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Interdependence, Morality and Human-Machine Teams: The Revenge of the Dualists

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ABSTRACT: Experience teaches that appearances can mislead, that deception frequents human affairs and that even reliable people misbehave. But for social scientists, based on their idea that the convergence of concepts derived from the intuitions of individuals (observations, self-reports, interviews) about social reality determine their primary model of the rational (social) world; i.e., what humans say they see is what exists; or, words matter; or, humans act as they cognitively think. But based on these models, the social sciences have accrued so many failures across the decades in building predictive theory that a theory of teams has until now been unimaginable, including in economics where results re-labeled as irrational have won Nobel prizes but without a foundational theory. Seemingly, concepts based on the individual promote transient norms by which to judge morality; e.g., the passing fad of self-esteem; the newest fad of implicit racism; the old fad of positive thinking. And yet, irrational and biased humans in freely organized and competitive teams manage to innovate year after year. In contrast to traditional social science, the most predictive theory in all of science is the quantum theory, each prediction confirmed by new discoveries leading to further predictions and discoveries, but the dualist nature of the quantum theory renders the meaning of physical reality meaningless despite more than a century of intense debate. By ignoring meaning, we introduce to the science of teams the quantum-like dualism of interdependence where social objects co-exist in orthogonal states. To judge the ethics of Artificial Intelligence (AI), our theory of interdependence makes successful predictions and new discoveries about

human teams that account for the poor performance of interdisciplinary science teams; explain why highly interdependent teams cannot be copied; and begin to address the newly arising problem of shared context for human-machine teams.

KEY WORDS: Interdependence, teams, subadditivity

Introduction

After Copernicus proposed his counterintuitive theory for the motions of the heavenly bodies, Kant (1755-70) reasoned that human intuitions do not conform to objects, rather,

> in a manner contradictory to the senses … [let us] seek for the observed movements not in the objects of the heaven but in their observer …

Ignoring Kant, relying on the convergence of intuitions derived from simple observations (e.g., polls), two leading decision theorists, Tetlock & Gardiner (2015), concluded that forecasting "is a skill that can be cultivated," and that prediction, politics and human affairs are not inscrutable, but rather like weather forecasting where predictions are possible, rational and accurate. To demonstrate the power with their model of superforecasting, they started a public website (Tetlock & Gardner 2015). However, their first "superforecast" that Brexit would not be supported by the British electorate failed, as did their second superforecast that Trump would not be elected the next U.S. President (Lawless 2017a,b). How does this relates to ethics?

To explain the failure of Tetlock-Gardiner and other social scientists, our research on the quantum-likeness of interdependence accounts for the dual nature of human affairs first theorized by Bohr (1955). In agreement, we have found that the more certain are social scientists about the human observations of behavior (e.g., based on converging data from interviews or self-reports on ethics), the less certain becomes the information gained about the human behavior being studied, nullifying predictability (Zell & Krizan 2014). Three examples: First, despite the strong claims over decades about the importance of self-esteem for academics and work (Diener 1984), in a 30-year meta-analysis, Baumeister and colleagues (2005) found virtually no association between self-esteem and either academics or work. Second, social

scientists extol the value of standardized tests, even though the variability in their results are unacceptable for the engineering of human-machine teams (e.g., Kuncel et al. 2007 argue that the standardized GRE test scores predict the success of graduate students, but their averaged observed correlation of less than 0.30, corrected to about 0.40, squared, means that between 80-90% in the variance of a graduate student's success is unknown; for a rehash, see Kuncel & Sackett, 2018). Third, from a news report in *Science* about an HIV prevention trial for the female mates of HIV positive males (Cohen 2013):

> The women reported using PrEP 90% of the time, and their unused returns seemed to validate that figure. But when the researchers later analyzed blood levels of drugs in the women, they found that no more than 30% had evidence of anti-HIV drugs in their body at any study visit. "There was a profound discordance between what they told us, what they brought back, and what we measured," infectious disease specialist Jeanne Marrazzo said.

These examples characterize a problem with measurements in social systems that Wendt (2015, 67) described for quantum systems as "the apparent impossibility of an objective measurement." For humans, based on the evidence, the claim can be made that the dualistic nature of interdependence creates a similar measurement problem of ethical behavior in human affairs (Lawless 2017a,b).

From Plato and Aristotle to Descartes, dualism has a rich history. An early devotee, James (1892) coined the term complementarity for different parts of consciousness sharing no knowledge with other parts (p. 206), confirmed by Gazzaniga's (2011) study of split-brain patients: "the left half did not know what the right half was processing." (p. 57) "Complementarity" is the term borrowed from James by Bohr for his theory of quantum indeterminancy (Pais, 1991, p. 424). Since Bohr, Einstein and Schrodinger, the quantum model has become the most successful predictive theory ever (Weinberg 2017). James, however, eventually rejected dualism in favor of the "practical pluralistic views" in pragmatism, a rejection transformed into today's experiential monism (Stubenberg 2017) that supports the "rational" model of making decisions. The student of James, Lovejoy (1930), remained in support of dualism:

> The revolt—within the realistic provinces of philosophical opinion—against dualism, both psychophysical and epistemological, has failed. (p. 264)

Lovejoy lost his battle. Similarly, the theory of group dynamics, introduced by Lewin (1951) has become a blind alley for his model of interdependence. Jones (1998, 6), an esteemed social psychologist, greatly admired the contributions of Kurt Lewin, the founder of group dynamics (p. 21),"Lewin argued explicitly against explanations involving individual differences … ," advice rejected by current social scientists (for a review of their focus on individual differences, see Deary, 2012). Jones (1998, p. 33) agreed that interdependence was central to social life, but he also claimed that:

> useful theory has been difficult to develop … [based on] the "*bewildering complexities*" involved in the study of interdependent relations. [emphasis added]

Not resolving these "bewildering complexities" has left researchers in the social (e.g., economic, humanistic, philosophic, networks, game theory) disciplines struggling to predict the outcomes of basic interactions, exemplified by the difficulty in replicating experiments (Nosek 2015) (The problem of replication has infected the physical sciences, notably astrophysics and other fields relying on machine learning to sift through large data bases (Wild 2018). This problem is the inability to understand how a solution was derived, to replicate results, or just to cross-examine the results (Somers 2018); left them aimless (Hofman et al. 2017); and stunned by the achievements of their colleagues in the hard sciences (e.g., physics, chemistry, biology, engineering). As well, the philosophy or history of science, engaged in endless debate, has been unable to build a foundation with which to study science (Nickles 2017).

Endless debate is a clue: Even as they preside over their exquisitely predictive discipline, quantum scientists have struggled for a century over their interpretation of the quantum (Weinberg 2017). Putting that aside momentarily, the social sciences have been built atop methodological individualism (MI), the supremeness of the individual but with no theoretical value generalizable to teams (Ahdieh 2009). Yet, at this point in human history, predictability is critical, to borrow from Kuhn (1962/1970, p. 169), to find "the solved problem" for a theory of human-machine teams, otherwise their construction and ethical use, unlike designing and perfecting bridges, will be *ad hoc*. Unlike swarms, we have learned that scientific teams,

especially the best performing ones, are highly interdependent (Cummings, 2015) (The first attack ever by a swarm of drones has already occurred: "A series of mysterious attacks against the main Russian military base in Syria, including one conducted by a swarm of armed miniature drones …" (Sly, 2018). Not having a theory of teams compounds failure; e.g., ignoring the warning by Jones about the bewildering nature of interdependence, the National Science Foundation (NSF) repeatedly and blithely calls for more interdisciplinary scientific teams in the pursuit of new research. Yet, based on the work of Cummings, the National Academy of Sciences (NAS; see Cooke & Hilton, 2015) reported that interdisciplinary scientific teams were the least productive. After a public discussion with Cummings, we concluded that the poor performance of interdisciplinary scientific teams was likely caused by redundancy.

We hypothesized that redundancy should impede the positive (ethical) effects of interdependence. However, using Shannon's information theory, Conant (1976) argued that teams and organizations should minimize interdependence (mutual information); similarly, experimental social psychologists recommend that interdependence should be statistically removed to increase the replicability of an experiment (Kenny et al. 1998, p. 235). Contradicting our hypothesis, the National Academy of Sciences had predicted that "more hands make light work" (Cooke & Hilton 2015, Ch. 1, p. 13); and Centola & Macy (2007) had predicted that social networks became more efficient as redundancy increased. But this advice from social scientists has led them along with Jones to discount the value of interdependence, analogous to believing that the study of the atom would be easier without having to deal with its "pesky" quantum effects.

In contrast, we have found that redundancy decreases interdependence (Lawless 2017a); increases the opportunity for corruption and unethical behavior (Lawless 2017b); and reduces the ability of teams to innovate (Lawless 2018). "Redundancy" is the tale of an unexpected discovery in social science based on our theory of interdependence for teams that provides mathematical metrics for human and human-machine teams. It is the first successful prediction made by our theory of interdependence (Lawless 2017a), subsequently replicated (Lawless 2017b) and leading to

new predictions and preliminary support for the work-in-progress briefly described later in this report (Lawless 2018).

In support, Cummings (2015) found that the most productive science teams maximize interdependence. From Wendt (2015), "humans live in highly interdependent societies (p. 150) … [where they form] organized, structured totalities in which parts and whole are dynamically interdependent …" (p. 134).

Interdependence transmits the dualism of constructive and destructive interference (Lawless 2017a,b). It is the social resource available to every society to innovate and evolve ethically (Lawless 2018). Typical of societies that evolve less are autocratic countries (e.g., Cuba, Venezuela, North Korea), corrupt, unethical countries (Russia, Iran, Turkey), or both (e.g., China). Interdependence signifies a communication between two or more agents, where the interdependence inherent in public competition, such as public debate, includes the constructive or destructive signals communicated to an audience of witnesses; e.g., politics, the practice of science, juries, entertainment. The interference transmitted by interdependence derives from the competition inherent in the checks and balances that limit power or unethical behavior, demonstrated by Justice Ginsburg's (2011) unanimous ruling rejecting the Environmental Protection Agency's (EPA) rule for CO-2 until it was made ripe by the maximum available "informed assessment of competing interests."

With National Security threats arising from hypersonic missiles; modernized nuclear weapons; and the advent of human-machine teams, the motivation for faster decision-making based on a shared context is increasing (Lawless et al., 2019). How human-machine teams construct context is increasingly important, brought to the fore by the Uber self-driving car accident in Arizona that killed a pedestrian in 2018. Unlike a toy ethics problem, after reviewing this accident, the National Transportation Safety Board (NTSB 2018) reported that the car saw the pedestrian 6s early; selected its emergency brakes 1.3s early; but the brakes had been made inoperable by Uber engineers to improve the car's handling. In contrast, the human operator saw the pedestrian 1s early and hit the brakes 1s after impact. The car performed as designed and faster than the human who performed

much slower. However, the car did not alert the driver of the change in context although it could have done so earlier, maybe in time to save the pedestrian; by not contributing to the context shared by the human-machine team, the car was a poor team player, a problem that we AI scientists must argue that can and should be fixed to improve social welfare.

Needed is a theory of teams like ours modeled by the mathematics of interdependence to build a shared context that we continue to develop and briefly review herein. Without a mathematics of interdependence, human-machine teams will remain ad hoc, inefficient or not effective; ethically, their contribution to social welfare may be poor. For a mathematical grasp of interdependence, which works like quantum entanglement, we have divided its effects into bistable views (e.g., action-observation; Tribe-1 versus Tribe-2; prosecutors versus defense attorneys; Einstein's interpretation of reality versus Bohr's); a measurement problem where the convergence of interpretations into the supposedly "ethical" one produces incompleteness and uncertainty by dismissing the rejected alternative interpretation (e.g., despite their lack of validity, thereby increasing the value of static questionnaires that falsely associated an individual's performance with "self-esteem," in Baumeister et al. 2005; implicit racism, in Blanton et al. 2009; or positive thoughts; in Diener 1984); and the inability to factor social states (e.g., the measurement of an interdependent social object affects the behavior and cognitions of the objects measured).

As a simple example of the effects of interdependence. Elk overgraze in forests without the presence of coyotes, making their forests unhealthy; in contrast, elk in forests where wolves have been introduced take a bite of grass and scan about in their vigilance for wolves, take another bite of grass and scan about again, continuously eating and surveilling, the intermittent eating producing a greener and healthier forest (Carroll 2016).

The bistable views of different tribes

In Kuhn's (1977) view, a set of ideas developed within a paradigm impede alternative views of reality arising between different cultures or groups (Tajfeld 1970), like liberalism versus conservatism, prosecutors versus defense

attorneys, or pre-Planckian physicists versus quantum physicists, generating tension whenever a questionable ethical event cannot be explained by groups holding different views or by the beliefs prevailing in a single group, easily dismissed when there are no means to test ideas about an ethics anomaly, but when there is, creating the tension essential to change (e.g., Martin Luther King's activism against Jim Crow laws; in Layne 2015). Unlike philosophy which is debatable but untestable, physical theories, made testable by their predictions with mathematics, create tension naturally when users consider an equation's (ethical) implications or its generalizations to establish new physical theory; still, without question, an equation's interpretations or (ethical) paradoxes derived from the predictions established by an equation can create unending conflict like with the endless quantum debates.

We have found that the value of the constructive-destructive interference transmitted by interdependence depends on the free movement of ideas, people and capital attracted by the different interpretations transmitted, why the first target of an autocratic government is to censor the interpretations it rejects (e.g., see the *New York Times* article about censorship in Turkey; in Gall, 2018; or the destruction of the entire Uighur culture by China to gain the fullest compliance of Uighurs to China's leadership; in Chin & Bürge, 2019); why a business might try to silence its opposition (NYT, 2018); or why a majority religion might choose to persecute a religious minority (Kishi 2017). By forcibly preventing the power of teams, tribes or cultures to flourish in favor of individuals who can be more easily controlled, however, the destructive interference of censorship kills the civic, ethical, social and intellectual productivity needed for innovation (for the effects of censorship in Russia, see Varadarajan, 2018).

Innovation. One of the largest producers of patents, China, has neutralized its advantage with wide-spread censorship. Consider that the R&D expenditures by China are second in the world to the U.S. (Zumbrun, 2018). But China's state directed finance, its weak intellectual property protections and its rampant corruption impede innovation and social welfare. In China (Tamplin 2018).

Small private-sector firms often only have access to capital through expensive shadow banking channels, and risk that some better connected, state backed firm will make off with their designs--with little recourse.

Convergence: The statistical convergence of evidence away from bistability in support of one or another concept assumes that individuals are independent; that the data generated by individuals is also independent (e.g., "detrended"); and that whatever is rejected by the evidence is noise and not a valid alternative. Social scientists look for the associations identified by correlations, accepting that while correlations do not establish causality, they believe that the lack of a correlation indicates no causal relationship. But "convergence" may not a satisfactory concept on which to base ethical judgments.

Orthogonality: If the lack of a correlation indicates no causal relationship, and the data produced is independent, a problem occurs when data is derived from orthogonal, bistable sources identified as independent by definition; e.g., husband-wife teams; CBS-Viacom businesses; pitcher-catcher role players. But after Gazzaniga's (2011) extraordinary discovery that the brains of split-brain patients produce interpretations of reality completely different for the two halves (p. 57), unexpected because no evidence of bistability existed beforehand, we assert that the lack of a correlation does not preclude causality. If members of a team are playing orthogonal roles (e.g., the bistable information arising from the different members of society's "team" in its ethical search for justice, composed of a judge, prosecutor and defense attorney), that incommensurability accounts for the negligible correlations from studies with concepts of behaviors versus actual behaviors (e.g., an alcoholic's "denial" of being an alcoholic; the different interpretations of the cause of conflict arising during a divorce; the negligible correlations between self-esteem and academic or work performance). Orthogonality accounts for the here-to-fore hidden value of teamwork; namely, humans are poor at multitasking (Wickens 1992), but multitasking by teammates playing orthogonal roles while working toward a common (ethical) goal is the function of teams (Lawless 2017a,b).

Measurement problem

When bistable views are censored for whatever reason, a measurement problem occurs. We have argued that censorship converts teams or tribes into a collection of individuals, allowing us to apply Shannon information theory to the result. From Shannon, in words, joint information is greater than (as the dependence between agents increases) or equal (as the independence between agents increases) to the information from its contributors (Where is the joint entropy of two sources or two agents and or is the entropy of one agent, giving):

$$information_{joint} \geq information_{agent1}, information_{agent2} \quad (1)$$

(mathematically, $H_{A,B}$ is the joint entropy by two independent sources or agents and H_A or H_B is the entropy of a single agent, giving: $H_{A,B} \geq H_{A,}H_B$). By applying Conant (1976) to Shannon information, censorship reduces the value of interdependence as a resource. In Shannon's model, deception has little to no biological value; but in biology and with humans, deceptive (and unethical) behavior serves a critical function (Chagnon 1988), especially under authoritarian governments.

In contrast to Ginsburg's (2011) "informed assessment of competing interests," few appreciate that the value of bistability transmitted by interdependence improves social welfare by solving (ethical) problems (Kuhn, 1962/1970). Instead, recently, there has been a turn away from the bistability inherent in "checks and balances" as a means to improve social welfare by replacing it with (Vermeule 2018):

> the administrative state ... [where its] agents may have a great deal of discretion to further human dignity and the common good, defined entirely in substantive rather than procedural-technical terms. ... agents with administrative control over default rules may nudge whole populations in desirable directions, in an exercise of "soft paternalism" …

Vermeule's hopes are wistful. In addition to the "soft paternalism" exhibited above by EPA rejected by Justice Ginsburg (2011), or the censorship promoted inside of Turkey or Russia, the turn away from checks and balances

threatens social welfare, illustrated by the time when the U.S. Department of Energy (DOE) operated almost unimpeded by public oversight, a time when DOE alone had the authority implied by the "soft paternalism" in its management of military nuclear wastes for the "common good" when, instead, DOE's single-mindedness produced extraordinary contamination of the environment across the U.S. (Lawless et al., 2014). Further, in the cleanup since, motivated by DOE's guidance to use the cooperation inherent in consensus-seeking for decision-making by DOE's Citizens Advisory Boards (CAB), its CAB at Hanford provides a comparison versus the bistability inherent in the majority-ruled CAB at DOE's Savannah River Site in SC, one of the sites which rejected consensus-seeking in favor of majority rules to make its decisions. The result: SRS has had a significantly better, faster and safer cleanup than the Hanford site, the latter mired in endless debate and legal strife; e.g., even though the process for the vitrification of high-level radioactive wastes was innovated at Hanford, vitrification began at SRS in 1996 but has not yet begun at Hanford, and may not start there for another decade if ever. As we had predicted, and as supported by the European Union (WP, 2001), consensus-seeking is how a minority censors or controls a majority by blocking its ability to make a decision:

> The requirement for consensus in the European Council often holds policy-making hostage to national interests in areas which Council could and should decide by a qualified majority. (p. 29)

Non-factorability

Applying Von Neumann's model of constructive and destructive interference to a state of interdependence, the joint information becomes less than (as the teamwork increases between agents) or equal (as the teamwork between agents ceases, becoming equal to Shannon information) to its contributors:

$$information_{joint} \leq information_{agent1} + information_{agent2} \quad (2)$$

(mathematically, $S_{A,B}$ is the joint entropy of two interdependent sources or agents and S_A or S_B is the entropy of one agent, giving: $S_{A,B} \leq S_{A,} + S_B$). Equation (2) accounts for non-factorability. Mindful of Kant, it confirms

the biological value of how deception is applied by "fitting in," including for humans (a con artist; a military feint; a private affair). But, more importantly, Equation (2) predicts that when a team is working to perfection, the information it generates disappears as the information from its interactions go dark, meaning that the effect of counting the contributions from a team's members by an outside observer is no longer trustworthy (viz., by reducing the degrees of freedom in a team as a team begins to operate as a "unit"; in Lawless 2017b). This result explains why the performance of a perfect team is difficult or impossible to copy, even by the perfect team itself (The inability to copy interdependence is similar to the "no cloning" rule in quantum information theory (Wooters & Zurek 2009, 77). It also explains why a coach or a leader for the best teams is often necessary, inadvertently making the "best" coaches invaluable.

Future research

To advance previous research (Lawless 2017a,b), the plan is to introduce the value of intelligence as a tool used by teams to manage interdependence. Here's the problem: Although game theory was introduced in social psychology by Thibaut & Kelley (1959), Kelley (1979) abandoned it after realizing that no matter the strength of preferences chosen on paper by subjects before playing a game, subjects were too responsive to the interdependent feedback from the choices made by their opponents during actual games (Lawless, 2017a). Kelly abandoned game theory for close relationship theory, but correlations for that theory also failed to establish the value of interdependence for two similar reasons: First, matching two people for a relationship based on choices selected with a piece of paper is again overwhelmed by the (constructive or destructive) interference from interdependence inherent in a partnership. Second, interdependence theory indicates that the best relationships are those built around partners in orthogonal roles (e.g., all else equal, instead of the inferior performance derived from the destructive interference caused by two catchers and one pitcher playing in a baseball game simultaneously, a better arrangement is the constructive interference from only one catcher, one pitcher and one first baseman playing together at a time). Orthogonal

information, however, produces zero correlations. Intelligence enters when making the partnership choices that minimize destructive and maximize constructive interference among partners and only when the partners agree to a superordinate (ethical) goal for their team.

The prevalence in the social interaction of interdependence forces social navigators to rely on intelligence during a competition to craft a social path that achieves a team's superordinate goal (mission, ethical behavior) by amplifying its skills with constructive interference, mindfully using destructive interference to sharpen its focus, by deploying team boundaries to block outside interference, but thereby making its decision process opaque (zero correlations). Intelligence determines the members selected for a team (constructive); the shape of a team's structure that produces maximum entropy (MEP; see Wissner-Gross & Freer 2013; i.e., maximum work output for a team of workers; or maximum exploration of a solution space for a team of scientists); and the shortest social path with MEP to overcome obstacles (Martyushev 2013) to achieve a team's superordinate goal to guide and measure its progress (Lawless 2018). The quantum-like nature of interdependence causes tension between the intuitions leaders use in tradeoffs under uncertainty that shape a team and its structure to achieve MEP (e.g., to maximize performance, leaders choose the skills a team needs in its competitions, their internal communications, and the configuration of the structure that shapes the configuration of its members; in England, 2013).

Conclusions

In a free society, because of the costs of extras, interdependence automatically reduces redundancy. While the meaning of interdependence is meaningless (Jones' *bewilderment*), we conclude that interdependence is the primary resource free societies harness to shape their teams and structures to improve (ethical) social welfare. That is the reason authoritarians attempt to quash interdependence as their first order of business (by censoring free speech; by ending the freedom to assemble; by preventing the free exercise of religion; by destroying competing cultures; etc.).

Interdependence is the science of human and human-machine teams, organizations and societies; it lends itself to mathematical models, to trial and error tradeoffs, but not to a single interpretation; it could rehabilitate the social sciences and, with Kant, the integration of the philosophy of science with the history of science (e.g., Nickles 2017). It is a social science that offers interdisciplinary teams the opportunity to contribute when their skills are demanded to complete a team, but not for the specious purpose of satisfying the bureaucratic whims of an agency like NSF or DOE. It is the science of dualism with social people, organisms and future robots working with humans to build human-machine teams. Finally, to end the interminable quantum debates, Weinberg (2017) wants quantum theory to be revised so it does not give a status to human observers; good luck with that!

Interdependence is not a silver bullet. It is a trial and error approach to selecting the best members of a team with the least redundancy possible. Choosing the best teammates possible is critical. Training is essential. Supporting players by offering rest or providing relief or substitution is necessary (e.g., even the best teams aboard Navy ships need relief after 8-hour or longer shifts; in Holmes, 2018). But the extraordinary value of interdependence to societies also helps to reduce the alarm from armies of robot slaves: armies of slaves will be no match for intelligent teams operating at maximum performance.

MI theories are neither foundational nor do they afford additive building blocks; unlike MI, interdependence advances social theory. It will lead to more ethical behavior and better judgments of what is, or is not, ethical. At a minimum, AI must provide a context that both humans and machines can share and come to trust, unlike the Uber car that did not share its context with its human operator. That way, when there are rules to follow that society has helped to establish (e.g., guided by Justice Ginsburg 2011), human-machine teams will be able to use their intelligence to abide by the (ethical) rules and complete their mission.

In closing, Wendt (2015, 34) adds that a quantum-like model "offers the potential for revealing new social phenomena", which we have demonstrated by establishing the value of team boundaries, the multitasking nature of teams, and the size of teams, heretofore an open problem (Cooke & Hilton

2015, 33); e.g., for the latter, to wit, in agreement with the second law of thermodynamics, the smallest size of a perfect team is one that minimizes its redundancy, maximizes its interdependence and yet still manages to complete its mission (Lawless 2017a,b).

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