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Designing in Teams

Does Personality Matter?

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Twenty-six multidisciplinary student design teams (n = 128) each built a robot that had to perform a specific task in a design contest. For these teams, an input–process–output framework of team member personality (input), generic and specific design behaviors (process), and contest result and supervisor and team member ratings of the design (output) was researched using correlations. Agreeableness and conscientiousness were positively related to generic design behaviors in both the concept and elaboration phase of the design process. Generic design behaviors were positively related to contest result and team member ratings of the design's technical realization. The conclusions hold implications for design research (multiple process and outcome measures are needed) and practice (attention for personality differences in teams and particular design behaviors in specific design phases foster design outcomes).

Keywords: *design behavior; personality; Big Five; teams; performance*

Design processes that take place in teams have been studied many times and in many ways (e.g., Baird, Moore, & Jagodzinsky, 2000; Cross, Christiaans, & Dorst, 1996; Reid, Culverhouse, Jagodzinski, Parsons, & Burningham, 2000; Stempfle & Badke-Schaub, 2002; Valkenburg, 2000). Nevertheless, it is still far from transparent exactly how design processes contribute to the successfulness of designs as this relationship has received only limited scientific attention (Badke-Schaub & Frankenberger, 2002).

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Furthermore, as there would be no design processes without designers, studying the relationships between design team member characteristics and design processes is indispensable. Here again, only a few studies are available (Kichuk & Wiesner, 1997; Robinson, Sparrow, Clegg, & Birdi, 2005). Fifteen years ago, King and Anderson (1990) already signaled the need for more scientific studies that would address the effect of team composition and processes which take place in innovative teams. As it appears now, scholars have only partly been able to give rise to this call and, in spite of all their research efforts, we still have precious little understanding of how design team member characteristics contribute to design processes and how both contribute to design team effectiveness.

The aim of this study is to add to the knowledge of how design processes relate to design team member characteristics and design effectiveness (in terms of the design product). To do so, research was conducted among 26 student teams that completed a "real life" design task. The teams participated in design contests held at the three Dutch universities of technology known as "Createch" in Eindhoven and Enschede and as the "Techniek Workshop" in Delft in the fall of 2003. Each team had to design and build from scratch a robot that had to perform a specific task. At the university in Eindhoven, the teams had to build a floating device that could pick up balls from the water and deliver them at a designated spot. At the university in Enschede, the teams had to build a vehicle that was remote controlled and had to be able to move over dry surface and through water, take in water, and pump it out to extinguish fires along a route. And finally at the university in Delft, the teams had to build a remote-controlled vehicle that could drive and pick up and throw balls. All designs were built in a predefined period of time and immediately after building the designs competed in an arena to determine which team built the best performing design. For this, sample relationships based on an *input-process-output* framework of team effectiveness proposed by Hackman (1987) were studied. This framework posits that inputs combine to influence team *processes* on one hand and team *output* on the other hand and that team processes and team outputs are related to each other. Such an integrative or comprehensive approach to studying design team effectiveness has, to our knowledge, not been adopted before. To present our input-process-output model of designing in teams, we discuss design team member characteristics, design processes, and design team performance in more detail in the remainder of the introduction, working from back to front. Thereafter, we present the research hypotheses and questions and these are summarized in the research model.

Design Team Performance

Studying design team effectiveness is not a simple matter. This mainly has to do with the definition of a successful design. It can adhere to the quality (which also encompasses innovativeness), the timely delivery of the design, or to the costs made to come up with the design (compare Badke-Schaub & Frankenberger, 2002). These outcomes are more or less intertwined. Time, and thus costs, can be spared by shortening the design process but this may diminish the quality. Moreover, if you buy cheaply, you may pay dearly if a lot of incremental designing is needed before the design can be taken into production. On the other hand, a highly innovative product may turn out to do so well on the market that despite a long and costly development time, return on investment in terms of both time and costs is high. So the interdependence is such that there will be trade-offs between quality, timeliness, and costs. Furthermore, the value of quality is not univocally determinable (Dorst, 2003, p. 30; Gann & Whyte, 2003). Designs that may seem to lack quality or innovativeness now may turn out to be very useful for incremental designing on the same product or for the design of new products tomorrow.

In organizational practice, companies employ their own guidelines regarding quality, timeliness, and costs depending on their organizational mission, business strategy, and market. And even within a single organization, design teams may have to work under different constraints. Dissimilarities that arise as a consequence of differences in choices that are made within a single organization or between organizations make it difficult to generalize findings concerning organizational design team effectiveness. To counteract this incomparability of outcomes, design teams have often been studied in laboratory settings,[1] which may naturally raise questions regarding the external validity of such results.

A related complicating matter is the measurement of the design team effectiveness. Time and costs involved appear to be easily and objectively measurable quantities but this may hold true for time only. Regarding costs, the lack of clarity in definition makes it difficult to measure them. If costs were well defined, measurement could proceed objectively if data were available. Defining quality is even more difficult. And even if the concept of quality were well defined, its measurement remains problematic because the issue of who should rate it immediately arises. A choice has to be made between design team members, design team leaders, supervisors, clients, or independent raters. In other words, the operationalization of quality will have consequences for the objectivity of the measurement as well as for relationships to be established between input and process variables on one hand and output variables on the other hand. Rating quality from multiple perspectives (compare 360° assessment; e.g., Milliman, Zawacki, Norman, Powell, & Kirksey, 1994) may present researchers with the most complete and reliable results.

To reiterate, we can state that the interrelatedness of quality, time, and costs, the definition of costs and quality, the operationalization of quality, and the choice of rater are all factors that complicate research into design team effectiveness. To address this complexity, we use several objective and subjective outcome variables in this study.

Design Processes

To enhance our understanding of design team processes, design team member communication, negotiation, reflection, and social processes have been studied in depth but in isolation (Cross & Clayburn-Cross, 1996; Eckert & Stacey, 2001; Stempfle & Badke-Schaub, 2002; Stumpf & McDonnell, 2002; Valkenburg, 2000). Lately, a more integrative approach toward the study of designing is advocated. Working from such an integrative approach, Peeters, Van Tuijl, Reymen, and Rutte (2007) performed a task analysis of designing in multidisciplinary teams. Interviewing design team members from various backgrounds via the Critical Incident Technique (Flanagan, 1954), they collected a set of behaviors supposedly critical for successful design task completion. The *Design Behavior Scales for Teams* were based on this set of behaviors. After testing the structure of a subset of these scales, the *Design Behavior Questionnaire for Teams* (DBQT) was constructed.

The DBQT consists of 55 critical design team member behaviors divided over three main categories, namely, *design creation*, *design planning*, and *design cooperation*. Within these 3 main categories, 12 subcategories are distinguished which we name here and, where necessary, we briefly clarify them. Subcategories under the main category "design creation" are the following: First, *design task organization* addresses the organization of the work once the design problem has been established. Second, *information-based designing* relates to developing the design thoroughly based on all available and relevant information. Third, *building the solution space* concerns the generation of possible solutions. Fourth, *confining the solution space* is about restricting the number of possible solutions. Fifth, *phase transitions* bear on the extent to which conscious transitions are made between phases in the design process, for instance, between determining the concept and elaborating the design. Sixth, *reflecting on the design* is about reflection on the development of the design. Seventh, *adjusting based on reflection* relates to the way the design and design behaviors are adjusted on evaluations. The 8th through 12th subcategories need no additional clarifying, they are labeled *planning time*, *keeping schedule* (both belonging to the main category "design planning"), and *cooperation*, *reflecting on team functioning*, and *making decisions* (all three belonging to the main category "design cooperation").

Phases in the Design Process

In design research, scholars have established that design teams go through different design process phases in establishing a design concept (King & Anderson, 1990; Stempfle & Badke-Schaub, 2002). These phases and the transitions between them are reflected in the DBQT's main category "design creation." Moreover, for project teams in general it was found that their work proceeds through two phases (Gersick, 1988, 1989; Ockhuysen & Waller, 2002; Waller, Zellmer-Bruhn, & Giambatista, 2002). In her punctuated equilibrium model, Gersick (1988, 1989) distinguished one phase before and one after the so-called midpoint transition. In the phase before the midpoint transition, teams explore their task, the problem, and alternative solutions (compare *information gathering phase* [Ockhuysen & Waller, 2002] and *orientation phase* [Waller et al., 2002]). At the midpoint transition, teams decide what alternative solution will be elaborated on in the remainder of the project and how they will proceed in doing so. In the phase after the midpoint transition, details of the selected solution are worked out (compare *resolution phase* [Ockhuysen & Waller, 2002] and *evaluation and control phase* [Waller et al., 2002]). The first project phase (pre–midpoint transition, information gathering, or orientation phase) maps well onto the design project phase in which the concept has to be established, which—in line with Peeters et al. (2007)—we refer to as the *concept phase* from this point forward. The second project phase (post–midpoint transition, resolution or evaluation, and control phase) maps well onto the design phase in which the selected concept has to be elaborated and built. We refer to this phase as the *elaboration phase* (Peeters et al., 2007) from this point forward.

Based on the finding that in project teams activities differ in both phases, for design teams design activities can be expected to differ in the concept and elaboration phase and this may also hold for design team member behavior. Having noted this, we conclude that the DBQT has to be administered in both the concept and elaboration phase to arrive at an accurate description of design team member behavior throughout the design project.

Team Composition in Terms of Design Team Member Personality

As King and Anderson (1990) noted, there are a number of design team characteristics that are worthy of scientific attention (e.g., leadership, team composition, minority influence, team structure). Robinson et al. (2005), for instance, studied effects of design team member competencies. What's more, over the last decade, a line of research has been built up in which the importance of team member personality with regard to team performance is underscored (e.g., Barrick, Stewart, Neubert, & Mount, 1998; Mohammed & Angell, 2003; Neuman, Wagner, & Christiansen, 1999; Van Vianen & De Dreu, 2001). More specifically, Kichuk (1999) and Taggar (2000) demonstrated effects of team member personality on team performance for samples that consisted of design teams only. As personality has an influence on team performance in general and on design team performance in particular, it is interesting to pose the question how both design team member personality and design team performance relate to design processes.

A well accepted and consistently replicated (John, 1990; Mount & Barrick, 1995) framework with which personality is described is the Five-Factor Model of personality, also known as the Big Five. The five factors or traits that are distinguished within this framework are *extraversion*, *agreeableness*, *conscientiousness*, *emotional stability*, and *openness to experience* (De Raad, 2000; McCrae & John, 1992; Wiggins, 1996). Personality, described in terms of these five traits, remains relatively stable over time and across situations (Hofstee, Kiers, De Raad, Goldberg, & Ostendorf, 1997; John & Srivastava, 1999; McCrae & Costa, 1997). The extent to which a trait applies to a person predisposes him or her to behave in a certain way (Robertson & Callinan, 1998). Extraverts can be characterized as social and talkative, whereas introverts are silent and prefer solitude. Agreeable people are gentle and cooperative, whereas nonagreeable people are bossy and impose their will on others. Conscientious persons are self-disciplined and organized as opposed to nonconscientious persons who are sloppy and have chaotic work styles. Emotionally stable individuals can be described as calm and poised, whereas emotionally unstable or neurotic individuals are easily upset or stressed. Finally, people who are open to experience are critical and imaginative; conversely, people who are not open to experience form no opinion of their own and follow the majority (Costa & McCrae, 1992; Hendriks, Hofstee, & De Raad, 1999).

To be able to study the effects of personality at the team level, researchers typically convert individual personality trait scores into *mean* and *variability* scores to reflect team composition in terms of personality (Barrick et al., 1998; Kichuk & Wiesner, 1998; Mohammed & Angell, 2003; Neuman et al., 1999; Van Vianen & De Dreu, 2001). So, when studying the effects of team composition in terms of personality on team processes and outcomes, one best uses the mean and variability scores for each of the Big Five traits, which is what we do in this study.

This Study

Because there is hardly any empirical evidence present on which to build hypotheses regarding the relationship between design team composition in terms of personality and design team member behaviors, we take the overall results of the meta-analysis on team composition in terms of personality and team performance as point of departure (Peeters, Van Tuijl, Rutte, & Reymen, 2006).[2] In this meta-analysis, it was shown that mean levels of agreeableness and conscientiousness relate positively to team performance and that variability in agreeableness and conscientiousness relate negatively to team performance. These meta-analytical results form the basis of our first set of hypotheses regarding input–output relationships:

Hypothesis 1a: Mean agreeableness is positively related to design team outcomes.

Hypothesis 1b: Mean conscientiousness is positively related to design team outcomes.

Hypothesis 1c: Variability in agreeableness is negatively related to design team outcomes.

Hypothesis 1d: Variability in conscientiousness is negatively related to design team outcomes.

As the DBQT was constructed based on the question "Which design team member behaviors contribute to the successful completion of a design?," all items in the DBQT can be expected to positively contribute to design team performance in both the concept phase and elaboration phase of the design project. Each of the subcategories can also be expected to be positively related to design team performance. However, as we expect different behaviors to be relevant in the concept phase compared to the elaboration phase of the design project, relationships between DBQT subcategories and team performance may also be different for each phase. This results in the following hypotheses regarding process–output relationships:

Hypothesis 2a: The combined DBQT behaviors are positively related to design team outcomes in both phases of the design project.
Hypothesis 2b: The DBQT subcategories are positively related to design team outcomes but relationships may differ between phases of the design project.

When we extrapolate the hypotheses regarding the effect of mean and variability in conscientiousness and agreeableness on design performance to design behavior, we arrive at the subsequent hypotheses regarding input–process relationships:

Hypothesis 3a: Mean agreeableness is positively related to the combined DBQT behaviors.
Hypothesis 3b: Mean conscientiousness is positively related to the combined DBQT behaviors.
Hypothesis 3c: Variability in conscientiousness is negatively related to the combined DBQT behaviors.
Hypothesis 3d: Variability in agreeableness is negatively related to the combined DBQT behaviors.

The DBQT consists of 12 behavioral categories. To arrive at more detailed results, we explore relationships between both mean and variability in agreeableness and conscientiousness and all DBQT subcategories to answer the following research questions:

Research Question 1a: To which DBQT subcategories is mean agreeableness related?
Research Question 1b: To which DBQT subcategories is mean conscientiousness related?
Research Question 1c: To which DBQT subcategories is variability in agreeableness related?
Research Question 1d: To which DBQT subcategories is variability in conscientiousness related?

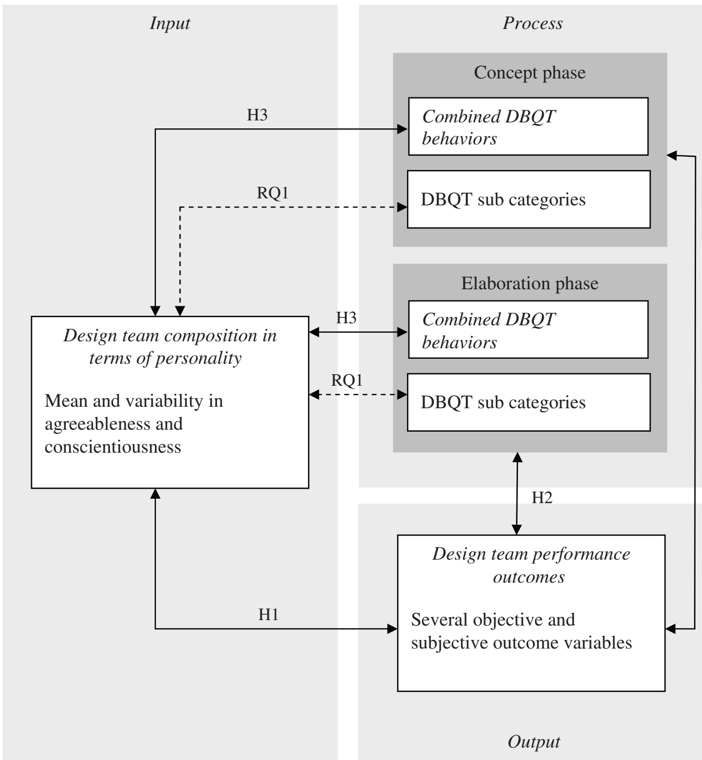
Expected relationships among the study variables are summarized in the hypothesized input-process-output model of designing in teams (Figure 1).

Method

Participants

We conducted the research among student teams that completed a “real life” design task. Respondents were all students at one of the three Dutch

Figure 1
Hypothesized Input-Process-Output Model of Designing in Teams



universities of technology. They participated in the design contests held in the autumn of 2003 at each of those three universities, known as "Createch" in Eindhoven and Enschede, and as the "Techniek Workshop" in Delft. At all three universities, the design contest project was offered as an optional course for which course credits were awarded. The students could register as a team, part of a team, or individually. The course supervisors at each university saw to it that the teams were about equal in composition considering the disciplinary background of the team members. The teams under study were best characterized as self-managed teams.

As we were interested in team composition, teams had to be sufficiently complete to include them in the research. We defined "sufficiently complete" as all or all minus one team members filled out the personality questionnaire. Of the 33 design teams that competed in the contests ($N = 158$), personality data on 26 teams met this criterion ($n = 128$). Of these 26 teams, the size ranged from 4 to 6 members with an average team size of 5.12. Teams were predominantly male: 15 teams were all male and of the remaining 11 teams, on average, 61.7% of the members were male. The team composition ranged from two up to four disciplinary backgrounds. Of the respondents, 107 (83.6%) were male and 21 (16.4%) were female. Their age ranged from 19 up to 28 years with an average of 21.5 years.

Assignments

In this section, we elaborate on the assignment descriptions given above. At the university in Eindhoven, the teams had to build a floating device the steering and velocity of which was controlled by a spring animal remote. The depth and direction of the bend made on the spring animal determined the speed and direction of the vehicle. The vehicle had to be able to move in water, to pick up balls that floated on the water, and to drop the balls on a dedicated area of a slowly rotating disc situated 5 cm above the water surface at the other side of the basin. Functions related to the taking in, lifting, and dropping of the balls had to be controlled by a handheld remote. At the university in Delft, the teams had to build a vehicle controlled by a remote. It had to be able to move out of a castle courtyard through a gate with a height of about 55 cm, to move around the arena, and to pick up balls from the arena floor. The balls had to be lifted to a height required to either throw them over the castle wall (height 65 cm) on the opponent's side of the arena or drop them into one of the window holes situated approximately 70 cm above the arena surface in the opponent's castle towers. At the university in Enschede, the teams had to build a vehicle that was controlled by a remote and had to be able to move over dry surface and through water. After the vehicle had left the starting area, it had to enter a small water basin via a descent and take in water once in the deeper part of the basin. Next, it had to be able to move out of the water via an ascent at the other side of the basin and the water that had been taken in had to be put under pressure. A pumping device on the vehicle had to be used to extinguish a number of small fires alongside a route of about 3 m that was entered next. At the end of this route, the vehicle had to stop in the end station and signal its finish electronically.

Working on the Project

At each university, there was a dedicated space in which the teams could design and build their vehicles. The teams each had their own workspace but they could see the other teams at work as their workspaces were separated by movable walls. At the university in Eindhoven, the project was spread out over a period of 6 weeks. In this period, the teams could work on the design project in the time they had available next to the activities on their regular course schedule. At the universities in Delft and Enschede, the project was condensed into a week that was dedicated to this project only (Monday till Sunday). The teams could work during the day and during the evening until 22.00 hr (and 24.00 hr on the final night) at each of the three universities. Although the project period differed between universities, the actual designing and building time was roughly similar.

Before the contest started, the teams were centrally briefed on the project plan, assignment, rules and conditions, and on the contest itself. Each participant received a booklet in which these topics were addressed in more detail. After having handed in the concept of the design (to the supervisors), the teams received an assignment-specific standardized tool and material kit to construct their design with. Furthermore, the teams at each university had a small and fixed “budget” (of credits) with which they could acquire additional materials from or under approval of the contest coordinators (teaching assistants). The contest coordinators saw to it that project regulations were adhered to and provided assistance where needed to facilitate the building and testing of the designs without ever interfering with the construction of the designs themselves. At the deadline of the design period, the designs had to be placed on an exhibition table to be judged (by course supervisors and a contest committee of judges). Once it had been placed on the exhibition table, the teams could no longer work on the design.

Contest

At all three universities, an arena was built specifically for the design contest. At the universities in Eindhoven and Delft, the designs met in the arena and could thus interfere with each other; in Enschede, there were two separated, mirrored routes. All contests took place in rounds, starting with qualifying rounds, followed by quarter finals (Eindhoven only), semifinals, and a final. Per university, the matches were identical over rounds: For each match, there was a fixed amount of time (only the finalists had about a third of the regular match time added, which was announced in advance) and the teams received points for each ball dropped or each fire extinguished. The teams that received the most points proceeded to the next stage of the contest. In between matches, the teams could fix damage that their design had sustained during the battle.

Procedure

The research was introduced as part of the central opening presentations held at each of the universities. Students were told that the research team was interested in how design processes and outcomes in teams varied as a function of the team's composition because team members differ in various ways (teamwork approach, personal goals, subject of study, willingness to invest effort). They were also informed of how their anonymity would be ensured. At the end of the presentation, the students were asked to volunteer as participants in our research, and, if they did, they were asked to fill out the personality questionnaire at the end of the opening presentation. At that same time, they could indicate whether they appreciated feedback on their personality scores and a summary of the study results on a separate sheet. Students from all teams participated. Next, design behavior was self-rated using the DBQT when handing in the design concept and once more when reaching the end of the elaboration phase (when approximately 10% of the project time remained). Finally, respondents filled out an evaluation of the design and the project immediately after the finished designs had been put on the exhibition tables. In the week after the contest, respondents received the feedback on their individual personality scores. They received a summary of results after the study had been completed.

Measures

Input. Team member personality was measured via a self-report of the Five-Factor Personality Inventory (FFPI; Hendriks et al., 1999). Using the extensively validated FFPI, each of the Big Five traits was measured by 20 items (10 positively and 10 negatively formulated). Each item was scored on a 5-point Likert-type scale varying from 1 (*not at all*) to 5 (*completely*). Examples of items for the traits used in this study are *agreeableness* "Orders people around" (negative) and *conscientiousness* "Does unexpected things" (negative).

To arrive at mean scores, individual team member scores were aggregated to a team mean score for each trait. Trait variability is operationalized by most team personality researchers as a team's variance or standard deviation score for a certain trait. Lately, a variability measure has been introduced that assesses dissimilarity to other team members at the individual level (Peeters, Rutte, Van Tuijl, & Reymen, 2006). We used that measure in the present study. Variability scores were thus computed by aggregating individual dissimilarity scores to a team mean dissimilarity score. As most team personality researchers use trait variance or standard deviations to operationalize team variability, we also conducted our analyses with the standard deviation (as recommended by Bedeian & Mossholder, 2000). This yielded results that were nearly identical to those obtained with the aggregated individual dissimilarity scores.

Process. Design process behaviors were measured using the DBQT (Peeters et al., 2007). For all 55 DBQT items, respondents indicated to what extent they agreed with them on a 5-point Likert-type scale varying from 1 (*highly disagree*) to 5 (*highly agree*). For each of the 12 subcategories we present the number of items and an exemplary item. *Design task organization* was measured by three items, for example, "We determined the subdivision of the design problem in mutual consideration." *Information-based designing* was measured by five items, for example, "We used all available information." *Building the solution space* was measured by two items, for example, "We came up with as many solutions as possible." *Confining the solution space* was measured by two items, for example, "We restricted the number of solutions." *Phase transitions* were measured by three items, for example, "We consciously made the transition from determining the concept to elaborating the design." *Reflection* was measured by five items, for example, "We signaled and reported inconsistencies between subdesigns." *Adjusting based on reflection* was measured by four items, for example, "We adjusted subdesigns to the overall design." *Planning time* was measured by five items, for example, "We made a realistic overall time planning." *Keeping schedule* was measured by seven items, for example, "We reminded each other of timely delivery of subresults." *Cooperation* was measured by nine items, for example, "We helped and supported each other." *Reflecting on team functioning* was measured by three items, for example, "We brought each other's functioning up for discussion." *Making decisions* was measured by seven items, for example, "We substantiated decisions."

We assumed the DBQT subcategory scores to be "shared unit properties" (Kozlowski & Klein, 2000) meaning that individual scores could be aggregated to a team mean score to reflect the team's position on a particular category. The theoretical assumption of the sharedness of the properties can be statistically checked via computation of the agreement measures ICC(1) and ICC(2). ICC(1) can be seen as the reliability with which an individual rating reflects the group mean (Bliese, 2000, p. 356). ICC(1) values typically range from .00 to .50 according to James (1982), but Bliese (2000) narrowed this range down from .05 to .20 and in exceptional cases to .30. ICC(2) represents an estimate of the reliability of the group mean (Bliese, 2000, p. 356). Higher values indicate more reliability. Mean ICC(1) for the DBQT subcategories was .22 (range .01-.50) for the concept phase and .21 (range .10-.48) for the elaboration phase. Mean ICC(2) for the DBQT subcategories was .57 (range .06-.84) for the concept phase and .56 (range .37-.83) for the elaboration phase. These values are such that aggregation of the individual scores to a team mean score is justifiable.

For three DBQT subcategories, data were missing for one up to three teams in the concept phase. We used an EM (expectation-maximization) algorithm to calculate estimates for the missing data as this strategy has been shown to be superior to other missing data treatment strategies (Dormann & Zapf, 2002).

The *combined DBQT behaviors* were operationalized by summing the scores on all 55 DBQT items per individual team member and aggregating these summed scores to a team mean score. ICC values indicated that aggregating the combined scores to the team level was justified ($ICC[1]_c$ = .33, $ICC[1]_e$ = .23, $ICC[2]_c$ = .71, and $ICC[2]_e$ = .61).

Outcomes. To accommodate for the complications signaled in the introduction, we used several outcome measures in this study: (a) The design project was evaluated and graded by independent raters; (b) the design products were qualitatively ranked per university based on a competition against each other; and (c) team members rated the technical realization of the design. These performance measures differ in degree of objectivity and together provide a comprehensive measurement of the effectiveness of the design. We discuss below each outcome in more detail.

Supervisory ratings of team performance (project grade) were based on the quality of the design. The quality was evaluated by multiple design expert course leaders based on the concept of the design, the design itself, and the project report and by contest judges based on their evaluation of the design before the contest took place. So, the course grade was not dependent on the result of the contest.

Contest results were derived by ordering team results across universities per round starting with the finalists, followed by the semifinalists, and lastly quarter finalists and qualifying rounds based on the three subsequent criteria:

(a) the place achieved in the contest (from highest to lowest), (b) the number of matches that had to be played to reach this place (from many to few), and, if further differentiation was needed, (c) within one university, the score achieved in that round (from highest to lowest). By applying these criteria an unambiguous ordering could be made. This order was reversed so that higher scores indicate better contest results. When testing differences in mean ranking between universities (Kruskal-Wallis), no significant differences were found ($\chi^2[2] = 3.09$, *ns*).

Design team member rating of the design's technical realization was given on design completion before the contest took place. Team members were asked to indicate the technical realization of their team's design compared to those of the other teams on a 5-point Likert-type scale ranging from 1 (*much worse*) to 5 (*much better*). Individual scores were aggregated to derive a team level indication of the design's technical realization (ICC[1] = .38 and ICC[2] = .75).

Data Analysis

Considering the small sample under research, Hypothesis 1 through Hypothesis 3 were tested using correlations, one-tailed with an alpha of $p = .05$. To answer Research Question 1, correlations were inspected two-tailed with an alpha of $p = .05$. Spearman's Rho correlations were computed for the contest result variable and Pearson's product-moment correlations were computed for all other variables.

Results

Descriptive statistics for team composition in terms of personality for agreeableness and conscientiousness, the combined DBQT behaviors in the concept and elaboration phase, the supervisory rating of team performance, the contest results, and team member rating of the design's technical realization are shown in Table 1 (mean, standard deviation, range, and Cronbach's alpha). The internal consistency was satisfactory for all scales with the exception of the DBQT subcategory "design task organization," for which consistency was somewhat below acceptable levels.

The correlations that are used to test Hypothesis 1 (a through d), Hypothesis 2a, and Hypothesis 3 (a through d) are shown in Table 2 and are discussed in the text as well. For reasons of parsimony, we present the correlations between input and outcome variables and the DBQT subcategories

Table 1
Descriptive Statistics for All Study Variables

Variable	*M*	*SD*	Range	α
Input				
Mean				
Agreeableness	3.73	.20	3.38-4.13	.84
Conscientiousness	3.27	.20	2.93-3.64	.90
Variability in				
Agreeableness	.53	.20	.23-.97	—
Conscientiousness	.68	.27	.25-1.23	—
Process				
Combined DBQT behaviors[a]	3.37/3.41	.30/.26	2.46-3.97/2.82-4.07	.93/.92
DBQT subcategories				
Design task organization[a]	3.57/3.48	.46/.66	2.67-4.75/1.83-4.67	59/.65
Information based designing[a]	3.51/3.64	.55/.66	1.93-4.45/2.40-4.56	.74/.78
Building the solution space[a,b]	3.59/3.68	.57/.56	2.00-4.88/2.50-5.00	.55***/.57***
Confining the solution space[a,b]	3.70/3.87	.51/.56	2.75-4.83/2.75-4.83	.28**/.24*
Phase transitions[a]	2.88/2.71	.55/.70	1.33-4.00/1.00-3.67	.78/.88
Reflection[a]	3.51/3.67	.47/.45	2.35-4.40/2.80-4.44	.79/.74
Adjusting based on reflection[a]	3.69/3.88	.42/.47	2.50-4.25/2.81-5.00	.84/.81
Planning time[a]	2.53/2.48	.60/.57	1.00-3.52/1.00-3.30	.81/.80
Keeping schedule[a]	2.73/2.83	.60/.63	1.43-3.43/1.00-3.66	.91/.89
Cooperation[a]	3.93/3.91	.30/.32	3.07-4.44/3.28-4.42	.87/.88
Making decisions[a]	3.84/3.75	.59/.71	3.00-4.57/3.14-4.43	.74/.74
Reflecting on team functioning[a]	2.54/2.79	.35/.32	1.33-3.67/1.00-4.33	.88/.86
Output				
Supervisory ratings of team performance	7.23	.59	6.00-9.00	—
Contest result	—	—	1.00-33.00	—
Team member rating of the design's technical realization	3.06	.71	1.80-4.67	—

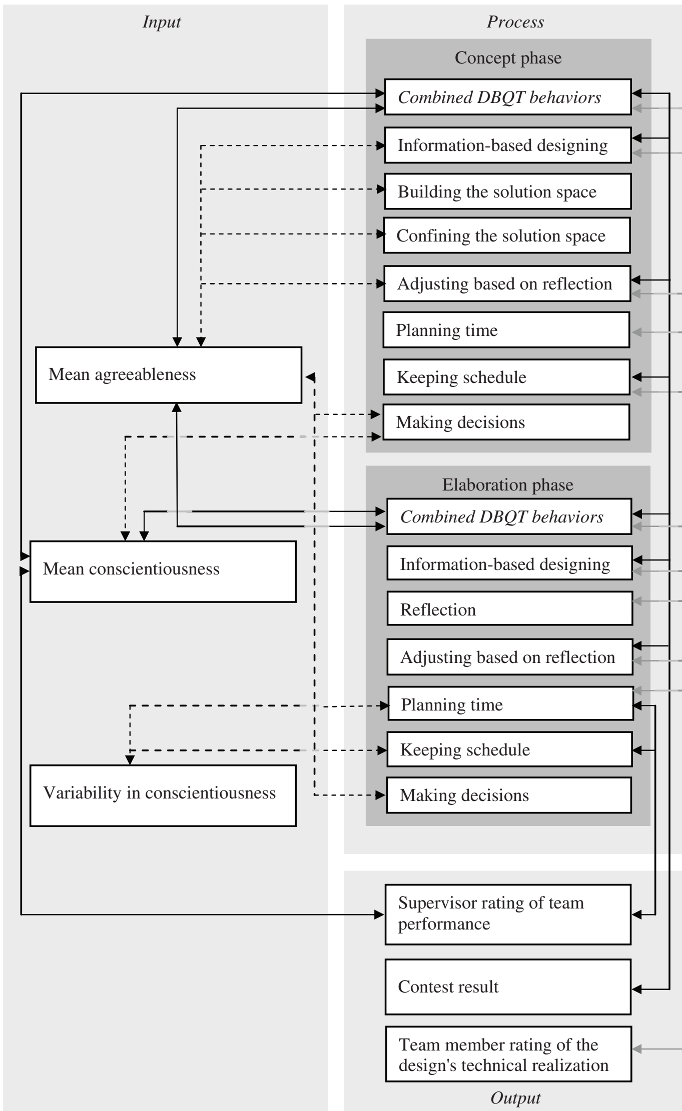
a. Descriptives for the concept phase are presented first, those for the elaboration phase last.
b. For two item categories correlations instead of αs are presented.

in the text only (Hypothesis 2b, Research Question 1). In addition, results regarding input–process, input–output, and process–output relationships are presented in Figure 2.

Composition and Team Outcomes (Hypothesis 1)

Contrary to our expectation, mean agreeableness and the supervisory rating of team performance are not correlated ($r = -.15$, *ns*), so Hypothesis 1a was not confirmed. Mean conscientiousness and the supervisory rating of team performance are significantly correlated ($r = .34$, $p = .05$), which

Figure 2
Observed Input–Process, Input–Output, and Process–Output Relationships of Designing in Teams



Note: All arrows in the figure represent positive relationships.

Table 2
Correlations Between Team Composition in Terms of Personality, Combined DBQT Behaviors, and Team Outcomes

Variable	1	2	3	4	5	6	7	8
1. Mean agreeableness[a]	—							
2. Mean conscientiousness[a]	.39*	—						
3. Variability in agreeableness[a]	–.13	–.07	—					
4. Variability in conscientiousness[a]	.02	.32	.32	—				
5. Combined DBQT behaviors (concept phase)[a]	.34* (Hypothesis 3a)	.36* (Hypothesis 3b)	–.14 (Hypothesis 3c)	.23 (Hypothesis 3d)	—			
6. Combined DBQT behaviors (elaboration phase)[a]	.40* (Hypothesis 3a)	.38* (Hypothesis 3b)	–.16 (Hypothesis 3c)	.24 (Hypothesis 3d)	.82**	—		
7. Supervisor ratings of team performance[a]	–.15 (Hypothesis 1a)	.34* (Hypothesis 1b)	.18 (Hypothesis 1c)	.17 (Hypothesis 1d)	.23 (Hypothesis 2a)	.26 (Hypothesis 2b)	—	
8. Contest results[b]	–.01 (Hypothesis 1a)	–.08 (Hypothesis 1b)	–.03 (Hypothesis 1c)	–.11 (Hypothesis 1d)	.33* (Hypothesis 2a)	.35* (Hypothesis 2b)	.40*	—
9. Team member rating of the design's technical realization[a]	.06 (Hypothesis 1a)	.11 (Hypothesis 1b)	–.06 (Hypothesis 1c)	–.17 (Hypothesis 1d)	.46** (Hypothesis 2a)	.39* (Hypothesis 2b)	.48**	.72**

a. Pearson's product-moment correlations.
b. Spearman's Rho correlations.
$*p \leq .05$, one-tailed. $**p \leq .01$, one-tailed.

confirms Hypothesis 1b. Neither variability in agreeableness (*r* = .18, *ns*) nor variability in conscientiousness (*r* = .17, *ns*) is related to the supervisory rating of team performance. So, our Hypothesis 1c and Hypothesis 1d were not confirmed for this outcome. The team performance measures contest results and team member rating of the design's technical realization are not related to either the mean or the variability in the personality measures studied.

Combined DBQT Behaviors, DBQT Subcategories, and Team Outcomes (Hypothesis 2)

In line with our expectations (Hypothesis 2a), the combined DBQT behaviors correlate significantly with the contest results in the concept (*r* = .33, *p* = .05) and elaboration phase (*r* = .35, *p* = .04). The same was found for correlations between the combined DBQT behaviors and the team member rating of the technical realization of the design in both the concept (*r* = .46, *p* = .01) and elaboration phase (*r* = .39, *p* = .02). Although the correlations between the combined DBQT behaviors and supervisory ratings of team performance are positive, they are not significant (concept phase *r* = .23, *ns*; elaboration phase *r* = .26, *ns*).

In answer to Hypothesis 2b, we inspected correlations between the DBQT subcategories and team outcomes and report significant correlations per outcome. The supervisory rating of team performance is significantly related to planning time (*r* = .43, *p* = .01) and keeping schedule (*r* = .35, *p* = .04) in the elaboration phase. The results of the contest relate significantly to the DBQT subcategories information-based designing (*r* = .51, *p* = .004), adjusting based on reflection (*r* = .36, *p* = .04), and keeping schedule (*r* = .38, *p* = .03) in the concept phase and to information-based designing (*r* = .44, *p* = .01) and adjusting based on reflection (*r* = .55, *p* = .002) in the elaboration phase. Finally, the design team member's rating of the technical realization of the design relates significantly to information-based designing (*r* = .47, *p* = .01), adjusting based on reflection (*r* = .35, *p* = .04), planning time (*r* = .36, *p* = .04), and keeping schedule (*r* = .62, *p* = .001) in the concept phase and to information-based designing (*r* = .43, *p* = .01), reflection (*r* = .34, *p* = .05), adjusting based on reflection (*r* = .40, *p* = .02), and planning time (*r* = .36, *p* = .04) in the elaboration phase.

As hypothesized in Hypothesis 2b, the results show that relationships between DBQT subcategories and team outcomes are somewhat different for the concept phase and elaboration phase. Generally, information-based designing, adjusting based on reflection, planning time, and keeping schedule appear to matter in both phases of the design project. However, in the elaboration phase, reflection is added as a DBQT subcategory that relates significantly to team outcomes. Furthermore, the DBQT subcategories planning time and keeping schedule relate to different outcomes of the teamwork in each of the project phases.

Team Composition and Combined DBQT Behaviors (Hypothesis 3)

As expected, mean agreeableness and the combined DBQT behaviors in both the concept phase ($r = .34$, $p = .04$) and elaboration phase ($r = .40$, $p = .02$) are significantly correlated, which confirms hypothesis 3a. The same is found for mean conscientiousness and the combined DBQT behaviors in both the concept phase ($r = .36$, $p = .04$) and elaboration phase ($r = .38$, $p = .03$), which confirms Hypothesis 3b. Neither variability in agreeableness, nor conscientiousness, nor the combined DBQT behaviors are correlated with design behavior in either of the phases (concept phase: agreeableness $r = –.14$, *ns*, conscientiousness $r = .23$, *ns*; elaboration phase: agreeableness $r = –.16$, *ns*, conscientiousness $r = .24$, *ns*), which is not in line with expectations presented in Hypothesis 3c and Hypothesis 3d.

Team Composition and DBQT Subcategories (Research Question 1)

When inspecting the correlations between mean agreeableness and the DBQT subcategories (Research Question 1a), we found that agreeableness was positively related to information-based designing ($r = .40$, $p = .04$), to building ($r = .47$, $p = .02$) and confining the solution space ($r = .39$, $p = .05$), to adjusting based on reflection ($r = .51$, $p = .01$), and to making decisions ($r = .57$, $p = .003$) in the concept phase. Furthermore, it was positively related to making decisions ($r = .60$, $p = .001$) in the elaboration phase. We found a significant relationship between mean conscientiousness (Research Question 1b) and the DBQT subcategory making decisions ($r = .48$, $p = .01$) in the concept phase but none in the elaboration phase. Variability in agreeableness had no significant relationship with any of the DBQT subcategories in any of the phases (Research Question 1c). Variability in conscientiousness was not related to any of the DBQT subcategories in the concept phase, but it was significantly related to planning time ($r = .41$, $p = .04$) and keeping schedule ($r = .44$, $p = .03$) in the elaboration phase (Research Question 1d). Correlations between the personality measures and all other DBQT subcategories were not significant.

Discussion

Based on an input-process-output model of team effectiveness, relationships between team composition in terms of designer's personality, design processes, and design outcomes were researched. We discuss our findings first and subsequently reflect on limitations, strengths, and implications of our results.

Input–Process Relationships of Designing in Teams

Regarding input–process relationships, we found mean agreeableness to be related to most design process variables. In the concept phase, mean agreeableness is positively related to the combined DBQT behaviors, information-based designing, building and confining the solution space, adjusting based on reflection, and making decisions. In the elaboration phase, it is positively related to the combined DBQT behaviors and making decisions. The fact that there are many relationships between mean agreeableness and design behavior subcategories in the concept phase but only one in the elaboration phase might be explained by the fact that team members are relatively unacquainted with each other in the concept phase. Behaving friendly and cooperatively in this phase may be an important prerequisite to get a feel of one another and to make design processes run smoothly. Later on in the project, team members have gotten to know each other and work relationships have been established. Behaving agreeable remains important, but it does not influence specific design processes as much as when the project had just started.

As expected, mean conscientiousness is positively related to the combined DBQT behaviors in both project phases and to making decisions in the elaboration phase. Finally, variability in conscientiousness is positively related to planning time and keeping schedule in the elaboration phase of the project. This input–process relationship is surprising as variability in conscientiousness was expected to be negatively related to design processes (which in turn would positively influence team outcomes). The fact that variability in conscientiousness has a positive influence in this study might be explained by the fact that it is related to specific behavioral categories in a specific design phase and not to team performance in general (compare Peeters, Rutte, et al., 2006). In teams in which team members differ in the extent to which they are conscientious, the more conscientious team members may signal the need for scheduling and monitoring of time toward the end of the project just to keep their less conscientious team mates on track.

Input–Output Relationships of Designing in Teams

Meta-analytical findings regarding input–output relationships between both mean agreeableness and conscientiousness and team performance (Peeters, Van Tuijl, et al., 2006) were only replicated for the positive effect of conscientiousness on team performance. The fact that mean agreeableness was of no influence on team performance is in line with findings from the moderator analysis that the effect of agreeableness was absent in student teams (Peeters, Van Tuijl, et al., 2006) and strengthens this meta-analytical result. Effects of variability in both agreeableness and conscientiousness on performance were—as expected—generally negative though nonsignificant. As the meta-analytical effects of variability in agreeableness and conscientiousness were negative in both the overall and the student team sample, the nonsignificance of our findings in this respect is remarkable. It may be attributed to the relatively small sample we studied.

Process–Output Relationships of Designing in Teams

The combined DBQT behaviors relate positively to multiple outcome measures (contest results, design team member rating of the design's technical realization, and to a moderate extent to supervisor ratings of team performance). Furthermore, five of the 12 DBQT subcategories (information-based designing, reflecting, adjusting based on reflection, planning time, and keeping schedule) have positive relationships with one or more outcomes. It goes without saying that our findings should be reestablished in future design process research, but based on these results, the DBQT holds promising methodological and predictive qualities. The main categories "design creation"—from which the subcategories information-based designing, reflecting, and adjusting based on reflection stem—and particularly "design planning"—which is fully made up of the subcategories planning time and keeping schedule—provide the most cause to be included in future research.

Phases in the Design Process

We expected that specific design behaviors might relate differently to team outcomes in the concept and elaboration phase of the design project. Based on our results, we can conclude that, to come up with a qualitatively good design, different behaviors are important in different phases. For high team performance, it turns out to be important to integrate all relevant information and to adjust the design and design behavior when new information becomes available while developing the design concept. This result is in line with findings from Gersick (1988, 1989) regarding behaviors displayed in the pre–midpoint transition phase. These kinds of behavioral actions have also been found to be important in design research (e.g., Badke-Schaub & Frankenberger, 2002; Stempfle & Badke-Schaub, 2002) and in problem solving theories (e.g., Carroll & Johnson, 1990; Lipshitz & Bar-Ilan, 1996). When elaborating the design, these behaviors remain important, but planning and monitoring the use of time now has also become important. We found that displaying time-related regulatory behavior later on in the project is positively related to supervisor and team member's ratings of team performance. This is in line with Gersick's (1988) notion that team members realize that project time is running out once they have passed the project's midpoint and with findings that planning in the execution phase of the project supports team performance (Gevers, Van Eerde, & Rutte, 2001). The fact that we also find different input–process relationships in each of the project phases strengthens our conclusion in this respect.

Input–Process Versus Input–Output Relationships of Designing in Teams

If we look at our results from the input–process, input–output, and process–output framework of team effectiveness (Hackman, 1987), we have to conclude that team composition in terms of personality affects design processes much more than it does team effectiveness. These findings provide support for team personality researchers who attempt to establish input–process relationships (e.g., Barrick et al., 1998; Van Vianen & De Dreu, 2001).

Limitations, Strengths, and Directions for Future Research

The main limitation of this research is that, due to the small sample size, analyses have been mainly of a correlational type. Even though the longitudinal character of our data (personality was measured before processes, which in turn were measured before outcomes) may give us some confidence in the causality of the relationships we found, conclusions would be much more powerful had they been based on results from regression analysis or even structural equation modeling in which effects of process variables were controlled for those of team composition variables. Here lies an opportunity for future research in this field.

Another limitation has to do with the way we tested effects of personality. When testing for effects of a single personality trait, scholars advise to control for the effects of the other personality traits (Kozlowski & Klein, 2000; McGrath, 1998) as by doing so the concept of personality as a whole is best reflected in the results. Again, due to the size of the sample under study, we were not able to follow this recommendation. Although the meta-analyses on which we based our hypotheses also only used single trait correlations, it would have been desirable to have established the effects of agreeableness and conscientiousness while controlling for effects of the other traits (compare Mohammed & Angell, 2003; Peeters, Rutte, et al., 2006).

A final limitation has to do with the relationships between design processes and the team member rating of the design's technical realization. These relationships may have been affected by common method or single source variance as both process and outcomes were rated by team members themselves. The fact that the other outcomes are not affected by such bias compensates for this limitation as does the fact that both variables were rated at other points in time during the project. However, it might be interesting to have both team members and independent observers fill out the DBQT in future research and to compute interrater agreement measures or compare relationships between DBQT categories and other variables for both ratings. One might argue that this limitation also applies to input–process relationships but as personality scores were aggregated to team composition measures and former research has established convergence between self-report and other's report of personality (e.g., Albright, Kenny, & Malloy, 1988; Bernieri, Zuckerman, Koestner, & Rosenthal, 1994; Funder, Kolar, & Blackman, 1995) we think this form of bias was of neglectable influence here.

Bearing these limitations in mind, we consider it a strength that we have conducted our research in a relevant sample of design teams: The teams were multidisciplinary, performed a "real life" design task, worked under constraints and toward a hard deadline, were in competition with each other, and could take notice of the work of the other teams. These are all conditions that professional design teams face as well and they thus add to the generalizability of our conclusions.

Furthermore, we have been able to measure design outcomes in three different ways. The measures differed in content and in source of measurement. If we inspect correlations among them, we can conclude that they are related (as all correlations are significant) but that they adhere to different aspects of performance (as correlations are not of such magnitude that they explain no unique variance). The strong correlation between the team member rating of the design's technical realization and the contest result ($r = .72$, $p = .00$) may indicate that designers themselves have good insight into the quality of the design they made. As the outcomes relate to different aspects of the design process, future design researchers are advised to include multiple outcome measures in their research.

Finally, we have been able to present a number of input–process, input–output, and process–output relationships and thus accomplished the aim of this study: add to the knowledge of how design processes relate to design team member characteristics and design effectiveness. Our findings, though preliminary, hold implications for design research and design practice. For design research, our results may be encouraging and may even stimulate design researchers to adopt an approach similar to ours in their research. For design practice, our results have implications for team composition and design processes. As the personality of design team members is related to both design processes and outcomes, mapping (differences in) team member personality and creating awareness of effects of both mean agreeableness and conscientiousness and of variability in conscientiousness among team members is an advisable course of action. If at all possible, teams might even be composed in such a way that it facilitates design processes and team performance. With respect to design processes, our results show that careful integration of information, reflecting on the design, and making adjustments based on outcomes of these reflections are important determinants of design performance throughout a design project. Display of such behaviors should therefore be encouraged, for instance, by scheduling these topics on the regular team meeting agenda or by assigning a team member the task of monitoring the team behavior and signaling problems regarding results ensuing from these behaviors. Furthermore, planning and monitoring the use of time becomes of particular importance when the deadline comes in sight. In the end phase of the project, teams should thus be aware of the remaining time, for example, by visualizing their time schedule, expressing temporal reminders, or by regularly reviewing accomplishment of the time schedule in team meetings. With regard to our recommendations on both team composition and design processes, team members might benefit from explicit training. As this research addressed student designers, such training activities could be integrated in the regular curriculum. By means of a final recommendation, we propose that student designers experience a lot of realistic design teamwork during their education as they most likely will become members of a multidisciplinary design team once they start their career as a professional designer.

Figure 3 (or Photo 1)
Members of a Design Team at Work in Between Battles at the Technische Universiteit Delft

Source: http://www.io.tudelft.nl/public/workshop/

Figure 4
The Battle at the Technische Universiteit Eindhoven

Source: http://library.tue.nl/catalog/MedialinkFrame.csp?OpacLanguage=dut&RequestId=414570_2&Profile=Default&RecordNumber=1&URL=http://www.tue.nl/cursor/bastiaan/jaargang46/cursor07/nieuws/n_12.html&SearchMethod=Find_1

Notes

1. An additional complicating issue of studying design teams in organizational practice is the sensitivity of the information that might be disclosed during the study of such teams. This might make organizations reluctant to allow researchers to study their design teams.

2. Because Peeters et al.'s overall sample was already relatively small, we chose to base our hypotheses on results from that sample and not on those resulting from the moderator analysis on student teams, which may seem more appropriate considering the type of team under study.

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