Network Tension and Innovation in Teams: Deep Success in Jazz

Balazs Vedres, University of Oxford

Tunde Cserpes, Aarhus University

Prior scholarship paid insufficient attention to the creative potential of open and strong relationships, because—rooted in a long sociological tradition of balance theory—it assumed that strong ties are always closed, and only weak ties bridge diverse structural locations. We develop two graph level measures to capture tension in open and strong ties: the relative frequency and the strength of strong, open triads. Our results show that in recorded jazz music–a uniquely synergistic domain of collective creativity—tension is more prevalent than expected, and it is a predictor of several success measures, including deep success, while within-team brokerage (the presence of an orchestrator) and closure are not. We also measure the structural availability of tension to each session and show that unexpected tension (where musicians go beyond chance to bring imbalance into their bands) has an additional contribution to deep success. We discuss implications for creative teams and organizations where collective innovation is crucial.

social networks, innovation, teams, tension, jazz

INTRODUCTION

As teamwork becomes more prevalent in creative fields, we need to understand how collectives can recognize and implement new ideas (Vera and Crossan 2005; Wuchty, Jones, and Uzzi 2007). Teams can pool individual experiences of members, as well as experience from collaborations (DiBenigno and Kellogg 2014), and thus come to a shared understanding about their task. But if the task is innovation, how can novelty arise from shared understanding—a supposedly conservatizing force?

Teams facing an innovative task need to solve a paradox of experience: They need to rely on their experience, but they also need to avoid falling back on conventional solutions (Deken et al. 2016). Experience in the team should help deliver a product without losing sight of fresh approaches (DeFillippi, Grabher, and Jones 2007). However, teams building from prior experience run the risk of groupthink, when experience narrows to one dominant practice, limiting the scope of attention (Sunstein and Hastie 2015), leaving new ideas unexplored (Cerulo 2008; Vaughan 2016; Zerubavel 2015). Repeated collaborations can lead to *network closure*, narrowing the cognitive horizon in teams (Janis 2019; Perry-Smith 2006; Romero, Uzzi, and Kleinberg 2019), locking them into routine solutions (Reagans and McEvily 2003; Sosa 2011).

One way to avoid conventional solutions is to bring new talent to a team: adding newcomers – capable team members without established experience –, can help seasoned members identify fresh approaches (Ferriani, Cattani, and Baden-Fuller 2009; Perretti and Negro 2006), bringing new perspectives to reinterpret past experiences (Soda, Mannucci, and Burt 2021). But as newcomers can quickly assimilate to dominant practices (Hansen and Levine 2009; Rink et al. 2013), another solution is relying on a *diversity* of experiences, hiring seasoned team members bringing building blocks of new ideas with them (Guillaume et al. 2017; Paulus, van der Zee, and Kenworthy 2019). Diverse teams, however, often find it hard to communicate effectively[1] and to stay committed to turning their ideas into a product. In sum, there is no consensus yet about how collective innovation emerges from past experiences (Perry-Smith and Mannucci 2017).

However, there is consensus that *structural diversity*, ties to disconnected others is a key predictor of innovation in teams (Ahuja 2000; Obstfeld 2005; Tortoriello, McEvily, and Krackhardt 2015; Tortoriello, Reagans, and McEvily 2012). Those who maintain diverse ties are more likely to come up with valuable new ideas (Burt 2004). Teams with a mix of closed and structurally diverse ties outperform teams with only closed ties when the task is artistic

[1] A meta-analysis of 37 articles analyzing diversity and social integration of teams found a weak negative correlation: more diverse teams were slightly less integrated (Horwitz and Horwitz 2007).

creation (Uzzi and Spiro 2005). Several publications underline the significance of organizational boundary-straddling ties and creativity (Ahuja, Soda, and Zaheer 2012; Cattani and Ferriani 2008; Fleming and Marx 2006; Fleming, Mingo, and Chen 2007; Kilduff and Brass 2010; Perry-Smith and Mannucci 2017; Tiwana 2008).

Most research on structural diversity share a fundamental assumption that strong ties and structural diversity are mutually exclusive: weak ties connect to diverse regions of the network, and thus grant access to new ideas, while strong ties connect to a local, densely interconnected and homogenous set of actors with familiar ideas (Kwon et al. 2020; Schowalter, Goldberg, and Srivastava 2020; Stovel and Shaw 2012). This "strength of weak ties hypothesis" (Granovetter 1973) has been tested extensively and was recently elaborated in the diversity-bandwidth tradeoff argument (Aral and Van Alstyne 2011), where high bandwidth (strong) ties give access to more, but less diverse information. Groups in this perspective are expected to benefit from external structural diversity, and internal closure (Burt 2001). Previous approaches thus excluded strong tie diversity from the substantial discussion: the possibility that strong ties within groups can lead to disconnected others.

We argue that strong ties are sometimes open, and when they are, these strong, open ties contribute to creative success more so than weak open ties, brokerage, and closed ties. Generating a novel idea is an exceptional event that requires an exceptional social structure[2]. Open triads of strong ties are exceptional conjunctures of two dyadic collaborative histories, enabling team members to recognize and implement a new combination out of two distinct experiences. In this article we show, in the context of jazz recordings, that the more strong and

[2] Research on networks and innovation found that the importance of connections in general increases as innovation becomes more central. There is evidence for the increasing importance of relational innovator roles, as the innovativeness of a project increases (Gemünden, Salomo, and Hölzle 2007; Zhou and Li 2012). Similarly, the innovativeness of a group was shown to be related to the network embeddedness of that group within a broader organizational context (Lee et al. 2010; Tsai 2001).

open triads a jazz session has, the more opportunities musicians have to discover and synthesize interesting combinations of dyadic styles.

Crucially for innovation, open and strong triads serve a dual purpose: they are an occasion to discover diverse approaches to collaboration, and they are opportunities to rely on trusted and strong collaborative ties to realize an emerging idea in a product[3]. Open and strong triads are opportunities to benefit from overlapping practices and to avoid an early lock-in into a dominant practice. At the same time, these strong, open triads are structurally imbalanced (Cartwright and Harary 1956; Heider 1946; Hummon and Doreian 2003), and thus are *sites of tension*, where two different ways of thinking, two different sets of practices, come to a clash. This tension, and the resulting cognitive imbalance might produce stress to those involved[4] but might also serve to energize and motivate the search for improved solutions[5]. Thus, we believe, *network tension* is the key to solve the paradox of experience in creative teams.

We contrast network tension with brokerage within the group. Both are concepts of structural diversity in networks, but they represent different mechanisms. Tension is about opportunities to recognize and implement novel combinations of dyadic experiences (Rosing et al. 2018), while brokerage frames structural diversity as opportunities for control and privileged access

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[3] Approaches to network predictors of innovation often segregate the problem of generating an idea, and the problem of implementing a product and seek to identify distinct network structures for each (Baum, McEvily, and Rowley 2012; Obstfeld 2005; Uzzi and Spiro 2005). Teams that can switch between idea generation (a learning orientation) and implementation (a performance orientation) were shown to be more successful with radical innovation (Lameez and van Knippenberg 2014), so a network structure that enables both generating and implementing ideas is especially helpful for radical innovation.

[4] David Krackhardt and coauthors have demonstrated how open and strong ties embedded in overlapping clique structures lead to stress via conflicting expectations (Krackhardt 1999; Krackhardt and Kilduff 2002), in line with prior studies showing that boundary spanners experience more stress than others (Podolny and Baron 1997).

[5] Tension in general was shown to have a creative potential for teams (Jehn 1995; Jehn and Mannix 2001; Shah et al. 2020; Simons and Peterson 1998), and specifically in string quartets (Murnighan and Conlon 1991). In the context of "Simmelian ties" (overlapping clique structures), the innovative potential of strong, bridging ties and overlapping three-person cliques was also demonstrated before (Tortoriello and Krackhardt 2010; Tortoriello, Reagans, and McEvily 2012).

to information (Burt 2004). When a team faces the challenge of innovation, brokerage gives an answer only to a part of this challenge: Brokers can excel in the recognition of a new idea, while they often lack the embeddedness needed to implement ideas (Lingo and O'Mahony 2010; Obstfeld 2005; Tortoriello and Krackhardt 2010). Within a group, brokers can facilitate innovation if they can orchestrate exploration in the network (Dhanaraj and Parkhe 2006; Nambisan and Sawhney 2011). However, earlier research did not find a positive link between brokerage and success in creative enterprises, such as movies (Bechky 2006; Ferriani et al. 2009; Jones 1996) or video games (De Vaan, Stark, and Vedres 2015).

We define two measures of network tension: the relative frequency of strong, open triads, and the strength (relative tie weight) of strong, open triads. These two measures capture different mechanisms in the same underlying process of network tension, which gives us an opportunity to put our ideas to a strong test. The first measures the number of innovative possibilities: distinct opportunities to recombine collaborative practices. With this measure we think of tension as an ingredient of innovation: increasing the amount of this tension ingredient should increase creative success. A team that has more strong, open triads will have a better chance of finding a novel combination that is also a viable novelty. The second measure is the strength of innovative opportunities: the length of collaborative histories that have come to a generative contact. A team's network might have only a few strong, open triads, but it might not be the number of such structures that matters, but rather the strength of strong ties in an open triad. With this measure we think of tension as a spice of innovation: it is the strength of tension, not the amount that sparks innovation.

Our case is jazz: a uniquely innovative field where bands succeed by novel sounds (Askin and Mauskapf 2017), and a field that has offered many lessons to scholarship on organizations

(Barrett 2012; Berliner 1994; Doffman 2011; Phillips 2013)[6]. Jazz is a strategic field to understand team network processes, as teams are assembled often, and jazz musicians readily join various collectives to experiment with fresh sounds[7]. From a product perspective, a jazz band operates with high complementarity, as every musician is heard on the record: everyone's contribution is critical (Gilson et al. 2015). We use data on 175 064 jazz recording sessions—the complete population—spanning the entire history of recorded jazz, using the Tom Lord discographic database. We can thus follow musicians as they go through their creative careers, forming bands and recording jazz sessions, and, at exceptional times, generating successful novel combinations. Our findings indicate that jazz recordings are more successful on several dimensions if the bands' collaboration network features a higher relative frequency of tension triads, and when tension is stronger in triads. As a comparison, brokerage consistently but negatively predicts various forms of success, including deep success, underscoring the importance of considering the structural diversity of strong ties.

Beyond investigating the impact of tension triads on success, we also use computational methods to understand to what extent these structures are unexpected. The unlikeliness of strong and open triads is an often repeated argument in prior scholarship (Aral and Van Alstyne 2011; Granovetter 1973), thus it is reasonable to test whether the extent to which a particular strong and open triad is unexpected has any consequences for success. To assess evidence on organizing efforts of teams (as opposed to lucky accidents) indirectly, we generate a

[6] A piece of evidence for the innovative nature of the jazz field is the constant experimentation with diverse instrumentations: we encountered 11,940 unique instruments (after considerable effort to clean and collapse instrument entries). As a comparison, the largest collection of musical instruments, the MIMO project (Musical Instrument Museums Online; mimo-international.com), lists a total of 1140 different kinds of instruments – an order of magnitude less. From car parts to pots and digital noises, jazz musicians go far beyond conventions.

[7] Jazz is a field where innovation is intimately linked with network ties (Dowd and Pinheiro 2013). Musicians developing networks across clusters are also ones that are likely to adopt transgressive styles (Kirschbaum and Ribeiro 2016). Musicians were developing unique styles if their connections to the core venues were looser (Phillips 2011).

counterfactual null hypothesis for each recording session by computing a population of objectively possible sessions, that stay within the broad constraints of musicians and sessions. We find evidence that unexpected tension adds explanatory power to several measures of innovative performance, including deep success, while brokerage is not a predictor of success. Our results point to the importance of organizing effort other than orchestration by central players.

STRONG TIES AND STRUCTURAL DIVERSITY

The concept of structural diversity refers to the value of maintaining ties to regions of a network that are themselves not densely connected to one another (Aral and Van Alstyne 2011; Ugander et al. 2012). A key advantage of such ties is that one can access diverse information, as people in a densely connected region in the network are likely to develop distinctive knowledge (Gould and Fernandez 1989; Stovel and Shaw 2012). Another advantage is control, because a lack of coordination between disconnected partners in negotiations offers opportunities to exploit (Burt 1995; Simmel 1950). Structural diversity, however, needs to resist closure: there is a natural tendency for unconnected partners to become connected eventually (Burt 2005).

As the pressure for closure is higher with strong ties, researchers assumed that all structurally diverse ties are weak. Following Mark Granovetter's discovery of the strength of weak ties for structural diversity, it was repeatedly demonstrated that strong ties are more likely to be found in closed triads than weak ties, hence early research's focus on weak and open triads[8]. In the original formulation of structural holes by Ronald Burt, the strength of ties was seen as irrelevant for structural diversity: "Whether a relationship is strong or weak, it generates

[8] The strength of a social tie, following Granovetter's original definition (Granovetter 1973:1361), is a combination of subjective closeness, such as emotional attachment or intimacy, and observable interaction intensity. Scholars often measure it by the frequency, duration, multiplexity, or reciprocity of ties (Lin, Ensel, and Vaughn 1981; Marsden 1990; Marsden and Campbell 1984).

information benefits when it is a bridge over a structural hole." (Burt 1995:28). The formula of structural constraint proposed by Burt in the same book penalizes egos with mixed tie weights but is invariant to tie weights as long as they are equal. Thus, categorization of network ties as either weak bridges or strong bonds, plus a residual category for all others, is deemed to be entirely justified two decades later as well (Burt 2005:25).

In the literature on structural diversity the high weight of ties is seen as an obstacle, a hindrance to brokerage possibilities (Fararo 1983; Pattison and Robins 2002; Schowalter et al. 2020; Stovel and Shaw 2012; Tutić and Wiese 2015; Yang, Dong, and Chawla 2014). Overlapping closed triads or dense networks around contacts in brokerage situations are deemed to be an obstacle (Burt 2015; Krackhardt 1999; Krackhardt and Kilduff 2002; Reagans and Zuckerman 2008). More recent reformulations of the strength of weak ties thesis evaluate conditions under which strong ties might be more beneficial for obtaining diverse information than weak ties (Aral and Van Alstyne 2011; Bruggeman 2006; Centola and Macy 2007). However, even these arguments sideline strong tie structural diversity as an unlikely network structure, even though it is seen to promise the most novelty. Aral and Alstyne present a fourfold table (their Figure 3 on page 110), with combinations of high and low bandwidth, and high and low structural diversity. They note in the cell of high bandwidth and diversity (that is, high weight open ties), that such high bandwidth and open structures are "most strongly predict access to novel information," but "are also the least likely to be observed in real social settings," thus it is excluded from further discussion (Aral and Van Alstyne 2011:110).

In Granovetter's original formulation, open but strong triads were exceptions and were thus labeled forbidden triads. In his seminal article on the strength of weak ties, Granovetter cites sociometric evidence from the sixties and seventies that strong ties form closed networks. As his focus was on weak, bridging ties, he disregarded any occurrence of strong, open triads, because "processes of cognitive balance tended to eliminate it" anyway (Granovetter

1973:1364). We agree that processes of cognitive balance tend to eliminate strong and open triads, but we also argue that *when* strong, open triads do persist, the cognitive imbalance involved can become a creative force. Thus, we develop the concept of network tension, when a strong and open triad becomes the opportunity to recognize and implement a novel idea.

NETWORK TENSION IN A TRIAD

We define network tension by the imbalance of tie weights in a triad. When we observe an open triad, it is a significant structure to the extent that it was likely to be closed in the first place. The higher the edge weights in an open triad, the higher the probability that the triad will become closed, by the transitivity of emotional closeness, and the probability of two disconnected alters meeting one another if they frequently interact with the same person (Granovetter 1973:1362). Thus, we define the *tension in an open triad* to be proportional to the strength of the connected edges: An open triad with two weak ties presents little tension, as it is easy to manage—both in practical and emotional terms—the separation of two alters that are only weakly tied to ego.

Strong, open triads are imbalanced structures fraught with tension in the sense that they violate powerful mechanisms that were repeatedly demonstrated to balance triads in networks (Askarisichani et al. 2019; Cartwright and Harary 1956; Doreian and Mrvar 1996; Heider 1946; Hummon and Doreian 2003; Rambaran et al. 2015). Balanced triads in the original formulation are those where negative and positive ties are arranged in a way that the product of signs is positive (Cartwright and Harary 1956). Subsequently, this definition of balance was extended from negative and positive ties to infrequent and frequent interactions, arguing that a triad where two of the interactions are frequent, and one is infrequent is imbalanced (Davis and Leinhardt 1972)[9].

Starting from exploration and sensemaking that happens in dyads, we can capture the moment when new combinations of experiences emerge at the triadic level (Balachandran and Hernandez 2018). A strong, open triad is an opportunity for discovery, a conjuncture of two dyadic histories (Tilly 2000). Figure 1 shows triads with weighted edges in a two-by-two table, adopting the classification of structures from Aral and Alstyne's discussion on how tie weight (bandwidth) and structural diversity are related to novelty (Aral and Van Alstyne 2011:110). Panels "a" and "d" are structures that Granovetter (1973) described as most likely. Panel "c," weak closure is unlikely, as it is expected to quickly develop to panel "a", strong closure. Panel "b" was expected by Aral and Alstyne to bring about the most novelty, but was bracketed as an unlikely structure: the forbidden triad from Granovetter (1973).

Figure 1 about here

Why would a strong open triad be an occasion for generative, rather than merely disruptive tension? Borrowing from the psychology of innovation, we believe that the overlap of practices in a strong open triad becomes an occasion to innovate, because it serves as a *diversifying experience*, and thus opens possibilities for *perspective-taking*. Diversifying experiences "disrupt conventional and/or fixed patterns of thinking, thus enabling a person to view the world in multiple ways" (Damian and Simonton 2014:375). Taking such multiple viewpoints at once are shown to be related to increased creativity (Steffens et al. 2016), as exposure to multiple cultural contexts leads to more openness to question assumptions and practices

[9] Explaining why such imbalanced structures emerge is beyond the scope of this article. We are primarily interested in showing the over-representation, and positive consequences of imbalanced structures.

(Gocłowska, Damian, and Mor 2018; Tadmor, Galinsky, and Maddux 2012), and this openness leads to increased creativity (McCrae 1987). In the strong, open triad, a team member faces two colleagues with whom she has had long but separate collaborative experiences. By this, she is confronted by two different sets of tacit knowledge, and two different aspects of her professional identity (Chua 2018). The cognitive imbalance in an open but strong triad stems from the intersection of two distinct dyadic histories: two histories of collaborative experiences, and with them two distinct perspectives and two facets of identity.

As a thought experiment, let us compare a triad with network tension to a triad where two experienced members with a long history of collaborations invite a newcomer to play with them (Ferriani et al. 2009; Perretti and Negro 2006). Taking the case of panel 'b' on Figure 1 as a comparison, consider a trio with a strong tie between two members and an isolated newcomer. This situation embodies no imbalance as the two well-connected incumbents are both disconnected from the newcomer. It is up to the persuasiveness of the newcomer and the curiosity of the incumbents to discover a new idea (Hansen and Levine 2009; Rink et al. 2013). In contrast, a tension triad generates a challenge to be solved, it is a provocation to innovate not easily ignored.

NETWORK TENSION IN A GROUP

It was previously demonstrated that tensions in the form of conflict and disagreement about tasks and in relationships can contribute to innovativeness in teams (Jehn 1995; Jehn and Mannix 2001; Simons and Peterson 1998), and task-related tensions can be beneficial to team performance in general (Shah et al. 2020), also in the case of musical collaboration specifically (Murnighan and Conlon 1991). We aim to understand the network mechanism of how tension leads to innovation and creative success by arguing that generative tension in a triad will benefit the entire team within which the triad is situated. Switching from the triadic to the graph level, we need to conceptualize how the creative opportunity represented by a strong, open triad can become an innovative benefit for the whole group. There are several arguments about how a collective is enriched by maintaining diverse traditions. Population geneticists have long recognized that evolution in separate subpopulations brings a larger set of solutions to environmental challenges that can be later recombined to benefit the entire population (Wright 1932). These ideas have been translated from genetic to cultural evolution, showing how local diversity benefits the entire collective (Creanza, Kolodny, and Feldman 2017). Recent experimental studies of cultural evolution have shown that collectives that feature a diverse set of separate traditions within innovate more, compared to a more uniform community (Barkoczi and Galesic 2016; Derex and Boyd 2016).

In organizational settings, membership in multiple teams enhances people's learning potential (Gronow, Smedlund, and Karimo 2020; Lameez and van Knippenberg 2014; O'leary, Mortensen, and Woolley 2011; Wuchty et al. 2007). According to these studies, communities with longer separate histories of exploration have a better chance to generate distinctive cultural combinations by avoiding early lock-ins into consensus. If diverse experiences are not connected by network ties, team members can easily overlook them, as no one would be in a special position to bring diverse experiences together (Hoever et al. 2012). In such a fragmented organization, subsets of members become segregated into homogenous subgroups that are not exposed to one another. Diversity in itself can be a challenge for team communication, and breeds conflict, without organizational networks to turn it into an asset (Guillaume et al. 2017; Paulus et al. 2019). Strong, open ties make it more likely that team members contrast their diverse experiences, and consider possible syntheses (Lu, Akinola, and Mason 2017).

Network tension leads to innovation at the team level when opportunities stemming from strong, open triads become translated into an innovative collective product. There might be various mechanisms by which the translation from the triadic to the team level can take place (as a group beyond a trio might have a number of connected triads of various structures). We consider two mechanisms here: one in which the relative frequency of tension triads (relative number to all connected triads) leads to collective innovation and one in which the strength of tension triads (strength relative to closed triads) leads to collective innovation.

Tension as frequency captures a threshold process, where the number of distinct opportunities to innovate is what counts. In each strong, open triad, there is a probability that members will recognize a chance for a novel combination, another probability that members will find that combination viable and take to experiment with it. Then there is a probability that the new combination will, in fact, be acceptable as part of the final collective product. When there are more strong, open triads, there is a higher probability that at least one of them can contribute novelty towards the group product.

Tension as strength captures another threshold mechanism within the strong, open triad that depends on the strength of ties in the triad. When the ties in an open triad are stronger, the length of history in the connected edges of the triad is longer. This means that the tacit knowledge in the two overlapping practices (as depicted on panel "b" in Figure 1) are elaborate. When such elaborate practices come to overlap, there might be a higher probability for profound novelty: a combination that re-orients the way team members are thinking. When we think of tension as strength, instead of the number of opportunities, we consider the profoundness of opportunities to innovate.

The key hypotheses that we test are, first, that jazz sessions with higher tension (measured as either frequency or strength) will be more likely to *succeed in any form* of success, keeping brokerage (and other factors) constant. Second, we will test that jazz sessions with higher tension (measured as either relative frequency and strength) will be more likely to *achieve deep success*, keeping brokerage (and other factors) constant.

Strong and open triads are often described as exceptional and rare (Aral and Van Alstyne 2011; Fararo 1983; Granovetter 1973, 1983; Tutić and Wiese 2015), but the definition of rare in this respect is never operationalized. Thus, we propose to add unexpectedness to the definition of network tension and explicitly quantify the unexpectedness of network tension. In complex graphs, the null hypothesis is also complex and requires numerical simulations. The most widespread solution is the configuration model: a set of random graphs with a fixed degree sequence, that matches the observed graph (Bender and Canfield 1978; Molloy and Reed 1995). We test the hypothesis that the tension of jazz sessions, on average, is higher than expected compared to a prediction from a configuration random graph model.

We will also test hypotheses that sessions with unexpected tension (measured as either relative frequency or strength) will be more likely to succeed. While we do not have systematic data about how jazz musicians organize tension (as opposed to just find themselves in networks of tension by chance), reliance on a computational null hypothesis is our second-best option. We rely on similar efforts, for example, when others in pooled time series approaches measured the relative strength of a structure to the maximal expectation given by marginals (Wachs et al. 2019). The closest effort in the context of creative teams is of Uzzi and co-authors' who demonstrated that unexpected patterns of combinations lead to success (Uzzi et al. 2013). In sum, this approach allows us to measure the impact of the unexpected nature of tension structures for each team, compared to an expectation from the configuration model.

COLLABORATION AND DEEP SUCCESS IN JAZZ

Our empirical context is jazz: a creative field that had been studied before to understand how collaboration yields novelty (Ake 2002; Doffman 2011; Dowd and Pinheiro 2013; Phillips 2013). Jazz is a strategic field, because the product—a studio recording—is a highly synergistic and detailed record of collaboration, enabling us to formulate valid propositions about the link between the contribution of team members and success. A jazz recording is a faithful record of all the notes played by all team members, and thus each musician can make or break the performance (Faulkner and Becker 2009). There are typically no overdubs in jazz sessions: the quality of play mostly depends on skillful co-improvisation with diverse partners (Berliner 1994). Jazz is also a good case as sessions happen frequently, leaving fine-grained data about the frequency of collaborations and success.

Musical experience develops in collaborative ties, and as musicians play repeatedly *with* one another, they are refining a distinctive way of playing *off of* each other (Dowd and Pinheiro 2013). Musicians build up their skills playing their part in diverse session settings, as one experienced base player points out: "…the only reason we are able to do it is because we all have enough experience under our belts playing a lot of different kinds of things as sidemen, and we're bringing, without even thinking about it, we are bringing all that information to the bandstand…" (Dockery 2013:801).

We only consider co-recording as a form of collaboration and network tie, and do not have data about other forms of ties, as for example friendship, kinship, neighborhood, school, casual co-play, communication, or simple awareness. Partly, because systematic data on such ephemeral ties is not available, and partly because co-recording represents a significant collaborative endeavor with high stakes, that is much less true about other forms of ties mentioned above. In this we follow the analytical strategy of prior works on jazz (Kirschbaum and Ribeiro 2016; Phillips 2011; Phillips and Owens 2004), musicals (Uzzi and Spiro 2005), video games (De Vaan et al. 2015), or film (Cattani and Ferriani 2008; Soda et al. 2021). This means that a missing tie is a missing co-recording tie, and not a complete lack of awareness in our dataset. Tension, and the potential to discover new sounds stems from a lack or co-recording history, not from a lack of any awareness and communication[10].

Skillful band leaders compose sessions of both individuals and collaborative ties, with at least as much attention as they would devote to composing the music. Miles Davis was a bandleader who strived to channel the experience of musicians towards new expressions (Walser 1993), by removing them from their comfort zones:

> "See, if you put a musician in a place where he has to do something different from what he does all the time, [...] he'll be freer, will expect things differently, will anticipate and know something different is coming down. I've always told the musicians in my band to play what they know and then play above that. Because then anything can happen, and that's where great art and music happens." (Davis and Troupe 1989:220)

To a large extent, the dislocation Miles Davis was after was relational: he was composing sessions out of unexpected constellations of pair-wise playing experiences. The most successful session of Miles Davis is an excellent illustration—the session on March 2, 1959 that was released on the album "Kind of Blue." Miles brought on board a new piano player, Wynton Kelly. Even though Kelly played only one tune on the album, "Freddie Freeloader", Miles acknowledged his special contribution to the freshness of the music: "Wynton's the light for a cigarette. He lights the fire and he keeps it going."[11] But Kelly was neither a novice, nor a newcomer to the musicians in the session. Considering the number of prior co-plays as a proxy for dyadic experience, we see that Kelly recorded with Chambers and Cobb more than ten times, but never with Miles. Miles recorded several times with Chambers and Cobb, so the triads of Miles-Chambers-Kelly, and Miles-Cobb-Kelly combines long but distinct dyadic experiences.

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[10] For those of us familiar with academic collaboration, it is probably clear that it is quite different to experience collaborating with a colleague when writing a paper together, and being aware of a colleague by meeting at a conference.

[11] Liner notes by Nat Hentoff from Wynton Kelly's 1960 album "Kelly At Midnight" (https://jazzprofiles.blogspot.com/2019/10/wynton-kelly-1931-1971-pure-spirit.html).

Jazz is also a strategic field to understand success. Success in music is often measured by prestige (Fraiberger et al. 2018), number of recordings (Phillips 2011; Vedres 2017), or chart position (Askin and Mauskapf 2017). However, as prior works on artistic consecration had suggested (Allen and Lincoln 2004; Cattani, Ferriani, and Allison 2014), musicians need to excel along more than one dimension of success, and using just one metric would not capture truly outstanding performances. We refer to deep success as success that transcends dimensions, proving excellence in the eyes of varied audiences, and success by diverse mechanisms of succeeding. To find the relevant measures of success that would provide us with sufficient diversity, we need to understand how artists succeed.

Considering publics, success in art is of a dual nature: one can work towards recognition in the eyes of insiders and peers or strive to please outsider audiences (Bourdieu 1996; Cattani et al. 2014). The sociology of art has long recognized differences of sophistication in tastes (Hume 2015) and the diversity of roles in art worlds (Becker 1982), ranging from protagonists on the inside to the audience on the outside. The case of smooth jazz illustrates this point: performers in this sub-genre achieved popular and financial success, but were derided by critics as palatable, diluted, anodyne, or sellout (West 2008). Jazz scholars would dismiss this genre as elevator music, a vehicle to access a wider body of listeners who would never listen to jazz proper (Giddins and DeVeaux 2009).

The distinction of insiders and outsiders is about a difference in stakes and motivations: insiders are invested in a role structure and thus attributing success to others impacts their standing as well (Bourdieu and Johnson 1993; Cattani et al. 2014). The by-product of art fields is a status system (Podolny 2008; White 2002), with critics playing a crucial role (White and White 1993).

Beyond the distinction of insiders and outsiders, we need to take another distinction into account about the mechanism through which success is conferred: the duality of voice and trace. Art is an arena where opinions about quality, style, worth, and the nature of jazz itself are voiced and debated (Emirbayer and Sheller 1999). Awards, critical acclaim, or polls are forms of success by voice. But success in art can also be accumulated from traces that actions of others leave behind, not with the intention of conferring success on an artist: declarative, and nondeclarative aspects of consuming culture are two distinct paths to success for producers (Lizardo 2017). Audiences typically vote with their feet and wallets, and the aggregated traces of their decisions become a measure of success for the artist.

Works on the duality of art tend to conflate the insider-outsider distinction with the voice-trace distinction: insiders have a voice, outsiders leave traces. We take into account the voice of outsiders, and the traces of insiders as well (Cattani et al. 2014; Fabiani 2003). Deep success is when the same session achieves multiple kinds of success, at the pinnacle of accumulating both voice and trace success from both insiders and outsiders.

DATA AND METHODS

We collected data from the Tom Lord Discography (Lord 2010), arguably the most comprehensive data source on jazz (Charry 2005). The Tom Lord Discography is a database of recording sessions, offering data on the date of a session, the tracks recorded, the musicians present, the instruments musicians played, and the catalog numbers of recordings that contain material from the session. We used all the data available on sessions, starting from the very first vax cylinder recording sessions from 1896, all the way to sessions in digital studios in 2010. Our primary data table is a tripartite graph of sessions, musicians, and instruments, while we also use a session table with record catalog numbers and dates. The resulting dataset contains entries on recording sessions, band leaders (or band names), and musicians playing instruments. The original data tables yielded a multipartite graph that we collapse into a musician-to-musician graph. We analyze the frequency of collaborations, the count of all sessions two musicians collaborated in the past[12]. Moving from the tripartite graph to a one-mode projection, the weighted collaborative network among musicians for a given session was generated by summing the prior co-plays for each musician dyads. Thus we define a weighted collaborative tie between two jazz musicians as the total number of sessions they have played together in the past. To ensure strict temporal ordering, we only include sessions that certainly predated the focal session: For each session we compute the number of prior session-plays up to and including the preceding year in which the session was recorded. For example, in the case of the "Kind of Blue" session of Miles Davis recorded on March 2, 1959, we include a collaboration tie between Paul Chambers and John Coltrane with the strength of 35, meaning that Paul Chambers and John Coltrane had played in 35 recording sessions together from the start of their careers up to 31st of December 1958 (the end of the preceding year).

MEASURING TENSION

Since imbalance can only arise in connected triads (triads where none of the three nodes are isolates), we restrict our measurement of tension to these. We use two measures to classify connected triad types: minimal triplet legs weight and weakest edge connectedness. Triplet legs are the two stronger edges in the connected triad, $w_{(3)}$ and $w_{(2)}$, the third (that is, the strongest) and the second strongest edge weights in ascending order of triad edge weights. (The subscripted parenthesized numbers indicate the ascending order statistic for edge weights in the triad.) Minimal triplet legs weight is $w_{(2)}$, the second weight in ascending order, that captures the strength of the triad edges, independently of closure.

[12] Measuring jazz collaborations as a one-mode projection did mean losing information from the original, multi-mode data. We nevertheless think this strategic loss of detail (Healy 2017) is justified as a gain in validity, as it allows us to focus on the extent of dyadic experience, and provides sufficient structural variation in the resulting weighted graphs.

In a weak, open triad $\tau_{\Omega w}$, the weakest edge $w_{(1)} = 0$ (hence the triad is open), and the other two connected edges are weak ties. To distinguish weak ties from strong, we use a threshold t, below which ties are weak, and at and above which ties are strong. (We test robustness of our findings to altering this threshold in Table S9 in our Supplement.) In other words, $w_{(2)} < t$, in an open triad the minimal legs weight is smaller than threshold t, again, if this threshold separates weak ties from strong ties. A closed triad τ_{Δ} has three connected edges regardless of tie weight. And finally, a strong and open (tension) triad τ_{so} is open in the sense that $w_{(1)} = 0$, but the minimal legs weight $w_{(2)} \geq t$, hence the two connected edges are both strong ties (both stronger than t). Thus the definition of a strong open triad is:

$$\tau_{so} = \begin{cases} 1 & if \quad w_{(2)} \geq t \quad \& \quad w_{(1)} = 0 \\ 0 & otherwise. \end{cases} \tag{1}$$

Figures 2 (and Figure S1 in our Supplement) shows strong and open triads in the "Kind of Blue" session of Miles Davis. While the session featured highly experienced musicians (with no novices), the significance of including Wynton Kelly was clearly recognized by David himself as well: he was participating two strong and open triads.

Figure 2 about here

Since our argument is about graph level (that is, team level) network tension, we need to aggregate strong and open triads to the whole graph. Our first graph level tension measure is *Tension as frequency*:

$$T_{fre} = \frac{\sum \tau_{so}}{\sum \tau}, \tag{2}$$

where τ denotes connected triads, and the measure ranges from zero (no strong, open triads) to one (all triads are strong, open).

The assumption behind this measure is that what matters for collective success is the relative frequency of strong, open triads: the frequency of creative opportunities. In our context of jazz, the more strong and open triads a jazz session has, the more opportunities musicians have to discover and synthesize interesting combinations of dyadic styles. This measure depends only on the t threshold for a strong tie. (In auxiliary analyses (Supplementary information, Table S9), we test the robustness of our findings to varying t thresholds.)

We develop a second measure to capture *Tension as strength*. This measure is the sum of geometric means of relative edge weights in open triads, normalized by the number of open triads. Our measure follows the same considerations that underlie the development of weighted clustering coefficients, where the geometric mean of relative edge weights is used, as it is more robust to extreme weight values (Onnela et al. 2005; Opsahl and Panzarasa 2009; Saramäki et al. 2007). Following the logic of how weighted clustering coefficients are calculated, we first calculate relative edge weights by dividing each weight by the maximum weight, $\widehat{w}_{ij} = w_{ij}/\max(w)$. We then calculate the geometric mean of weights in open triads, $\widehat{w}_{\Omega} = (\widehat{w}_{(2)}\widehat{w}_{(3)})^{1/2}$, for the two non-zero weight edges. The measure of *tension as strength* is then calculated by the following formula:

$$T_{str} = \begin{cases} \frac{\sum_{\tau_\Omega} \widehat{w}_\Omega}{\sum \tau_\Omega} & if \quad T_{fre} > 0 \\ 0 \quad otherwise. \end{cases} \tag{3}$$

This measure captures the weight in strong, open triads independently of the proportion of such triads. T_{fre} is set to zero for full graphs where T_{fre} = 0, and T_{fre} is not applicable for graphs with no connected triads. The measure ranges from zero, with no weight in open triads, to one, with all open triads having ties that have the maximal tie weight in the graph.

The assumption behind this measure is that it is not the number of tension triads that counts, but the strength of them. When an open triad has high weights, it means that the triad is composed of high-weight dyads—pairs of nodes with an exceptionally long history of experience that now meets in a triad. Juxtaposing these long dyadic experiences can then lead to more striking, novel combinations.

This measure is also normalized by the highest tie weight in the session, making the strength of the collaborative experiences relative. The assumption behind this is that combining diverse experiences needs to compete with well-rehearsed conventions in closed triads. A strength coefficient of 0.5 suggests that there is at least one closed triad with a tie weight that is twice as high as the weight in an open triad, regardless of the absolute tie weight.

We contrast our two mean measures of network tension with brokerage, as most arguments that link structural diversity with innovation build from mechanisms of brokerage (Schowalter et al. 2020). Starting from the measure of node level constraint, as proposed initially by Ronald Burt (Burt 1995), using the unweighted topology in a session network (Bruggeman 2006). We aggregate node level constraint to a graph level brokerage measure in the following way:

$$B = 1 - \mathrm{Min}(C_i), \tag{4}$$

where C_i is node level constraint. This measure ranges between zero and one, where zero is a network with all nodes being fully constrained (thus, the network offers no potential for brokerage), and one is a network where there is one node with zero constraints. Node level constraint can only approximate zero for the center of large star graphs, so one is only a theoretical maximum.

Our measure of brokerage is different from typical prior usage that uses brokerage to capture external network benefits (Burt 1992, 2001, 2004), rather than within-group benefits of orchestration (Dhanaraj and Parkhe 2006; Nambisan and Sawhney 2011; Paquin and Howard-Grenville 2013). For us, brokerage is a crucial control variable, that captures an alternative explanation to creative tension, where open ties are tools for control in the hands of a central musical leader, and this structural leadership capability is the cause of subsequent group success.

DEPENDENT VARIABLES OF SUCCESS

We use six dependent variables to reflect the dual nature of success and ensure to have at least one representing each quadrant in Table 1.

Table 1 about here

Two variables measure the explicit evaluation of success by insiders. The first is the *NEA award.* Every year since 1982, the National Endowment for the Arts (NEA) honors outstanding jazz musicians with its "Jazz Masters Fellowship" award[13], recognizing outstanding artistic achievements over the entire career. We code this variable as 1 for all sessions that predated the award for an awarded artist, and we drop subsequent sessions. Thus, the variable captures sessions of a band that will be awarded, in line with the retrospective nature of this recognition.

The second indicator of success evaluated by insiders is the *Critics' Poll.* One of the leading and longest-running jazz magazines, the DownBeat magazine, announces winners of its critics poll since 1961. They ask jazz critics in several categories each year to name outstanding artists. The most prestigious category is the "Hall of Fame[14]", which honors the most outstanding artists in that year overall. Again, we code this measure as 1 for all sessions that predated being named in the poll for the first time, and drop subsequent sessions.

We use one variable to indicate explicit judgment by outsiders: results from *Readers' Poll* surveys. Besides polling jazz critics, DownBeat Magazine also surveys its readers each year, for votes to name "Hall of Fame[15]" members. The award dates back earlier than the Critics'

[13] The most recent NEA Jazz Masters Fellowship nominations at the time of writing was 2019, available here: https://www.arts.gov/honors/jazz.
[14] The most recent Hall of Fame from the Critics' Poll at DownBeat Magazine at the time of writing was the 2019 results, available here: https://downbeat.com/digitaledition/2019/DB1908_critics_poll/_art/DB1908.pdf.
[15] The most recent Hall of Fame from the Readers' Poll at DownBeat Magazine at the time of writing was the 2019 results, available here: https://downbeat.com/digitaledition/2019/DB1912_Readers_Poll/_art/DB1912.pdf

Poll, back to 1952. Voters do not need to be subscribers to DownBeat, thus the survey represents wide audience opinion. Just as with the *NEA Award* and the *Critics' Poll*, we code this measure to be equal to 1 for all sessions that predate the poll win and drop subsequent sessions.

Besides explicit judgment, we can follow behavioral traces of insiders and outsiders to measure the success of a session. *Book mentions* indicate the decision by editors and authors to mention sessions in canonical jazz textbooks. We create an indicator variable to signal whether a book on jazz history (see Appendix A for full details) explicitly mentions a jazz session in an unambiguous way. Instead of recording the total number of mentions, we only indicate the presence of any book mentions (=1) versus no book mentions, as only a few (199) sessions appear more than once, and hence the count variable is highly skewed.

Survival is the most elementary trace of success. It indicates willingness of a set of band members to continue recording under the same band name. We measure the end of a band's career indirectly: We use recording histories from bands that had at least two sessions and code the last observed session as 1. We also calculate a "clock" variable to indicate the time passed (in days) since the first recorded session in a given band's history. We use the exact date of the sessions to calculate this measure. Where multiple sessions took place on the same day (27% of sessions), we randomize the order of those sessions. We repeated this process several times to ensure consistency of our results.

Finally, we use a variable to indicate the behavioral traces of outsiders: *Releases* captures the behavior of record companies in response to audience demand by releasing recordings repeatedly. As the probability of seeing an additional release is proportional to the time passed since recording, we normalize release counts by the number of decades passed since recording. For its skewness, we use the logarithmically transformed version of this variable in subsequent analyses.

Besides the six dependent variables, we also define *Deep success*: the total number of dimensions in which a session was successful. To calculate this variable, we transform all dependent variables to the same scale. Since the majority of our dependent variables are binary, we transformed our variables *Releases* and *Survival* to the same binary scale. For *Releases*, we record sessions with releases in the top five percentile as 1, and the bottom 95 percentile as 0. For survival, we switch the reference category and assign a 0 to the last session of the band, and we assign 1 to sessions that were not the last. We excluded canonical book mentions from the definition of *Deep success*, because it would have imposed an unnecessarily strict time frame to our models, and a loss of the majority of our observations[16]. We calculated deep success by summing up the binary versions of our success measures for each session, thus this variable ranges from 0 (no success along any of our measures) to 5 (success along all dimensions).

CONTROLS

Network size is a factor to consider as the most crucial structural determinant. A larger network – a session with more musicians – has more triads, and by chance can have more tension triads as well. At the same time a larger band can be more successful, as there are more musicians that can attract critical attention. This could render the relationship between tension and success spurious, so we control for the *Number of musicians in the session* in all models.

Musician experience measured by the number of recording sessions a musician had been part of can predict both tension and success. Tension triads are by definition composed of edges that represent a high number of past sessions (while weak open triads or closed triads can be composed of fewer past sessions). A larger number of past sessions can be also a

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[16] See Samples and Methods section for the details of the book mention models.

predictor of success, so we need to control for experience. We measure experience as *Session tenure* that sums the total number of unique past sessions musicians had played in:

$$T_S = \sum_{m=1}^{M} \sum_{i=1}^{S} [\![m \in s_i]\!] : s_i \in S, \tag{5}$$

where *S* are sessions that had taken place before our focal sessions (up to the preceding year), and *M* are the set of musicians in the focal session. We decided to use the sum, as session with less than four total past plays have structural zeros for both tension variables (and thus these sessions are filtered from our analysis). An alternative is to use the mean (Soda et al. 2021), which we also tested, and found not to alter any of our results.

The weight of ties in dyads might serve as an alternative explanation to tension: it is conceivable that what predicts success is the strength of connections among musicians, regardless of the triadic pattern of these connections. Tension requires high weight edges, and success might also be a function of high weight edges, rendering the association between tension and success spurious. We thus include an overall measure for the weight of ties as the median of weights in the graph of the focal session:

$$W_M = \text{Median}\left[A_{i,j}\right] \, whenever \; i \neq j, \tag{6}$$

where *A* is the weighted adjacency matrix of the focal session, recording the number of co-plays between musicians *i* and *j*, excluding the diagonal.

A track record of past success can be a predictor of both session success, and also tension in the band. Past success helps musicians to follow proven recipes. Musicians can be noted for the or past success and be invited to a session even if they have not played with some of the band members before, thus resulting in tension triads. We control for past success by taking each past session that musicians on our focal session had played on, recording the number of additional releases (a sign of demand for the recording). We define our measure *Release history* as a binary indicator, that equals one if the median number of additional releases on past sessions is greater than zero:

$$R = [\![\text{Median}[r_S] > 0]\!] \,, \tag{7}$$

where r_S is the (integer) number of additional recordings on past sessions for our musicians. This measure might seem convoluted, but we intended to minimize the risk that we violate the temporal ordering of independent and dependent variables. Unfortunately, we have no information about the issue date of additional releases, and it is conceivable that preceding recordings of musicians are becoming successful after the success of the focal session. Thus to minimize the risk of violating time ordering, we only record the fact that there were past sessions that had seen at least one additional release.

Finally, the instruments the band plays can differentiate them from others, and might contribute to their success via a unique sound (Phillips 2013). It is conceivable that it is such a distinctive instrumentation what predicts success, while it is also positively correlated with tension. Inviting a player with an instrument not often paired with the instruments other band members are playing might also mean inviting a musician not connected to many band members by past co-plays, thus we need to control for *Distinctiveness of instrument combinations*. We accomplish this by first calculating the cosine distance d_{ij} of a focal session, *i*'s instrument vector to all other sessions (*j*) in a preceding five-year window[17]:

$$d_{ij} = 1 - \left[\sum_{k=1}^{K} f_{ik} f_{jk} / \left(\sum_{k=1}^{K} {f_{ik}}^2\right)^{1/2} \left(\sum_{k=1}^{K} {f_{jk}}^2\right)^{1/2}\right], \tag{8}$$

where function f_{ik} equals 1/*K* if instrument *k* is used in session *i* (and *K* equals the total number of instruments used in the session) and 0 otherwise. Cosine distance has been used to capture similarity between stylistic elements in creative fields, without penalizing differences in the number of elements (here instruments) used (De Vaan et al. 2015). For each session we record a vector of cosine distances to all other sessions in a preceding five-year window. Our final

[17] We decided to use five years, as the overall style of instrumentation is constantly shifting in jazz, and comparing the instrumentation of a session to old recordings would not capture distinctiveness, but rather the overall evolution of the field. We did test the robustness of our measure to altering this time window, and found that it did not influence coefficients of tension.

variable of *Distinctiveness of instrument combinations* is the average of these distances for our focal session *i*:

$$D_i = \sum_{j=1, j \neq i}^{N} d_{ij} / N. \tag{9}$$

SAMPLES AND METHODS

Although we had information on the entire history of recorded jazz, which included 158,537 recording sessions and 34,251 band leaders, the features of the empirical context and methodological considerations required slightly different samples for each of the six dependent variables of interest. (Please see Table S1 in our Supplement to follow a detailed account of how we filtered observations.)

To estimate winning the NEA, Critics' Poll, Readers' Poll awards, and book mentions, we fit maximum likelihood models with a logistic function to predict recognitions of sessions. Even though bands receive awards and poll nominations for their careers, we kept recorded sessions as the unit of analysis as we measure tension at the session level. To ensure the temporal ordering of independent and dependent variables, we only used sessions up to the year preceding the award, for those bands that received the award. In auxiliary analyses, however, we ran models at the band career level, and report them in our supplement (Table S2, Model 3 and 6 for NEA Award; Table S3, Model 3 and 6 for Critics' Poll; Table S4, Model 3 and 6 for Readers' Poll). In these auxiliary models, we summarized network tension by calculating its mean throughout the band's career (again, excluding the year of award and following years for awarded bands). As this exercise significantly shrinks variation on the dependent variables, we used penalized likelihood logistic regression to correct for the rare events bias (King and Zeng 2001).

The sample sizes of the maximum likelihood models varied across specifications, as we excluded sessions of a band that took place after they received the award for in the NEA, Critics' Poll, and Readers' poll models. For the book mention models, we only used sessions between 1940 and 1970. We omitted early sessions to have reasonable overlap across books in the period discussed. We also excluded later sessions as the books we collected were published over a wide range of dates, and books reviewing the history of jazz tended to vary more in their discussion of recent sessions. We restricted all these models to sessions with at least 4 past sessions across all musicians to avoid clear structural zeros in our tension measures. In a session with less than 4 prior sessions, it is impossible to observe a strong and open triad. We also omitted sessions with three and fewer musicians, as these have only one, or less than one triad. As a result, the sample size for the NEA models is 61,984, for the Critics' Poll models is 61,592, for the Readers' Poll models is 61,713, and for the book mention models is 20,281.

We chose a different model specification to estimate survival. We estimate semi-parametric piece-wise exponential models with a continuous rate of band survival. To make the baseline relationship between survival and band career-length flexible, we include time pieces in our models for career stages. The cut-points divide up survival time to early, mid, and late careers, where we assume the baseline hazard to be constant. Unlike other models, we used the full range of event histories of bands that had at least two recorded sessions (so we can define time from the first event until failure or censoring). We included a dummy variable, *missing,* for sessions in which tension and brokerage variables were structural zero. The resulting sample comprises 85,340 observations.

Our strategy to study the association between releases and success was the following. We fit linear models to predict the logarithmically transformed version of this measure (releases per decade). Our dataset spans the years between 1896 and 2000, leaving a ten-year window (2000 to 2010) to mitigate the effect of right censoring for the relatively recent sessions. As with other models, we restrict the sample to sessions with sufficient history (four prior sessions) to avoid structural zeros in tension measures. Out of the six dependent variables, the number of releases was the only measure with missing values: 1.5% of the release variables were missing. As it is customary to not use imputation techniques on missing dependent variables, we had no option but to use list-wise deletion on these cases (Allison 2009). Our regressions to model releases include band fixed-effects, as we can assume unobserved heterogeneity in releases at the band level. It means that an album from Miles Davis will be more likely to be re-released, regardless of the network tension in the session, compared to a relatively unknown jazz band. The final sample size of the release model was 61,300.

Finally, to model *Deep success*, we used an ordinal logit model, to predict stepping up in the levels of success., while we tested robustness to specification by using an OLS specification directly with the ordinal dependent variable. The sample size for this model was 54,418. Full models for all specifications for all dependent variables are available in our Supplement, tables S2 to S8.

RANDOM JAZZ WORLDS

To estimate null hypothesis expectations for the frequency of tension structures in general, and to calculate expectations for structural availability of tension structures for each session, we generated 100 random jazz worlds by rewiring the observed tripartite dataset (of sessions, musicians, and instruments). Importantly, we generated rewirings at the original tripartite graph level, and not at the projected one-mode (musician-to-musician) level graph. We did so to follow the principle of objective possibility: We were re-allocating musicians to sessions in a way that could have happened in real life (with, albeit, a small probability), and avoided composing sessions that were not possible according to available evidence. In other words, we were generating jazz worlds with synthetic sessions that the recording companies could have recorded.

The first principle for rewiring was to preserve the number of musicians in the session. Second, we kept the number of sessions a musician played within a window of one year. If a trumpet player recorded five times in the year when the session happened, we allocated that player to five sessions in the rewired jazz world over that one-year period. We were also using 2, 5, and 10-year windows, but the one year window is the closest to the logic of the jazz field, and it is also the strictest in the availability of musicians. Third, we preserved the instrument combination of the session, as the recorded material would have been different without the same instruments. Finally, we were only allocating musicians to a session to fill an instrument slot if they played the instrument over the current and previous year. Musicians often play multiple instruments, and it makes a considerable difference if a musician has played the instrument in question only a decade in the past.

RESULTS

Musician careers are, on average, short: they take part in an average of 6.94 sessions during their careers, but this central tendency masks the general positive skewness of the distribution. Musicians also play in different bands. Table 2 shows descriptive statistics of our variables based on the population data with sessions as the unit of analysis. (Further details with a full scatterplot matrix of all variables is available in our Supplement on Figure S2.) A cursory look at the averages overlooks important differences in variations between bands across the number of musicians, session tenure, median co-plays, and release history. Success—reported in the last seven rows—while still heterogeneous in its variability, is a rare event on average. As for the team network measures, tension is rare, while brokerage and closed triads are common.

Table 2 about here

Table 3 about here

As there is a high risk of cross-correlation between network measures due to the obvious violation of the independence of observations assumption, we computed bivariate correlations among the focal independent variables and controls (Table 3). We find that multicollinearity in the variable set was not of concern, apart from the .83 correlation between the two variables measuring tension. (We will not enter these two variables together into our statistical models.) The maximal VIF in the variable set otherwise (not entering the two tension variables together) was 1.29.

The correlation coefficients among the original six dependent variables of innovative performance are low (here the maximum is .31). This confirms our expectation that bands in jazz can succeed in diverse, unrelated ways. Deep success—when bands succeed along multiple dimensions—is indeed a significant and non-trivial achievement. The bivariate correlations between tension variables and success are all positive (keeping in mind that *Band failure* is recording the absence of success, which negatively relates to tension).

TENSION IN OBSERVED AND RANDOM JAZZ WORLDS

To chart the distribution of sessions by the prevalence of triad types, we use ternary plots (Figure 3). A ternary plot is a specialized multi-dimensional histogram suitable when three variables add up to a constant (Wickham 2009). The way we measured it, strong open, weak open, and closed triads add up to unity. To read the composition of session networks represented by each hexagon, locate one number on each side that is angled in a way that its extension line reaches the hexagon. For example, in Figure 3 panel (b), sessions that belong to a dark shaded hexagon in the middle of the triangle (highlighted by a red hexagon outline), are composed of 0.2 open triads, 0.5 closed triads and 0.3 weak, open triads. You can read this by following the red reference lines: for example, a horizontal line from 0.3 on the right side indicates 0.3 of the triads are strong and open. The darkness of the shade represents the probability density (relative frequency) of sessions, measured on a log scale.

Figure 3 about here

Figure 3, panel (a) represents a hypothetical "Granovetterian" world, in which only two kinds of triads exist: weak open triads, and closed triads. We created this counterfactual figure by re-classifying strong, open triads as weak, open triads. In this case, we would observe all our session networks on the bottom of the triangle where only the number of weak open and closed triads changes, but the number of strong, open triads stays zero. Compared to this scenario expected by the dominant thinking about network structure, observed data charted on panel (b) shows that strong, open triads are a non-trivial ingredient. Admittedly, there are many sessions with only one kind of network element (the triangle's corners): 67.4% of all sessions feature only closed triads, 11.3% of sessions have only weak open triads, and 3.4% of sessions feature only strong, open triads. Networks with only closed triads are sessions where all pairs of musicians have played together at least once in the past. Moving away from the three corners of Figure 3, panel (b), there are 17.8% of sessions combining various kinds of triads. About two-thirds of these, 11.8% of all sessions, contain strong, open triads.

As we have seen above, jazz session networks are closed on average. This tendency of network closure leaves only one-third of the sessions where any strong, open triads (any form of network tension) can be observed. As we have seen, 11.8% of all sessions—and about a third of all sessions that are not entirely composed of closed triads—feature tension structures. To evaluate whether this is very little, just about expected, or many more than expected, we would need a basis of comparison: a null hypothesis. We will use our counterfactual random jazz worlds as a baseline.

Figure 3, panel (c) shows how observed proportions of strong, open triads relate to expected proportions. On this panel (c), we chart Z-scores as opposed to relative frequency. The color coding of hexagons on the plot range from dark blue (highly negative Z score where sessions have fewer than expected strong, open triads) to dark red (highly positive Z score where sessions have more than expected strong, open triads). If strong and open triads were merely a product of the marginals (number of musicians and their availability to play, and the instrument combination in the session), then this triangle would be filled with white hexagons, where all sessions have a Z-score close to zero. This is not the case, and especially higher proportions of strong, open triads are above the baseline expectation: the upper part of Figure 3 panel (c) shows many red hexagons.

To test the hypothesis that the tension of jazz sessions, in general, is higher than expected compared to a prediction from a configuration random graph model, we move to consider triads as units of analysis. We used data on 5,338,093 observed triads (the full population of connected triads) and added a matching uniform random sample without replacement of another 5,338,093 connected triads from our random jazz worlds (that altogether had 89,327,277 connected triads). With the dataset of 10,676,186 triads, we computed a logistic regression model, where the dependent variable is a closed triad (*y*=1), as opposed to an open triad (*y*=0). The independent variables are: first, the triad belongs to the observed triads ($x_o = 1$), as opposed to the rewired (random jazz world) triads ($x_o = 0$), second, a variable recording the minimal triplet legs weight (x_w), and third, the interaction between the observed triad indicator and minimal triplet legs weight ($x_o * x_w$). The logistic regression equation we identified was:

$$\ln \frac{\mathrm{P(y=1|X)}}{1-\mathrm{P(y=1|X)}} = -2.98 + 2.71 * \mathrm{x_o} + 1.10 * \mathrm{x_w} - .64 * (\mathrm{x_o x_w}), \tag{10}$$

where all coefficients were statistically significant (at p<.00001), using a permutation test to estimate coefficient standard errors.

Figure 4 about here

Figure 4 visualizes the relationship we found between triplet legs weight (the strength of edges in the triad) and closure. We charted model predictions for observed jazz triads and simulated jazz triads separately. First, observed jazz triads have a higher baseline probability of closure. This is hardly surprising, as random jazz worlds have no bias to repeat collaborations present in real jazz sessions. Observed sessions are often in the context of jazz bands that repeat collaborations of the same musicians. Observed sessions are also geographically and stylistically bounded—again increasing the probability of repeated collaborations of three or more musicians. Second, as triplet legs weight increases, the probability of closure increases slower in observed jazz triads, compared with the random expectation. Thus, jazz musicians have a tendency to tolerate openness, to tolerate tension triads (strong, open triads) above and beyond of what is expected by the null hypothesis.

NETWORK TENSION AND SUCCESS

For all seven dependent variables (six forms of success, and their combination, *Deep success*), we present two models, entering each of our two focal independent variables: *Tension as frequency* and *Tension as strength*. In these models we also enter our variable for *Brokerage*, and controls to account for alternative mechanisms that might render our tension coefficients spurious. Table 4 summarizes our results. To provide a manageable overview, we omit coefficients for control variables. (Full model tables are available in the Supplement.) Detailed model tables, and alternative specifications are available in our Supplement (tables S2 to S8).

Insider voice. We used two measures of indicators of insider voice: receiving an NEA Award (Table 4 Column I) and winning the DownBeat Magazine Critics' Poll (Table 4 Column II). Both network tension frequency and strength raise the odds of receiving the NEA award even after accounting for individual and dyad-level mechanisms that contribute to innovative performance (models I.1 and I.2). Similarly, both tension measures are statistically significant antecedents of winning the Jazz Critics' award (Table 4 Model 3 and 4). Network tension (frequency and strength) thus consistently predict creative success evaluated by industry insiders.

These findings are robust with alternative specifications: our findings hold without entering the brokerage variable (Table S2 Model 2 and 4 in the Supplement for *NEA Award*; Table S3 Model 2 and 4 for *Critics' Poll*). Our tension coefficients are significant and positive when we model at the band level (which is arguably appropriate as awards are given to bands; see Table S2 Model 3 and 6 for *NEA Award*; Table S3 Model 3 and 6 for *Critics' Poll*). Our findings are robust to increasing the threshold t for a strong tie, where $w_{(2)} \geq t$, to 5 with *NEA Award*, and to 3 with *Critics' Poll* (see Table S9 Columns I and II). The findings for both tension variables are highly robust across all 65 combinations of control variables (see panels (a) and (b) on figures S3 and S4 in the Supplement).

Outsider voice. We modeled success measured by the outsider audience by using Readers' Poll results (Table 4 Column III). The frequency of network tension (Table 4 Model 5) raises the odds of a public accolade, while the coefficient for the strength of tension (Table 4 Model 6) is not significant. Once we model at the level of the band, both tension variables are positively and significantly related to Readers' Poll nomination (Table S4, Models 3 and 6 in the Supplement). Recording success evaluated not only by insiders but also by the wider audience seems to be related to tension.

Findings about the odds of a Readers' Poll nomination are robust to modeling at the band level, as already noted above. The positive significant coefficient for *Tension (frequency)* is robust to increasing the threshold t for a strong tie where $w_{(2)} \geq t$, to 5 (see Table S9 Column III). The findings for both tension variables are highly robust across all 65 combinations of control variables (see panel (c) on figures S3 and S4 in the Supplement).

Insider trace. Models of success from behavioral traces of jazz insiders use *Book mentions* (Table 4 Column IV) and band *Survival* (Column V) as dependent variables. The odds of having the session mentioned in canonical books of jazz history increases when network tension structures are more frequent (Table 4 Model 7). While results are similar in sign, the positive relationship between the strength of tension and book mentions is only significant at the .10 level (Model 8). Our piece-wise exponential models indicate survival benefits of network tension (both frequency and strength) (Models 9 and 10). In sum, we find that network tension predicts performance measured by insider behavior.

Findings about book mentions are considerably robust, although less so than all the other models (possibly due to the restricted time range of 1940 to 1970). Our *Tension (frequency)* coefficient is significant in the original model, and in the model entering standardized variables without *Brokerage* (see Table S5 Models 1 and 2). For Tension (strength) coefficients are positive but below the .05 level. We were unable to reproduce results by a zero-inflated negative binomial model directly modeling the number of mentions. When taking all combinations of control variables, we see that for all models both tension variables stay positive, and in about two thirds of the models the coefficient is statistically significant (see panel (d) on figures S3 and S4 in the Supplement).

Our findings about survival are highly robust: alternative specifications with a logit model of survival (Table S6 Models 2 and 5), and proportional hazard models (Table S6 Models 3 and 6) lead to the same conclusions. Taking all combinations of control variables in the logit model, we see that for all models, both tension variables stay positive, and in 86% of the models the coefficient is statistically significant (see panel (e) on figures S3 and S4 in the Supplement).

Table 4 about here

Outsider trace. Beyond considering insider behavioral traces for success, we also measure success by public traces. We use the number of releases, as record companies respond to demand by re-releasing material (Table 4 Column VI). Results from linear models predicting the number of releases (specifically the log number of releases normalized by the number of decades elapsed after the session—on Table 4 models 11 and 12) we replicate a previous finding (Vedres 2017) and show a positive association between release numbers and network tension frequency but not strength. This model includes fixed effects for band, the coefficient shows the impact of tension across sessions of the same band on the number of subsequent releases. This is the only dependent variable where we see a positive significant coefficient for *Brokerage*: sessions where the network structure shows a musician with outstanding structural autonomy can see an advantage in commercial success only.

The finding about the positive impact of *Tension (frequency)* is robust to model specification: we see a positive significant coefficient with a logit model predicting top five percentile release number (Model 2 in Table S7 in the Supplement), and with a zero-inflated negative binomial model predicting the raw number of additional releases (Model 3 in Table S7). The logit specification shows a positive significant coefficient for *Tension (strength)* as well (see Model 5 in Table S7). Taking all combinations of control variables in the logit model version, we see that for 91% of models, both tension variables stay positive, and in 85% of the models, the coefficient is statistically significant (see panel (f) on figures S3 and S4 in the Supplement).

Up to this point, when we review coefficients, we see a rather consistent pattern: Tension is a robust network correlate of success, regardless of which audience evaluates the performance (insiders or outsiders) and which mechanism generates success (voice or trace). These results, however, do not specify whether successful sessions on different measures are the same or different ones, as our separate models do not include coinciding success. Our next step is to see if network tension helps jazz sessions to succeed along multiple dimensions.

Deep success. As our ordinal logit models show, network tension contributes to deep success: Both measures, network tension frequency (Model 13 on Table 4), and strength (Model 14) are positively associated with deep success. The odds of achieving success along an increasing number of dimensions are 1.28–1.31 times larger if we compare sessions with maximal network tension versus sessions with no tension. Network tension, while considerably robust in predicting diverse measures of success one-by-one, is, therefore, also an enabler of coinciding success.

This finding is highly robust to specification: it holds when we switch to an OLS model (Models 3 and 6 in table S8 in the Supplement), and we see a significant positive coefficient when we change the strong tie threshold of *Tension (frequency)* from 2 to 3, 5, or 10 (see Table S9 column VII in the Supplement). Our findings are also perfectly robust to entering any combination of control variables alongside our tension variables (see panel (g) on figures S3 and S4 in the Supplement).

Besides focusing on network tension, all presented models (1–14) test the contribution of within-group brokerage to predict various success measures. Results reveal that brokerage within jazz bands is unlikely to solve the creative dilemma of generating novelty by relying on a network orchestrator to bring out the best from other musicians. In line with expectations that structural diversity within groups is not helpful (Burt 2001), brokerage is almost always negatively associated with innovative performance measures, including deep success. This indicates that productive structural diversity within the team is more about creative tension, rather than opportunities for control and orchestration.

Musician prominence is a key alternative explanation of success, that might render the association between tension and success spurious. While all models include controls for various aspects of musician prominence (*Session tenure, Release history, Brokerage*), we have also tested whether our findings of tension hold when we delete the most prominent artists from our dataset. We replicated our models by deleting all sessions of those artists who have received both National Endowment for the Arts (NEA) "Jazz Masters Fellowship" and the "Critics Poll" award from DownBeat Magazine. This leads to the deletion of 2,191 most prominent jazz recordings – likely the only recordings that an average jazz enthusiast would even recognize. We then re-ran all of our models, and found that there is no change in the explanatory power of tension, brokerage, or closure. These models are included in our Supplement (tables S2 to S8, Models 7 and 8).

EFFECT MAGNITUDES OF NETWORK TENSION

Network tension—both as the frequency and strength of tension triads—is a significant and positive predictor of a diverse battery of success measures, including deep success. But how well does it explain success compared to other network measures? Figure 5 reveals how consistently tension and three other network measures predict success. We designed this graph so we can compare point estimates for five standardized independent variables (columns), each predicting our six distinct measures of success and our composite measure of deep success. To make our estimates comparable we standardize our independent variables to have a mean of zero and standard deviation of one. Also, we now code all dependent variables (except deep success) as binary on the 0-1 scale, to compare magnitudes across models. We use binary logit models for the six original dependent variables, and ordinal logit for the deep success variable. To accomplish this standardization, only two of our six dependent variables, *Survival* and *Releases,* needed to be re-coded. We used 1-*Band failure* to code *Survival,* and coded the new *Releases* variable to be equal one if the session achieved top 5% release numbers, and zero otherwise. On Figure 5 if the 99% confidence interval line does not cross the horizontal line at one, it means that the effect of that independent variable is statistically significant at the p<.01 level at least. If the line is above the horizontal line at one, it means that the specific network measure is positively associated with a specific outcome variable.

The consistency of the positive impact of network tension frequency and strength comes to a sharper contrast if we compare it with other network measures. Results reported in the first two columns re-confirm our previous finding that network tension frequency and strength consistently predict diverse measures of success, including deep success. *Tension (frequency)* is a significant positive predictor of all success measures, most importantly *Deep success*. The only two non-significant estimates for *Tension (strength)* are predicting *Readers' poll* and *Book mentions* – but the point estimate for *Deep success* is significant positive here as well.

Figure 5 about here

Columns 3, 4, and 5 report magnitude models for three other network measures: *Weak open triads (frequency)*, *Closed triads (frequency)*, and *Brokerage*. Although weak, open triads are beneficial for survival, this measure is also a significant negative predictor of *Readers' Poll*. This indicates that it is about the strength, not only the openness of open triads that enables them to generate creative success.

Networks rich in closed ties are negatively associated with most measures of success. Only the coefficients for *Readers' Poll* and *Critics' Poll* nominations are not significantly negative. This finding is in contrast with expectations that within group cohesion helps success (Burt 2001), and brings further support to the hypothesis that groupthink is a real risk in closed networks. Finally, considering brokerage, sessions in which there is a central actor with non-redundant ties—a clear network orchestrator—do not result in successful albums. The *Brokerage* point estimate is negative in most models (except for survival, where is insignificant). This reinforces prior findings that in creative fields where the product requires truly collective work, brokerage is detrimental (Bechky 2006; Ferriani et al. 2009; Jones 1996), and is in line with expectations that within-group brokerage does not predict performance (Burt 2001).

BENEFITS OF UNEXPECTED TENSION

We have seen that network tension is a consistent predictor of success, more so than other network structures of interest. Tension was not tested before for positive effects on success, as imbalanced structures of tension were deemed to be too unlikely and rare to be of any interest. Our main results thus far have not accounted for whether this unlikeliness contributes to success. Specifically, we are interested in separating tension as a lucky accident from tension where we see evidence for a conscious and strategic effort from band members. In this section, we compare our empirical jazz networks to simulated random graphs, as a yardstick for expectable structure. We aim to understand whether network tension (frequency and strength) leads to creative success, depending on whether these structures are more or less likely to occur in the session than in counterpart sessions from 100 random jazz worlds. In doing so, we separate the effects of the agency of the band from lucky accidents that arise from the opportunity structure in the network around the session. We will, however, not be able to determine if the agency is an instantiation of innate instinct, cognitive heuristics, or rational-instrumental action.

Once we generated the random jazz worlds as explained before in our methods section, we took network tension measures from the observed sessions and computed a Z-score measuring the distance of the observed and expected values for each session. We then created new variables for *Tension (frequency)* and *Tension (strength)* each in the same way, to capture unexpectedness, each with three categories:

$$T_{unexp} = \begin{cases} 2 \ \ if \ \ T > 0 \ and \ Z \geq 2 \\ 1 \ \ if \ \ T > 0 \ and \ Z < 2 \\ 0 \ \ otherwise, \end{cases} \tag{11}$$

where T stands for either of our two measures of tension. Our substantive interest is to estimate the difference between values of 2 and 1: between sessions where tension was significantly unlikely (with $Z \geq 2$ there were only about 5% of simulations where we saw tension as large as in the observed session network) and sessions where tension was not significantly different from the expectable ($Z < 2$). Thus, we run models in which we set the value of 1 (sessions where $T > 0 \ and \ Z < 2$) as the reference category, cases in which network tension is the outcome of a lucky structural accident. Coefficients reported in Table 5 under network tension *> 0 and Z>=2*, thus reveal that compared to the reference category what happens to sessions in which concerted organizing effort creates tension.

Table 5 about here

Our findings about the importance of unexpected tension—tension that possibly required some kind of effort to go beyond what the network of jazz musicians readily offered at the time—seem to contribute to success in seven out of the fourteen models that we ran. Unexpected tension seems to be more important for success by voice: success that is reached by a public declaration (award or poll). Of the six models from 1 to 6 on Table 5 that concern success by voice, we see five instances where unexpected tension means a significant advantage over expectable tension. As a comparison, we see only one out of six models that concern success by behavioral trace where unexpected tension seems to be an advantage. (For *Releases* we do even see a significant negative coefficient for unexpected tension.) Considering *Deep success*, the unexpected frequency of tension triads is a strong positive predictor, while the unexpected strength of tension is somewhat below the $p<.05$ level ($p=.10$).

Findings about success by voice (*NEA Award, Critics' Poll, Readers' Poll*) are robust to model specification, when we model at the band level (see Tables S13, S14, S15 in the Supplement).

DISCUSSION AND CONCLUSIONS

What is the role of collaboration in innovation? We started with a paradox of experience: successful teams need to build from the experience of members—and recording jazz requires considerable experience from musicians—while the team needs to avoid locking into routine solutions (Deken et al. 2016). The network structure that we have identified as a possible solution to this paradox, network tension, is itself a paradoxical structure: it mobilizes and engages a team to pursue new ideas via an imbalanced network structure that is expected to push members apart (Davis and Leinhardt 1972). The sociology of networks has mostly been built on the assumption of balance, that strong ties are closed, and open ties are weak (Aral and Van Alstyne 2011; Granovetter 1973). While more recently there were others who have pointed to potential interest in overlapping closed ties (Gronow et al. 2020; Rost 2011; Rowley, Behrens, and Krackhardt 2000; Tortoriello and Krackhardt 2010; Vedres and Stark 2010), imbalanced structure and mechanisms of generative tension were not linked explicitly before. With this we further the agenda of reconceptualizing networks as tools of collective exploration, where the locus of action is a team discovering new solutions (Lameez and van Knippenberg 2014; Wuchty et al. 2007). By shifting the focus to tension in a network, we also propose to shift the fundamental imagery of a network from circulation of information to the local generation of new knowledge (Podolny 2001). Network tension opens the path to recognizing and implementing novel combinations of dyadic experiences (Rosing et al. 2018).

We have shown that network tension is a rare but important ingredient of jazz sessions: musicians tolerate a lack of closure with strong ties beyond what we would expect in a multi-mode configuration model, and tension triads are present in 11.8% of jazz sessions. Tension is not very common (just as true innovation should not be very common), but it is significantly more frequent than expected. Our findings indicate that both frequency and strength-based measures of network tension are consistent predictors of creative team success. Unlike open and weak triads, brokerage, or closure (which are mostly negative predictors), network tension positively predicts a diverse range of success measures, and it is also the only consistent positive predictor of deep success.

Our findings are overwhelmingly robust: we modeled seven diverse dependent variables using two distinct operationalizations of tension across 42 models in total (testing our results with several alternative specifications). We found a significant positive coefficient in 33 of these (about 80%). Furthermore—to test the sensitivity of our results to the omission of particular controls—we ran models with all combinations of control variables (910 models in total), of which 86% (781 models) showed positive significant coefficients for tension. In sum, we are confident that tension predicts success in jazz.

We tested the positive association of tension with success while accounting for several potential other explanations. For example, network tension is not about recruiting musicians with an unexpected mix of instruments, as we control for instrument diversity. It is also not just about pulling together a set of highly experienced musicians as we account for level of experience. Tension is also more than just a band leader pulling together a diverse set of his frequent collaborators, as we include a brokerage variable that would capture the presence of such a central orchestrator. We believe that by controlling for such factors, we empirically account for a large share of the explanations that others have (or would) put forward to explain how a team's network might matter for innovative success[18]. Beyond the fixed effects for

[18] An observational research design could never fully account for all potential confounds. Even after controlling for many factors, one might still point to unobserved individual creative capacity as an omitted lever. Our observations are also limited to recording session co-plays, and we are unable to assess musician familiarity in settings that are not recorded in our data (for example, un-recorded club gigs).

bands in our releases model, we think of our simulation approach as a way to estimate the impact of individual organizing effort. We find evidence that conscious effort has an additional benefit on top of what lucky accidents offer. In judging the quality of their outputs, bands with unexpected tension have a higher likelihood of creating successful products.

Our findings offer generalizable lessons to other fields and organizational settings (such as academia, video game production, or business project teams). Our empirical case of recorded jazz represents teamwork where value generation depends highly on synergy. The music on the record is the result of synchronous team effort, where all instruments sound together (recorded typically without overdubs). It is enough to have only one team member playing out of the tune or out of rhythm and hopes for success evaporates: any vision of a new sound needs also to cohere. Thus the value of a tension triad is associated with the synergistic nature of playing in a band: the freshness of performance comes from the excitement that a pair of highly experienced musicians are playing together for the first time. At the same time, coherence in the performance is ensured by having a two-step path of strong ties between these two musicians. As an example, think of a base player in the middle of a tension triad, who quickly figures out how to play with the long-time Cuban-jazz flavored drummer collaborator *and* the long-time swing-oriented pianist friend, now invited to the same session.

Arguably, however, for most creative team settings synergy is not as extreme as it is in jazz: an outstanding coauthor can correct mistakes of a less experienced one before manuscript submission. A core set of seasoned video game developers can salvage a mediocre game project before release, and experienced team managers can put a business project back on track after underperforming employees had been removed. In these settings, the individual innovator (an orchestrator, possibly a broker) can play a bigger role. In such settings a perspective that emphasizes network flows over tensions can have more validity and explanatory power.

However, even in these settings, one needs to account for the *discovery* of new ideas in the first place. An academic manuscript might be tightened by the most seasoned coauthor before submission, but getting the core idea might need true team effort (Perry-Smith 2006), with opportunities for diversifying experiences (Balachandran and Hernandez 2018; Damian and Simonton 2014; Steffens et al. 2016). It is network tension in the team that can light the initial sparks of thinking outside the box, even if the product itself does not require close synergies later, and subsequent development of the new idea can be taken over by brokers and orchestrators.

Our results contribute to the broader debate about how, and to what extent, can an innovative team *be organized* (Vera and Crossan 2005). Our analysis of unexpected tension indicates that conscious organizing effort helps innovative success, but the orchestration of a central broker does not[19]. We found evidence when tension is unexpected (and it took effort to bring musicians with tension triads into the session), it adds to the prediction of success. This finding offers an important contrast with our finding about brokerage: it is important for musicians to *get organized*, but they are not *being orchestrated*: seeking tension in the network helps, but ties organized around a central player do not. Organizing an innovative team seems to take more of a collective search, a daring inclusion of imbalance, rather than centralized rallying around a key player.

Taking the most successful session in jazz as an example ("Kind of Blue" of Miles Davis), we would not find Miles Davis in the center of a centralized network (as we have shown on Figure 2). Moreover, tension triads in that network features missing links between Davis and

[19] It is difficult to have access to systematic data at scale about organizing effort, so our approach was indirect: We measured network structure in a session against a counter-factual expectation of jazz musicians coming together in sessions only driven by their availability, instrument expertise, and the needs of the session for players of various instruments. In other words, we created hypothetical sessions that were certainly un-organized. Measuring the network tension of the actual session against the un-organized expectation gave us an indication of the extent of structural deviation—part of which might be due to organizing effort.

Wynton Kelly—something we would not expect around an orchestrating broker. While it might be clear that Miles Davis was not a broker orchestrating his sessions, it might be less clear what model of organizing would describe jazz sessions better. We can only follow hints, from for example the autobiography of Miles Davis, where he describes his ambition to expose musicians to unexpected settings (Davis and Troupe 1989:220). Great band leaders build structures that provoke innovation, rather than orchestrating, brokering the flow of information themselves.

What practical lessons are transposable from jazz to other settings on how to create a diverse team (Reagans and Zuckerman 2001; Reagans, Zuckerman, and McEvily 2004)? First, to benefit from tension in strong and open triads, an organization needs to enable individuals to cultivate unconnected collaborations. This requires a stable and safe context, where actors can forgo the safety and comfort of closed triads and short path-lengths. Placing individuals in diverse project teams can generate a set of un-connected but close collaborations, that can be exploited in later projects with innovation goals. While we have found no evidence for non-linear effects, it is an open question whether there are excessive levels of network tension that are counter-productive for innovative goals (Zhou et al. 2009). Second, organizing teams with tension with a dominant central player (in a brokerage position) would probably be counterproductive. Bringing a team together with tension is itself a task of innovation: innovative organizing. It is an open question how this task of innovative organizing itself is organized: how the social search for team members with diverse perspectives and open ties can be most efficient. A culture of innovation should be open to the formation of tension triads in groups with a mission to innovate, while such culture should also include practices to mitigate conflicts and emotional burden that stem from tension networks.

APPENDIX A: BOOKS USED TO MEASURE MENTIONS OF JAZZ SESSIONS

Book	Number of sessions mentioned
Thom Holmes, 2005: *Jazz (American Popular Music).* New York, NY: Facts on File.	261
Lewis Porter, Michael Ullman, and Edward Hazell, 1992: *Jazz: From its Origins to the Present.* Upper Saddle River, NJ: Prentice Hall.	220
Benito De Mar-A Mox, 2002: *El Jazz : de Nueva Orleans a Los Anos Ochenta*. Mexico City, Mexico: Fondo de Cultura Economica USA.	175
Leonard Lyons, 1980: *The 101 Best Jazz Albums: A History of Jazz on Records.* New York, NY: W. Morrow.	128
Gary Giddins, and Scott DeVeaux, 2009: *Jazz.* New York, NY: W. W. Norton.	101
Alyn Shipton, 2008: *A New History of Jazz*. London, UK: Continuum.	84
Ted Gioia, 1998: *The History of Jazz.* London, UK: Oxford University Press.	80
Brian Priestley, 1989: *Jazz on Record: A History*. London, UK: Hamish Hamilton.	78
Frank Tirro, 1993: *Jazz: A History*. New York, NY: W. W. Norton.	75
Mark C. Girdley, 2008: *Jazz Styles: History and Analysis*. London, UK: Pearson.	63
James Lincoln Collier, 1979: *The Making of Jazz: A Comprehensive History*. New York, NY: Dell.	60
Ben Ratliff, 2002: Jazz: *A Critics's Guide to the 100 Most Important Recordings*. New York, NY: Times Books.	59
John Szwed, 2000: Jazz 101: A Complete Guide to Learning and Loving Jazz. New York, NY: Hachette Book Group.	51
Richard M. Cook, and Brian Morton, 2006: *The Penguin Guide to Jazz Recordings.* London, UK: Penguin Books.	47
Loren Schoenberg, 2002: The NPR Curious Listener's Guide to Jazz. New York, NY: TarcherPerigee.	47
Gary Giddens, 2000: Riding On A Blue Note: Jazz And American Pop. Boston, MA: Da Capo Press.	19
Eric Hobsbawm, 2014: The Jazz Scene. London, UK: Faber and Faber.	10
Barry Kernfeld, 1997: What to Listen for in Jazz. New Haven, CT: Yale University Press.	9
Scott DeVeaux, 1999: The Birth of Bebop: A Social and Musical History. Oakland, CA: University of California Press.	2
Ben Ratcliff, 2002: Jazz: A Critics's Guide to the 100 most important recordings. New York, NY: Times Books.	1
Total	1670

Table 6: Books used to enumerate session mentions.

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TABLES

		public	
		insider	outsider
conferrence	voice	*1. NEA Award* *2. Critics' Poll*	*3. Readers' Poll*
	trace	*4. Book mention* *5. Survival*	*6. Releases*

Table 1: Typology of dependent variables of success in jazz.

Variable	*N*	Mean	SD	Min	Max
Tension (frequency)	124,285	.07	.18	.00	1.00
Tension (strength)	124,285	.07	.16	.00	1.00
Brokerage	101,668	.55	.31	.00	.98
Weak open triads density	124,285	.15	.28	.00	1.00
Closed triads density	124,285	.44	.43	.00	1.00
N musicians	124,285	7.48	6.69	1	113
Session tenure	124,285	182.48	260.33	0	5511
Median co-plays	124,285	1.04	3.56	.00	141.00
Release history	124,285	.34	.47	0	1
Distinctiveness	124,284	.66	.12	.00	1.00
Year (1896=1)	124,285	82.01	22.11	3	114
NEA Award	124,285	.06	.24	0	1
Critics' Poll	124,285	.03	.17	0	1
Readers' Poll	124,285	.04	.20	0	1
Book mention	124,285	.00	.06	0	1
Band failure	124,285	.13	.34	0	1
Releases	122,566	-.21	.36	-1.05	1.48
Deep success	124,285	1.07	.60	0	4

Table 2: Descriptive statistics.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
Independent variables																	
(1) Tension (frequency)	…																
(2) Tension (strength)	.83																
(3) Brokerage	.19	.24															
(4) Weak open triads density	.03	.13	.25														
(5) Closed triads density	-.14	-.10	.54	-.23													
(6) N musicians	.11	.16	.43	.22	.27												
(7) Session tenure	.29	.20	.30	.21	.06	.31											
(8) Median co-plays	.01	.00	.15	-.09	.28	.01	.15										
(9) Release history	.04	.02	.11	.00	-.04	-.01	.10	.05									
(10) Distinctiveness	-.17	-.19	-.19	-.23	-.31	-.32	-.26	-.11	-.12								
Dependent variables																	
(I) NEA Award	.06	.04	.05	.03	.00	.04	.18	.04	.16	-.05							
(II) Critics' Poll	.02	.01	.02	.00	-.01	.01	.09	.02	.14	-.03	.28						
(III) Readers' Poll	.04	.02	.05	.00	.02	.02	.10	.09	.20	-.08	.31	-.04					
(IV) Book mention	.02	.01	.01	.01	.00	.00	.02	.02	.07	-.03	.10	.05	.14				
(V) Band failure	-.04	-.03	-.04	.00	.02	.02	-.06	-.04	-.15	-.01	-.09	-.06	-.08	-.02			
(VI) Releases	.03	.03	-.01	.03	.03	.04	.07	.01	-.04	-.07	.01	.03	.06	.05	.19		
(VII) Deep success	.06	.04	.06	.01	.00	.01	.17	.08	.25	-.07	.64	.44	.50	.13	-.56	.14	…

Table 3: Correlations.

	I. NEA Award (logit odds ratio)		II. Critics' Poll (logit odds ratio)		III. Readers' Poll (logit odds ratio)		IV. Book mention 1940-1969, (logit odds ratio)	
	1	2	3	4	5	6	7	8
Tension (frequency)	1.238***		1.241*		1.315***		1.601*	
	(.083)		(.122)		(.111)		(.342)	
Tension (strength)		1.353***		1.378**		1.150		1.521†
		(.103)		(.154)		(.114)		(.378)
Brokerage	.380***	.363***	.203***	.194***	.415***	.397***	.295*	.269**
	(.050)	(.050)	(.039)	(.038)	(.078)	(.068)	(.146)	(.131)
Constant	.061***	.062***	.160***	.162***	.801	.842	.000***	.000***
	(.010)	(.010)	(.039)	(.040)	(.176)	(.185)	(.000)	(.000)
Controls included	yes	yes	yes	yes	yes	yes	yes	yes
Year trend included	yes	yes	yes	yes	yes	yes	yes	yes
Band time included	no	no	no	no	no	no	no	no
Band fixed effect included	no	no	no	no	no	no	no	no
N	61,984	61,984	61,976	61,976	61,713	61,713	20,281	20,281
R^2	.077[1]	.077[1]	.075[1]	.075[1]	.132[1]	.132[1]	.070[1]	.070[1]
AIC	31,700	31,695	17,290	17,287	21,941	21,949	3,255	3,257
BIC	31,781	31,776	17,372	17,368	22,022	22,030	3,326	3,328

Table continued	V. Survival (hazard ratio)		VI. Releases (per decade, log; OLS)		VII. Deep success (ordinal logit odds ratio)	
	9	10	11	12	13	14
Tension (frequency)	.806***		.014*		1.281***	
	(.044)		(.006)		(.083)	
Tension (strength)		.789***		.008		1.308***
		(.044)		(.006)		(.108)
Brokerage	1.186	1.239*	.065***	.063***	.456***	.435***
	(.107)	(.112)	(.013)	(.011)	(.100)	(.096)
Constant	.818*	.802*	-.791***	-.790***	.557***[3]	.573***[3]
	(.078)	(.076)	(.032)	(.017)	(.211)	(.217)
Controls included	yes	yes	yes	yes	yes	yes
Year trend included	no	no	yes	yes	yes	yes
Band time included	yes	yes	no	no	no	no
Band fixed effect included	no	no	yes	yes	no	no
N	85,340	85,340	61,300	61,300	54,418	54,418
R^2			.095[2]	.095[2]	.061[1]	.061[1]
AIC	40,007	40,006			83,191	83,191
BIC	40,176	40,174			83,298	83,298

Notes: 1: Adjusted McFadden pseudo R-squared. 2: R-squared for within-band model. 3: Baseline odds of moving from no success to one kind of success. †: p=.09; *: p<.05; **: p<.01; ***: p<.001

Table 4: The effect of network tension (frequency and strength) and brokerage on seven measures of success.

	I. NEA Award (logit odds ratio)		II. Critics' Poll (logit odds ratio)		III. Readers' Poll (logit odds ratio)		IV. Book mention 1940-1969, (logit odds ratio)	
	1	2	3	4	5	6	7	8
Tension (frequency) > 0, and Z ≥ 2	1.264*** (.061)		1.270*** (.089)		1.270*** (.074)		1.101 (.178)	
Tension (strength) > 0, and Z ≥ 2		1.409* (.251)		1.882** (.463)		1.145 (.278)		2.988* (1.579)
Constant	.021*** (.002)	.021*** (.002)	.060*** (.007)	.063*** (.007)	.056*** (.006)	.058*** (.006)	.000*** (.000)	.000*** (.000)
Controls included	yes	yes	yes	yes	yes	yes	yes	yes
Year trend included	yes	yes	yes	yes	yes	yes	yes	yes
Band time included	no	no	no	no	no	no	no	no
Band fixed effect included	no	no	no	no	no	no	no	no
N	72,642	72,642	72,255	72,255	72,381	72,381	22,820	22,280
R^2	.084[1]	.083[1]	.079[1]	.078[1]	.128[1]	.127[1]	.062[1]	.062[1]
AIC	34,247	34,267	19,198	19,204	23,908	23,924	3,534	3,531
BIC	34,311	35,331	19,263	19,268	23,972	23,988	3,591	3,587

Table continued	V. Survival (hazard ratio)		VI. Releases (per decade, log; OLS)		VII. Deep success (ordinal logit odds ratio)	
	9	10	11	12	13	14
Tension (frequency) > 0, and Z ≥ 2	.941 (.039)		-.012** (.004)		1.486*** (.047)	
Tension (strength) > 0, and Z ≥ 2		1.131 (.168)		-.027 (.017)		1.240† (.164)
Constant	1.062 (.038)	1.039 (.035)	-.809*** (.030)	-.811*** (.030)	.128***[3] (.006)	.141***[3] (.007)
Controls included	yes	yes	yes	yes	yes	yes
Year trend included	no	no	yes	yes	yes	yes
Band time included	yes	yes	no	no	no	no
Band fixed effect included	no	no	yes	yes	no	no
N	97,185	97,185	71,817	71,817	72,196	72,196
R^2			.107[2]	.107[2]	.058[1]	.058[3]
AIC	50,852	50,853			115,682	115,838
BIC	51,004	51,006			115,774	115,930

Notes: 1: Adjusted McFadden pseudo R-squared. 2: R-squared for within-band model. 3: Baseline odds of moving from no success to one kind of success. †:p=.10; *: p<0.05; **: p<0.01; ***: p<0.001

Table 5: Models of network tension with concerted organizing effort and six measures of success.

FIGURES

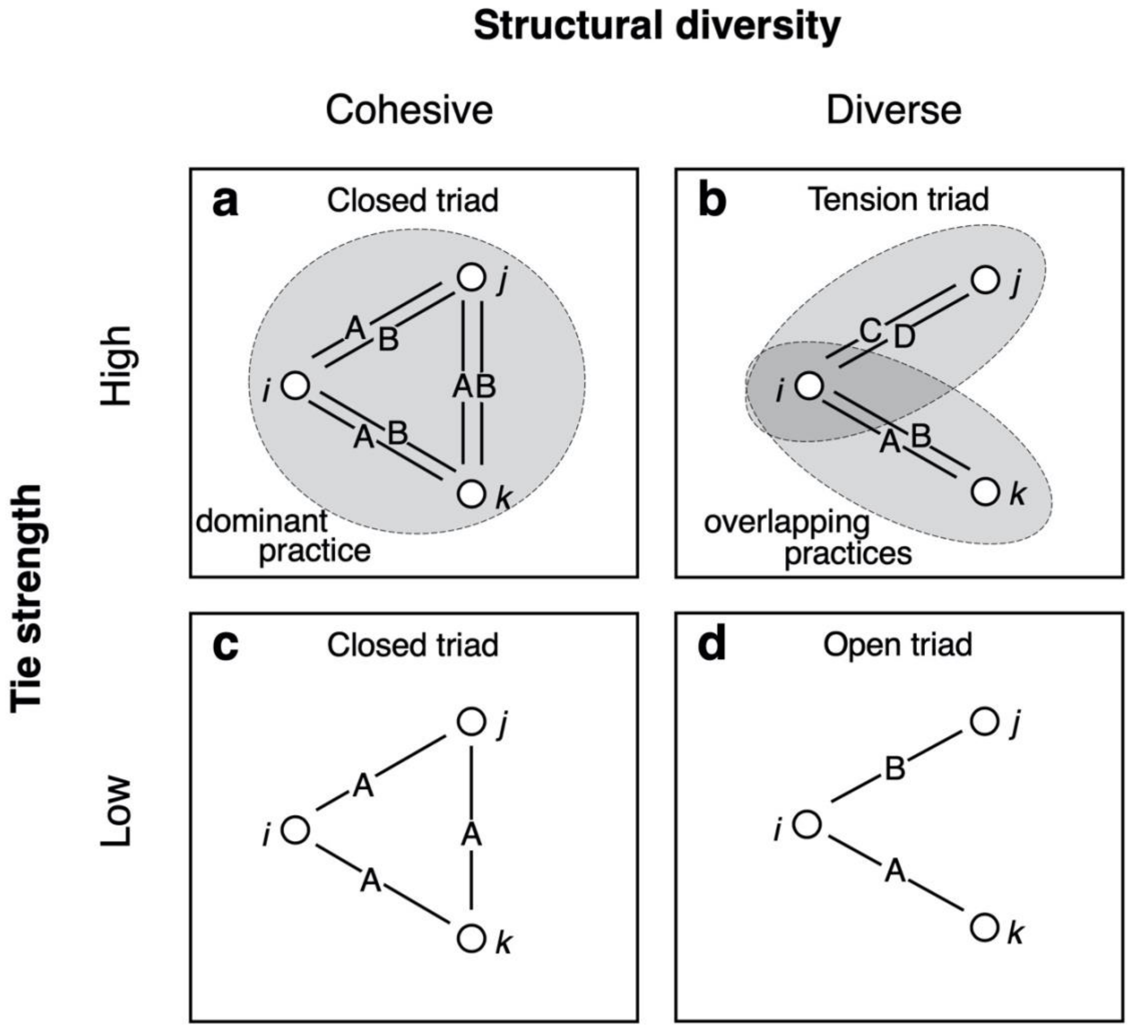

Figure 1: Triad types and emerging dominant practice. Letters I, j, and k are nodes; capital letters A, B, C, and D indicate occasions when nodes collaborated in the past; shaded areas indicate emerging dominant practice.

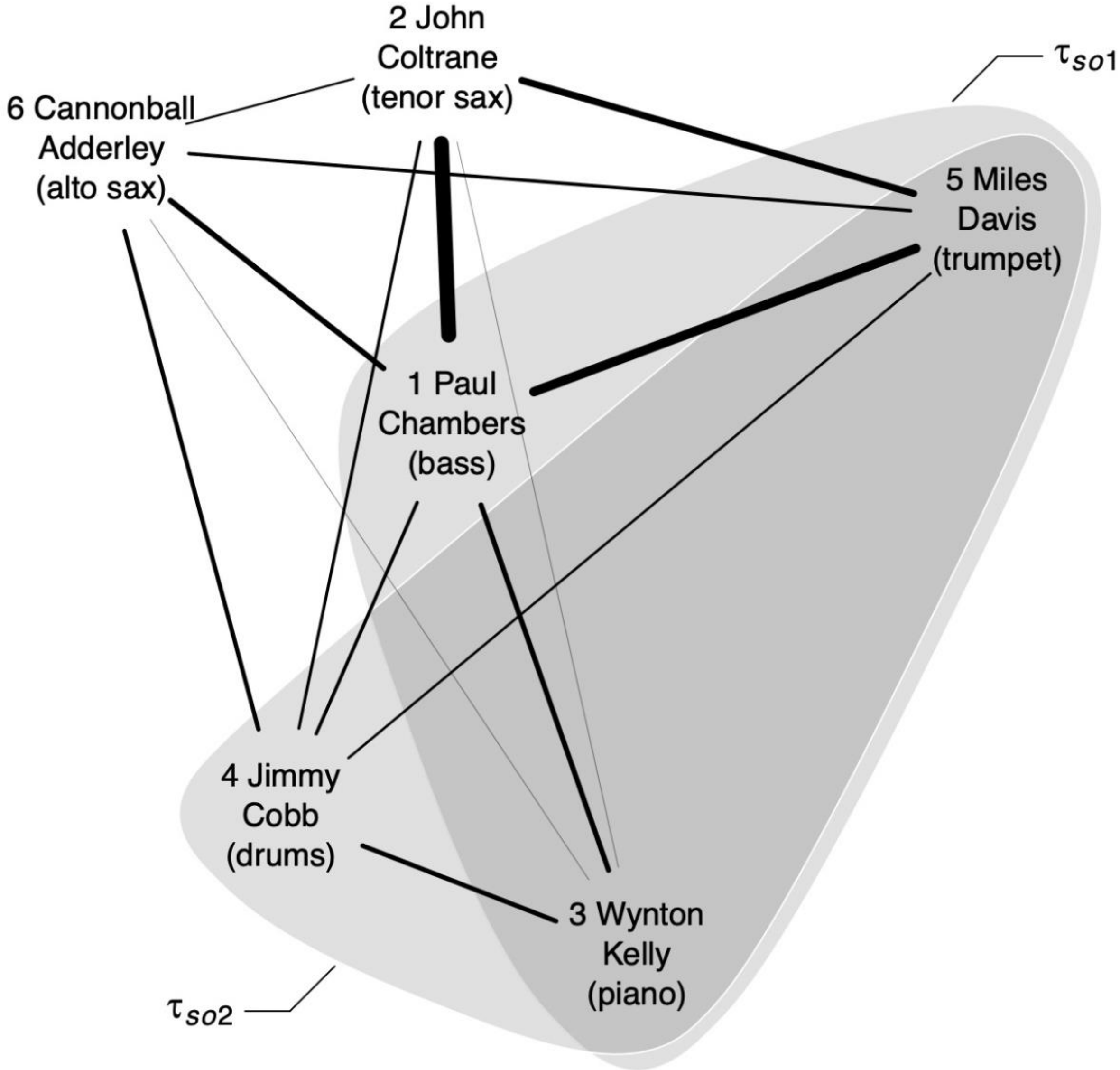

Figure 2: Graph of prior co-recordings in the session "Kind of Blue" (March 2, 1959). Strong and open triads (with threshold *t*=2) labeled τ_{so1} and τ_{so2} are marked by shaded areas.

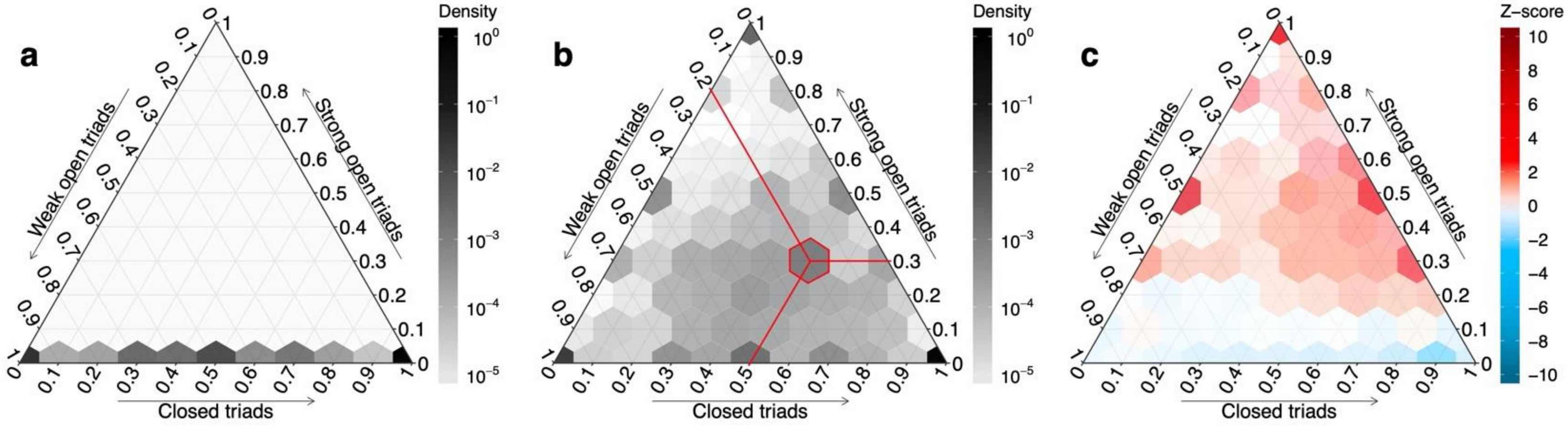

Figure 3: The composition of sessions by triad types. Panel a: Probability density of sessions as expected in a "strength of weak ties" theoretical model with only closed and weak open triads. Panel b: Probability density of sessions in the observed empirical data. Panel c: Median session level Z-score comparing the observed number of strong, open triads to the expected number in 100 random jazz worlds.

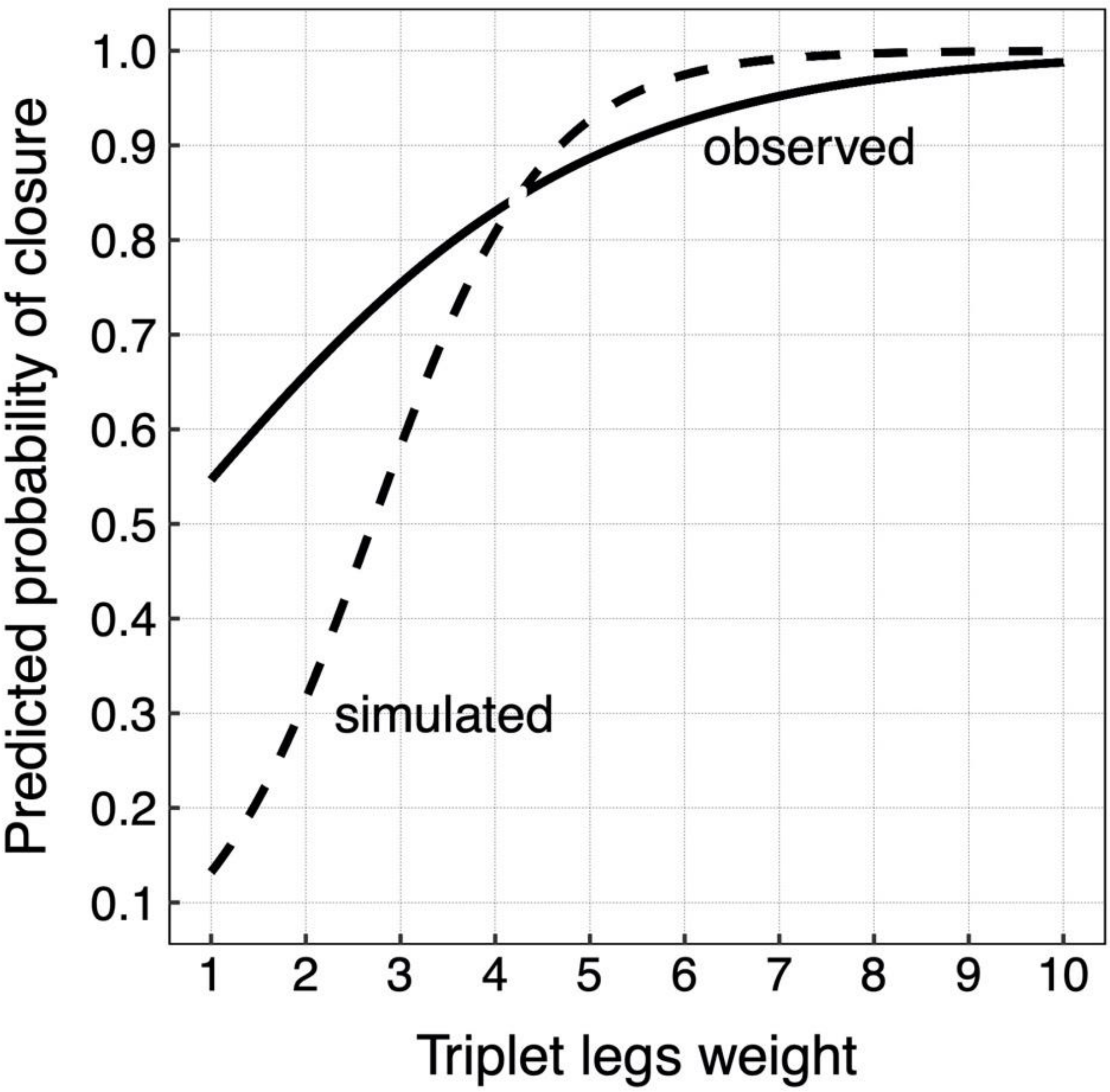

Figure 4: Predicted probability of closure in empirical and simulated networks. Predictions are statistically significantly different for the two lines, apart from the X-axis range of 4.19-4.29 (left blank on the continuous line), where the 99.999% confidence intervals overlap.

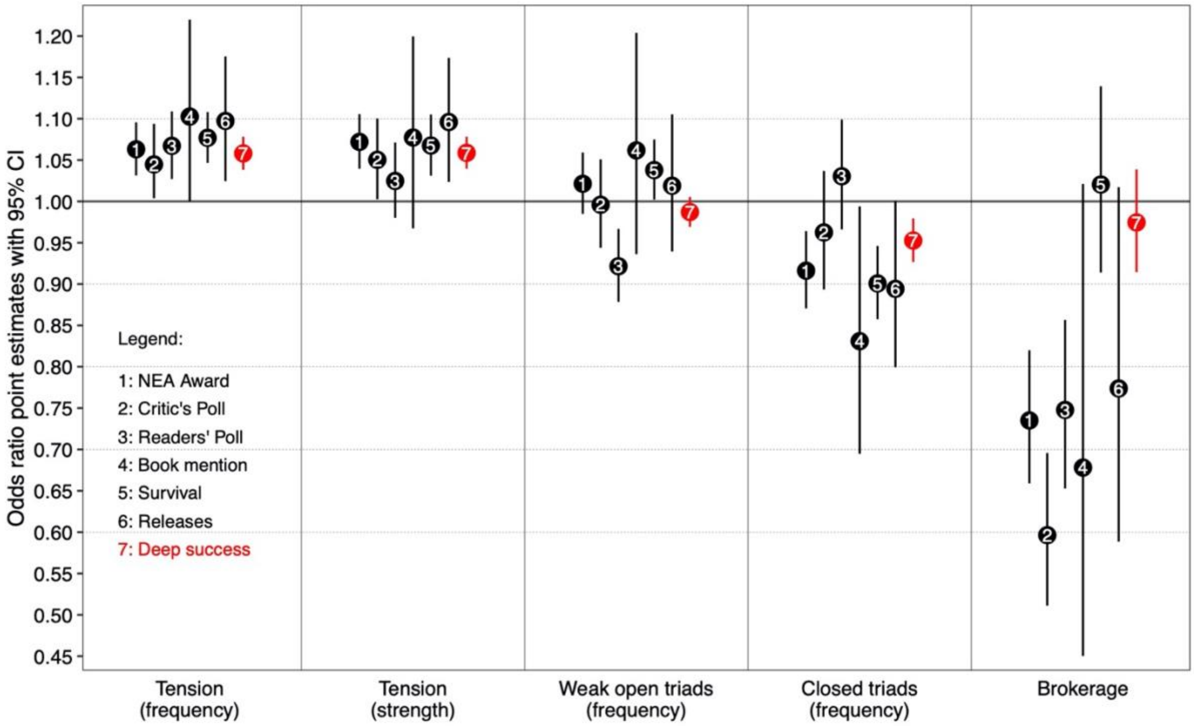

Figure 5: Point estimates (odds ratios) from logit models, with 99% confidence intervals for standardized independent variables. Estimates are grouped by independent variable (categories on the horizontal axis), and numbered from 1 to 7 by dependent variables.