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Interdisciplinarity in ferment: The role of knowledge networks and department affiliation

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ABSTRACT

This paper examines the relation between department affiliation and interdisciplinarity in terms of knowledge creation. While the claims made for the benefits or limitations of interdisciplinarity are diverse, they have been largely related to modes of academic governance or to the bare nature of disciplines. Less is known on the precise role of social networks in fostering or hindering interdisciplinarity within intraorganizational contexts. Thus, to explore the influence of network structure, tie strength and nodal properties in interdisciplinarity within higher education institutions, we study the structure and dynamics of academic's personal knowledge networks. It is used a mixed methods approach combining the delineation of personal networks with the ties' content analysis regarding a conceptual model specifically developed for this study. Personal network data were collected and semi-structured interviews were held with 32 academic staff members of the academic and research system in Catalonia, Spain. Findings suggest that belonging to a department decreases interdisciplinarity and that institutional constraints are more significant than the strength of the ties. Researcher's network centrality and strength of ties are positively related to interdisciplinarity. Structural holes control for certain organizational rewards and individual attributes but are not directly linked to interdisciplinarity.

1. Introduction

Despite the fact that research is generally not interdisciplinary (Zürcher, 2007) there is a conventional discourse in favour of interdisciplinary research and, at the same time, much indifference or even disregard for such research (Sperber, 2003). In addition, research shows that constraints to interdisciplinarity are posed both in scientific terms (e.g.: Collinet et al., 2013) but also in institutional terms (e.g.: Su, 2014), especially concerning governance modes (Cooper, 2013). The idea that interdisciplinarity in higher education is related to the framework of institutions, departments and courses is not new (e.g.: Carpenter, 1995; Pirrie et al, 1999; Wall and Shankar, 2008; Dykes et al., 2009). Curiously, for the most part, academic staff are positive about their own experiences of interdisciplinarity research but many are negative about attempts to promote this in ways that force the dominant university logic. For some, interdisciplinary research is seen as privileging over other types of research. For others, it is possible to see themselves as working in an interdisciplinary fashion without necessarily collaborating with anyone (Pisapia, 2012). In turn, Horta and Lacey (2011) showed that factors like international visibility and academic's communication are positively affected by research unit size. As a matter of fact, one of the dominant features of education in universities is that it is usually confined within one subject area and often to one discipline, especially in countries like England, Spain or Portugal. On the other hand, despite technological and economic forces for integration, or convergence, there are equal or perhaps greater forces for fragmentation that hinder truly interdisciplinary research. Literature (e.g. Seeber, 2013) shows that university steering is effective in some disciplines, suggesting that a managerial-like steering may privilege strongest groups and paradigms, while marginalizing minor or emerging streams of research. In this work, as a departure point, the term discipline regards the schema used by Biglan and Becher (1973, 1987) as it has been cited widely in higher education literature and has proven to be a useful tool for viewing disciplinary values, norms, and beliefs as they relate to teaching and research. Becher's typology classifies disciplines according to whether they are hard or soft (according to their level of paradigm development), and whether they are pure or applied (depending on the extent to which they are concerned with practical application).

Considering the institutional embeddedness of researchers, the focus of this paper is on researcher's set of relationships that shape the interdisciplinarity of their research. The purpose is to identify what aspects of the researcher's affiliation influence their personal networks and the interdisciplinarity of research. Looking at the disciplinary diversity of researcher's knowledge networks, the analysis puts forward systemic connexions between the rise of knowledge networks and the characteristics of departments that may promote or hinder interdisciplinarity among researchers. In this paper, departments are seen as a

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cluster to the extent that they are a spatially concentrated group of researchers competing in the same or related fields linked through vertical or horizontal couplings oriented to the transfer and creation of specific knowledge and exchange of ideas. Departments, regardless of the organizational model of their institutions, stem from specialisation, though that is more acute in university research centres than in teaching departments (Su, 2014). In this study, the concept of department will not be restrained to teaching departments as our focus is on research. Given the political context of Catalonia, where the data was collected, three types of institutional departments are surveyed and considered with regard to the respondents (the whole set of relations studied belong to a wider range of institutions): two public universities, the Spanish National Research Council that belongs to the Spanish Ministry of Economy and Competitiveness through the Secretary of State for Research, Development and Innovation (the largest public institution dedicated only to research in Spain and third largest in Europe) and the Catalan Institution for Research and Advanced Studies, which is supported by the Catalan Government and directed by a Board of Trustees.

2. Definition of interdisciplinarity

Interdisciplinarity as a concept and a practice is one of the most hotly debated topics among academics and has spun a complex web of development strategies and theorizing. For instance, the emphasis on productivity and competitiveness produces an ideological system that serves the economic regulation at universities, encouraging an overemphasis on research projects and courses (e.g.: the proliferation of summer schools). In the face of this increased turnover on interdisciplinarity, there is a compromise in the efficiency level of the institutions, but the increased emphasis on presenting profits/outputs with minimum transition periods ensures that institutional and group decisions are based on shorter timespans, instead of long-term investments, just like it happens in the corporate world (Mintzberg and Van Der Heyden, 2002). However, its lack of standardization continues to be an issue, namely in universities that have traditionally hermetic departments and a lack of communication embedded in the academic culture.

Usually, interdisciplinarity means the integration of disciplinary perspectives (e.g., Birnbaum; Cotterell; Hanisch and Vollman; Hausman; Klein; Kockelmans; Epton, Hermeren). As a matter of fact, the most known use of the term is when there is a concatenation of different disciplines or their components (e.g.: Rossini and Porter, 1979). Fairbairn and Fulton (2000) define it as a problem-based approach in which knowledge and methods are brought to bear as needed to solve a complex problem or to address an object study. It is a response to a felt need insufficiently addressed by solely disciplinary work; an identification of a gap of the university's mission and its surrounding community. Interdisciplinarity demands constant proactiveness, responsiveness and the ability to adapt to changing situations. As Sperber (2003) notes, often disciplinary boundaries and routines stand in the way of optimal research and that is why the solution is to go ahead with new research programmes, which requires institutional reshaping. A less debated dimension of interdisciplinarity concerns the individual and social epistemology of knowledge and science. In this regard, Lattuca (2003) brought an interesting view on the subject when reporting that rather than disciplinary training, it is the epistemological commitments of informants that result in an affinity for a particular kind of scholarship. Andersen and Wagenknecht (2013) also remind that interdisciplinarity involves: epistemic dependence between researchers with different areas of expertise, the combination of complementary contributions from different researchers through shared mental models and conceptual structures, and shared cooperative activity with interlocking intentions, meshing subplans and mutual responsiveness. Thus, literature has approached interdisciplinarity as a 'trans-epistemic arena' (Knorr-Cetina, 1999), as an emergence of scientific networks (Latour and Woolgar, 1979) and, more recently, through the coordination modes between interacting actors depicted from the analysis of scientific works (Collinet et al., 2013).

This paper contends that interdisciplinarity, although difficult to separate out, is deeply embedded in institutional arrangements and that researchers' networks of relations strongly influence interdisciplinarity. That influence mirrors processes of personal and institutional adaptation, resistance, hindrance or enhancement of interdisciplinary research. For instance, researchers began to apply behaviours they practice in their living rooms or in the elevator: "What do you think about that paper/speech, etc?" This rise of peer production can be assessed by looking at the knowledge networks of researchers. It is possible to empirically understand the way disciplines are organized, the way research relations function and the institutional influences at work towards more or less interdisciplinarity.

In sum, both knowledge creation and interdisciplinarity are social phenomena, thus a social network approach can elucidate the role of the departments and its relation to interdisciplinarity in terms of knowledge creation.

3. Social network perspective

Instead of the traditional focus on individual attributes, a social network perspective emphasises the relationship among actors in order to understand the actors' behaviours rather than the actors themselves (Borgatti and Foster, 2003; Brass et al., 2004). The use of social network analysis (SNA) to understand the dynamics of interdisciplinary collaborations is a relatively new field. The SNA approach has been mainly used to characterize interdisciplinary collaboration among researchers in specific fields (e.g.: Aboelela et al., 2007; Haines et al., 2011); to explore collaborative and interdisciplinarity in higher education institutions through the analysis of co-publications (e.g.: Obermeier and Vlegels, 2010; Jung and Horta, 2013); to examine the effect of individual psychological differences on network structures (e.g.: Kalish and Robins, 2006); or to understand how interdisciplinary teams are formed, what makes them work, and what inhibits them (e.g.: Pisapia et al., 2012). Therefore, in most SNA studies interdisciplinarity is considered as co-publication activity (e.g.: Morillo et al., 2003).

More recently, Lazega et al. (2008) analysed the meso-level of interaction in the production of science, studying the duality of social life (Breiger, 1974). Their study showed that the position of an organization in the inter-organizational network is still more important in terms of attaining high levels of performance than the position of individual members in the network of the élite (Lazega et al., 2008).

Some attention has been drawn to understand the optimal network structure for interdisciplinary collaboration, mostly using citation databases, email contact and joint activities such as submitting research grants. Yet, little is known on the network factors linked to interdisciplinarity regarding the content of the knowledge networks where scholars are embedded. On the other hand, it is also important to consider the level of institutional affiliation because the prestige of one's departments is one of the criteria to select research partners (Bellotti, 2010). Knowledge networks are usually defined as a set of actors who are repositories of knowledge and who create, transfer and adopt knowledge (Phelps et al., 2012). The social connections among these nodes are seen as channels and/or conduits of information and knowledge (Owen-Smith & Powell, 2004). These two definitions emphasise node and tie properties for knowledge creation. However, less is known about how knowledge flows in the academy because of inherent difficulties in collecting data on large samples of networks over time and on a changing concept as knowledge is. McFarland and colleagues (Johri, Ramage, McFarland, & Jurafsky, 2011) also found that established authors in certain subfields have more deviation from their previous work than established authors in different subfields or their quantification of the extent to which some authors are more prone to being 'hedgehogs', whereby they heavily focus on certain specific areas,

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while others are more diverse with their fields of study and may be analogized with 'foxes'.

In short, there is not enough evidence about whether and under which circumstances network factors affect interdisciplinarity and on what other factors foster or hinder interdisciplinarity in faculty departments and research oriented institutions. To address this gap, this work combines a quantitative personal network approach with a qualitative approach. The local network that is relevant for interdisciplinarity is likely larger than collaboration partners alone, and a personal network approach, based on multiple name generators, allows delineating the relevant network.

In sum, based on literature review, this paper posits that social networks shape interdisciplinarity because universities are formed by networked actors whose relations are not only centred on place-based affiliation (though highly shaped by them), but also on niche knowledge and skill affiliations. However, we lack enough empirical data on researcher's knowledge networks to better understand how these networks shape the influence between faculty structures and knowledge creation in terms of interdisciplinarity and what the optimal structure for interdisciplinarity is. Especially the relationships between social network factors (i.e. network centrality, tie strength, similarity and structural holes, see Fig. 1) and interdisciplinarity will be addressed.

4. Methods

4.1. Sample

The analysis is based on the personal networks of a sample of 32 academic staff members of 4 institutions of the research system in Catalonia, Spain: University A ($n = 21$), University B (UB, $n = 2$), the National Scientific Council of Research in Catalonia (CSIC, $n = 5$), and the Catalan Institute for Research and Advanced Studies (ICREA; $n = 4$). These networks were retrieved between May and August of 2013. The analysis of these networks aimed at exploring the properties of the networks that relate to interdisciplinarity in higher education departments. For the selection of cases, it was intended to maximize variation in terms of academic positions, duration of tenure, and academic discipline, although for various departments, multiple staff members were selected to better understand the importance of contextual effects. The departments were selected according to the level of knowledge production (Martinez et al., 2007), and the level of interdisciplinarity of the research fields and variety of academic positions (see Tables 1 and 2 for the distribution of respondents in terms of academic positions and discipline).

4.2. Procedures

Computer-assisted personal interviews were held using the software EgoNet (http://sourceforge.net/projects/egonet/). Interviews had

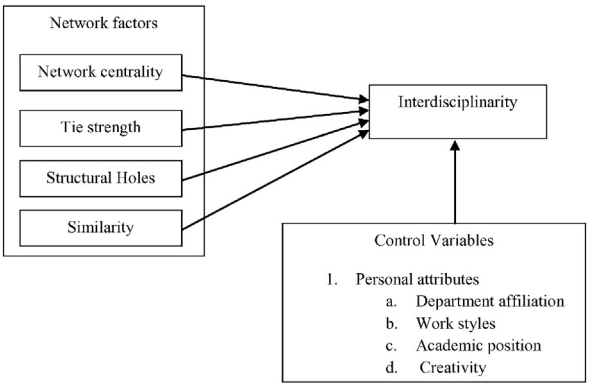

Fig. 1. Model of analysis.

Table 1
Number of respondents (ego) per each academic position.

Position	N° of respondents
Full Professor	2
Emeritus Professor	3
ICREA Professor	3
Associate Professor	11
Senior Researcher	7
Rámon Y Cajal researcher (tenure track)	1
Lecturer (non-tenured)	2
PHD STUDENT	2
Politician/Invited Professor	1
Total	32

two parts: a semi-structured and a structured one. The first part of the interviews was structured, and consisted of the following modules. The first series of questions addressed the respondent. Study participants were asked about their motivations for research, main sources of information, working style, work environment, career, gender, and their use of social media networks for research purposes. Then, a set of 9 name generators was used to delineate the personal knowledge networks of the respondents. Specifically, respondents were asked who influenced them, with whom they collaborated, with whom they discussed research and career related issues, from whom they received social support, and who were their bosses, which doctoral students they currently supervised, with whom they had conflicts, and who they would go to for advice. For each name generator, respondents (egos) were allowed to nominate as many network members (alters) as they wished. Subsequently, questions about alters (name interpreters) and questions about the relationships among alters (name interconnectors) were posed, to measure network composition and structure.

A semi-structured interview was then held aiming at, first, understanding how respondents explain how their institutional affiliation influences the level of interdisciplinarity of their research; and second, to further explore the content of ties among researchers that may contribute to the interdisciplinarity (or lack of it) in their work. The qualitative interviews focused on the respondent's perceptions on the networks of relations (attributes of the nodes), on the relational

Table 2
Number of respondents/alters per discipline.

Disciplines	N° of respondents/ego	N° of alters
Sociology	4	55
Philosophy	3	54
Geography	3	54
History	3	52
Artificial Intelligence	2	46
Physics	3	42
Chemistry	2	38
Communication Sciences	3	35
Arts (music, literature, digital art)		35
Maths	3	35
Chemistry	1	19
Educational Sciences	2	18
Psychology	1	17
Geology	1	14
Biology	1	11
Computer Sciences	–	10
Economy	–	9
Engineering	–	7
Environmental Sciences	–	4
Medicine & Nutrition	–	4
Archaeology	–	4
Anthropology	–	4
Nanotechnology	–	4
Politics	–	3
Linguistics	–	3
Philology	–	2
Business	–	1
Total	32	580

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attributes (values, friendship, knowledge, information and types of knowledge inherent to each tie) and on relational-based and network-based knowledge on the following topics: disciplinary differences, evolution of collaboration networks, mechanisms of embeddedness in institutions, criteria for research topics and curricula delineation.

The quantitative results will be contextualized with the detailed information retrieved from the qualitative interviews. In order to do so, qualitative content analysis (QCA) is combined with discourse analysis, being QCA used just as a method and in a subordinate function of discourse analysis. Through data-driven QCA, the arguments and discoursive nodes employed by the researchers interviewed in regard to interdisciplinarity are identified. In this critical QCA, categories refer not only to textual content, but also to the form aiming at uncovering ideology (Vorderer and Groeben, 1987; Schreier, 2012). The data provided factual descriptions of context, actors, events and decisions that influenced the development of interdisciplinarity in terms of research outputs. The interview transcripts and other materials (CVs and selected papers) were read and reread as data were collected; emerging themes were refined as this process progressed and checked through the repeat (by skype) of some interviews with the researchers in question. Views of different respondents from each case (discipline and institutional context) were also compared. The data analysis focused on the development of interdisciplinarity research within each institutional context and with regard to the elicitation of researcher's knowledge networks.

4.3. Measures

The dependent variable in our study is interdisciplinarity. For each of the alters, respondents were asked about the disciplines they worked on. In total, from the 580 ties analysed, 198 (34% of the ego–alter ties) belong to a different discipline in relation to ego's discipline and 380 were from the same discipline (65.5%).

The independent variables were degree centrality (the extent to which a node connects to all other nodes in a social network), tie strength (defined as a probably linear combination of the amount of time, the emotional intensity, the intimacy or mutual confiding and the reciprocal services which characterize the tie), similarity and structural holes. To measure tie strength, a set of relational attributes was used: affinity, frequency of contact and tie duration. *Affinity*, which is usually understood as a degree of similarity between individuals was measured with the question "Some colleagues get along well while others don't or have tense relationships among each other. How well do you get along with X?" Responses were rated on a five point scale, where 1 represented "not well at all" and 5 "very well". As "not well at all" and "not well" were chosen very scarcely, they were combined with the middle category "nor well nor badly". In some cases, where respondents had nominated network members whom they felt influenced by, but with whom they did not have any personal relationship, the response "does not apply" was chosen. For the analysis, this category was also combined with the lower three categories. Therefore, the variable affinity has three categories, 1 represents "no relationship or not a particularly good one", 2 "quite well" and 3 "very well". The *frequency of contact* was rated on an eight-point scale, ranging from 0 ("never") to 7 ("daily or more than 3 times a week"). *Tie duration* was measured in years, and was log transformed before adding it to the analysis.

To measure similarity we focused on whether ego and alter worked in the same (0) or in different (1) *disciplines* and on *similarity in academic positions* at the university. For the latter, we used three dummy variables to indicate whether alter currently has a higher position than ego, a lower position than ego, or no research or teaching position at the university. For both variables, similarity forms the category of reference.

To measure structural holes a measure of efficiency was adopted, which is calculated by dividing the effective size by the number of direct contacts in ego's network (Borgatti et al., 2002). Effective size is the number of alters minus the average ties of alters within the ego network, except ties to the ego. Efficiency was measured for the 32 egonetworks.

As for control variables, this study uses one type of control variables, including position, departmental affiliation, creativity and work styles to control for the influence the nature of work and organizational attributes have on interdisciplinarity.

4.4. Analysis

After presenting descriptive statistics and zero-order correlations, a series of multilevel logistic regression analyses was performed using MLwin (Rasbash et al., 2009), which predict the importance that alter has for ego's knowledge. In these analyses, respondents (and their personal networks) form the level 2 unit and network members the level 1 unit. After estimating an empty model, we added the tie strength variables (Model 1A) or the similarity variables (Model 1B), then we combined the two groups of variables in a single analysis and added two control variables (Model 2). In a third model, we added an interaction effect between similarity and tie strength, and in a fourth model we explored an observed random effect. As a last step, we estimated a full model with all main effects, including network structural effects. For the analysis, all non-binary variables were standardized in order to compare the effect sizes. To aid interpretation, interactions of (standardized or binary) effects were not themselves standardized.

After performing the multilevel analyses, quantitative results were contextualized with the information retrieved from the qualitative interviews.

5. Findings and discussion

5.1. Quantitative analysis

Table 3 shows descriptive statistics of the variables in our analysis. Among the respondents network size ranged from 9 to 32 elicited alters, with a mean of 18.3 (*SD* 6.4). For the 32 respondents combined, the total number of alters for our analysis is 580. The influence generator triggered most of these nominees (52%), followed by the collaboration (38%), the discussion (19%), and the social support generator (14%). Please note that these percentages do not add up to 100 as network members could be nominated on more than one generator. On average, network members were nominated on 1.4 generators each.

With regard to the dependent variable, 34% of the network members (alters) in the personal networks of the respondents work in different disciplines. It is also observed that, from the network members

Table 3
Descriptive statistics of the variables used in the analysis (before log transformations and standardization). Total $N = 580$ for level 1 (dyadic) variables — although the number may be slightly lower for some variables due to missing data; $N = 32$ for level 2 variables (ego and network level).

Dyadic similarity	Average	*SD*	Maximum	Minimum
Other discipline	0.34	0.5	1	0
Alter has higher position	0.27	0.5	0	1
Alter has lower position	0.23	0.4	0	1
Alter has no research or teaching position at university	0.5	0.3	0	1
Dyadic tie strength				
Affinity	3.6	1.7	5	0
Tie duration	12.7	9.6	45	0
Frequency of contact	3.9	4.7	99	0
Dyadic control variables				
Alter's creativity perceived by ego	3.2	0.9	4	0
Alter's degree centrality	6.2	5.0	23	0
Ego and network level variables				
Ego's position in university	7	4.1	17	1
Ego's number of publications	20.8	28.3	142	0
Network size	18.3	6.3	32	9
N components	3.4	3.9	15	1

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nominated in the collaboration generator, 34% belong to a different discipline and 66% work in the same discipline as the ego's. However, there is no correlation between collaboration network and the interdisciplinarity of respondent's network. In turn, with regard to the influence network, though the percentages are very similar to the ones found in the collaboration network, there is a strong correlation between the network of influence and interdisciplinarity. For the literature on collaboration networks, it is of interest to note that only 31% of the subset of alters who were nominated on the collaboration generator was mentioned as important for interdisciplinarity in their knowledge creation process. This corroborates that, in this study, there is no correlation between the collaboration network and interdisciplinarity. On the one hand, while co-authorship networks are often used as a proxy for knowledge networks, some co-authors are not relevant for knowledge creation nor to increase interdisciplinarity in research. On the other hand, there may be other than co-authors who can be relevant.

The strong correlation found between the network members nominated in the influence generator and interdisciplinarity is not surprising considering the current upheaval in which inventors and researchers are increasingly working independently outside academia. However, this finding reinforces that attention should be drawn into other players in higher education landscape rather than only large collaboration networks as these do not necessarily mean higher interdisciplinarity of the scientific outcomes.

For the explanatory variables, it is observed that 38% of the network members (alters) worked in positions at the same level as ego (on average the level of associate professor), 27% worked at higher levels and 23% at lower levels — with 12% not working in academic research and/or teaching. Table 3 further shows that respondents felt on average "quite close" (score 2) to their network members and they knew their network members for an average of 12 years, though this duration varied a lot (between 45 years and 1 year). They also thought that their network members were on average "quite creative" (score 3), although again, this average varied considerably across networks, from 2 (little creative) to 3.8 (where almost every alter is regarded highly creative).

Given that this paper aims at studying the relationship between interdisciplinarity and department affiliation, it is worth analysing whether and under which conditions interdisciplinarity occurs. We used multiple linear regressions to explore the influence of the variables of centrality, tie strength, structural holes, and similarity on the variable interdisciplinarity in ego's knowledge network.

Various indicators of the strength of ties between respondents and their network members were positively related to alter's importance for the interdisciplinarity of ego's research (B adjusted = 0.907, p = 0.04). Tie duration, closeness and affinity all had significant effects on interdisciplinarity. It is, thus, possible to conclude that stronger ties seem to be more conducive of interdisciplinary research than weaker ties. However, when we add the effect of department affiliation we observe that belonging to a department decreases interdisciplinarity. This is to take into account when 68% of egos' strong ties belong to the same department as the ego, and 54% of the weak ties worked outside the department of the ego. This suggests that the strength of ties is likely to be positively linked with interdisciplinarity, but the affiliation to a faculty department thwarts interdisciplinarity. Belonging to a faculty department increases the strength of ties, but belonging to a faculty department decreases interdisciplinarity. This suggests that in what regards interdisciplinarity, institutional constraints are more important than the strength of the ties. Some other findings may help to explain this result. For instance, it was observed that individuals who belong to a faculty department have less sparse networks, but the number of structural holes does not vary. However, findings do not suggest an association between more sparse networks and an increased interdisciplinarity as the index of structural holes is equally high or low whether individuals belong or not to faculty departments. If we look into the findings regarding tie strength and structural holes we find corroboration to literature claiming that weak network structures benefit from strong ties. This means that the strong ties are important to maintain the knowledge and practices within a department but they do not necessarily generate interdisciplinary knowledge within a department.

Findings show that network members who are dissimilar in terms of discipline and position at the university did not differ from similar others in their importance for the interdisciplinarity of respondents' knowledge. This may imply that the benefits (in terms of trust reciprocity and influence) and costs (in terms of the larger difficulty of collaboration) that were attributed to similar others are not supported in this research. For similarity, the dummy variable "higher position" had a considerable random effect (random slope 1.017 (*SE* .928)), which signifies that its effect varies across respondents. Descriptives showed that for some respondents, alters with higher positions were deemed more important for interdisciplinarity, whereas for others, the position was either not relevant or there was a very slight negative relation. This means that similarity does not necessarily hinder interdisciplinarity.

Finally, as for the control variables – department affiliation, work styles, academic position and creativity – only academic position of the ego is associated with interdisciplinarity (p = 0.01).

5.1.1. Findings of the multilevel analysis

In order to characterize more deeply the impacts of similarity and tie strength on interdisciplinarity, we now analyse whether and under which conditions these two mechanisms occur.

Table 4 shows the results of our multilevel logistic regression analyses predicting the importance of network members for ego's interdisciplinarity. As Model 1A in Table 4 shows, we observed that network members who are dissimilar in terms of discipline and position at the university did not differ from similar others in their importance for respondents' knowledge creation. This may imply that the benefits (in terms of trust and reciprocity) and costs (in terms of the larger difficulty of collaboration) that were attributed to similar others are either not supported in our research, or they play off.

In contrast, Model 1B shows that the various indicators of the strength of ties between respondents and their network members were positively related to alter's importance for ego's interdisciplinarity. Multiplexity, tie duration, and affinity all had significant effects, which imply that network members with whom respondents had multiple positive relationships, members with whom they shared a relationship for a longer time, and members with whom they got along well were thought to be more important for ego's knowledge creation. We therefore conclude that stronger ties seem to be more conducive of interdisciplinarity than weaker ties, although social desirability may also be at play here.

The findings hardly changed when we controlled for two other alter-level effects, creativity and degree centrality, none of which had significant effects themselves when controlled for the tie strength variables (creativity had a significant zero-order correlation with importance for knowledge creation).

When we combined the two sets of mechanisms in a single analysis and added interaction effects between the two sets (e.g. Model 3), it appeared that interaction effects were not significant (as an example, Model 3 shows the interaction effect of affinity and other disciplines). So, while the literature suggests that strong ties with diverse others may be more useful than either strong ties with similar others or weak ties with diverse others, this was not supported in our research.

We also tested whether the two sets of variables had random effects. For similarity, the dummy variable "higher position" had a considerable random effect (random slope 1.013 (*SE* .921), not in table), which signifies that its effect varies across respondents. Descriptives showed that for some respondents, alters with higher positions were deemed more important for knowledge creation, whereas for others, the position was either not relevant or there was a very slight negative relation. When interactions between this variable "higher position" and various

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Table 4
Findings of multilevel logistic regression analyses predicting the perceived importance of alter for ego's interdisciplinarity work. Regression coefficients and standard errors are presented ($N = 580$).

Predictors	Model 0 Empty model	Model 1A Similarity	Model 1B Tie strength	Model 2 TS, S and controls	Model 3 Interaction TS + S	Model 4 Random effect	Model 5 Structure
Intercept	−1.049 (.134)	−0.992 (0.210)	−1.293 (0.185)	−1.365 (0.276)	−1.330 (0.260)	−1.406 (0.252)	−1.410 (0.273)
Dyadic similarity							
Other discipline		−0.021 (0.252)		−0.120 (0.296)	−0.198 (0.303)	−0.017 (0.298)	−0.105 (0.297)
Alter has higher position		0.045 (0.276)		0.252 (0.335)	0.226 (0.327)	0.277 (0.371)	0.204 (0.340)
Alter has lower position		−0.454 (0.294)		−0.171 (0.358)	−0.248 (0.356)	−0.136 (0.357)	−0.138 (0.369)
Alter has no research or teaching position at university		0.764 (0.429)		0.937 (0.515)	1.033 (0.499)*	0.696 (0.544)	0.842 (0.528)
Dyadic tie strength							
Affinity			0.369 (0.168)*	0.387 (0.178)*	0.304 (0.191)	0.389 (0.175)*	0.335 (0.179)
Tie duration			0.704 (0.160)*	0.650 (0.172)*	0.633 (0.164)*	0.763 (0.172)*	0.657 (0.175)*
Frequency of contact			0.035 (0.159)	0.112 (0.175)	0.088 (0.165)	0.071 (0.167)	0.112 (0.177)
Multiplexity			0.785 (0.136)*	0.725 (0.140)*	0.795 (0.138)*	0.823 (0.138)*	0.711 (0.141)*
Dyadic control variables							
Perceived creativity alter				0.271 (0.152)			0.276 (0.153)
Alter degree				0.222 (0.161)			0.325 (0.176)
Interactions							
Other discipline × Affinity					0.335 (0.299)		
Alter higher position × *N* components						−0.666 (0.332)*	
Network variables							
Network size							−0.130 (0.217)
N components						0.517 (0.181)*	0.331 (0.197)
Level 2 variance (random intercept)	.143 (.123)	0.165 (0.132)	.362 (.215)	0.459 (0.248)	0.329 (0.208)	0.145 (0.194)	0.315 (0.208)
Level 2 random slope of discipline						0.253 (0.690)	
Level 2 covariance						0.494 (0.300)	

* $p < .05$.

network-level variables were introduced to explain this variation, the number of components in a personal network turned out to explain most of its effect. More specifically, alters with higher positions than the respondents were thought to have a higher importance for knowledge creation in centralized networks, but a lower importance in more modular networks (see Model 4).

None of the indicators for tie strength had significant random effects. As the few random effects already demonstrates, there was little variation in the size of the effects across respondents, so it is not surprising that individual characteristics (ego's position and ego's number of publications over the last five years) did not moderate the effects shown in Table 4. This implies that the attributes that distinguished important others from non-important others were similar for highly productive as for low productive staff members, as well as for highly and low positioned staff members in this (small) sample. Likewise, the dyadic effects were not moderated by network structure or network composition. So, whereas the literature suggested that the number of components in the network may moderate the effect of tie strength, we did not observe such an effect in our study. The network size and the number of components (not significantly related) did not have main effects on the proportion of alters indicated as important, either, as is shown in Model 5. In other words, it was not the case that in smaller, or more compartmentalized networks, larger proportions of alters were important for ego's knowledge creation.

5.2. Qualitative analysis

5.2.1. Belonging to a faculty department reduces interdisciplinarity

Several key differences in department level influence on interdisciplinarity development were identified between researchers affiliated to university departments and those affiliated to research institutes. Rather than seeing big variations between universities (12 departments from University A and 1 department from University B), findings suggest differences between the knowledge networks and research outputs among research institutions and university departments. In the former, academics were allowed to work on commercialization in addition to their academic duties. They also had more flexible schedules and the policy guidelines of the research institutions were clearly oriented to interdisciplinary collaborations both in terms of research and teaching (e.g.: doctorate supervisions). At the faculty department level, that flexibility to engage in different topics, different concepts, theories, methods, research projects and open initiatives with society was constrained by the existence or lack of support of the head of department or of other close department colleagues and even with colleagues with whom there was some type of conflict. The qualitative analysis, thus, explains the finding saying that belonging to a faculty department reduces interdisciplinarity. To better understand why it is important the fact that research institutions and university departments materialize the two contexts in which researchers embed their activity. One is scientific community itself and the other is the institutional context in which research is conducted (country, university, scientific field, department, group, etc.). Amidst the scientific community there are researchers who have a strong coupling in both contexts. In the case of the sample surveyed, these strong couplings include researchers from ICTA, CSIC or ICREA, leading groups of Maths or Biology. These researchers within strong couplings managed to change their institutional context in order to adapt to internationalization and, thus, influence the research agenda in their fields. These cases are the ones with more similar ties as their institutional coupling is already strong. A corollary of this situation is that internationalization does not necessarily lead to more interdisciplinarity. In turn, other researchers (including some heads of departments) have a weak institutional coupling and, therefore, have to vary and increase their accomplishments, share and lecture more diverse subjects, justify the legitimacy of other types of knowledge. Because they need, these researchers are more creative and engage more often with other disciplines and their individual agency is more critical. Both types of institutional couplings – strong and weak – are dynamic and change over time, especially in research oriented institutions.

5.2.2. The role of centrality and interdisciplinarity

The relationship between centrality and interdisciplinarity is mainly related to supple give-and-take that is on display, which is more common in collaboration ties. This is the most common one as it is transversal to all academic positions and assumes a more institutional nature (e.g.: recruitment of staff) and with larger impacts on the knowledge creation at the department level, but not at the personal level.

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In this type of configuration, knowledge is selected, transformed, and imported into the institutional spheres to serve as the basis for decisions taken by a small number of actors, who then implement them – as research agendas – drawing essentially on the norms and incidentally on incentives. In this case, individuals (alters) are mobilised to compose a narrative that would allow individuals to devise their actions and be convincing. This either serves as a partial substitute for standard-based collaborations or ties, or supplements it. Each agent becomes an actor, and it is increasingly his responsibility, in a necessarily complex and context-specific environment, to develop actions based on his knowledge, representations and values, which are precisely what central positions target. This is partly due to an increase in knowledge peddling. The latter gives rise to feelings of saturation and prompts stakeholders to attach more weight to strategies for disseminating their representations and knowledge. In part this also explains why, in this study strong ties have the same importance both in networks with more structural holes and in networks with less structural holes (taking into consideration the size of the sample to test the network effects). This relationship between interdisciplinarity and centrality also impacts on: 1) the tools adopted by each researcher towards their field, whether it is to embrace it, resist it, assimilate it or just go with the flow; 2) partnerships that abridge more or less academic freedom and curiosity-driven research; and 3) higher or lower adaptation to market-oriented entrepreneurialism or academic capitalism, to use the term adopted by Hackett (1990).

Conflicts with academics in central positions within the department also have an irreversible impact on the actor's academic research. "Within a department structure, it is extremely difficult to avoid that a simple epistemic disagreement does not turn into a life-time opposition that will reflect on my network of collaborations, on my support relationships within the faculty, on the topics I research and on the type of publications I submit my research" (E1).

5.2.3. Influence network and similarity

There is little agreement on the importance of weak and strong ties for interdisciplinarity and even less empirical work on the subject. The quantitative results support the notion that tie strength positively affects interdisciplinarity. However, the results do not corroborate the hypothesis that knowledge is created through the interaction of structural holes and strong ties. It was also found that, in terms of interdisciplinarity, the influence network is more relevant than the collaboration network. The next question was then to know what the source of these influencers is. It was found that in the group of hard/natural sciences scientific events and mobility (conferences, periods in other research centres, etc.) are the main sources of influence, which corroborates previous literature (e.g.: Molina et al., 2002). However, that is not the case for social sciences or for humanities; in these fields the history and institutionalization of disciplines seem to be more relevant to define the important network members who influence respondents (as well as the respective research agendas). In the case of more interdisciplinary scientific fields, such as artificial intelligence or psychobiology, the three main sources of influencers both for respondents and to the field are: institutional frame, amount of researchers in a *momentum* and emergence of groups with concrete proposals. These findings suggest that whereas integration of teaching and research is greater among faculty in soft disciplines (Colbeck, 1998), that may not be the case for interdisciplinary knowledge in the so-called soft disciplines. The latter presents thicker social and hierarchical structures which give fewer opportunities to interdisciplinarity. However, influence networks impact on researcher's choices, preferences or academic options but not on the organizational level.

If the quantitative findings show that network members who are dissimilar in terms of discipline and position at the university did not differ from similar others in their importance for the interdisciplinarity of respondents' knowledge, the qualitative analysis emphasises that similarity does not seem to be important either in the case of disciplines with a low level of institutionalization, such as History of Science. High levels of similarity within a research community are perceived to hinder or lower the possibilities of interdisciplinarity by each individual, especially if they belong to faculty departments. On the individual level, epistemological options (e.g.: theoretical and methodological approaches, leadership and values) are more relevant than the discipline. It is also highlighted that the position is never an alter characteristic that is mentioned by the respondents as important for their research, unless the alter is the director of the department, but even in these cases, such alters are only mentioned in response to the generator that asks for the name of their hierarchical superiors and they are not mentioned in the qualitative interviews. A few interviewees also shed light on the fact that career progression can induce similar ties and similarity in research topics, but that those ties were not exactly the most relevant for interdisciplinarity.

A brief note is still due regarding the cultural specificity of the context in which this study was carried out: Catalonia. In a period of 13 years, the number of higher education institutions in Catalonia increased from 3 to 12. The region has a unique identity with its own language and a distinct cultural heritage. The universities follow the Napoleonic model with a relative institutional autonomy and academics are seen as state civil servants. Since University Law (2001), recently modified on April 2007, and Science Law (1986), there has been a growing emphasis of the managerial discourses on issues such as the opening of university to society, universities as a key factor in the competitiveness and quality of life of cities, regions and countries, the increasing international competitiveness of higher education institutions and the internationalization of education and science. However, this has brought about increasingly complex managerial tasks as a result of current changes in higher education.

6. Conclusion

The main issue addressed in this paper is the relation between the role of the departments and its relation to interdisciplinarity in terms of knowledge creation at the interpersonal level. More specifically, the focus was to understand the conditions under which similarity or tie strength matters for individual knowledge interdisciplinarity. It was hypothesized that the social networks of researchers echo processes of personal and institutional adaptation, resistance, hindrance or enhancement of interdisciplinarity research. Egonetwork analysis proved to be a suitable contribution to the understanding of interdisciplinarity in today's universities. It is argued that the reach of these networks is not just a function of their distributed, interconnected and global nature but of the fact that the character and nature of ego networks mean that it is able to create and develop spaces and opportunities for emergent forms of knowledge and scientific research. That said, the potential of personal networks is not fully accomplished due to institutional constraints. One evidence is the fact that belonging to a faculty department increases the strength of ties, but belonging to a department decreases interdisciplinarity.

Drawing on data of 32 academic staff members of the university system in Catalonia (Spain), findings show that, in the Catalan context, tie strength (when defined by affinity, frequency of contact, tie duration, and multiplexity) is more relevant for interdisciplinarity than similarity/dissimilarity of the alters in terms of discipline and academic position. When considering discipline and academic position, there is no difference in the importance of dissimilar and similar alters for ego's interdisciplinarity. This finding may relate to some literature claiming that it can be too simplistic to refer to ties as similar or dissimilar or that a trend towards dissimilarity in ties has been increasing over time (Page, 2007). However, similarity plays a role in network interdependencies as the analysis of the interviews suggest. Tie strength on the other hand is positively related to alters' importance for interdisciplinarity, but department affiliation may hinder interdisciplinary research as institutional constraints overweigh the importance of strong ties.

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Regarding the controversy of the role between tie strength and structural holes (and the interaction between both) for interdisciplinary knowledge creation, our study shows that the number of components did not affect the number of alters who are important for knowledge creation, and that strong ties have the same importance for ego's knowledge creation when they are embedded in networks with many components as in networks that consist of a single component. These results also ask for an a more detailed conceptualization of bridging different social circles and structural holes, taking into account factors such as the heterogeneity of the network in terms of geographic origins and disciplines.

This study shows that the concept of interdisciplinarity itself is changing on the emergence of new modes of knowledge creation, especially the rise of peer production, which presents a stark challenge to conventional thinking about interdisciplinarity. Indeed, interdisciplinarity should not be understood only as the traditional concatenation of different disciplines. This study offers corroboration for the claim that interdisciplinarity is more about epistemological commitments and exchanges rather than disciplinary training. It is important to see these phenomena not as exceptions or ephemeral fads, but as indications of a fundamental fact about transactional knowledge forms and their relationship to the institutional conditions of knowledge creation. Therefore, this new way of looking to interdisciplinarity reinforces a third form of transaction in higher education institutions: social sharing and exchange. On the other hand, we coproduce and exchange knowledge, but we do not count this exchange in our institutional design. This, in turn, may be the reason social knowledge creation and interdisciplinarity have been shunted to the peripheries of academic organization landscape.

From the perspective of individual autonomy, the emergence of a networked interdisciplinarity (based on the interpersonal relationships of academics) offers a series of identifiable improvements in how we perceive the world around us and the range of enterprises we can seek to enter to pursue our choices. It allows us to form loose associations but it does not yet remove the structural constraints to those same associations.

This study has some limitations. The first limitation is the lack of generalization caused by research context and small sample size. This study has made use of personal network analysis to examine in more detail aspects of social interaction that affect interdisciplinarity. However, the findings are based on data from few cases from very few research institutions and universities, even though the difference of their missions expands a bit more the scope. Therefore, future lines of research would be to extend to larger scale samples on the one hand and to cross-case comparisons on the other, namely in regard to further explore the role of centrality measures. More comparative studies in other countries would be useful in determining if a culture or society influences the relationship between social networks and interdisciplinarity within faculty departments. Finally, this study approaches to a small extent the cognitive dimension of interdisciplinarity research and the cognitive impacts of each type of institutional frame on research. This should be a most needed line of future research.

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