation to one another (Littlepage, Schmidt, Whisler, & Frost, 1995). We used the moon landing task as a measure of performance in our study for various reasons: First, individual performance as well as group performance could be measured precisely by the same task, and therefore, the performances could be compared directly. Second, the moon landing task is a highly interdependent task. The association between interpersonal attraction and performance is more apparent when the group performance is affected by all group members (Beal et al.,

2003). The moon landing task offers the opportunity to discuss, negotiate, and choose options several times. Thus, a lot of interpersonal interaction can take place, and this also facilitates observable interpersonal behavior. Third, because none of the group members knew the right solution, all of the group members' opinions about the correct solution of the task should be equally important to the group, and memory effects should be near zero. Additionally, in the moon landing task, the contributions of all members might influence each other and therefore all flow into the group result. Thus, for this interdependent task, group performance should be affected by the average performance of the individual group members (and not just the best or worst members). Fourth, we did not expect learning effects from using the same task for individuals and groups because the participants did not know the task before the study and were given no feedback on their individual performances. Fifth, although our task could be criticized for not being linked to most people's real lives, Castaño et al., (2013) showed that a lack of realism in a discussion is not relevant to the investigation of group performance. In fact, problem-solving tasks are popular in investigations of the emergence of group performance (Robins & Beer, 2001).

In group research, an established method for evaluating performance is to examine how the group solved the task compared with a model solution developed by experts (Harris & Barnes-Farrell, 1997; Jordan & Troth, 2004; Robins & Beer, 2001; Zaccaro & McCoy, 1988). In the present study, we compared each item's (individual- or group-assigned) rank with its rank in NASA's expert solution; absolute differences between these two ranks were then calculated. For example, when the item *celestial map* was ranked third in the expert solution of the moon landing task, and a participant ranked the celestial map ninth, we first calculated the difference between the expert solution and the participant's solution (e.g., $3 - 9 = -6$). Then, the absolute value of this difference was taken (e.g., $|-6| = 6$). We repeated this procedure for each of the 15 items. A participant's final score was then computed by summing the participant's 15 values. The same scoring procedure was applied to the group solutions for the moon landing task. The higher the sum of the absolute differences across the 15 items, the worse was the individual's or group's solution. We recoded the data so that individuals or groups with better performances had higher values. Overall, a maximum of 112 points for the best performance was possible.

Because we analyzed all data at the group level, we calculated a composite score for individual performance at the group level by computing the mean of the performance scores of each individual in a group. In line with Kozlowski and Klein (2000), the measure of individual performance we obtained can be defined as composition emergence (vs. compilation emergence), that is, the level of individual performance in a group results from simply aggregating the individual performances of the group members. Note that a group's solution to the moon landing task as the measure of group performance was obtained at the group level. Therefore, no further data processing was required (i.e., in terms of averaging).

Measure of Interpersonal Behavior

The group's behaviors were videotaped while they solved the moon landing task. Ten independent observers (seven women) watched the videos to evaluate four different behaviors: cooperation, communication, coordination, and relationship conflict (see Kozlowski & Bell, 2003; Kozlowski & Ilgen, 2006). Each observer was given a manual that contained detailed descriptions of the four interpersonal behaviors. Indicators of *cooperative behavior* were purposeful cooperation, team orientation, trust, support, and compromise formation. Indicators of *communicative behavior* were exchange of information, circulation of information, and adherence to communication rules, such as listening and excuses. Indicators of *coordinative behavior* were coordinating the group members in their approach, mutual adjustments, integration of all activities for task management, solving obscurities, and active involvement of all members. Indicators of *conflict behavior* (relationship conflict) were aggressiveness, hostile humor, a tense group climate, disagreement, and criticism. Before the observers evaluated a behavior, they were trained by the first author to base their evaluations on a manual that provided precise definitions of the behaviors. Aiming to increase the reliability and validity of the behavioral assessments, each observer completed an observer training session along with the other observers to base their evaluations on the manual.

While watching the video, the observers focused on one of the four interpersonal behaviors (i.e., each of the 10 observers watched each video four times). The observers were asked to make global evaluations of the four interpersonal behaviors at the group level. That is, they were asked to focus on the interactions of the entire group (vs. focusing on special members or specific individual behaviors). All behavioral assessments were made on a 6-point Likert scale ranging from 1 (*very low presence*) to 6 (*very high presence*). Altogether, observers' judgments of the four behaviors showed agreement; cooperation: ICC [2, 10] = .74, communication: ICC [2, 10] = .54, coordination: ICC [2, 10] = .65, conflict: ICC [2, 10] = .77. For the analyses, the ratings of the 10 observers were aggregated per group for each behavior.

Results

We embrace the values of open science. The data and analysis scripts can therefore be retrieved from <https://osf.io/jkup3>.

Because the level of interest in the present study is the group level, we report all data at the group level (i.e., the mean scores from the individual-level data) in the main text (see Footnote 3 for the results from the multilevel structural equation models).

Descriptive Statistics

Table 1 presents the descriptive statistics and intercorrelations of the measures of individual performance, interpersonal attraction, group performance, and the four interpersonal behaviors. As expected, mean individual performance ($M = 68.18$) was significantly lower than mean group performance ($M = 79.10$), $t(40) = -8.51$, $p < .01$, $d = 1.33$. Thus, on average, groups generated a better solution to the task than individuals did alone.

As can be seen in **Table 1**, individual performance was positively correlated with group performance ($r = .51$, $p < .01$; providing support for H1), and interpersonal attraction was also significantly positively related to group performance ($r = .46$, $p < .01$; providing support for H2). No significant correlation between interpersonal attraction and individual performance emerged ($r = -.01$, $p = .95$). A hierarchical regression analysis showed that interpersonal attraction incrementally predicted group performance ($\beta = 0.47$, $p < .01$) beyond the mean level of individual performance ($\beta = 0.51$, $p < .01$). Furthermore, after individual performance ($R^2 = .26$) was accounted for, interpersonal attraction predicted another 22% of the variance in group performance. Thus, the two predictors together explained 48% of the variance in group performance.

The results in **Table 1** also show that there was only one significant correspondence between individual performance and interpersonal behavior (communication: $r = .33$, $p < .05$; providing weak support for H3a). Interpersonal attraction was significantly positively associated with three behaviors and marginally

Table 1: Descriptive Statistics and Intercorrelations.

	Descriptive statistics		Intercorrelations						
	<i>M</i>	<i>SD</i>	IP	IPA	GP	1	2	3	4
Individual performance (IP)	68.18	5.59	–	-.01	.51**	.19	.33*	.23	-.04
Interpersonal attraction (IPA)	4.10	.34		–	.46**	.41**	.35*	.27†	-.33*
Group performance (GP)	79.10	9.51			–	.31*	.42**	.35*	-.10
<i>Interpersonal behavior</i>									
1 Cooperation	4.23	.53				–	.66**	.68**	-.70**
2 Communication	4.12	.39					–	.80**	-.36*
3 Coordination	4.04	.48						–	-.30†
4 Relationship conflict	1.66	.44							–

Note: *M* = mean, *SD* = standard deviation, Pearson's correlation coefficient *r*, all variables reported at the group level. † $p < .10$. * $p < .05$. ** $p < .01$.

significantly correlated with the fourth interpersonal behavior (providing support for H3b). Furthermore, group performance was significantly correlated with three of the four interpersonal behaviors: cooperation, communication, and coordination. There was no significant correlation between group performance and relationship conflict (providing partial support for H4). Finally, the four interpersonal behaviors were significantly intercorrelated, ranging from $r = -.30$ to $r = .80$.

Predicting Group Performance by Individual Performance

In the first step, we investigated whether different individual performance indices could predict group performance. Preliminary analyses showed that group performance ($M = 79.10$) did not significantly differ from the performance of the best member in each group ($M = 79.47$), $t(40) = -0.27$, $p = .79$. Furthermore, group performance was significantly correlated with the performance of the best member, $r = .39$, $p < .05$, the performance of the worst member, $r = .33$, $p < .05$, and mean individual performance, $r = .51$, $p < .01$, but not the standard deviation of individual performance in the group, $r = -.02$, $p = .90$. Finally, a multiple regression analysis showed that mean individual performance predicted group performance, $\beta = 0.75$, $p < .10$, but all other variables did not, that is, the best performance ($\beta = -0.50$, $p = .55$), the worst group member ($\beta = 0.31$, $p = .72$), or the standard deviation of individual performance in the group ($\beta = 0.56$, $p = .75$). Thus, in line with Devine and Philips (2001) the mean performance of all members of the group was the most important predictor of group performance.

Note that this pattern of results remained when we removed the best group member from the computation of the group mean.

Finally, a hierarchical regression analysis showed that mean individual performance was a significant predictor of group performance, $R^2 = .26$, $p < .01$, and that adding the best and the worst members to the regression analysis as well as the variability of performance led to no significant change in the R^2 value, $\Delta R^2 = .01$, $p = .79$. However, adding interpersonal attraction to the regression model led to a significant increase in the amount of variance explained in group performance, $\Delta R^2 = .22$, $p < .01$.³

Mediation Analysis

In order to examine how interpersonal behaviors mediate the relations between individual performance, interpersonal attraction, and group performance (H5), we conducted mediation analyses. Standard errors were obtained using a bootstrapping approach with 5,000 bootstrapped samples. All of the reported mediation models had no degrees of freedom. Therefore, we do not report any fit indices for these models. First, all four interpersonal behaviors were considered as mediators in our model. The standardized path coefficients can be found in **Figure 2**.

Further results showed that whereas the direct effect (DE) of individual performance on group performance was significant, $DE_{IP1} = .48$, 95% CI [.20, .73], the indirect effect (IE) of individual performance on group performance via all four interpersonal behaviors was not, $IE_{IP1} = .04$, 95% CI [-.09, .16]. Similarly, whereas the direct effect of interpersonal attraction on group performance was

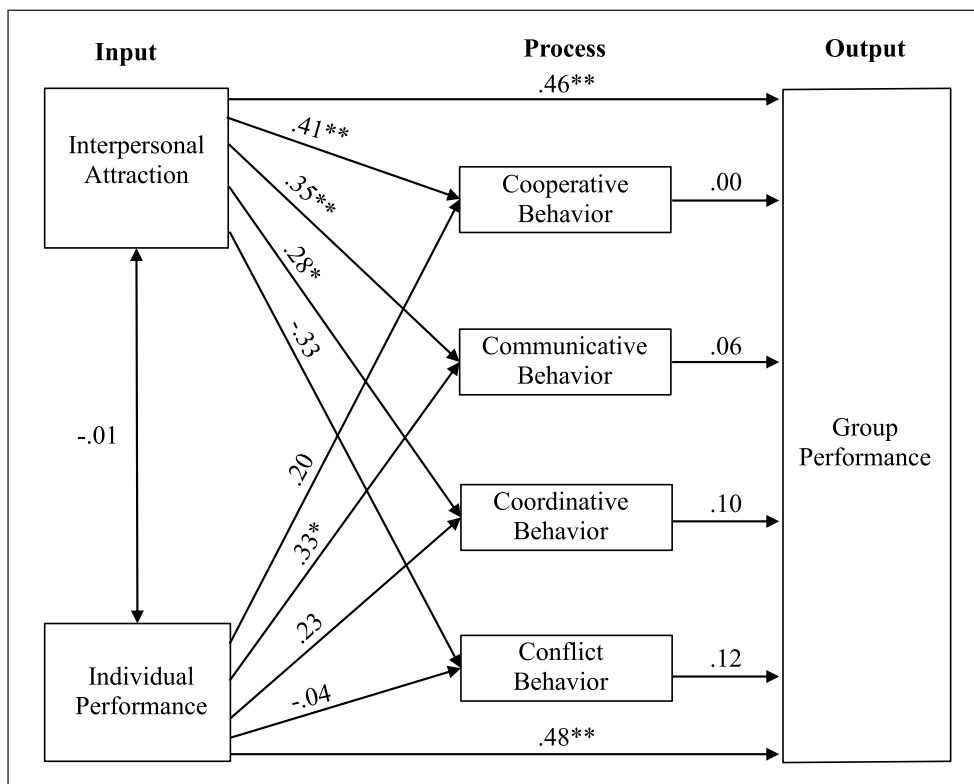


Figure 2: Model used in the statistical analyses: The specific input-process-output model was based on the literature review; interpersonal behaviors were allowed to correlate (intercorrelations of behavior can be found in Table 1). * $p \leq .05$. ** $p < .01$.

significant, $DE_{IPA1} = .46$, 95% CI [.21, .69], the indirect effect of interpersonal attraction on group performance via the four interpersonal behaviors was also not significant, $IE_{IPA1} = .01$, 95% CI [-.19, .17]. Taken together, both input variables affected group performance directly but not via interpersonal behaviors.^{4,5}

In a subsequent exploratory analysis, we examined whether the pattern of results changed when we considered communicative behavior as a mediator. This was the only variable that fulfilled the statistical conditions necessary for potentially acting as a mediator (i.e., it was correlated with both predictor variables and the criterion variable). The results showed (see **Figure 3** for the path coefficients) that neither the indirect effect of individual performance, $IE_{IP2} = .04$, 95% CI [-.04, .14], nor the indirect effect of interpersonal attraction, $IE_{IPA2} = .04$, 95% CI [-.04, .17], was significantly different from zero. However, when the separate mediation analyses for communicative behavior were computed for each input variable (see **Figure 3** again, values in parentheses), communicative behavior was a significant partial (but not full) mediator of the relation between individual performance and group performance, $IE_{IP3} = .09$, 95% CI [.02; .20], $DE_{IP3} = .42$, 95% CI [.19; .60], and it was also a partial mediator of the attraction-group performance relation, $IE_{IPA3} = .10$, 95% CI [.02, .25], $DE_{IPA3} = .36$, 95% CI [.10; .59].⁶

Discussion

Given the importance of working in groups in different areas of human life, the present research aimed to provide insight into the factors and processes that determine human group performances. On the basis of the input-process-output model (Hackman, 1987; McGrath, 1964), we investigated the interplay of individual performance, interpersonal attraction, and actual interpersonal behaviors in predicting group performance in a task with high interdependence. Moreover, we tested whether and how four directly observed interpersonal behaviors (cooperation, communication, coordination, relationship conflict) mediate the relations between the inputs (individual performance, interpersonal attraction) and the output (group performance).

We found that, on average, groups performed better in the problem-solving task than the individual members did alone (see Wittenbaum et al., 2004). Our results confirmed previous findings by showing that both individual performance (e.g., Devine & Philips, 2001) and interpersonal attraction (e.g., Beal et al., 2003; Castaño et al., 2013; Chung et al., 2017) predicted group performance. Furthermore, whereas individual performance was associated only with communication, interpersonal attraction was significantly related to communication, cooperation, and conflict (and marginally significantly related to coordination). Finally, with regard to the mediation hypotheses, we found that, although three of the four interpersonal behaviors demonstrated meaningful relations with group performance, they did not explain the relations between individual performance or interpersonal attraction and group performance as mediators in an overall model (i.e., both inputs in the same model). However, when we computed separate mediation analyses for each input variable and communication, partial mediating effects of communication occurred for both individual performance and interpersonal attraction as inputs with group performance as the output.

The results of our study are consistent with Hypotheses H1, H2, and H3b but only partly consistent with Hypotheses H3a, H4, and H5. For example, we surprisingly did not find an association between relationship conflict and group performance. This might be a result of the zero-acquaintance situation in our study because the behavior of relationship conflict may be unlikely to occur in groups of unacquainted members. Most importantly, we found only partial evidence for the mediation hypothesis. Specifically, communicative behavior was a partial mediator of the relations between individual performance and interpersonal attraction as inputs and group performance as the output in the separate mediation analyses. However, this result pattern did not occur when both inputs were considered together in one model. A potential explanation for this finding is that simultaneously controlling for individual performance and interpersonal attraction leads to a

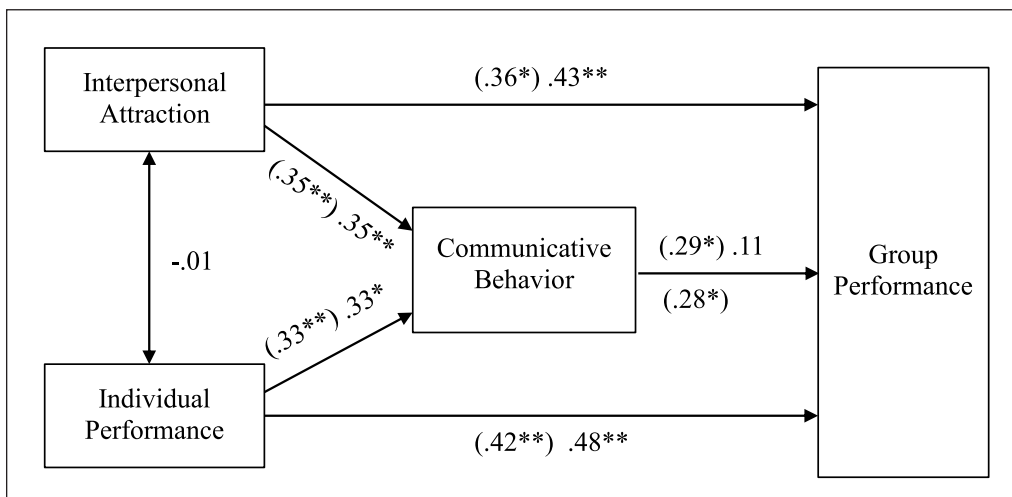


Figure 3: Mediation model with communicative behavior as the mediator, both when the other input variable was controlled for (values without parentheses) and when it was not (values in parentheses). * $p \leq .05$. ** $p < .01$.

communicative behavior variable that does not contain group differences in both task-related information and interpersonal processes. In this sense, the variable may reflect group differences in only the amount of talking, however, without task-related or relationship-related content (i.e., empty words remain under the label of communicative behavior). Thus, communicative behavior may be important for transferring intraindividual skills and evaluations into the group, but there are probably no incremental parts of communicative behavior itself that increase group performance. Accordingly, when only one input variable is considered, communicative behavior can mediate the relation between the one input variable and the group's performance by the remaining content of the other unconsidered input variable. This interpretation corresponds to the theoretical contributions of Kozlowski and Bell (2003), who described communication behavior as a "lens", i.e. a means enabling interpersonal processes within groups.

Because the other behaviors we investigated did not function as mediators, and given that the direct effects of individual performance and interpersonal attraction remained significant in all mediation analyses (i.e., partial mediation occurred; see MacKinnon & Luecken, 2008), there might be processes other than the four interpersonal behaviors we investigated that can explain how individual performance and/or interpersonal attraction affect group performance (e.g., motivation behavior). Although the interpersonal behaviors did not explain the relations between the input variables and group performance as mediators, our study provides evidence that the directly observed interpersonal behaviors, except relationship conflict, are relevant direct predictors of group performance. In sum, the results of our study suggest that communicative behavior might be a mediator that explains how individual performance and/or interpersonal attraction lead to group performance.

In our study, we decided to analyze the data on a group level, and this decision may have led to a reduction in statistical power. Therefore, we believe that future research should attempt to replicate our findings with larger samples (i.e., more groups with more group members). Moreover, future research might replicate these results with individual and group tasks other than the moon landing task used in our study. Furthermore, future research should also assess more than the four interpersonal behaviors we investigated here to explain the effects of individual performance and interpersonal attraction on group performance. Additionally, changes in the interpersonal behaviors during the group discussions would be worth exploring in future analyses, that is, exploring whether some interpersonal behaviors tend to occur more frequently at the beginning or at the end of the discussion or whether one behavior leads to another subsequent behavior.

Theoretical and Practical Implications

We believe that the results of our study might have important methodological implications for interdisciplinary research on the processes and

determinants of group performance. Our study clearly shows that researchers need to assess individual performances and interpersonal attraction when examining influences on group performance because both are important and independent predictors of group performance.

Furthermore, it is important to investigate actual behavior with behavioral observation because this is the only way to understand the processes that explain how individual performance and interpersonal attraction lead to group performance in real-life interactions. This methodological approach forms the basis for planning and implementing good interventions.

Our work also has a number of practical implications. For instance, to increase performance, individuals should work together in groups, at least when the task resembles the task type investigated here. Second, to create a high-performing group, it is important to have high-performing individuals in that group because group performance is determined by individual performance. Third, to compose a high-performing group, it also seems to be important to match individuals who evaluate their group members positively. Finally, and when the mediation across communicative behaviors can be replicated, we suggest that communicative behavior is important for transferring both task-related information and interpersonal processes. Thus, practitioners should encourage groups to communicate about task-relevant information as well as interpersonally relevant aspects when working on group tasks.

Finally, we would like to note that the structure of the present study's design (i.e., participants were first asked to solve an individual task and then to solve the same task together in a small group) is very similar to two-stage exams (see, e.g., Gilley & Clarkson, 2014; Zipp, 2007) in which students first have to solve a test individually. Afterwards, students form small groups and complete the same or a very similar test in these groups. This type of examination is quite innovative as it meets the requirements of networked work in most professions and is mainly introduced in very large classes. We believe that our study can provide some useful advice for conducting two-stage exams successfully: First, our research shows that groups perform better when the mean level of interpersonal attraction within the group is high. This result indicates that in two-stage exams, students should be allowed to choose their friends for group work and that groups should not be randomly assigned by the teacher (see also Chung et al., 2017). Furthermore, because cooperative, communicative and coordinative behavior had a positive impact on group performance, whereas relationship conflict had a negative one, recommendations for the students' behavior during the discussion should also have a positive effect on the success of the groups.

Conclusions

Research on interpersonal interaction in groups and research on the processes and factors that enhance group performance are highly relevant in interdisciplinary contexts of small group research (Castaño et al., 2013).

Therefore, the input-process-output model provides a useful theoretical framework from which to examine the emergence of group performance. This study highlights two important independent factors that affect group performance in one model for the first time: the individual performance and interpersonal attraction of the group members. Moreover, for the first time, we were able to show correlations between individual performance, interpersonal attraction, directly observed interpersonal behaviors, and group performance. Auspicious indications for the comprehension of the mediating function of communicative behavior between individual performance, interpersonal attraction, and group performance in an interdependent task were demonstrated. We hope we have shown with our study that the interplay of individual performance, interpersonal attraction, and interpersonal behavior is a highly relevant and convenient component for explaining the emergence of group performance in small groups.

Data Accessibility Statement

We embrace the values of open science. Data and analysis scripts can be retrieved from <https://osf.io/jkup3>.

Notes

- ¹ In a zero-acquaintance design, participants do not know each other, have never interacted before, and are encountering each other for the first time.
- ² Group performance was the last measure collected in the study design. Thus, it could not affect prior measures (individual performance, interpersonal attraction) but could be affected by them. In interpreting the results, group performance must be the outcome, and individual performance and interpersonal attraction must be the predictors because of the chronological order of the measures. To investigate the influence of group performance on individual performance or interpersonal attraction, other study designs are needed (e.g., group performance as the first task in the study or longitudinal designs).
- ³ As an alternative to the procedure reported here, group performance could have been predicted from the random intercepts of the predictors in a multilevel structural equation model. In this multilevel approach, individual interpersonal attraction and performance would be modeled as Level 1 variables and then their Level 2 parts (i.e., the parts of the individual's effects that belong to the group) would be used to predict the mediators and/or group performance. However, these parts are (latent) approximations of the mean of all individuals' performances per group or the mean value of the target effects of interpersonal attraction. Accordingly, the results of these analyses should not differ much from the results of the regression or structural equation model using the aggregates of individual performance and interpersonal attraction: In line with this reasoning, we found that individual performance and the target effects of interpersonal attraction significantly predicted group performance ($\beta_{IP} = 0.64, p < .01$; $\beta_{IPA} = 0.50, p < .01$; model fit:

CFI = 1.00; SRMR_{between} = .03; $\chi^2 = 45.97, p < .01$) in a multilevel structural equation model. However, when we embedded the mediators in the multilevel structural equation models, the results were not trustworthy because some of the coefficients did not match the correlational patterns (e.g., communicative behavior was negatively related to group performance: $b = -9.54, p = .05$). One possible reason for this is that the intercept variance of attraction was low which in turn might be due to that there were not enough people in the groups of four participants to obtain reliable estimates of the random intercepts (see Lüdtke et al., 2008). Because the group-mean values correspond to the random intercepts in the multilevel approach, we decided to report the results of the models using the aggregates of performance and attraction in the main text.

- ⁴ Because the four interpersonal behaviors were highly correlated (see **Table 1**), we computed another mediation model in which we used the aggregate of the four interpersonal behaviors ($M = 3.93, SD = 0.38$) as the mediator. However, in line with the results of the main analyses, we also did not find a mediation effect of the aggregated interpersonal behavior indicator ($IE_{IPA} = .02, 95\% \text{ CI } [-.10, .15], IE_{IP} = .01, 95\% \text{ CI } [-.06, .09]$).
- ⁵ To investigate differences between the all-female groups (i.e., 92 women in 23 groups) and the all-male groups (i.e., 72 men in 18 groups), we computed a multiple-group path model. In the first model, we computed the mediation model for the all-female groups and the all-male groups without any parameter constraints. The fit of this model (which was perfect given that the model's degrees of freedom equaled 0) was compared with the fit of a second model in which all path coefficients were set to the same value across the two types of groups. The results for the second model showed that the model fit the data very well, $\chi^2 = 14.99, df = 14, p = .38$. Altogether, these results show that there were no significant differences between the parameter estimates in the two types of groups.
- ⁶ In a subsequent regression analysis, we aimed to investigate the interaction between individual performance and interpersonal attraction as an additional predictor of group performance. However, the interaction term ($T = .003; VIF = 307$) was too highly correlated with the other inputs, individual performance ($r = .69, p < .01$) and interpersonal attraction ($r = .72, p < .01$), so that the analysis did not produce interpretable results (no significant prediction of group performance from interpersonal attraction, $\beta = 1.26, p = .41$; individual performance, $\beta = 1.27, p = .38$; or the interaction between individual performance and interpersonal attraction, $\beta = -1.10, p = .60$).

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

- Contributed to conception and design: S. Krause
- Contributed to acquisition of data: S. Krause
- Contributed to analysis and interpretation of data: L. Nikoleizig, S. Nestler
- Drafted and/or revised the article: L. Nikoleizig, S. Krause
- Approved the submitted version for publication: L. Nikoleizig, S. Krause, S. Nestler

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