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Drivers for performance in innovative research groups: The mediating role of transactive memory system



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Abstract This article contributes to research on transactive memory systems (TMSs) by analyzing the relationship between trust, collective mind (CM), and network ties (NT) as antecedents of performance in innovative university research (IUR), and the mediating role of the TMS in these relationships. The conceptual model grounded in seven hypotheses is tested through structural equations modeling. The data analyzed are drawn from 257 directors Spanish university research groups. The results show that TRUST, CM, and NT are positively related to the TMS and that the TMS is positively related to IUR. The most striking result is that the TMS mediates the relationships of TRUST, CM, and NT to IUR, becoming a necessary condition for TRUST, CM, and NT to improve IUR. These results support the conclusion that managers of university research groups should promote the development of TMSs to stimulate IUR in order to make these groups more competitive.

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Introduction

Increasing innovative performance is currently a crucial element in the development of organizational productivity and competitiveness (Mattes, 2014; Fan et al., 2016; Vázquez-Urriago et al., 2016; Verdu-Jover et al., 2017; Ardito and Messeni, 2017; Serrano-Bedia et al., 2017). Seeking methods that explain this innovative performance is always beneficial, but such inquiry is especially important now that

innovation is recognized as a dynamic capability (Danneels, 2002; Verona and Ravasi, 2003; Verdu-Jover et al., 2017) and generative source of differentiation (Haavisto, 2014; Ruiz-Jiménez and Fuentes-Fuentes, 2016; Verdu-Jover et al., 2017). Although innovation is primarily associated with private firms, innovative orientation also develops in the public sector, specifically in universities (Hewitt-Dundas, 2012; Spanos et al., 2015; Hormiga et al., 2017).

University research must cover continual and demanding changing needs. To improve performance and differentiation, the research must be innovative, and this need has led to the concept of innovative university research (IUR). IUR can be defined as the generation of pioneering research by

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university groups, according to the content or process that research uses.

To analyze the IUR in university research groups, this study focuses on the role of the transactive memory system (TMS), a variable that has recently been attracting attention from academics and practitioners (Kotlarsky et al., 2015; Fan et al., 2016; Cao and Ali, 2018). The TMS explains how each member takes responsibility for his/her area of work, contributing knowledge to the group as a whole (Cabeza et al., 2013; Cao and Ali, 2018) while simultaneously fostering cohesion among members (Heavey and Simsek, 2015). Since the TMS comprises trust in the reliability of others' knowledge and the group's efficacy in identifying the differentiated knowledge of each member (Lewis, 2003; Fan et al., 2016; Cao and Ali, 2018), it may facilitate IUR in groups.

Research on TMSs has focused on explaining groups' cognitive processes, the factors that affect these processes, and the results of the group's actions for other processes (Huang, 2009; Lewis and Herndon, 2011; Kotlarsky et al., 2015; Cao and Ali, 2018). Many studies of the TMS have thus been performed in research laboratories (Hollingshead, 2001), with samples of students (Lewis, 2004) or teams from a single organization (Austin, 2003). There is, however, an empirical gap in analysis of TMS in research groups from different organizations, particularly in the university context to improve IUR – notwithstanding the fact that researchers propose organization of work in groups as a crucial factor for developing effective transactive memory (Zajac et al., 2014; Rasmus and Conny, 2015) that can benefit group IUR (Fan et al., 2016). Research analyzing the TMS from a managerial perspective is also necessary to understand the point of view of those responsible for the groups and to propose strategies and tools to enhance the benefits of the TMS.

Existing literature on TMS analyzes characteristics of the group's members (Zhang et al., 2007; Fan et al., 2016; Hood et al., 2015; Cao and Ali, 2018) and communication processes but not teams' characteristics, goals, managerial perceptions and work climate (Zhang et al., 2007; Kotlarsky et al., 2015). Mariano and Al-Arriayed (2017) propose that, another fruitful research area may regard the analysis of how organizational practices are influenced by TMS. This research addresses this call and analyzes how TMS mediates the relationship between group variables and IUR.

Our study analyzes descriptive variables of behavior that may be related to TMS and IUR: trust, collective mind (CM), and network ties (NT). Anderson et al. (2014) posed as an important topic in their research on Innovation and Creativity in Organizations, that few studies have been conducted to focus on an understanding of effects of general or specific personality dimensions on innovative behavior. Therefore, in our study, we propose, to give continuity to this idea through, trust and networking as elements that can improve innovative behavior. Since the TMS may enhance IUR, and the variables TRUST, CM, and NT can be considered as cognitive variables that improve the TMS, we propose TMS as a bridge between these variables and IUR. The main goal of this paper is thus to analyze how the variables TRUST, CM, and NT are related to IUR, and whether the TMS mediates the relationships of these variables to IUR in the university.

This article contributes to the literature in several ways. First, university research represents a specific and suitable context for the analysis of the TMS, IUR, and its drivers. Second, in this context, our research contributes to existing literature by demonstrating that TRUST, CM, and NT are antecedents of the TMS; that the TMS is related to IUR as a measure of performance; and that the TMS is a mediating variable in the relationships described above. Third, we extend the existing literature on cognitive variables and personality to improve performance and research group management, complementing existing studies on groups through analysis of managerial perceptions of these variables. From the perspective of practice, managers of research groups should attempt to develop TMSs in their work groups to obtain better results in IUR in order to make greater contributions to society. Our results offer some recommendations that university research group managers can use to improve internal group processes and management of them to enhance IUR.

The article is structured as follows: after this introduction, we present a literature review to develop the relationship between the variables and study hypotheses. We then present the methodology and data analysis. Finally, we discuss the results and present the main conclusions, limitations, and future lines of research.

Theoretical framework and hypotheses

The research context

One of universities' main objectives is knowledge creation (Hewitt-Dundas, 2012; Zhanga et al., 2013; Hemmert et al., 2014; García-Sánchez et al., 2017), and universities' research activities are a major force driving the growth process in advanced economies (Hewitt-Dundas, 2012; Meo and Usmani, 2014; Vásquez-Urriago et al., 2016; García-Sánchez et al., 2017). University research is comprised of activities that develop theories and models to explain and predict natural reality (Pavitt, 1998). The average figure of 213,405.70 scientific documents published in European universities from 1996 to 2011 – primarily in the sciences and social sciences (Meo and Usmani, 2014) – attests to the importance of university research, justifying the need to advance knowledge on it (Lai and Tsai, 2010; García-Sánchez et al., 2017). Empirical studies show that academic knowledge is beneficial because the world of the university offers new theoretical perspectives, innovative techniques and abilities that are very difficult for other organizations to develop (Prajogo and Hong, 2008; Un and Asakawa, 2015). These characteristics permit the application of valuable knowledge and abilities developed through experience to solve new and complex problems.

To develop their IUR, universities form research groups as one of the main sources contributing innovative results to regional and national socioeconomic development (Caldera and Debande, 2010; Patanakul and Pinto, 2014). The literature proposes that organizations increasingly trust groups as a work tool to overcome challenges (Lee et al., 2014; Kotlarsky et al., 2015), as in the case of the groups that run university research (Bouncken, 2011; Scarbrough et al., 2015; Fan et al., 2016).

University research groups are the foundation on which the work of university research is constructed (Bayona et al., 2002). Composed of researchers who specialize in specific lines of research, a university research group is a unit of researchers whose lines of work share common interests and who perform research activities autonomously (Ryan and Hurley, 2007). Their research can be performed alone or in collaboration with other groups. Scholarly publications, books, and completion of research projects, among other results, have been established to evaluate this collaboration (García-Aracil et al., 2006; De Saá-Pérez et al., 2017).

TRUST, CM and NT, and the TMS

The concept of the TMS was proposed by Wegner (1986) while studying the processes by which intimate couples codify, store, and recover knowledge. The TMS is currently defined as the cooperative work that occurs between members of a group to learn, remember, and communicate relevant knowledge about the group (Hollingshead, 2001; Kotlarsky et al., 2015; Cao and Ali, 2018). More specifically, transactive processes refer to communication between people, to the way they codify, store, or recover information (Wegner, 1987; Wegner, 1986; Hollingshead, 2001). Credibility and coordination form part of the TMS: credibility, or the capacity to trust in the reliability of others' knowledge; and coordination, which is related to efficacy in the organization of differentiated knowledge (Lewis, 2003). Use of the TMS is being extended to work groups (Ren and Argote, 2011; Rasmus and Conny, 2015; Kotlarsky et al., 2015; Cao and Ali, 2018) because groups are structures composed of people with complementary abilities committed to a common purpose and set of goals (Katzenbach and Smith, 2000; Rasmus and Conny, 2015; Cao and Ali, 2018).

Successful functioning of a TMS depends on the formation of many transactive memory structures, that is, on each member of the group connecting to the others' knowledge within the system itself (Wegner, 1986). People form cognitive representations in which knowledge and communication inherently enable more effective cooperation and coordination of tasks (Rasmus and Conny, 2015). It is in these cognitive representations that TRUST, CM, and NT act.

While the literature has explored each of these variables individually, it has not analyzed their joint connection with the TMS (Lewis and Herndon, 2011; Mouzas and Henneberg, 2015). TRUST is the belief an individual or group of individuals has in another individual or group (Cumming and Bromiley, 1996). It is based on honest, cooperative actions (Bhattacharjee, 2002; Dolfsma and Van der Eijk, 2016; Benítez-Ávila et al., 2018). TRUST is a psychological construct produced by experiencing the interaction of people's values, attitudes, frames of mind, and emotions (Gill et al., 2005; Robertson et al., 2013; Benítez-Ávila et al., 2018). People characterized by TRUST are more willing to give useful knowledge (Zand, 1972; Huang, 2009; Dolfsma and Van der Eijk, 2016) and more receptive to listening to another's knowledge (Mayer et al., 1995)—actions that facilitate credibility and coordination. When TRUST exists

between group members, all contribute to success (Uribe et al., 2013), as TRUST facilitates willingness to act according to colleagues' criteria and helps to create affective bonds with the other members of the group (Ferres et al., 2004; Robertson et al., 2013; Benítez-Ávila et al., 2018). As units that organize and manage research activity, all of the abovementioned elements are applicable to university research and to development of these groups' internal processes. A group brings together a set of researchers with full capability to develop the research activity planned and controlled by the group's manager due to stable agreement on their objectives and shared infrastructures and resources (Cabeza et al., 2017; García-Sánchez et al., 2017). We therefore propose the following hypothesis:

Hypothesis 1. TRUST is positively related to the TMS in university research groups.

Weick and Roberts (1993) define CM as a pattern of interrelations attentive to actions in the social system. More recently, Huang (2009) defines it as the cohesion created by the different interrelations among group members. CM refers to the structures related to the collective meanings that emerge and coordinate the group's activities (Ackerman et al., 2007; Brown, 2015). When members recognize their role and contribution in these interrelations, their activities are more likely to be integrated and coordinated with other members' activities. They will depend on each other and perform tasks as a united group (Dougherty and Takacs, 2004), combining their efforts (Huang, 2009) and encouraging development of credibility and coordination in the TMS. Higher levels of CM in university groups lead their members to undertake actions together. The group coheres in responsibility for the tasks, people encourage each other, and actions are integrated to achieve the goal proposed (Huang, 2009; Brown, 2015). CM thus facilitates the TMS by helping to develop the collective competences to overcome obstacles as a research group, the desire to work together until goals are achieved, and group assumption of consequences, both positive and negative (Fernandez and Winter, 2003). We therefore propose that:

Hypothesis 2. CM is positively related to the TMS in university research groups.

With organizations increasing use of networked labor (Chen et al., 2012; Lungeanu and Contractor, 2015), NT have rapidly become an important topic in scholarly research (Lungeanu and Contractor, 2015). Defined as the real set of all types of connections among a set of individuals (Mitchell, 1973), NT are strongly related to frequency of interaction and communication among team members (Chiu et al., 2006). In essence, the theory of social capital proposes that the resources residing in the ties created by workers in a network generate benefits for network members (Nahapiet and Ghoshal, 1998), but the literature still seeks a more dynamic view of networks and their constant evolution (Human and Provan, 2000; Hite and Hesterly, 2001). Networks' connection with the TMS can provide such analysis, and this relationship has important implications for opportunity creation in groups. Researchers represent a specific

type of networked worker (Dimitrova et al., 2013; García-Sánchez et al., 2017), one who collaborates explicitly and exclusively (Lungeanu and Contractor, 2015). Being tied into a network enables team members to feel comfortable working with each other (Taylor and Greve, 2006; Lungeanu and Contractor, 2015) and fosters development of interpersonal cohesion characterized by the resulting social interaction (Huang, 2009). Further, by providing privileged information and access to opportunities, NT permit network members to obtain resources, encouraging credibility and coordination in the TMS (Lee et al., 2014). As Dolfsma and Eijk (2017) remarked, networks have a great importance as strategic tool.

The TMS provides benefits of integration conceptually similar to those described in network theory (Lee et al., 2014). In university research groups, the development of networks fosters research capabilities through synergies in the shared use of resources, coordination, and greater and better use of advanced technologies (Cabeza et al., 2017; García-Sánchez et al., 2017). NT enable better use of members' knowledge, helping them to be more effective in fulfilling creative tasks (Monge and Contractor, 2003; Wu et al., 2009) and thus encouraging the TMS in university R&D activities. As a result, we propose that:

Hypothesis 3. NT are positively related to the TMS in university research groups.

Relationship between the TMS and IUR

Although much research demonstrates that the TMS has positive effects on the performance of groups and organizations (Liang et al., 1995; Moreland and Myaskovsky, 2000; Fan et al., 2016; Cao and Ali, 2018), the connection between the TMS and university research performance has not been empirically tested. Some theoretical frameworks have emerged, however, that link work groups to university research, such as the interactionist theory of innovation proposed by Woodman et al. (1993), which links group cohesion and communication to university research. The new line of study of the role of the TMS linked to the development of new research studies and publications performed in university research groups makes an important contribution to the literature and to university management.

The TMS facilitates exchange and diffusion of tacit information through shared memory, helping to promote effective use of human resources and reduce individual responsibility for cognitive development (Akgun et al., 2006; Galunic et al., 2014; Cao and Ali, 2018). Such exchange and diffusion are very important to the success of new research. The TMS is responsible for ensuring the availability of important information and enabling recovery of it. For Moreland and Myaskovsky (2000), group members who need information but do not remember it or who distrust their memory can refer to the other team members for help, creating a climate that encourages IUR. Key mechanisms for IUR also emerge in groups that have developed a TMS and can thus coordinate interactions more effectively (Austin, 2003; Zhang et al., 2007; Fan et al., 2016; Cao and Ali, 2018).

Based on the foregoing, we propose the following research hypothesis:

Hypothesis 4. TMS is positively related to IUR in university research groups.

Mediating role of the TMS

Although many studies show the TMS to be vital for improving the group's performance on all levels (Ren and Argote, 2011; Kotlarsky et al., 2015; Cao and Ali, 2018), little research has investigated the TMS in mediation relationships (e.g., Peltokorpi and Hasu, 2011; Fan et al., 2016). We believe that the TMS may be the perfect mediator in the relationship of TRUST, CM, and NT to IUR in university research groups. First, the TMS mediates the relation between TRUST and IUR by making the individuals' motivations, attitudes, and behavior operative in the context of the team (Lewis and Herndon, 2011; Fan et al., 2016), thereby encouraging IUR. TRUST does not generate a positive result per se. It requires a mechanism that establishes this attitude to determine specific actions. The TMS is thus an important resource fostering individual and team participation (Kotlarsky et al., 2015) in tasks related to IUR (Fan et al., 2016).

Second, the collective thinking that emerges from CM attempts to unite all members of a group through the goal of constructing knowledge (Brown, 2015). With CM, members who coordinate with each other in work on tasks believe in the knowledge and work of the other group members, and the TMS enables this coordination. Such a situation benefits IUR because CM causes each individual mind to work independently of its total capability, while simultaneously contributing with others (Brown, 2015). Due to these characteristics, the TMS mediates the relationship by permitting the internal attributes of the group's or organization's members to grow through the constant interrelation between them (Brown and Duguid, 2001; Mouzas and Henneberg, 2015). Members of a group are more likely to seek solutions that recombine disconnected ideas – further increasing IUR – when they have different abilities, capabilities, and knowledge (a TMS) (Guimera et al., 2005; Lungeanu and Contractor, 2015).

Finally, we believe that the TMS mediates the relationship between NT and IUR. The characteristics of the TMS enable it to increase the unity of existing networks. Generation of innovative ideas requires the capability to recombine (Fleming and Sorenson, 2001) the team's diverse areas of knowledge (West, 2002) and produces a situation in which the work group's members feel comfortable with each other (Guimera et al., 2005; Taylor and Greve, 2006). Multidisciplinary teams, where representatives of different knowledge domains work tied into a network to perform a common task, face challenges related to differentiation and integration of knowledge when working to achieve a common result (Liao et al., 2015; Majchrzak et al., 2012). The TMS's mediation of this relationship can make better use of the members' knowledge and achieve greater coordination. Such groups are more effective in fulfilling the creative tasks that benefit IUR.

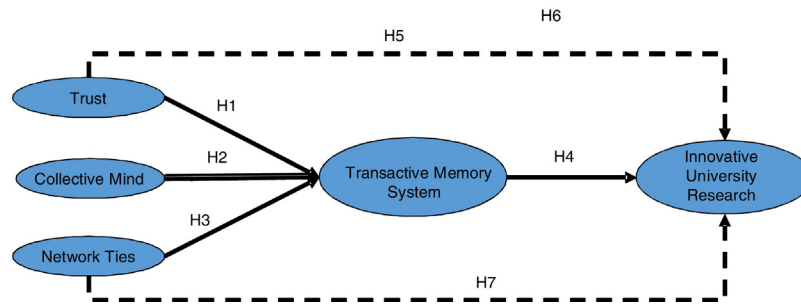


Figure 1 Research model.

Consequently, we propose the following hypotheses:

Hypothesis 5. The TMS mediates the positive relationship between TRUST and IUR.

Hypothesis 6. The TMS mediates the positive relationship between CM and IUR.

Hypothesis 7. The TMS mediates the positive relationship between NT and IUR.

Based on the foregoing discussion, Fig. 1 illustrates the hypothetical relationships in the research model.

Research methodology

Sample and data collection

Spanish university research is composed of formal research groups housed in different university faculties and research centers. The groups are usually composed of university professors and research assistants, and managed by university professors. To select the sample, we first composed a database of the full study population, which was made up of 12,434 university research groups. For a group to belong to the population, it had to be located within a Spanish university and have contact information available on the web. We selected a sample of 3000 groups through simple random sampling. Sampling was random so that each of the items would have the same probability of being selected to ensure that each member was highly representative of the population and that the only factor possibly endangering its representativeness was chance. Random sampling also eliminated systematic sampling bias (Moore and McCabe, 2006). The fieldwork was performed from March to May 2010. The data were collected by emailing a questionnaire with a cover letter to the director of each group. We obtained 260 questionnaires but rejected three because they were incomplete. We ultimately analyzed 257 questionnaires, giving a response rate of 8.57%, a sampling error assuming an infinite population of 6.1%, and a confidence level of 95% (see Table 1).

The groups belonged to all areas of knowledge and were chosen independently of their size, region, age of group, and area of knowledge (see Table 2). Choice of a sample of firms located in a single, relatively homogeneous geographic, cultural, legal, and political area minimizes the

Table 1 Questionnaires received for empirical research.

Questionnaires	Quantity
Received	260
Rejected	3
Total accepted	257

impact of variables that cannot be controlled in the empirical investigation (Alder, 1983). As mentioned above, the groups were managed by a university professor who knew the group, its functioning, and its members, and who was constantly receiving extensive information about the group. For these reasons, we decided to use the groups' managers as our key informants. Further, managers perform an important role in informing and molding the study variable by determining the types of behavior expected and requiring support by the group's leadership (Baer and Frese, 2003).

The groups in the sample generally had 5–10 researchers (groups of this size represented 50% of the total). 37% of the groups had over 10 researchers, and only 13% had fewer than 5. Significantly, Johnston affirms that the minimum group size for a group to compete internationally is 4–6 members, supported by four more technicians or research assistants.

Finally, in the period studied, 43.19% of the groups had budgets of 120,000€ devoted to R&D, 19.84% had 60,000€–120,000€, and 36.96% less than 60,000€.

It is important to evaluate how responding early or late to the survey affects the responses given and to what extent this situation influences generalization of the results to the total population. We thus tested for significant differences between early and late respondents by analyzing the variance of the variables whose scales could be measured. As we did not find significant differences, we assume that response time causes no significant bias. This analysis tests possible nonresponse bias, considering the last group of respondents as the one most likely to resemble nonrespondents (Roldán et al., 2017). We also compared relevant descriptive characteristics of the sample obtained for the population to those of prior studies that analyze the same unit in order to demonstrate that the results can be extrapolated to the population. Research groups in Spanish universities must have at least three members, of whom at least one must be a civil servant, as must the director of the group (De Saá-Pérez et al., 2017). Further, the distribution of the sample by area is similar to that of other studies performed

Table 2 Demographic profiles of the respondents.

	Frequency final sample (n=257)	Percentage	Frequency target sample (n=3000)	Percentage
<i>Area of knowledge</i>				
Social sciences	46	18.00	469	15.63
Humanities	54	21.00	699	23.3
Experimental sciences	73	28.00	780	26.00
Technology	23	9.00	382	12.73
Health sciences	61	24.00	670	22.33
Total	257	100.00	3000	100.00
<i>Autonomous region</i>				
Andalusia	32	12.45	314	10.47
Aragon	15	5.84	243	8.10
Canary Islands	14	5.44	102	3.40
Cantabria	20	7.78	205	6.83
Castilla-La Mancha	18	7.00	188	6.27
Catalonia	19	7.39	186	6.20
Community of Madrid	21	8.17	210	7.00
Navarre	31	12.06	340	11.33
Valencia	12	4.67	205	6.83
Extremadura	14	5.45	210	7.00
Galicia	10	3.89	196	6.53
Balearic Islands	12	4.67	195	6.50
Rioja	6	2.33	132	4.40
The Basque Country	15	5.84	105	3.50
Asturias	12	4.67	97	3.23
Murcia	6	2.33	72	2.40
Total	257	100.00	3000	100.00

with Spanish university research groups (De Saá-Pérez et al., 2017; García-Sánchez et al., 2017). The sample analyzed fulfills all of the above-mentioned conditions, enabling us to assume that it is representative of the population.

Measurement: scales used

The scales were selected based on an in-depth review of the specialized literature on the topic, enabling us to determine the scale that best fits the sector under study in each case. All scales were accompanied by a 7-category Likert scale (1 disagree completely to 7 agree completely). The measurement scale for TRUST was adapted from that proposed by Jarvenpaa and Leidner (1999) because it fits analysis of TRUST in groups well and has been used to study R&D groups in Taiwan (Huang, 2009). CM was measured by adapting the scale proposed by Yoo and Kanawattanachai (2001), because this scale has been used satisfactorily in R&D groups to measure their effectiveness. The authors draw on the study by Weick and Roberts (1993) on collective mind in organizations. The small number of studies in the literature on collective mind tends to be theoretical, and very few studies have evaluated the construct empirically (e.g., Cabeza et al., 2016). Finally, NT was measured by adapting the scale proposed by Chiu et al. (2006), which has been used in similar contexts and fits our goals. To analyze TMS, the scale proposed by Akgun et al. (2005) was adapted to achieve better contextualization to the sector studied and the research goals (Cabeza et al., 2013). Finally, to measure IUR, we

adapted the scale proposed by Prajogo and Sohal (2006), previously validated in research environments (Prajogo and Sohal, 2006). Table 3 lists each item included in the scales and its descriptive statistics.

Assessing common method variance

The questionnaire was conducted with highly knowledgeable informants, as individuals higher in the group's hierarchy have a more comprehensive awareness of organizational TMS processes (Peltokorpi, 2004; Peltokorpi, 2014). Additionally, the respondents were asked to consult with other group members and answer questions in a round table to avoid key informant bias (Akgun et al., 2005). This flexibility was important to gain information about new, unexplored phenomena (Kvale and Brinkman, 2009; Peltokorpi, 2014).

Nonetheless, we analyzed the possibility of common method variance. First, the scales were pre-tested by experts in the field to eliminate possible errors and confusion (Podsakoff et al., 2012). Second, since the presence of common method bias would mean that a single factor explained most of the variance (Podsakoff et al., 2012), we first observed whether an unrotated factor analysis showed the presence of 4 different factors (Rhee et al., 2010). We then performed Harman's one-factor test for model fit with a single factor, using confirmatory factor analysis (Chang et al., 2010) to determine whether the result produced very low values ($\chi^2/df = 10.257$; CFI = 0.571; RMSEA = 0.190; NFI = 0.548; and NNFI = 0.523). The results

Table 3 Scale items and validation.

Items	Mean	S.D.	Standardized factor loadings (>0.4 ^a ; $t > 1.96^a$)	Reliability R^2 (>0.5 ^a)	Composite reliability (>0.7 ^b)	AVE (>0.5)	Cronbach's alpha (>0.7 ^b)
Trust (TR)					.921	.701	.929
<i>The members of my team have great integrity. (TR1)</i>	6.18	1.088	.762	.581			
<i>I can trust the people I work with on my team. (TR2)</i>	6.33	1.001	.893	.797			
<i>The members of my team are highly trustworthy. (TR3)</i>	6.35	.965	.866	.750			
<i>We consider the feelings of each team member. (TR4)</i>	6.16	1.091	Eliminated				
<i>The people on my team are nice. (TR5)</i>	6.36	.917	Eliminated				
<i>There is a spirit of collaboration on my team. (TR6)</i>	6.15	1.127	Eliminated				
<i>There is great trust among the people I work with. (TR7)</i>	6.14	1.164	.822	.675			
<i>In my team, we trust each other. (TR8)</i>	6.15	1.105	.839	.704			
Collective mind (CM)					.928	.765	.928
<i>The members of my team have a global perspective that includes outside decisions and the relationships amongst themselves. (CM1)</i>	5.27	1.367	.810	.656			
<i>The members of my team relate research actions carefully amongst themselves. (CM2)</i>	5.13	1.437	.891	.793			
<i>The members of my team make their decisions carefully to maximize the team's total performance. (CM3)</i>	5.10	1.398	.943	.889			
<i>The members of my team have developed a clear understanding of how each research activity should be coordinated. (CM4)</i>	5.16	1.437	.851	.724			
Network ties (NT)					.890	.671	.883
<i>I maintain a close social relationship with some members of my team. (NT1)</i>	5.45	1.603	.883	.780			

Table 3 (Continued)

Items	Mean	S.D.	Standardized factor loadings (>0.4 ^a ; $t > 1.96^a$)	Reliability R^2 (>0.5 ^a)	Composite reliability (>0.7 ^b)	AVE (>0.5)	Cronbach's alpha (>0.7 ^b)
<i>I spend a lot of time interacting with some members of the team. (NT2)</i>	5.42	1.509	.763	.582			
<i>I know some members of my team on a personal level. (NT3)</i>	5.93	1.397	.843	.711			
<i>I communicate frequently with some members of the team. (NT4)</i>	6.22	1.065	.781	.611			
Transactive memory system (TMS)					.868	.624	.862
<i>I have felt comfortable accepting procedural suggestions from other team members. (TMS1)</i>	6.37	.944	Eliminated				
<i>I trust the knowledge of other members concerning the research. (TMS2)</i>	6.33	.946	Eliminated				
<i>I really trust the information that team members bring to discussion. (TMS3)</i>	6.19	.944	.744	.553			
<i>My team has worked in a collaborative, well-coordinated way. (TMS4)</i>	5.68	1.308	.721	.520			
<i>We manage to perform tasks efficiently and without problems. (TMS5)</i>	5.58	1.147	.822	.675			
<i>There is no confusion about how tasks should be performed. (TMS6)</i>	5.71	1.123	.866	.743			
Innovative university research: (IUR)					.892	.625	.889
<i>We are innovative in the group's new research. (IUR1)</i>	5.83	1.209	.753	.567			
<i>We use the latest technological innovations in new research. (IUR2)</i>	5.52	1.358	.802	.644			
<i>Our speed in developing new research is high. (IUR3)</i>	4.97	1.432	.823	.678			
<i>Our group has introduced a high number of new research studies in the market. (IUR4)</i>	4.66	1.729	.799	.639			
<i>A high number of our research studies pioneer in the scholarly community. (IUR5)</i>	4.82	1.596	.775	.601			

^a Hulland (1999).^b Nunnally (1978).

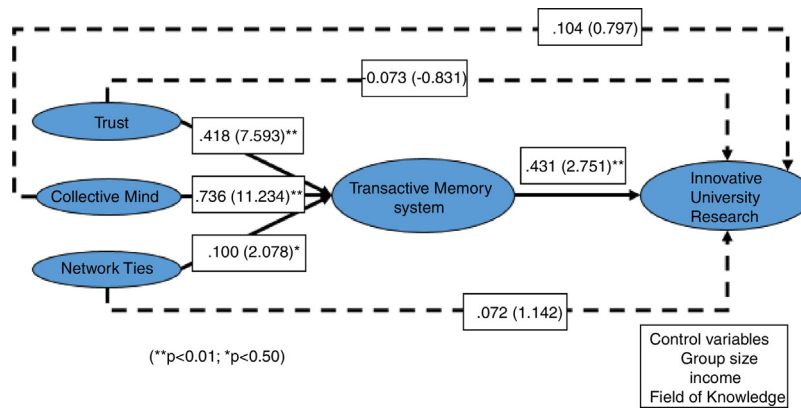


Figure 2 Structural model.

of these tests confirm the absence of problems related to common method variance.

Results

Scale validation

To ensure valid, reliable analyses, we subjected the measurement scales to a validation process. First, we studied the scales' one-dimensionality through principal component analysis. The results showed that each scale explained a single factor, confirming the scales' one-dimensionality. Second, to observe potential problems of multicollinearity between variables, we calculated the factors of inflation variance (FIV) and the condition index. Results showed acceptable values, discarding the possibility of multicollinearity (Gutierrez-Gutierrez et al., 2012; Tamayo-Torres et al., 2014). Next, we examined the scales' reliability, calculating the Cronbach's alpha for each scale (see Table 3 for results). As all values exceed the recommended minimum of 0.7 (Nunnally, 1978), we confirm that all scales show a good level of reliability. For both this and the previous test, we used SPSS 22.0 software.

Finally, we ran a confirmatory factor analysis and validated the measurement model using the robust estimation method with EQS 6.1 software. This validation process eliminated three items in the scale for TRUST and two in the scale for TMS because they did not fulfill the minimum standards of reliability. The test examined whether the factor loadings for each item were significant (t -value > 1.96 , $p < 0.05$) and whether their individual reliability (R^2) exceeded the recommended minimum of 0.5 (see Table 1 for item values). The indicators ensure the scales' convergent validity. The fit indices for the measurement model show values above the required minimums (RMSEA = 0.063; CFI = 0.904; IFI = 0.905; NFI = 0.828; NNFI = 0.890) – minimum recommended values for the RMSEA are below 0.08, the values for the CFI and IFI above 0.9, and the values for the NFI and NNFI above 0.5 (Byrne, 1998; Mulaik et al., 1989). To complement these tests, we analyzed the scales' composite reliability and average variance extracted (AVE). All scales fulfilled the minimum recommended values of 0.7 and 0.5, respectively (Nunnally, 1978).

Structural model

To analyze the hypotheses, we followed Rhee et al. (2010) in performing decomposition of effects. Decomposition establishes that the total effect of an independent variable on a dependent variable is disaggregated into its indirect and direct effects (Tabachnick and Fidell, 2007; Rhee et al., 2010). The presence of a significant indirect effect indicates that a significant part of the relationship between the dependent and independent variables is explained through the mediating variable. Fig. 2 presents the relationships established between the variables and the results obtained in the structural model, including the direct and indirect effects. We used EQS 6.1 software to perform structural equations modeling (SEM).

We examined the estimated parameters of the relationships between the variables to contrast the hypotheses. For the variables that act as antecedents of the TMS in the proposed model, the results show significant and positive relationships between TRUST and the TMS ($\lambda = 0.418^{**}$, t -value = 7.593), between CM and the TMS ($\lambda = 0.736^{**}$, t -value = 11.234), and between NT and the TMS ($\lambda = 0.100^*$, t -value = 2.078). These results lead us to accept Hypotheses H1–H3, respectively. For the dependent variable, the results of the structural model show a positive and significant relationship between the TMS and IUR ($\lambda = 0.431^{**}$, t -value = 2.751). We can thus accept Hypothesis H4. To analyze the mediating effect of the TMS, we examine the direct relationships of the variables of TRUST, CM, and NT to IUR. The results ($\lambda = -0.073$, t -value = 0.831; $\lambda = 0.104$, t -value = 0.797; $\lambda = 0.072$, t -value = 1.142, respectively) show non-significant relationships between all variables, indicating that the relationships of TRUST, CM, and NT to IUR occur through the TMS, which exercises a mediating effect on the variables observed,¹ supporting Hypotheses H5–H7. The structural model includes three control variables: number of members in the group, field of knowledge, and income level. The relationships of group size ($\lambda = 0.154$, t -value = 1.447)

¹ To complement this analysis, we used the method proposed by Baron and Kenny (1986) to confirm the existence of mediating effects. All conditions are satisfactorily fulfilled, confirming what the authors call "total mediating effect."

Table 4 Additional mediation analysis.

TRUST			
	TMS	IUR	IUR
TRUST	0.7132 ^{***}	0.4845 ^{***}	0.0756
TMS			0.5733 ^{***}
Indirect effect of TRUST on IUR (TMS)	0.4089	Confidence interval (0.2633–0.5763)	
CM			
	TMS	IUR	IUR
CM	0.5838 ^{***}	0.4454 ^{***}	0.2047
TMS			0.4123 ^{***}
Indirect effect of CM on IUR (TMS)	0.2407	Confidence interval (0.1103–0.3721)	
NT			
	TMS	IUR	IUR
NT	0.2206 ^{***}	0.1894 ^{**}	0.0557
TMS			0.6060 ^{***}
Indirect effect of NT on IUR (TMS)	0.1337	Confidence interval (0.0586–0.2357)	

95% confidence level.
^{**} $p < 0.05$.
^{***} $p < 0.01$.

and field of knowledge ($\lambda = -0.073$, t -value = -0.902) to IUR were not significant, but the relationship between income level and IUR was ($\lambda = 0.354$, t -value = 4.282). This result indicates that neither group size nor belonging to sciences or humanities is related to innovative performance but that groups with more financial resources are more likely to be innovative.

Next, we analyzed goodness of fit in the structural model by examining various indices and their minimum recommended values: goodness of fit index (GFI) = 0.833, adjusted goodness of fit index (AGFI) = 0.788, normed fit index (NFI) = 0.842, non-normed fit index (NNFI) = 0.912, comparative fit index (CFI) = 0.925, Bollen's fit index (IFI) = 0.926, and root mean square error of approximation (RMSEA) = 0.053. All fit indexes obtained exceed the required minimum values mentioned above. In sum, the SEM estimation indicates a model with indicators of acceptable and reliable fit whose estimations permit us to accept all hypotheses proposed.

To ensure robust results, we ran an additional mediation analysis following [Darlington and Hayes \(2016\)](#) and employing the PROCESS macro for SPSS 23.0. As observed in [Table 4](#), these results corroborate those obtained in the SEM, reinforcing its robustness.

Finally, following [Rhee et al. \(2010\)](#), we estimated an alternate model that included the TMS as exogenous rather than mediating variable. An χ^2 difference test showed significant differences between the two models ($\Delta\chi^2(1) = 324.386$, $p = 0.00$), and the results of the alternate model had less exploratory power (GFI = 0.756; AGFI = 0.691; NFI = 0.796; NNFI = 0.804; CFI = 0.851; IFI = 0.853; RMSEA = 0.079), also supporting the decision to include the TMS as a mediating variable in the model.

Discussion

Contributions

The goal of this study was to determine the relationship between the variables TRUST, CM, and NT as antecedents of IUR, and the mediating role of the TMS in these relationships. Despite the importance of these variables for group work, no studies consider their value for IUR in groups. Although there remain far larger literatures at the individual and organizational levels of analysis, research into work group innovation is very important and valuable as organizations have moved to more group-based structures and will often be reliant upon groups to develop and implement innovative solutions. Our results contribute to previous lines of research on creativity and innovation in organizations (e.g. [Anderson et al., 2014](#)).

In this meaning, the empirical findings indicate that the three antecedents studied play a considerable role in facilitating the TMS, which is positively related to IUR in university research groups. The most striking result is the mediating role of the TMS in the relationship of TRUST, CM, and NT to IUR.

Our results thus help to establish a solid foundation for literature about group management, the TMS, and university research. The findings are framed and reinforced by the interactionist theory of innovation proposed by [Woodman et al. \(1993\)](#), which links group cohesion and communication to IUR. Our results indicate that TRUST is positively related to the TMS in research, specifically university research.

TRUST permits university research to develop better credibility and coordination within the TMS, encouraging creation of more effective work teams that distribute

tasks and responsibilities appropriately, thereby developing different roles and domains of knowledge (Brandon and Hollingshead, 2004; Cao and Ali, 2018). Such trust-created team integration has a positive impact on credibility and coordination within the team (Fan et al., 2016). Our results indicate that teams whose members learn to resolve a task together develop differentiated knowledge that inheres in the TMS and thus obtain a larger quantity of information relevant to the task than teams whose members are trained separately (Moreland and Myaskovsky, 2000). Further, individuals in such teams use knowledge better to access the competences required at each moment and to coordinate their actions (Sánchez et al., 2006; Praveen et al., 2015; García-Sánchez et al., 2017).

Next, our results agree with literature on CM as an element signifying cohesion and important for groups because it creates connections between their members (Huang, 2009; Brown, 2015). Messeni (2011) affirms that prior connections increase exchange in groups. CM also enables development of knowledge incusted in the group's members, improving the way team members individually coordinate, share, distribute, and recombine knowledge amongst themselves (Brown and Duguid, 2001; Brown, 2015). CM thus facilitates growth of the internal attributes of the members of the group or organization through the constant interaction created, producing an environment of trust and mutual knowledge. As our results show, these circumstances encourage the TMS, since they develop in an environment created by and sustained in an organizational culture that encourages them.

NT also encourages the TMS because network members share a series of beliefs and conditions that enable them to believe in and feel secure with the members who are tied into the network. Our results corroborate the importance of network as a strategic tool (Dolfsma and Eijk, 2017). NT enable better communication and closer links between individuals and groups. Such a situation nurtures university research groups by enabling them not only to integrate but also to access new knowledge (Jin Bih and Chun, 2015) and all other benefits of being tied into a network, thereby encouraging the TMS.

The TMS is positively related to IUR. The literature recognizes that groups are key mechanisms for improving university research (Gibson and Gibbs, 2006; Fan et al., 2016), and our results provide empirical evidence for prior theoretical studies that connect group processes to university group research (Moreland and Myaskovsky, 2000; Chen et al., 2013; Fan et al., 2016). This research adds empirical evidence to the existing literature on teamwork and coordination of technical knowledge among group members, which have been recognized as important elements for team effectiveness (Zhang et al., 2007; Chen et al., 2013). Teams that are coordinated and whose members believe in the knowledge of the other members organize differentiated knowledge effectively, positively influencing university research (Fan et al., 2016) and enabling increased competence in new product development (Rothaermel, 2001).

Finally, the mediating effect occurs through the TMS as a system enabling exchange, coordination, and feedback, in which individual members of the group serve as external memory aids for other team members. The TMS creates distributed memory in which each team member takes care of

an area of knowledge, which is coordinated to complement and strengthen the other members, decreasing the problem of having to know everything. Knowing who specializes in what is important in facilitating knowledge exchange at the group level (Huang and Huang, 2007; Fan et al., 2016). Developing IUR is recognized as a difficult task, and the TMS facilitates it by integrating the different functions, activities, and information flows between the members of the group. The mediating effect of TMS implies that the links it creates lead to greater commitment to increase IUR in groups. As the mediating role of this variable has never been analyzed in this context, our result makes a significant contribution to the literature. This finding may explain why prior studies have not found direct positive relationships of the variables TRUST, NT, and CM to elements related to performance in innovation and research (Lewis and Herndon, 2011; Mouzas and Henneberg, 2015).

To conclude, the positive relationship obtained between the income of the university research group and the IUR should be highlighted. Each organization should adapt and contextualize the innovation process to its own financial resources, as resources affect the group's performance. Income level is associated in the literature with the innovation process in organizations (McDermott, 1999; Mackelprang et al., 2015).

Managerial implications

Research groups are the basic units around which much of universities' research activity is organized. Our results are thus very significant because they provide management recommendations for managers who try to improve the performance of their groups in highly competitive environments. First, managers of university research groups that strengthen aspects such as TRUST, CM, and NT will be able to develop their TMS to stimulate IUR. This in turn will produce more competitive groups that are better organized in achieving their research goals. Second, the group structures that develop powerful TMSs will be very effective for the development of university research, since they enable the members to focus on their own areas and to use the experience and knowledge of others. The leaders of the group should thus foster attitudes that help to develop transactive structures and training in these topics to foster the variables studied.

By following these steps, Spanish universities will benefit from the improvements recommended, since they depend increasingly on group structures to facilitate the creation of innovative knowledge. Having managers who know how to manage groups successfully, thereby improving their IUR, will increase the institution's productivity, improving, for example, its position in international rankings.

Limitations and future research

Although this study obtains important results, it has several limitations. First, its transversal nature requires that the results be analyzed with prudence due to the dynamic character of the constructs evaluated. This limitation can be overcome by long-term studies that provide more information on the topic. Second, the restriction of the sample

to Spanish research groups may condition the results due to Spanish's particular cultural, political, social, legal, and economic characteristics. Third, even though "individuals higher in the group's hierarchy" could be "highly knowledgeable informants," when studying multi-level concepts such as the TMS, TRUST, etc., future multilevel data collection (with several members per team) could make this study more complete. Fourth, it would be interesting to measure the group's performance (IUR) more objectively as, for example, results in the form of scholarly publications, research projects, or patents, among others. Fifth, the positive relationship between income and IUR suggests a possible line of research for future analyses. Finally, it would be interesting to study how to deal with different cognitive backgrounds, or multidisciplinary teams, and other distances between team members that may influence the TMS and IUR.

In addition, it would be beneficial for future research to complement this study by analyzing the university-industry relationship to consider the real impact of the IUR on society. There is already substantial literature on the university-industry relationship, to which studying factors such as the TMS and its influence on the training and functioning of these connections could contribute. Incorporating other variables of the group, such as the effects of network or location, and of the spatial and non-spatial proximity of the actors participating in the process, would continue the line of investigation begun in this study.

Conclusions

As universities' future depends on proper development and management of research teams, research on groups, especially university research groups, is growing. Nevertheless, many questions remain, such as what role internal group processes and managerial perceptions play, and how one can improve the performance of innovative research, particularly in the university context.

Our investigation presents an empirical study that analyzes the effects of TRUST, CM, and NT as antecedents of the TMS, and evaluates the mediating effect of the TMS on these relationships with IUR. Our results indicate that the facilitating elements TRUST, CM, and NT encourage creation of the TMS in university research groups. They also show that IUR is positively related to development of the TMS. Finally, they demonstrate mediation of the TMS in the relationship of TRUST, CM, and NT to IUR. The study contributes to analysis of management from a university research perspective and provides specific empirical information to enhance the TMS in this context. As the existing literature contains no empirical studies that analyze the relationships tested in university research environments, the results are important in enabling us to orient these organizations as they seek to improve their research strategy. The study serves as a model for groups who wish to strengthen in their research activities, as the results provide a work instrument for managers and researchers in universities. Further, our results provide empirical support for studies of groups and help us to trust increasingly in work groups as another tool for overcoming today's challenges.

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