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Team Familiarity in Cardiac Surgery Operations:

The Effects of Hierarchy and Failure on Team Productivity

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Project teams are regularly assembled by a variety of organizations in order to perform knowledge-intensive tasks. Previous shared experiences among their members can have a significant impact on team performance. In this study, we use a unique and detailed dataset of 6,206 cardiac surgeries from a private hospital in Europe, property of an American non-profit organization, in order to examine how past shared experiences of individuals affect future team productivity. Using transactive memory system as theoretical framework, we first decompose overall team familiarity into *horizontal* familiarity (e.g., surgeon to surgeon) and *hierarchical* familiarity (e.g., surgeon to nurse) and find that the former one is more beneficial for team productivity than the latter one. Next, we observe that horizontal familiarity of high-power, high-status individuals has a higher impact on team productivity than the one among subordinate individuals. Finally, we investigate how past failure experiences of individuals in the same team can increase future team productivity more than past shared successes. Our results provide useful insights for managers who aim to increase team productivity via better team allocation strategies.

Key words: transactive memory system, team familiarity, productivity, hierarchy, failure, cardiac surgery.

Introduction

"*We are now struggling to meet the standards and timeliness of care that the public rightly expect. It is unacceptable for such a large number of patients to be waiting over half a year in pain and discomfort for treatment.*" – Clare Marx, Royal College of Surgeons, former president, when asked to comment on the 180% increase in the number of patients waiting half a year for an operation (Independent, 2017).

Enhanced surgery productivity is paramount for healthcare providers, as the corresponding reduction in surgery waiting times is associated with better patient care quality (Prentice and Pizer, 2007) and improved cost efficiency (Nikolova et al., 2016). However, the inherently dynamic nature and operational complexities of surgery operations constitute important challenges for hospital managers, who strive to utilize available resources and staff in order to deliver high-quality patient care. The daunting-from an executional perspective-task of forming effective surgery teams has attracted considerable scholarly research (Singer et al., 2016), which attempts to identify factors that influence team productivity and to devise theories that delineate the effects of such factors under different circumstances. Surgical teams are hierarchical in nature, exhibit a short life span, as they dissolve after each operation, while their collective performance is instrumental to improving their productivity. Specifically, research has emphasized the crucial role of past interactions of team members, coined *team familiarity*, postulating that teams whose members have had many experiences working together in the past are more productive (Harrison et. al., 2003), a premise also validated in the context of surgery operations (Reagans et al., 2005).

Despite the established positive effect of team familiarity on productivity (Reagans et al., 2005; Espinosa et al., 2007; Huckman et al., 2009; Huckman and Staats, 2011; Staats, 2012) underpinning the intricacies of this relationship constitutes a challenging endeavor and a matter

of active research (DeChurch and Mesmer-Magnus, 2010a; 2010b). Scholars have operationalized familiarity as the average number of past interactions among team members (Reagans et al., 2005; Huckman et al., 2009; Huckman and Staats, 2011), which, although intuitive and parsimonious, does not acknowledge that familiarity built under different experiences or asymmetrically across team members could have varying effects on productivity. Concretely, one would expect that the nature of the experiences that shape familiarity influences the sediment and strength of the resulting familiarity and potentially its effect on productivity. In addition, team members who have different roles and responsibilities may experience the same events from a different perspective, developing bonds with team members to varying degrees and qualities, depending on the intensity and nature of their interactions. As a result, managers who strive to "keep teams intact" (Huckman and Staats, 2013) aiming at high productivity may come to realize that having frequent past interactions is only part of the answer.

Similarly, it is well-known that failures can promote organizational and individual productivity (Cannon and Edmondson, 2005; Baum and Dahlin, 2007) since they can lead to the adoption of new policies and strategies (KC et al., 2013). Nonetheless, little is known whether team failures generate experiences with a detrimental or beneficial effect on productivity. If, for example, familiarity based on experiences of failure is detrimental to productivity, then attempting to keep team members together could make an insidiously bad team formation policy. On the contrary, if failure-gained familiarity is actually beneficial, then keeping teams together may improve performance. Characterizing this effect is non-trivial, as complex cognitive processes take place during its formation.

Departing from these assertions, we study how within-team hierarchies and shared experiences that nurture the development of team familiarity determine its effect on team productivity. While hierarchical relationships among individuals have been studied in the past (Banks et al.,

2014), little is known about these relationships among subgroups within the same team (Staats, 2012). In addition, teams with distinct hierarchical levels, distributed knowledge and a lead decision maker have been studied in the literature (Hollenbeck et al., 1995; Hollenbeck et al., 1998), but the various manifestations of familiarity across hierarchies and the extent to which they enable team productivity remain largely unexplored. Hierarchical structures influence team dynamics in several ways, from manifestations of power or status to effective leadership style (Klein et al., 2006). Likewise, we expect that the structure of previous team member interactions and whether they are predominately hierarchical or horizontal will influence productivity of surgical teams differently. As such, we explore *which familiarity matters the most for productivity* in surgical teams, considering not only how it is distributed across and within hierarchies but also *what is the impact of common negative experiences on productivity*, as opposed to the impact of common positive experiences. Answering such questions paves the way to a better understanding of what makes such teams more or less productive.

In order to investigate the impact of different manifestations of familiarity we employ the lens of team cognition and in particular transactive memory system (TMS) theory as a theoretical framework on which we develop our hypotheses. In particular, we focus on the task-driven transactive memory system introduced by Brandon and Hollinsghead (2004) and corroborate the established relationship between familiarity and transactive memory (Kozlowski and Ilgen, 2006) to argue why past interactions and common experiences of team members having the same hierarchy exert higher influence on team productivity compared to cross-hierarchical gained familiarity. Similarly, this framework is also used to provide an explanation of why familiarity gained (predominantly) from past failures has higher impact on productivity than the one gained from successful operations.

The key role of transient familiarity dynamics and their -possibly asymmetric- impact on transactive memory formation allows us to better explain how familiarity affects productivity

of teams with recurrent member composition, which are commonly formed not only in the context of cardiac surgery operations but also in an array of other settings, such as in corporate projects. To this end, our study is the first to integrate a number of different streams of literature since we explicitly highlight the fact that familiarity, operationalized as the average number of previous member interactions at the dyadic level, is a prerequisite for TMS development. To the best of our knowledge, this connection has not been made before, as there exists a body of literature examining team familiarity (e.g., Huckman et al., 2009) and its relationship with other constructs, such as group cohesion (Hackman, 1987) and another one (e.g., Lewis, 2003) investigating the effect of TMS on team performance.

In addition, our work extends past team-related studies by examining the asymmetric impact of past team member interactions within teams with overlapping membership and hierarchical structure. We introduce an explanatory theory that postulates the differentiated effect (i) of horizontal and hierarchical familiarity, (ii) of horizontal familiarity among high-power, high-status individuals and among subordinate members themselves and (iii) of past failed and successful experiences. Our findings extend the established knowledge that team familiarity improves team productivity by suggesting that it is horizontal familiarity and familiarity gained from past failures that are instrumental to team productivity. These are key insights toward forming productive teams and are enablers of effective team formation policies. As such, they are relevant not only to academics but also to managers.

Literature review and theory development

Team setting and classification of surgical teams

Following the conceptual framework of Hollenbeck et al. (2012), surgical teams can be characterized as having high authority and skill differentiation and low temporal stability. As such, they are classified as hierarchical, when it comes to the structure of their decision making (Klein et al., 2006; Hollenbeck et al., 2012), highly differentiated with respect to their skill set (Hollenbeck et al. 2012), and short-term, following the framework of Joshi and Roh (2009). It

is interesting to note that the concept of team familiarity, as used in past studies (Reagans et al., 2005; Huckman et al., 2009; Huckman and Staats, 2011) and in our work, resembles the temporal stability dimension of Hollenbeck et al. (2012). The subtle yet important difference between the two concepts is that Hollenbeck et al. (2012) characterize temporal stability as a structural property of a certain team type, while the operationalization of familiarity we employ differentiates across teams of the same type. Thus, while surgical teams have inherently low temporal stability, one surgical team can have higher or lower familiarity compared to another one, depending on how many times their corresponding members have interacted in the past.

Our teams are fluid since they are dissolved after the completion of the operations and some members of each team may be reassigned together in future operations. Hence, our setting is appropriate for examining how past interactions influence productivity over time within teams with overlapping membership. To this end, in order to explain the impact of past interactions on team performance we adopt the theoretical framework of Brandon and Hollingshead (2004), who delineate how transactive memory develops in task-performing groups. This framework is appropriate for our study because it explains the evolution of transactive memory, thereby providing a solid theoretical foundation for our setting, which is largely dynamic. In addition, cardiac surgery teams are formed by individuals who have different roles in the operating room (Nembhard and Edmondson, 2006), which makes our team setting suitable to investigate the effect of past collaborations among individuals with different roles and hierarchies. Furthermore, our teams might experience failures due to the death of their patient during or after an operation. Hence, we are able to capture team familiarity gained from failure and examine its impact on team productivity.

Within the operating room surgeons tend to enjoy more prestige than other physicians (like anesthesiologists) and have the highest status (Coburn, 1992; DeSantis, 1980; Dingwall, 1974; Friedson, 1970; Fuchs, 1974; Hafferty and Wolinsky, 1991; Shortell, 1974; Wolinsky, 1988;

Edmondson, 2003a). Surgeons are also least likely to advocate a flat hierarchy (Sexton et al., 2000) since they tend to feel (in contrast to the other team members) that they are part of a team with different "subteams" (Mitchell and Flin, 2008) and have differences in perception of communication, teamwork and situation awareness from the other team members (Wauben et al., 2011). We therefore believe that surgeons are the ones who have the decision authority and ultimate responsibility on the outcome of the surgery (Yule et al., 2008; Rydenfalt et al., 2015). This does not mean that surgeons are the only ones making decisions within the operating room. Every team member has his/her own autonomy and is required to take influential actions and important decisions (Rydenfalt et al., 2015). For example, scrub nurses engage in decision making and problem solving during an operation (Sexton et al., 2000). In fact, it has been reported that scrub nurses -after the surgeons- tend to exercise the most decision making and have more power than the other members (including the anesthesiologist) within the operating room (Rydenfalt et al., 2015). This is of course not always true since anesthesiologists can also have higher decision-making power than the scrub nurse (Nembhard and Edmondson, 2006). Hence, while there is consensus that surgeons constitute the leading hierarchical level within the operating room, other team members might exercise similar level of power within the team that differs depending on the surgery type and other factors (Rydenfalt et al., 2015).

Following past healthcare studies that focus on interpersonal relationships in the operating room and distinguish surgeons from the rest of the team (Tan et al., 2014), we also consider two levels of hierarchy: Surgeons vs. non-surgeons. A major factor driving our choice is that surgeons are the perceived leaders in the operating room with respect to the operation's coordinating authority (Yule et al., 2008; Rydenfalt et al., 2015), and while other members have decision making autonomy for other important tasks, such as the position of the patient, their coordinating power over the whole procedure is lower. Anesthesiologists, in particular, have a special status as doctors (Lingard et al., 2002; Lingard et al., 2006) but the fact that

surgeons have the coordinating authority, their distinctly different role and the fact that research has highlighted communication issues between surgeons and anesthesiologists (Goyal, 2013) justify their inclusion in the non-surgeons' group.

Although we study the context of surgical teams, our findings are applicable to teams that share similar characteristics. Examples of other teams that resemble surgical teams under the Hollenbeck et al.'s (2012) framework are aircrew, maritime teams, accident investigators or firemen. Such teams have a hierarchical structure, in which one or more members have higher responsibility, liability for the outcome and the main decision-making authority.

Team effectiveness and emergent states

Our work focuses on team productivity, which is an objective manifestation of team effectiveness. For the latter, prior research postulates that it depends largely on *team processes*, i.e., the nature of interactions across team members (Marks et al., 2001), and on *emergent states*, i.e., dynamic conditions that enable effective teamwork, broadly classified as cognitive, motivational and affective. We next consider cognitive emergent states, for two important reasons. First, surgical teams are formed to carry out cardiac operations, for which the nature of interactions across team members is relatively homogeneous, and therefore team processes are unlikely to explain variability in team performance. Second, our theoretical focus is on the impact of familiarity on team productivity. For fluid teams, familiarity is a dynamic construct instrumental to effective teamwork, which enhances team cognition.

The generic notion of *cognition* is used to describe the collective activities or actions under which individuals acquire information and process it to generate knowledge. *Team cognition* is a cognitive emergent state that characterizes the manner in which knowledge-critical information is acquired, organized, represented and disseminated across the group members, and is also the very mechanism that enables individual team members to anticipate and execute actions (Kozlowski and Ilgen, 2006). Team cognition can be represented in various forms, such

as strategic consensus or expertise specialization, and *transactive memory* is a predominant construct, employed by a large number of researchers (DeChurch and Mesmer-Magnus, 2010a). Specifically, it is used to address how team knowledge is organized, represented and disseminated (Kozlowski and Ilgen, 2006; Klimoski and Mohammed, 1994) and encompasses three important qualities (Lewis and Herndon, 2011): (i) Differentiated knowledge among team members; (ii) a dynamically-evolving nature and (iii) transactive cognition processes. Given that familiarity is formed by interactions of *specific* team members, transactive memory constitutes an appropriate theoretical framework as it embodies both the collective and uniquely held knowledge of specific groups. Figure A1 of Appendix illustrates a visual representation of the antecedents of team effectiveness.

Transactive memory system development

The beneficial effects of team familiarity are mainly attributed to the development of a transactive memory system within teams with past common experiences (Kozlowski and Ilgen, 2006). Organizational research has defined transactive memory as a group-level shared mechanism through which members encode, store and retrieve relevant team knowledge (Hollingshead, 2001; Lewis, 2004; Zhang et al., 2007; Ren and Argote, 2017). Wegner et al. (1985) first introduced it in order to explain the way couples share information and divide responsibility within their relationship. Later, Wegner (1986) extended this concept for groups describing how such a shared system of knowledge could reduce their cognitive load and enhance their productivity. It is important to highlight that transactive memory is not only a knowledge typology of "who knows what", but it encompasses a set of "knowledge-relevant transactive processes" (Wegner, 1986; Lewis and Herndon, 2011), through which the group coordinates its members' learning, retrieval of knowledge and access to information. This is particularly pertinent in our context, because although the *structural* component of TMS (i.e., the shared understanding of who knows what) is largely role-driven, this is not the case for the

TMS *processes*, which are predominately group-specific coordination, information storage, retrieval and processing mechanisms. We next elaborate how the task nature of surgery operations exerts influence on the development of transactive memory.

Cardiac operations exhibit high task interdependence, in the sense that the actions of individual members carry an impact on others' outcomes, and no team member can guarantee a good outcome on its own. They also consist of complex, non-routine tasks that require considerable coordination among group members (Lingard et al., 2002; Salas et al., 2008). Such conditions, stimulate *cognitive interdependence* (i.e., that the storing of information is done not only individually, but it is perceived as a collective shared responsibility too). Such an interdependence, coupled with the fact that team members perform different functions (Wegner, 1986), stimulate the development of a TMS among the surgery team members.

Once team members develop cognitive interdependence, they make connections between specific team members, tasks and expertise (Brandon and Hollingshead, 2004). For example, imagine a surgeon who requests a set of tools throughout the realm of a specific operation. A tool nurse who has many prior interactions with this surgeon is likely to anticipate the surgeon's requests and prepare these tools in advance. Thus, the nurse associates the task (i.e., prepare tools) not only with the person's expertise (i.e., surgeon) but with the person itself. Such Task-Expertise-Person (TEP) associations develop dynamically via repeated interactions (Wegner, 1995) and are the fundamental blocks of a TMS. It should be noted that expertise and experience are not equivalent. Nonetheless, expertise can be technical and non-technical and while the former one is unrelated to past experience, the latter one can be developed via repeated interactions. Therefore, the level of perceived specialization developed via a transactive memory goes beyond the role-based specialization and coordination, which is also found in teams with no prior interactions. For example, Lingard et al. (2004) report that a common miscommunication pattern happens when the nurses and anesthesiologist decide how

the patient will be positioned for surgery. As surgeons have specific positional requests, the position of the patient may have to be changed before the surgery commences. The development of a transactive memory would lead a surgeon to trust that the specific nurse-person and anaesthetist-person have "access to required information", and therefore can carry out the task of patient positioning, while others may not be trusted. In the absence of such TEP units, a surgeon will have to make the decision herself, possibly at the expense of another activity. A TMS develops when all group members share close perceptions of TEP units and utilize them in a similar fashion. For this to occur, each TEP is evaluated, via group feedback mechanisms and utilized, i.e., made operational by a specific member. As TEPs undergo these cycles, differences in perceptions are reduced and convergence is finally achieved, projected in a shared mental model at the team level (i.e., common information across group members). The emergence of such a shared mental model is argued to be the lever behind improved team performance. In order to achieve this state, the member-specific TEPs undergo a dynamic evolution, while their convergence depends on the amount and quality of prior interactions among team members.

Several related empirical studies have highlighted the beneficial effect of past interactions on team productivity. The construct of team familiarity, operationalized as the average of past interactions of team members, has been argued to improve coordination (Huckman et al., 2009; Huckman et al., 2011), enhance the relationships among team members (Weick and Roberts, 1993; Chillemi and Gui, 1997; Faraj and Sproull, 2000; Reagans et al., 2005), enhance member safety (Edmondson, 1999) and create cohesion among team members (Hackman, 1987; Evans and Dion, 1991; Mullen and Copper, 1994; Gully et al., 1995). The relationship between team familiarity and the above constructs can be manifested through the theoretical lens of team cognition and transactive memory. Concretely, Kozlowski and Ilgen (2006) have established that familiarity is a lever of transactive memory (Liang et al., 1995). In the same line, DeChurch

and Mesmer-Magnus (2010a, p. 34) have argued that "*motivation and cognition [are] important emergent states that crystallize through repeated interactions, shape behavior and sustain both performance and viability*", underlining that team familiarity is a driving factor of motivation and cognition. As a result, familiarity is a driver behind team cognition and a lever for the development of transactive memory.

The role of horizontal and hierarchical familiarity

Although past research is useful to comprehend how the distribution and task composition of overall familiarity impact productivity, they leave a key question open: *Which* familiarity (that among surgeons; among non-surgeons; or across surgeons and non-surgeons) is more influential on productivity, and why? To better illustrate the difference between horizontal and hierarchical familiarity, Figure A2 of Appendix demonstrates two cases in which teams exhibit the same average familiarity, but radically different horizontal and hierarchical familiarities. Specifically, although both cases have identical overall average familiarity (each node represents one past interaction), horizontal familiarity is higher in case (a), while hierarchical familiarity is higher in case (b). Our theory postulates that, ceteris paribus, team productivity will be higher in case (a) than in case (b).

The average number of past interactions within a group is a generic indicator of familiarity, which cannot capture *who* is familiar with *whom* within a team. The distribution of familiarity over dyads of same or different hierarchies is likely to be related to the degree of interaction and information exchange within and across hierarchical subgroups. Staats (2012) has examined the effects of horizontal and hierarchical familiarity in software development teams, finding differentiated effects. The key difference with our context is that such teams are not only lower in interdependency compared to surgical teams, but also higher in temporal stability: The median task duration is half a year and does not have the sense of urgency and criticality of an hours-long surgery. Specifically, the majority of the arguments employed by

Staats (2012), such as advice seeking, peer review and testing, and retrieving best practices from a project management system, do not apply in our context. However, we also expect that the importance of familiarity will be differentiated depending on whether it is predominantly hierarchical or horizontal, but due to reasons specific to the low temporal stability, the strong task interdependence, the extreme task nature of surgical teams and the corresponding development of transactive memory.

In many settings like ours, team members have clear roles and responsibilities (e.g. aircrews) (Carthey et al., 2003). The seminal study of Hollenbeck et al. (1995) first addressed such hierarchical teams by proposing constructs at the team, individual and dyadic level that could explain significant variance in decision-making accuracy. While these core constructs provide useful insights, they are based on the premise that team members can recommend actions to the leader. In the case of surgery operations, the lead surgeon bears the responsibility for the outcome of the operation but may also consider recommendations from the non-lead surgeons, especially when they have considerable experience compared to him or her. Following research on team hierarchies (Magee and Galinsky, 2008), surgeons enjoy high status, as they are the most respected in the eyes of other team members, and high power, as they bear responsibility and have control over team resources. Thus, although there is a clear status and power differentiation, the team decision structure trivializes core constructs such as staff validity and dyadic sensitivity, as effectively there is no flat hierarchy within the operating room. In such an environment of distinct hierarchies and distributed expertise, the effective development of transactive memory via repeated member interactions may depend on the degree to which such interactions are predominately cross-hierarchical or not.

Specifically, the hierarchy in the operating room is defined by Hollenbeck et al. (1995) as unequal status among members. This, combined with the high-stake nature of cardiac surgeries, can make subordinate members, such as nurses or perfusionists, unwilling to take responsibility

(Schmitt, 1990; Edmondson, 1999; Tucker and Edmondson, 2003; Nembhard and Edmondson, 2006). For example, nurses might hesitate to speak up openly to surgeons even if they suspect that something might be wrong (Edmondson et al., 2001; Kennedy, 2001). Past research has also proposed that member heterogeneity may hinder information sharing in groups, as individuals are less willing to share information to team members that perceive as different from themselves (Miranda and Saunders, 2003; Mesmer-Magnus and DeChurch, 2009). Therefore, teams with inherently high skill and authority differentiation may have a lower propensity to engage in enhanced cross-hierarchical information sharing. In addition, the low temporal stability of surgical teams and task urgency of surgical operations can only amplify this tendency.

However, communication and information sharing are instrumental in the development of a TMS (Liang et al., 1995; Rulke and Rau, 2000; Hollingshead and Brandon, 2003; Lewis 2004). Brandon and Hollingshead (2004) argue that the effectiveness of a transactive memory relies upon (i) how accurately each member's TEP units reflect reality, (i.e., accuracy) (ii) the extent to which members share similar TEPs, (i.e., sharedness) and (iii) the degree to which members' expectations correspond to other members' actions, (i.e., validation), all of which are affected negatively by reduced communication and information sharing. They are key processes in the development of a TMS, as they involve learning the type of information that each team members knows (Wegner, 1995; Hollingshead, 1998; Palazzolo, 2005; Pearshall, 2010) and how accurate the understanding of each member's mental models is from other group members (Huber and Lewis, 2010). In such conditions, when information sharing occurs more often within hierarchies, a transactive memory is likely to be more developed between members of the same hierarchy, because the enhanced information sharing stimulates development of TEPs within each hierarchy (Brandon and Hollingshead, 2004). Hence, transactive memory theory suggests that due to the reduced communication between surgeons and the other team

members, their familiarity might not promote team productivity significantly since it will not promote efficient communication among individuals from different hierarchy levels. Hierarchical familiarity therefore might have a low (or even non-existent) impact on team productivity in our setting.

In addition, while the relationships between surgeons and non-surgeons could be quite formal and hierarchical, due to surgeons' status in the room (Edmondson, 2003a), relationships among members of the same hierarchy (i.e., horizontal familiarity) are likely to be more casual. Relationships within horizontal teams, on the other hand, are generally stronger, and motivational states, such as cohesion are more likely to develop among members of the same hierarchy level (Druckman, 1988; Horn and Walker, 2008), leading to higher productivity (Hackman, 1987; Evans and Dion, 1991; Mullen and Copper, 1994; Gully et al., 1995).

As a result, we expect that horizontal familiarity (familiarity among surgeons themselves or among non-surgeon members themselves) will have a high impact on team productivity. Especially compared to the hierarchical familiarity, we expect horizontal familiarity to be more important since when two individuals of the same hierarchy level work together they will develop much more impactful familiarity than the one developed between two individuals from different hierarchy levels within the same team. Therefore, although the raw frequency of interactions between two individuals could be identical, their hierarchical relationship influences the extent to which such interactions result in higher productivity.

Researchers in the past have also shown that in high-pressure environments, improvements and important decisions tend to be hierarchical and not democratic (Staw et al., 1981; Foushee and Helmreich, 1988; Driskel and Salas, 1991). An operating room constitutes such an environment. As an interviewee surgeon of Klein et al. (2006, p. 610) pointed out for surgical teams of a Trauma Center: "*If you do a democracy, patients will suffer. You don't take a vote on what to do with the patient*". Cardiac surgery operations constitute a highly critical task, in

which the patient's life is at stake. As a result, subordinate group members-such as nurses and perfusionists-are unwilling to take responsibility and therefore hesitant to participate in crucial decisions and instead tend to focus on procedural tasks that fall within their role and responsibility in the operating room (Klein et al., 2006). At the same time, high-status individuals (i.e., surgeons in our setting) are often characterized by high egos and expectations which can make it harder for them to share information, collaborate with the other subordinate team members and generally engage in a relationship with them that will promote team productivity (Hambrick, 1994; Groysberg et al., 2011). In particular, surgeons might also be unwilling to take into account subordinate group members' opinion since they are considered to be responsible for the patient. Such an unwillingness hinders validation, thereby reducing the effectiveness of TMS (Brandon and Hollingshead, 2004). Hence, we expect that hierarchical familiarity will be less beneficial than horizontal one since the former -in contrast to the latter one- will not necessarily translate into better cooperation, extended communication and a meaningful relationship between surgeons and the other team members.

In conclusion, in working teams that operate under pressure and have clear hierarchies with a dominant group, such as surgeons for a surgical team, we expect that information sharing and transfer of knowledge among the two subgroups to be more limited than within the same subgroup, making horizontal familiarity more beneficial than hierarchical one with respect to their effect on team productivity.

Hypothesis 1: *Horizontal familiarity has a higher impact on surgical team productivity than hierarchical familiarity.*

Next, we focus on the effect of different types of horizontal familiarity on team productivity. In our setting we have two types of horizontal familiarity: The one among surgeons and the one among the rest of the team members. Since surgeons make the crucial and key decisions and tend to enjoy higher social respect and control over the other team members in the operating

room (Coburn, 1992; DeSantis, 1980; Dingwall, 1974; Friedson, 1970; Fuchs, 1974; Hafferty and Wolinsky, 1991; Shortell, 1974; Wolinsky, 1988; Edmondson, 2003a; Nembhard and Edmondson, 2006), we expect that their familiarity will have a higher impact on team productivity than the familiarity of the rest of the team members. Hence, we expect surgeons' collaboration in the operating room to be more important than that of the other team members of the same hierarchy level. We therefore expect surgeons' past common experiences to be more beneficial for team productivity than the other members' past collaborations.

Moreover, since surgeons also enjoy high power, expressed as resource control, their familiarity is more likely to be more impactful of that of other members, whose tasks are of more executional nature. Non-surgeon members indeed tend to perform more repetitive tasks as opposed to surgeons (Avgerinos and Gokpinar, 2018). Hence, despite their decision-making autonomy within the operating room for simple but important tasks (such as the position of the patient or the adjustment of the operating table) (Rydenfalt et al., 2015) and the fact that their role is important in the execution of the task as the underlying technology is an O-ring (Kremer, 1993), their familiarity will have a smaller impact on team productivity. Specifically, we expect that the marginal benefit of familiarity is higher for more complex tasks than executional ones. Therefore, since surgeons carry out more complex tasks the effect of their familiarity will be more profound than the effect of familiarity across non-surgeons. The root cause of this mechanism is the high skill differentiation of surgical teams, which leads surgeons carry out tasks that can be improved via repeated interactions more profoundly compared to executional tasks.

Literature on psychological power also suggests that the existence of multiple high-power team members could enhance team performance in case members exert dynamic delegation (Klein et al., 2006). This is the case in our setting too, as our surgeons indeed exert dynamic delegation, thereby bringing less-senior surgeons on board with respect to their duties and

improving their leadership and coordination abilities via their repeated interactions. In summary, when the high-status and high-power individuals of the team (i.e. surgeons in our setting) are familiar with each other, their effective collaboration will promote team productivity more than the equal familiarity of subordinate team members. As such, we postulate that:

Hypothesis 2: *Familiarity among high-status, high-power members has a higher impact on surgical team productivity than familiarity among subordinate members.*

Team familiarity and failure

Finally, we focus on the effect of past shared experiences from failure on future team productivity. Failure is generally defined as deviation from desired results, which includes both avoidable errors and unavoidable negative outcomes of uncertain actions (Cannon et al., 2001; Edmondson, 2004). Hence, it does not necessarily imply fault, since it is inevitable in many knowledge-intensive settings and it subsumes both human errors and problems caused by the task itself (Cannon et al., 2001; Edmondson, 2004). In our setting, where individuals perform highly critical tasks with uncertain outcomes (Edmondson, 2004), we define as failure the death of a patient. Note that, although in other environments defining failure may be challenging or ambiguous, in our setting the death of a patient constitutes a frequently used measure of failure (Aiken et al., 2002; Aiken et al., 2003; KC et al., 2013). In order to isolate the impact of failure-acquired familiarity, we decompose overall team familiarity into two components: One gained from cases that resulted in the death of the patient and one gained from cases that resulted in the survival of the patient. Then, we expect that team familiarity gained from failure is more beneficial than team familiarity gained from success, with respect to their impact on team productivity.

First, failure may change the way individuals communicate and process information (KC et al., 2013) since it reveals that past approaches are not entirely correct (Sitkin, 1992). Hence, they

will engage in an information-seeking endeavor that will increase their learning (Argyris and Schon, 1978) and may allow them to avoid future potential failures (KC et al., 2013). Success on the other hand, while promoting satisfaction, tends to make individuals feel that they already have the necessary knowledge to complete similar tasks in the future, which will limit their search for additional information (Gino and Pisano, 2011; KC et al., 2013). Rather than change, they are most likely to refine already existing approaches (Lant, 1992). Failure will therefore most likely result in an increased communication and more meaningful interactions within the team compared to successful cases, which according to transactive memory theory promotes efficiently future productivity (Liang et al., 1995; Lewis, 2004).

Specifically, increased and meaningful communication after failures has a profound effect on the development of shared mental models, which in turn stimulate effective transactive memory. As described also above the effectiveness of transactive memory depends on accuracy, sharedness and validation (Brandon and Hollingshead, 2004). Specifically, accuracy is related to the perceived expertise that each group member has. Although technical expertise in surgical teams is role-based and can be measured objectively, this is not the case for non-technical expertise, which is often the cause for communication breakdowns and errors (Wahr et al., 2014). It is such expertise whose accurate representation can be improved after failures within a group, leading members to better appreciate who is truly good at what and not who *could* be good at what (Moreland et al., 1996), which can otherwise emerge as a result of role-based stereotypes (Hollingshead and Fraidin, 2003). Information exchange has the added benefit that it improves the sharedness of the individual TEPs, namely the degree of group-level agreement of TEP representations. Finally, group discussions encourage the validation of transactive memory, since the open communication and honest assessment of each members' nontechnical skills bridges the distance between expectations and reality at the group level. Concretely, team members assess their individual TEPs, share them with the group and update

them if necessary. As a result, the group develops "convergent expectations" (Hollingshead, 2001) that stimulate the sharedness of TEPs and the validation of collective perceptions. To sum up, failures can be followed by meaningful group interactions which enhance the effectiveness of transactive memory leading to improved team productivity.

Specifically in our context, such intensified interactions can also reduce communication breakdowns, a very common problem in complex healthcare tasks (Rafter et al., 2015). Past studies in cardiac surgeries have also indicated how failure can promote team learning and productivity as surgeons encourage meaningful communication (Edmondson, 2003b; 2004). We therefore expect a similar effect through team familiarity obtained from past failures.

In addition to the development of a more efficient transactive memory, after a failure, individuals tend to be more motivated while they perform the previously failed task (Cyert and March, 1963; Locke et al., 1981). In contrast, success can promote overconfidence among individuals (KC et al., 2013), which can in turn decrease their motivation during the performed task (Gino and Pisano, 2011). Similarly, team familiarity promotes motivation among team members (Weick and Roberts, 1993; Edmondson, 1999; Reagans et al., 2005). Individuals that share past common experiences are more willing to engage in a relationship as part of the team (Reagans et al., 2005), which will also promote validation and therefore increase the effectiveness of a transactive memory (Brandon and Hollingshead, 2004). As team-based learning involves a conscious personal effort to successfully complete a series of interdependent tasks (Wagner, 1995; Edmondson, 2004), we believe that team members' collective effort and commitment will be further increased after a team has experienced a failure in the past. Its members will be more motivated and willing to work harder to avoid a similar failure and reach the team's goals. As a result, familiarity obtained by past common failure experiences will promote learning and productivity more than familiarity obtained by past successful experiences.

Finally, past failures tend to promote more the development of cohesiveness among team members than past successes within a high commitment environment (Turner et al., 1984), since individuals tend to identify as a group the source of failure and try to avoid next time (Turner at el., 1984). Similarly, highly familiar individuals tend to form cohesion which in turn promotes productivity (Hackman, 1987; Evans and Dion, 1991; Mullen and Copper, 1994; Gully et al., 1995; Barrick et al., 2007). Past team failures will therefore promote more cohesion among team members than past successes and will result in an improved future productivity.

Hypothesis 3: *Team Familiarity gained from past failed operations has a higher impact on surgical team productivity than familiarity gained from past successful operations.*

Setting, data and variables

Our dataset consists of all cardiac surgery operations that were conducted in a 300-bed private hospital in Europe from 01/01/2004 to 31/03/2011. The hospital is property of an American non-profit organization and serves more than 2,000 patients per year. Our dataset consists of 6,206 operations, of which 6,171 have no missing data. In order to include an operation in our final sample there should be information regarding the duration, the surgery type, the members of the surgical team, the patient's characteristic and the outcome of the operation. There are 216 cases of in-hospital mortality, with 42 of them including the death of the patient during the operation and 174 of them including the death of the patient after the operation. Our sample therefore allows us to trace past interactions among team members from the same and different hierarchical levels and to connect them with past failures. We removed the 42 operations during which the patient died since the duration of these operations (our metric for team productivity) can be misleading, as a short duration for these operations will not indicate a high team productivity. Finally, we also removed the operations for which the team did not have at least

two surgeon and at least two non-surgeon members. After these removals, our final sample size was 5,894 operations.[1]

Each operation is characterized by the hospital as “Mild”, “Medium” or “Severe” according to the patient’s condition prior to the operation. We conducted a limited number of interviews in order to understand the different surgery types and potential hospital policies. According to our interviewees, our dataset consists of the following nine major surgery types: 3,273 Coronary Artery Bypass Grafts (CABG), 1,324 Valve Repairs/Replacements, 86 Congenital Surgeries, 70 Heart Failures, 20 Tumor Removals, 185 Routine Cardiac Surgeries, 78 Other Normal Surgeries (where we include operations that are not characterized by any of the previous categories), 965 Double Surgeries (including two previous categories during the same operation) and 128 Triple Surgeries (including three previous categories during the same operation). Mild cases usually include routine surgeries such as replacement of a pacemaker and hemostasis and possibly valve operations and Coronary Artery Bypass Grafts, depending on the patient’s historical records and condition. Severe cases include more complicated procedures such as congenital surgeries and heart failures but also other types like valve operations, again depending on the patient. It is worth noting that all operations from the categories Double and Triple are characterized as “severe” and that all deaths in our sample come from the category “severe”. Finally, medium is the most common group in our sample and includes operations from all categories except Double and Triple ones.

Each surgical team consists of one to four surgeons, zero to one anesthesiologist, zero to one perfusionist and zero to three scrub nurses. We have 115 individuals in total: 44 surgeons (Lead and Assistants), 12 anesthesiologists, 10 perfusionists, and 49 nurses. 51 of these individuals

[1] To check the robustness of our results, we repeated our analysis for H3 after including these operations and found full support.

(19 surgeons, 9 anesthesiologists, 3 perfusionists, and 20 nurses) joined the hospital after the beginning of our dataset, whereas 37 (13 surgeons, 6 anesthesiologists, 4 perfusionists, and 14 nurses) left the hospital before the end of our sampling period.

Variables

Dependent Variable. Similar to previous studies in cardiac surgery teams (Pisano et al., 2001; Edmondson et al., 2003) we use the operation duration in minutes as our dependent variable. Past researchers have used lower completion times for surgeons to represent higher productivity (Reagans et al., 2005; Ramdas et al., 2017; Avgerinos and Gokpinar, 2018). A potential concern is that lower completion times might lead to a worse medical outcome for the patient undergoing the operation. Nonetheless, past researchers have shown that longer durations of cardiac operations are also associated with worse clinical outcomes (Pisano et al., 2001) such as increased probability of surgery-site infection (Gaynes et al., 2001; Gibbons et al., 2011) or central system nervous complications (Roach et al.,1996).

Independent variables

Hierarchical Familiarity. This variable represents familiarity between two different hierarchy levels in a team. In order to capture hierarchical familiarity, we count the total number of times every pair that consists of two individuals who belong to different hierarchy levels in the team has worked together before (without including the current operation), take the sum for all those pairs in the team, and then divide this number by all such possible pairs in the team. Specifically, we count the number of times each surgeon in the team has worked together in the past with the nurses, perfusionist and anesthesiologist of the team, take the sum for all surgeons in the team and then divide this number by the product of the number of surgeons and the number of the other members (nurses, perfusionist and anesthesiologist) in the team. This variable represents average hierarchical familiarity within the team. Our approach is similar to past related studies (Reagans et al., 2005; Huckman et al., 2009).

Horizontal Familiarity. We have two main hierarchical levels in our teams, and therefore two types of horizontal familiarity: (i) Horizontal familiarity among surgeons, (ii) Horizontal familiarity among non-surgeon members. In both cases, we count the total number of times each same-hierarchy pair has worked together in the past (excluding the current operation), take the sum for all members, and then divide this number by all possible pairs of the same hierarchy level within the team. Specifically, for surgeon familiarity we count how many times each surgeon has worked with each other in the past, take the sum for all such pairs and then divide this number by all possible surgeon-pairs in the team (likewise for non-surgeon members). Similar to Hierarchical Familiarity, our approach for capturing average Horizontal Familiarity follows past related studies (Reagans et al., 2005; Huckman et al., 2009).

Failure Familiarity Percentage. In order to define failure, we focus on in-hospital mortality. This approach follows past management and medical literature: KC et al. (2013) also define patients' deaths as failure for cardiac surgeons. Past management studies in the same setting also use in-hospital mortality as a performance metric explaining that performance is successful if the patient survives (KC and Terwiesch, 2011; KC and Staats, 2012; KC et al., 2013). Finally, medical studies define the death of the patient after the operation as "failure to rescue" (Aiken et al., 2002; Aiken et al., 2003) indicating that the death of the patient is indeed considered as failure among healthcare professionals.

In order therefore to capture team familiarity from failure we first calculate how many times every pair in the team has worked together in the past in an operation that resulted in the death of the patient, take the sum for all pairs in the team and then divide this number by all possible number of pairs in the team. Next, we calculate how many times every pair in the team has worked together in the past, take the sum for all pairs in the team and then divide this number by the possible number of pairs in the team. Similar to previous researchers (Reagans et al., 2005) this way we capture the average level of familiarity of a surgical team. Finally, we divide

these two numbers and get team familiarity gained from past failure experience.[2] It is worth noting that we found no correlation between severe cases and teams that have experienced many failures in the past.

Control variables

Team Size. Previous researchers have shown that while larger teams have access to more resources (Reagans et al., 2005), they can be less productive due to coordination issues (Gladstein, 1984; Hackman, 2002). Team size is also different depending on the operation type as one can see at Table A1 of the Appendix.

Individual Average Direct Experience. This variable captures the experience of each team member on the performed operation type and is expected to have a positive effect on team productivity (KC and Staats 2012). Specifically, for each individual we count how many operations of the same type he/she has performed in the past (excluding the current one). We next take the sum for all team members and divide by the team size.

Indicators for severity of the case. During the first hours of admission each patient is classified by the hospital in one of the following categories: "Severe", "medium" and "mild". This procedure is characterized by high consistency since severe cases have priority over the medium and the mild ones. This allocation is done by the lead surgeon and the physician examining the patient and depends on the patient's characteristics and the operation's type. This is similar to but less granular than the commonly used cardiac operation risk evaluation score (EuroSCORE) (Roques et al., 2003) for pre-operative risk assessment of cardiac patients and takes into account a large number of critical factors such as age, clinical history, past complications, other existing health problems, etc. We use "medium" as our reference category

[2] We also repeated our analysis without dividing by average team familiarity and got full support for all hypotheses.

and hence we include two dummy variables: Dummy variable “severe” is equal to one if the operation is allocated to the perspective category and zero otherwise, and similarly dummy variable “mild” is equal to one if it is allocated to the mild category and zero otherwise. Severe operations tend to last longer than medium and mild ones.

Month. In order to control for technological advancements, hospital policy changes or an unobserved exogenous shock that could affect duration (Ramdas et al., 2017), we include a counting variable indicating the number of months passed since the beginning of our dataset.

Age. We control for the age of each patient since it can affect duration (KC and Staats, 2012).

Male. We include a dummy variable equal to one if the patient is male and zero otherwise since the sex of the patient could also impact surgery duration (KC and Staats, 2012).

Finally, in every model we include the lead surgeon fixed effect (to control for the lead surgeon’s skill and other unobserved factors about him/her), the procedure fixed effect (to control for the different surgery types since each type has different requirements and therefore duration may vary) and the day of the week fixed effect since past studies have shown that it can affect an operation (KC and Staats, 2012; Avgerinos and Gokpinar, 2018).

Results

Our dataset is essentially structured as time series data at the operation level and our level of observation is each operation. A Durbin-Watson test revealed first-order serial autocorrelation, hence similar to past related studies (Reagans et al., 2005; Avgerinos and Gokpinar, 2017) we use Ordinary Least Squares Regression with AR(1) covariance structure to control for serial correlation among consecutive operations in order to test our hypotheses. The ordering is based on the time of the start of the operation. We also checked for normality of residuals and for heteroscedasticity. The Breusch-Pagan test (1979) revealed heteroscedasticity so we use robust standard errors. Finally, there is no indication of severe multicollinearity in any of our models

since the variance inflation factors are all below 10. Table 1 shows descriptive statistics and correlations among the variables.

[Please insert table 1 here]

Table 2 shows the results for all our hypotheses. The number of observations is equal to 5,893 due to the AR(1) covariance structure. In model 1, we include only control variables. As expected, *Individual Average Direct Experience* and the dummy variable *Mild* are significant and negative whereas *Team Size* and the dummy variable *Severe* are significant and positive. Also, our variables *Month* and *Male* are significant and positive indicating an increasing *Duration* as time goes by and for male patients. In model 2, we include *Horizontal* (consisting of *Surgeon's Familiarity* and *Non-surgeons' Familiarity*), *Hierarchical Familiarity* (which represents familiarity between surgeon and non-surgeon members) and *Failure Familiarity Percentage*. The increase in the adjusted R^2 is 3.09% (or 0.9 percentage points) and an F-test suggests that model 2 is superior to model 1 (at 1% level). While both coefficients of Surgeons' Familiarity and of Non-surgeons' Familiarity are significant (at 1% level and 5% respectively) and negative, Hierarchical Familiarity is insignificant, providing support for our first hypothesis. In addition, the coefficient of Surgeons' Familiarity (i.e., -0.069) is higher in magnitude than the coefficient of Non-surgeons' Familiarity (i.e., -0.010), which is also confirmed by a t-test at 1% ($p = 0.0070$) providing support for our second hypothesis. Our results provide full support for our third hypothesis too, since the coefficient of Failure Familiarity Percentage is negative and significant at 1%.[3]

[Please insert table 2 here]

[3] Please refer to the online Appendix for the equation of our model and all our additional analyses for all the robustness checks conducted in order to eliminate possible alternative explanations.

Discussion

Our study contributes to the existing literature in teams by examining the role of team composition dynamics (i.e., team familiarity) on team productivity through detailed and nuanced mechanisms. Despite their increasingly important role within organizations, there is limited work examining how teams should be formatted based on past shared experiences of their members (Avgerinos and Gokpinar, 2017). Making use of a unique dataset spanning over a time period of more than seven years, we contribute to the existing related literature by introducing a newly acknowledged differentiated effect of team familiarity based on different hierarchy levels and past failures of individuals in teams with overlapping membership.

In doing so we use transactive memory system as our theoretical framework and specifically, the task-driven framework introduced by Brandon and Hollinsghead (2004). Using both theoretical and contextual arguments we explain how familiarity, operationalized as the average number of previous member interactions at the dyadic level, is a prerequisite for TMS development. Our study is therefore the first one to integrate a number of different but related streams of literature on teams. Specifically, we merge past literature that supports that TMS (and therefore increased performance) is developed through repeated interactions (e.g., DeChurch and Mesmer-Magnus, 2010a) with the one examining team familiarity (e.g., Reagans et al., 2005, Huckman et al., 2009) and its effect on team performance.

Our second contribution is the decomposition of team familiarity into horizontal and hierarchical familiarity and the introduction of their differential effects on team productivity. We argue that past interactions of same-hierarchy members are associated with more meaningful information sharing, which influences the effective development of TMS, since it stimulates accuracy, sharedness and validation at the subgroup level. Horizontal familiarity therefore has a higher impact on team productivity than hierarchical familiarity. Next, by recognizing the importance of high-status and high-power individuals on team performance,

we observe that horizontal familiarity among such individuals (i.e. surgeons in our setting) has a higher positive impact on team productivity, and therefore seems to be more significant for team productivity than the one among subordinate team members.

Finally, we introduce the concept of team familiarity gained from past failures and investigate its effect on team productivity. Specifically, we argue how past failure common experiences will increase more future team productivity than familiarity gained from successful experiences through increased motivation and more meaningful communication which will promote more efficiently the development of a TMS among team members.

Practical implications

Our results are significant both statistically and managerially and highlight the importance of past shared experiences among team members for cardiac surgery operations. Hospital managers can decrease the duration of such operations via better team allocations strategies, which can result in a higher number of operations conducted in the hospital, lower waiting time for patients, better clinical outcomes for the patients (Gaynes et al., 2001; Gibbons et al., 2011) and higher financial performance for the hospital (Pisano et al., 2001).

Managers tasked with the formation of teams should notice that assigning members of the same hierarchy with high levels of past shared experiences seems to be more impactful than assigning members from different hierarchy levels that share common experiences. In addition, familiarity of the high-status individuals among them seems to be more impactful than the one among subordinate members. Specifically, according to Table 2 an increase of one standard deviation of Surgeons' Familiarity decreases duration by: 266.2641*0.069/296.0877 = 6.2% (=18.37 minutes). This is translated into 21.84 hours savings in operation times on a monthly basis (or around 53.11 additional operations per year) as a result of gaining familiarity. A similar increase on Non-surgeons' Familiarity decreases duration by: 51.17*0.010/296.0877 = 0.17% (= 0.51 minutes). This translates in around 0.61 hours savings in operation times on a

monthly basis (or around 1.48 additional operations per year). Similarly assigning members that have shared failure experiences in the past seems to be more efficient than using individuals that have only succeeded together in the past. An increase of one standard deviation on Failure Familiarity Percentage decreases duration by: 0.0286*227.352/296.0877 = 2.2% (= 6.50 minutes) which translates into 7.73 hours savings in duration on a monthly basis (or around 18.8 additional operations per year).

Given that the lead surgeons are assigned at a rotating schedule, a simple policy that makes use of our insights could be the following: First, managers could assign the assistant surgeons using their familiarity with the lead surgeon and choose the ones with the highest number of past failures with her/him in case of two assistant surgeons who are equally familiar with her/him. This way our insights from surgeons' familiarity will be used. Next, for the other members, managers could make use of our team-level results about past failures. Specifically, they could assign the anesthesiologist, perfusionist and nurses that have the highest number of past shared failures with the surgeons and then pick the ones with the highest familiarity among them in case of a "tie" on the past shared failures criterion. Finally, in many settings like ours there is a high turnover as many professional service companies suffer from high turnover rates (PwC Saratoga, 2012/2013) that can have major productivity loss for them. It is therefore inevitable that new individuals will join already existing project teams in which their team members will be largely familiar with each other. Hence, we suggest that managers could initially assign newly hired team members in a rotating schedule so that the newly hired individuals will build familiarity with all the other workforce and eventually adjust in and follow our described suggested policy. Essentially, due to high turnover the resulting policy will be a mixture of our insights and a rotating policy that will allow managers to make use of our results without creating significant problems to teams due to newcomers.

By employing better team allocation strategies, hospital managers can successfully reduce operation completion times. This in turn can result in lower waiting times for patients needing an operation, which constitutes a major issue for hospitals (Independent, 2017). Lower completion times can also be translated in more operations given that hospitals can adopt a flexible surgery schedule which will allow them to take advantage of any potential time savings as a rigid schedule structure might constitute a barrier in such an effort.

Finally, our results can be applied with caution in other settings where teams experience similar communication and coordination challenges and are characterized by different hierarchical levels. Specifically, there is a looming medical literature underpinning that communication and procedures in the operating room share many similarities with aviation settings. Both settings use standardized communication protocols and checklist systems in order to improve communication and minimize related errors among their members (Lingard et al. 2002; 2004). The American Heart Association also recognizes that effective communication strategies in aircraft crews can be transferable to the operating room (Wahr et al., 2013) whereas learning from aviation accidents (that were related to communication failures) has led to the emergence of crew resource management (CRM), which has been transferred to the operating room (Helmreich et al., 1994; Davies, 2001; 2005). We therefore believe that the different types of past collaborations of individuals from settings sharing these characteristics can also have the differentiated effects described in our study.

Limitations and future research

As in all empirical studies, ours comes with its limitations. Our findings on the effect of different types of familiarity should always be interpreted carefully since our setting is a high-pressure, tacit-dominant environment and our sample is derived from a single hospital. The high turnover for instance may be affecting our findings. Hence further studies in similar settings or replications studies in the same setting are necessary to evaluate further our results.

Our dataset also includes neither detailed information about the medical condition of the patients prior to their operation (such as EuroScore) nor other patient related data such as body-mass index or cholesterol measures. Nonetheless, the existence of three patient groups depending on their condition (mild, medium and severe), similar to Huckman (2003), allows us to control for patients' condition prior to the operation. Hence, we do postulate that controlling for the allocation of the patient, his/her age and sex and the operation type fixed effect provides us a set of satisfying control variables. In addition, information about surgeons' and other team members' tenure was not available in our sample. Hence, we cannot capture their experience prior to joining our hospital. Nonetheless, we control for the lead surgeon fixed effect in order to account for such unobserved factors for the lead surgeon who has the main control during the operation. Furthermore, we focus only on team productivity since our sample does not include quality measures such as adverse events, hospital revisits etc., and all deaths in our sample are observed on the patient group "severe". Hence, we were not able to detect any relationship between in-hospital mortality and our variables of interest.

Future work could examine the effects of our familiarity metrics on in-hospital mortality or other quality variables such as 30-days readmission and adverse events, on the productivity gains (Vashdi et al., 2013) by comparing the booking time and the actual operation time or on the actual bypass time since it is more important than the total time in the operating room and has been connected with negative health outcomes (Madhavan et al., 2018). Nonetheless, these variables were not available in our sample. Another interesting extension could also be the investigation and comparison of the effects of familiarity gained from past failures, among individuals of the same and different hierarchical levels within teams. Finally, in our setting there are clear roles and levels of hierarchy among individuals (Nembhard and Edmondson, 2006). Hence, one should be cautious when interpreting our insights in different contexts where there is not clear distinction of roles and hierarchy levels. Future work could also examine the

effect of hierarchical and horizontal familiarity in firms with variable hierarchy levels, which could have a differentiated effect than our study.

Our study should also ideally provide evidence on how the transactive memory of teams has evolved and validate its relationship with familiarity. However, recording the transactive memory changes of each team after each operation in our sample would had been a prohibitively industrious and time-consuming task. A qualitative study could also shed further light on the specific mechanisms (Gibson, 2017) behind the productivity increase from the development of horizontal and hierarchical familiarity and from past shared failures but such a study was not possible in our setting. A follow-up laboratory experiment is a better setting to examine the co-evolution of familiarity and transactive memory and further validate our corresponding arguments. Finally, while we clearly distinguish failures from successes, there can be other cases that could lead to increased team productivity like near misses (KC et al., 2013) but detecting them is not possible in our sample.

Conclusion

Despite its limitations, our study contributes to the existing team literature by introducing the differentiated effect of familiarity based on hierarchy levels within the same team and past failures of teams. As described above, our results indicate that managers can make use of horizontal familiarity among individuals of the same hierarchical level and past shared experiences among all team members in order to devise simple team allocation strategies that will allow them to increase team productivity. By decomposing team familiarity into hierarchical and horizontal components, we show that not every part of familiarity might be useful for teams, which can lead to different approaches when assigning individuals to teams. Finally, by introducing the failure-based familiarity, we indicate that assigning individuals who have experienced past failures together can act as a driver for better future productivity.

Table 1. Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
1. Duration	296.088	65.472	29	870	1											
2. Surgeons' Familiarity	342.294	266.264	0	2414	0.010	1										
3. Non-surgeons' Familiarity	57.0838	51.170	0	489	0.037**	0.381**	1									
4. Hierarchical Familiarity	205.190	151.458	0	960.5	0.092**	0.708**	0.739**	1								
5. Failure Familiarity Percentage	0.045	0.029	0	0.8	-0.061**	-0.256**	-0.168**	-0.279**	1							
6. Individual Average Direct Experience	298.527	280.458	0	1375	0.168**	0.599**	0.379**	0.675**	-0.241**	1						
7. Team Size	5.481	0.733	4	8	0.193**	-0.139**	-0.004	-0.067**	0.102**	-0.274**	1					
8. Severe	0.289	0.284	0	1	-0.006	-0.022+	0.021	-0.020	0.092**	-0.150**	0.110**	1				
9. Mild	0.2120	0.414	0	1	-0.050**	0.015	-0.039**	-0.016	-0.028*	0.071**	-0.129**	-0.165**	1			
10. Month	43.323	24.616	1	87	0.212**	0.215**	0.282**	0.412**	0.038**	0.370**	0.262**	0.025+	-0.109**	1		
11. Male	0.736	0.441	0	1	0.022+	-0.016	-0.009	-0.011	0.005	-0.018	-0.002	0.013	-0.003	-0.033*	1	
12. Age	64.8619	12.104	8	96	0.002	-0.000	0.004	0.009	0.003	0.001	-0.014	-0.002	0.025+	-0.014	-0.085**	1

+, * and ** denote significance at 10%, 5% and 1% levels respectively
Duration is in minutes

Table 2

Regressions of Familiarity on Surgery Duration

Variable	Duration	
	Model: (1)	(2)
Surgeons' Familiarity		-0.069**
		(0.023)
Non-surgeons' Familiarity		-0.010*
		(0.005)
Hierarchical Familiarity		0.016
		(0.015)
Failure Familiarity Percentage		-227.352**
		(72.457)
Individual Average Direct Experience	-0.018**	-0.052**
	(0.005)	(0.011)
Team Size	9.425**	11.480**
	(1.613)	(1.680)
Month	0.650**	0.635**
	(0.049)	(0.051)
Severe	14.294**	15.351**
	(3.695)	(3.706)
Mild	-3.683*	-0.017**
	(1.615)	(0.006)
Age	0.047	0.034
	(0.060)	(0.060)
Male	4.224**	3.966*
	(1.612)	(1.602)
Constant	163.749**	186.416**
	(14.643)	(16.662)
Observations (N)	5,893	5,893
Adjusted R^2	0.291	0.300
BIC	64,219.21	64,173.50
Lead Surgeon Fixed Effect	Yes	Yes
Procedure Fixed Effect	Yes	Yes
Day of the Week Fixed Effect	Yes	Yes

+, * and ** denote significance at 10%, 5% and 1% levels respectively
Duration is in minutes

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