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Exoskeletons and the Future of Work: Envisioning Power and Control in a Workforce Without Limits

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Abstract

Exoskeletons are an emerging form of technology that combines the skills of both machines and humans to give wearers the ability to complete physically demanding tasks that would be too strenuous for most humans (Sarcos Corp, 2019). Exoskeleton adoption has the potential to both enhance and disrupt many aspects of work, including power dynamics in the workplace and the human-machine interactions that take place. Dyadic Power Theory (DPT) is a useful theory for exploring the impacts of exoskeleton adoption (Dunbar et al., 2016). In this conceptual paper, we extend DPT to relationships between humans and machines in organizations, as well as human-human communication where use of an exoskeleton has resulted in shifts of power.

Keywords: exoskeletons, human-robot communication, interpersonal power, Dyadic Power Theory

There is a growing movement in industry to combine the strength, precision, and performance of machines with the agility, intelligence, and creativity of humans through the use of wearable robots, among other technologies (de Looze et al., 2016; Kong et al., 2019). One of the largest sectors within the $130 million wearable robotic industry includes the development of exoskeleton suits for medical, military, or industrial settings (Demaitre, 2019). Generally, industrial exoskeletons are defined as "a wearable device used to support and assist the strength and mobility of the wearer" (Upasani et al., 2019, p. 2). Human-centered

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design seeks to increase the productivity of users of new technologies while improving the user experience, increasing accessibility, and reducing discomfort and stress (Giacomin, 2014). But new technologies often increase stress for the users, especially when technology adoption results in a user's role being open to change or reinterpretation. New technologies often create new roles and shift the balance of power toward those who can more easily adopt the new technologies. Decades of research on technology adoption in organizations have shown that emerging technologies can reshape relationships between coworkers, create role reversals, and disrupt expertise (Barley, 1986; Beane, 2019). In this conceptual paper, we discuss the potential of industrial exoskeleton technologies to shape human-machine and human-human power relationships across a variety of industries and theorize how power dynamics might change in these settings. As Fortunati and Edwards (2020) explain, the power imbalance between humans and machines necessitates adaptation on the part of human actors and can cause frustration when robots and other machines constrain our interactions.

Power is the ability to influence and affect the behavior of others (Dunbar, 2015). Specifically, in this paper we examine a theory of interpersonal power, dyadic power theory (DPT; Dunbar, 2004; Dunbar et al., 2016), which is an interpersonal theory of power that explains the effects of power differences on the outcomes of interaction such as satisfaction. We use DPT to explain how new technologies affect organizational power relationships (using exoskeletons as a case study) in two ways. First, human power hierarchies are based on status and access to resources. Adding a scarce new technology into the workplace means that those with access to that technology and the knowledge about how to use it will have increased power even if there isn't a change to the formal organizational hierarchy. Second, humans often treat machines like coworkers and anthropomorphize their interactions with other technologies like avatars (e.g., Gambino et al., 2020; Nowak & Biocca, 2003) and we expect that exoskeleton users will do the same thing, supported by anecdotal evidence of early adopters. We therefore follow previous scholarship in acknowledging the interdependent and communicative relationships between humans and increasingly agentic machines that impact power dynamics (Banks & de Graaf, 2020; Guzman, 2018). While there might be many other theories of power that could be relevant here (see Dunbar, 2015 for a review of interpersonal theories) and media theories of power that may also be relevant (see Fortunati's 2014 discussion of media tools as sources of empowerment), we emphasize the interpersonal relationships in the workplace that are affected by the introduction of exoskeletons which is why we chose DPT as our theoretical focus.

What Are Exoskeletons?

Passive exoskeletons do not have a power source; instead, these devices rely on counterweights to collect energy from the wearer's own movements. Passive exoskeletons are primarily used to support healthy postures or prevent injury in work that requires repetitive tasks. An example of an upper-limb passive exoskeleton currently on the market is the *EksoVest* (Ekso Bionics, 2019). The EksoVest is designed for workers who engage in repetitive overhead movements that can strain the upper limb, shoulders, and upper back area. The EksoVest can provide full range of movement, is fully customizable to all heights and body types of workers, and can offer a lift assistance range of 5–15 pounds.

In contrast to passive exoskeletons that reduce fatigue, prevent injuries, and minimize the degeneration associated with repetitive strain, *active exoskeletons* can be used to dramatically augment human abilities or performance in physical taskings (Zaroug et al., 2019). Active exoskeletons are powered through actuators, such as electric motors, pneumatics, levers, hydraulics, or some combination of these components (McGowan, 2018). Active exoskeletons were previously developed for use in military settings, including Raytheon's XOS 2 powered armor suit which gave wearers the capability to lift 200 pounds while exerting little physical energy (Kopp, 2011). Emerging forms of active exoskeletons leverage the same capabilities as the Raytheon XOS powered suit but are designed for industrial contexts in the private sector (Kara, 2018). An example of a full-body active exoskeleton being developed for industry is the Guardian XO suit by Sarcos Corp (Sarcos Corp, 2019). Similar to the XOS 2, the Guardian XO will allow humans to lift up to 200 pounds with little energy exertion and will also allow full range of motion so that wearers can perform highly precise tasks with industry-specific equipment. Additionally, the XO contains around 125 onboard sensors with roughly three servers worth of computing power in order to capture and analyze the massive amounts of data being collected by the suit as it's being worn (Horaczek, 2020). Data currently being collected primarily consists of movement information; however, future designs will include more robust information such as operating environment and diagnostics.

Although active exoskeletons are not widely available for commercial purchase, glimpses of these new forms of wearable technologies demonstrate the potential of active exoskeletons to transform work practices across traditionally blue-collar industries such as shipping warehouses, construction sites, manufacturing plants or distribution centers, and also other settings such as hospitals. Unlike passive exoskeletons which are more like a harness or heavy backpack, active exoskeletons are more like robots and are likely to be anthropomorphized, as we discussed above. One important social implication of active exoskeletons is the way these technologies may impact power dynamics in human-machine and human-human interactions. Given the potential for active exoskeleton adoption to transform human-machine interactions across many organizations, researchers need to have theories that can be used to explore the power balances felt in human-exoskeleton interactions. We turn to a discussion of those theories next.

Exoskeletons and Power

Power is one of the most important aspects of all human interactions because it operates *under the surface*, affecting the communication choices we make even if we are not overtly aware of them (Dunbar, 2016). When a new technology is introduced into the workplace, it has the potential to shift the balance of power between members in an organization (Burkhardt & Brass, 1990). Power shifts can be especially salient when there is a gulf of expertise between novices and advanced users of the technology. For instance, in their ethnographic research in the medical industry, Barley (1986) found that the adoption of computerized tomography (CT) scanners resulted in role reversals between radiologists and technologists. In these role reversals, radiologists relied on technologists to help identify pathologies in CT scans because although technologists were not supposed to diagnose pathologies, they were the most skilled at reading the scans (Barley, 1986). More recent research on robot adoption in the workplace has shown that emerging technologies continue to disrupt expertise in roles (Beane, 2019). In a case study on a cadre of beginner surgeons, Beane found that the new collaborative relationships with robots in surgery interrupted the normal training process for surgeons and required that they prematurely chose an area of specialization. Although these studies do not explicitly mention changing power dynamics amidst technology adaption, it is clear that in role reversals and changes in expertise that organizational members experience changes in relative (or informal) authority. The change in relative authority across these contexts showcases the need for researchers interested in technology adoption to more critically engage with how power dynamics change in these contexts.

Emergent technologies also can impact interpersonal dynamics or disrupt levels of autonomy between different stakeholder groups in organizations (Guzley et al., 2002). A useful theory for exploring these phenomena is DPT, which looks at the dyadic nature of power and emphasizes the relative perceived power of two actors in a relationship (Dunbar et al., 2016). DPT is an especially relevant theory when discussing the adoption of emergent technologies because it addresses how individuals perceive their own level of power as well as power balances across their relationships. In DPT, an actor's perception of their power is influenced by two key factors: authority and access to resources. We use the exoskeleton context to extend DPT to relationships between humans and machines in organizations, as well as human-human communication where use of an exoskeleton has resulted in shifts of power.

Although DPT has largely been used in interpersonal communication, its clear explication of power variables and scalable potential across different units of analysis make it useful for exploring exoskeleton adoption in the workplace. In the following sections we explicate DPT mechanisms, demonstrate potential impacts of exoskeletons in workplace human-machine interactions, and extend core DPT propositions to relationships in the exoskeleton context (see Table 1). In our revised propositions, we apply DPT to two units of analysis including power balances in the relationship between humans and active exoskeletons and power distribution across work teams that use active exoskeleton technology.

Power Definitions and Interactional Phases

From a DPT perspective, an actor's perception of their power and perception of power balances in their relationships is influenced by authority and access to resources (Dunbar et al., 2016). However, in DPT, perceptions of power and power itself are explicated differently. In DPT, power is conceptualized as an ability of an actor to influence behavior of another to achieve context-specific goals or outcomes (Dunbar, 2015). Dunbar explained, based on the work of Komter (1989), that across interactions there are three types of power: manifest power, latent power, and invisible power. In manifest power there are visible displays of power within an interaction such as open conflict, identifiable verbal behavior, or nonverbal behavioral cues that lead to desired goals or outcomes. Latent power operates in interactions when a less powerful person identifies the needs and desires of a more powerful person and accommodates in order to avoid conflict. Invisible power includes social or psychological mechanisms that manifest themselves in systematic power inequities such as gender norms or racial inequalities. Although DPT was created to bring understanding to how humans use power to influence behavior and achieve certain outcomes in social inter actions, new forms of technology also can influence human behavior or constrain human agency (Boudreau & Robey, 2005; Huber, 1990; Jones, 1999). Therefore, we argue that manifest, latent, or invisible forms of power can be present in interactions between humans and exoskeletons as well as between exoskeleton wearers and non-wearers in the workplace. These types of power are evident in the discussion that follows because whether or not power is evident or operating *below the surface* is a result of the relationship between the two interaction partners.

TABLE 1 Applying DPT Propositions to the Exoskeleton Context

DPT proposition	Revised DPT proposition	Explanation
P1: Increases in relative authority will be related to increases in relative resources.	P1: Relative authority and access to resources will have a positive reciprocal relationship.	In the context of technology adoption, access to the exoskeleton will help wearers gain expertise with the suit which will increase their relative authority in the workplace.
P2: Increases in relative resources produce an increase in relative power.	P2: Increases in relative resources for humans or machines will produce an increase in relative power.	Exoskeletons that are imbued with enhanced capabilities for surveillance or workflow management will have increased power over wearers.
P3: Increases in relative authority produce an increase in relative power.	P3: Increases in relative authority for humans or machines will produce an increase in relative power.	Exoskeletons that imbued with relative authority to guide and influence wearer behavior will have increased power over wearers.
P4: The relationship between perceived power and control attempts is curvilinear.	No revision needed.	Exoskeleton wearers (at the individual, team, or department levels) perceive less power distance between each other and will engage in control attempts such as disciplining each other.
P5: Greater control attempts will lead to more control over outcomes.	P5: In human-machine relationships with high power discrepancies, control attempts by the more powerful actor are likely to succeed.	When a more powerful actor (whether human or exoskeleton) exercises a control attempt they are more likely to achieve their/its desired outcome in an interaction.
P6: As a partner's perception of their own power relative to their partner's power increases, counter-control attempts will increase as well.	No revision needed.	Exoskeleton wearers (either at the individual or team level) who engage in control attempts will likely be met with counter-control attempts.

DPT proposition	Revised DPT proposition	Explanation
P7: Counter-control attempts will hinder control over outcomes.	No revision needed.	Counter-control attempts mitigate the risk of one wearer or team from dominating their peers and may be needed to keep power balances in check.
P8: The relation between perceived relative power and relational satisfaction is curvilinear.	P8: Perceived power imbalances between humans and machines will have a negative effect on overall job satisfaction.	Perceived power imbalances, such as decreases in autonomy as a result of exoskeleton adoption, can lead to a variety of factors (such as increased stress) which will decrease overall job satisfaction.
P9: Control/counter-control attempts will be more frequent in high-high dyads than low-low dyads.	No revision needed.	In organizations where exoskeleton technology is considered valuable, workers who use exoskeletons will have higher power balances and are likely to engage in more control attempts of one another.
P10: Within generally power-balanced relationships, conflict will occur more often in domains over which both partners have high power than in domains in which only one partner has high power.	No revision needed.	Team members of equal status who have high power in the exoskeleton domain are more likely to engage in conflict over use of this technology.
P11: Dyads in cultures that stigmatize open conflict will display less conflict than dyads in cultures that do not stigmatize open conflict.	No revision needed.	While the corporate culture where the exoskeleton is deployed might be relevant, it is not explicitly discussed in this paper.
P12: Heterosexual couples in strongly patriarchal cultures will have less conflict than couples in less patriarchal cultures.	No revision needed.	Not relevant to exoskeleton context.
P13: Equal-power organizational dyads will display more control attempts than unequal-power dyads.	No revision needed.	Organizations that have equal access to exoskeletons are more likely to engage in control attempts such as industry regulations than organizations with unequal access to resources.

DPT proposition	Revised DPT proposition	Explanation
There is no P14 in DPT	P14: Teams with the agility to shift power domains between members will increase their effectiveness.	If teams are able to shift power based on situational demand, or expertise of team members then they will work more effectively.

Given that DPT is focused on power dynamics in dyadic social interactions, DPT propositions are separated into three distinct phases: pre-interactional phase, an interaction phase, and the post-interaction phase (Dunbar et al., 2016). DPT draws on the social exchange perspective and "predicts that pre-existing cultural, relational, and social factors and the resources that one has access to determine perceptions of one's own power that influences their behavioral tactics within social interactions" (Dunbar, 2015, p. 7). In the pre-interaction phase, the two pre-conditions of power that are likely to shape an interaction include authority and resources (Dunbar, 2015; Dunbar et al., 2016). The interaction phase and post-interaction phase are discussed in later sections.

Authority

Dunbar (2004) defines authority as norms regarding who *ought to* have control in a relationship. For example, whether to adopt exoskeleton technology in the workplace is likely a decision to be made by individuals who have a legitimized form of authority in an organization (such as CEOs, managers, or other individuals with formal decision-making power and spending authority). Authority is always in relation to the interaction partner (called *relative authority* in DPT terms) and can also afford the power to impact organizing processes as individuals with valuable skills, knowledge, or expertise can be influential in the workplace. An example could be that early adopters of exoskeleton technology have relative authority based on their expertise with the technology; they could use this authority to influence perceptions and coworker attitudes toward these technologies through manifest power. Additionally, increases in relative authority could lead to a hierarchical system in which users of the exoskeleton are seen as more valuable to the organization.

When considering human-machine interactions, scholars have long debated whether the human or the machine should have the authority to be the *leader* of the interaction (Draper et al., 1964 as cited in Kirkwood et al., 2021; Major & Shah, 2020). Should the human adapt to the exoskeleton or vice versa (or both)? This question conceptualizes technology as agent rather than tool in order to understand the influence on relationships, processes, and organizational structures and paves the way for researchers to apply human-human theoretical lenses to human-machine interactions (Gibbs et al., 2021). Previous research has found that people synchronize their behavior to machines despite the fact that these behaviors typically do not benefit their machine partners (Fujiwara et al., 2021). Although exoskeletons do not have artificial intelligence, humans may feel that they have to adapt to the machine when the machine does not follow their lead. This may reflect the common *media equation* effect which suggests that people unconsciously treat computers as social actors (Reeves & Nass, 1996).

In a recent unpublished pilot test with full-bodied, powered exoskeletons, users described working with the machine much like they would describe working with a human counterpart, " *. . . and, um, it would be really clunky to do that because that's—I guess not how the robot wants to walk*" *(P3)*. Participants felt they were the recipient of actions, rather than the initiator at times, "*it felt like sometimes I'd be pulled or shoved in a direction that I, I didn't feel like I caused*" *(P8)*. Additionally, many described battling with the machine for control over movement, "*if it's fighting you, uh, in an attempt to do something then that's usually a clear indication that it's not doing what it needs to do*" *(E4)*. These statements provide preliminary (and anecdotal) evidence that people perceive these machines as having some level of agency and feel the need to understand and adapt to the exoskeleton.

Resources

Dunbar's (2004) original conception of DPT defined resources as anything that helps a partner satisfy needs or attain goals. In this way, an exoskeleton is a resource that helps humans complete tasks but they also have the power to disrupt *organizational membership* in nuanced ways. Boudreau and Robey (2005) argued that tensions between human agency and material agency have led to skewed perspectives that overemphasize either one's effect on the other. While some perspectives overemphasize human agency to enact technology in varied ways (even in ways contrary to how the technology was designed; Orlikowski, 2000), other perspectives overemphasize the ability of technology to determine or shape human behavior (Huber, 1990). In response to the polarization between human and material agency in sociotechnical relationships, Jones (1999) offered a dialectic and emergent perspective in which, "the particular trajectory of emergence is not wholly determined either by the intentions of the human actors or by the material properties of technology, but rather by the interplay of the two" (p. 297). Due to the expense associated with powered exoskeletons, if they are a scarce resource available to only a few employees, having access to exoskeletons is a resource in and of itself.

Resources, Diversity, and Inclusion

Active exoskeletons can offer every employee the same lifting or moving abilities, this may diversify the types of candidates that are well-suited for traditionally physically demanding work. Although a person with physical limitations might currently be excluded from physically demanding jobs, active exoskeleton technology may allow the person to perform tasks they previously were unable to, such as lifting heavy objects or squatting. The diversification of organizational membership in traditional blue-collar industries (such as auto manufacturing or shipping warehouses) has implications at the individual and organizational level. On the individual level, diversifying organizational membership can challenge traditional definitions of expertise and professional identity which may impact whether laborers who once took pride in their strength will continue to do so. By disrupting what types of expertise are valued in organizations, through invisible forms of power, exoskeleton technology can have a direct impact on the relative authority of workers; disruptions to relative authority can impact an employee's perceptions of their power in social interactions. On the organizational level, diversifying organizational membership can help create a more inclusive environment which could lead to higher performance outcomes and better, more efficient problem-solving (Harrison & Klein, 2007; Jehn & Bezrukova, 2004).

Exoskeletons and Discriminatory Practices

Although active exoskeletons afford employers the opportunity to create a more diverse and inclusive workplace, the technology could also be used to discriminate against job candidates. The potential for an active exoskeleton to increase diversity and inclusion practices in organizations will be determined by organizational practices and how the suits are designed. Active exoskeletons are expensive to manufacture, and it is not clear which body types can be accommodated in the suits as they are currently created on a one-size-fits-all system (Zhang et al., 2017). For instance, while Sarcos Corp (2019) currently markets the enhanced physical capabilities afforded by the Guardian XO, the company does not provide information regarding the height requirements, weight limitations, or physical limitations that restrict who can wear the suit. While some suits have the capability to make minor sizing adjustments, humans vary widely in body shape and suits may not be designed to accommodate all body types. In addition to sizing, patterns of body movements vary from person to person. It is likely that individuals will have varying physical experiences with the exoskeleton with some finding it more challenging or more natural to embody than other users (Zhang et al., 2017). Knight and Baber (2005) emphasized that feelings of discomfort or pain are salient issues in wearable technology, and workers who have sustained workplace injuries or who have physical disabilities could be especially vulnerable to feelings of discomfort in the suit. Other industries have historically imposed weight or height requirements in order to exclude individuals from organizational membership (Murphy, 1998). In her study on flight attendant resistance, Murphy examined a case in which flight attendants challenged weight requirements and ultimately had the airline overturn those requirements. While the flight attendants in Murphy's study were able to create a more inclusive work environment, employees who are excluded from wearing an active exoskeleton may come across more obstacles when challenging their employer. These challenges can be exacerbated if it is expensive for organizations to modify the suits to make them adaptable or adjustable to all body types. Exoskeletons that cannot accommodate diverse body types may afford employers the power to exclude employees from roles which require exoskeleton usage; this could result in discriminatory practices within organizations. Thus, while exoskeletons are an important resource for workers in a variety of fields, they might operate to both enhance power equality by making certain physical tasks available to workers currently excluded from those opportunities but may also further exacerbate power inequality by highlighting physical differences that may lead to discrimination. Each individual organization should evaluate the effect that exoskeletons are providing to their employees based on their uses and availability.

Revised DPT Propositions

DPT originally had eight theoretical propositions (Dunbar, 2004). An additional five propositions were added in a subsequent revision and expansion of the theory (Dunbar et al., 2016). We explore how DPT can enlighten our understanding of the introduction of exoskeleton technology to the workplace by systematically considering several of the theory's propositions in this context. Although not all the propositions are relevant to the exoskeleton context, we offer some discussion of the most relevant propositions and how they might apply in exoskeleton-human interactions. We hope readers will find this expanded theory useful when studying the integration of exoskeletons into workforces (see Table 1 for a summary of the original propositions and revisions). While this paper addresses theoretical questions, methodological issues in testing DPT are addressed elsewhere (Dunbar et al., 2016). The first three propositions relate to the pre-interaction phase in dyadic interactions.

Pre-Interactional Propositions

The first proposition of DPT (P1) is that increases in relative authority will be related to increases in relative resources. Although it is certainly the case that legitimized authority in the organizational context can lead to increases in greater resources, it is also possible for increased access to resources to increase a person's relative authority. Relative authority can be operationalized with a variety of context-specific variables. In the technology adoption context, expertise with new technologies will increase an individual's relative authority. Within the exoskeleton context, early wearers are likely to be sought out by other organizational members for information about the suit, knowledge of how to use the suit effectively, and how work tasks may need to be modified considering these new technologies. Given this logic, we revise P1 accordingly:

> **P1:** Relative authority and access to resources will have a positive reciprocal relationship.

In this revised proposition it is important to *reiterate the distinction between relative authority and legitimized authority.* We are not arguing that access to an active exoskeleton will lead to a formal increase in authority (such as a promotion to management, etc.). Rather, relative authority can be informal in nature such as coworkers considering an early adopter of active exoskeletons as an expert in the technology.

The second and third propositions of DPT indicate that increases in relative resources (P2) and relative authority (P3) will produce an increase in relative power (Dunbar et al., 2016). While P1 explicates the relationship between relative authority and resources, P2 and P3 explicate the direct relationship that relative authority and access to resources have on relative power in social interactions. We argue that these propositions hold true not only for humans but for active exoskeletons as well. Some organizations may imbue the exoskeleton with additional resources (in the form of technological capabilities) that allow the technology to surveil employees and influence employee behavior. New capabilities afforded by algorithmic management and RFID tags have exemplified cases in which employers use technology to closely monitor their employees, collect personalized data on how employees work, and use that information to terminate employees or influence employee behavior (Chan & Humphreys, 2018; Lupton, 2020). While exoskeleton manufacturers have not marketed surveillance capabilities in active exoskeletons, these suits contain hundreds of sensors that collect and process information about a wearer's movements (Islam & Bai, 2020). While this data is necessary to control the exoskeleton, there are certainly opportunities for collecting and using this data to surveil and track employee movement and productivity. These forms of increased resources or capabilities of active exoskeletons are likely to increase the power these devices have in human-machine interactions. We revise P2 accordingly:

> **P2:** Increases in relative resources for humans or machines will produce an increase in relative power.

P2 is also relevant for human actors in dyadic interactions, as access to a resource such as an active exoskeleton will increase the relative power that the wearer has in interactions with non-wearers. It also increases the power of managers to surveil their employees and thus acts as a resource for them as well.

P3 directly addresses the positively associated relationship between relative authority and relative power. In addition to collecting personalized data on employee behavior and employee movement, active exoskeletons may also have a pedagogical element similar to other wearable technology such as Fitbits. Just as algorithms already manage employees in the rideshare context (e.g., Uber or Lyft; Rosenblat, 2019), it is possible that exoskeletons could be programmed with feedback mechanisms to manage employees such as telling them when to lift an item, where to move an item, or how fast to complete work tasks. We can conceptualize this pedagogical element as providing an increase in the active exoskeleton's relative authority, because the suit is interpreting data and providing guidance for wearers. This guidance may be used to optimize efficiency or could be used for other goals such as helping wearers increase workplace safety, help wearers control their movements, or help wearers have a more comfortable experience in the suit. We revise P3 accordingly:

> **P3:** Increases in relative authority for humans or machines will produce an increase in relative power.

P3 is also relevant for human actors in an exoskeleton adoption context. Early adopters of exoskeleton technology are likely to be seen as having cutting-edge technical expertise with these systems which is likely to increase their relative power to influence coworker behavior. This form of expertise can increase the relative authority an employee has in the workplace as other organizational members are likely to turn to these early adopters for information about the technology. In a network analysis of structural changes after technology adoption, Burkhardt and Brass (1990) found that early adopters of the technology increased their network centrality and power in their organization. In the following section we move beyond the pre-interactional phase and explore DPT propositions within interactions.

Interactional Propositions

Another major component of DPT involves predicting relationships between the perceived amount of power an individual feels they have and whether they are likely to attempt to control another's behavior in a social interaction. Dunbar (2004) argued that while dominant behaviors could constitute a control attempt, there are a multitude of other strategies that individuals can enact to control another's behavior. Multiple studies using DPT have revealed that perceived power and control attempts show a curvilinear relationship between power and dominance, as illustrated through dominant gestures, more interruptions, and more argumentative language (Dunbar, 2004; Dunbar & Abra, 2010; Dunbar & Burgoon, 2005; Dunbar et al., 2016). In the fourth proposition of DPT (P4), Dunbar et al. (2016) argued that individuals who feel they have high or low power in an interaction are less likely to engage in control attempts when compared to individuals who perceive equal, small, or moderate power differentials in a dyadic interaction. In other words, when trying to establish the "pecking order" in an organization, a built-in hierarchy means that coworkers at the same level will vie for position through dominance behaviors with one another (such as arguing or contradicting) more than they will with people above or below them in the hierarchy. Across several studies, Dunbar has found that indeed, equal-power partners use the most dominance followed closely by the high-power partners, while low-power partners use the least dominance (Dunbar et al., 2016).

While the fourth proposition does not need revision for the exoskeleton context, we emphasize that this proposition is scalable to larger units of analysis. In work environments where exoskeletons are seen as a resource, access to the exoskeleton suit will give wearers higher levels of perceived power in work interactions with non-wearers. When non-wearers perceive wearers as having more power, this perception may shape interactions between team members or dynamics between separate teams in an organization. Consistent with the curvilinear relationship between perceived power and control attempts, we argue that suit wearers will engage in more control attempts with one another since the power distance between wearers is relatively equal when compared to the power distance between a wearer and a non-wearer. These control attempts may also be observed between teams or departments made up of exoskeleton wearers. Since wearers (as individuals or teams) are likely to perceive relatively equal levels of power between each other, they will be more likely to discipline one another, influence how one another uses the suit, or spark conflict over disagreements regarding suit use. Given the larger power gap between non-wearers and wearers, non-wearers (at the individual or team level) may be less likely to engage in control attempts over a wearer or influence how the wearer uses the suit.

The fifth through the seventh DPT propositions (P5–P7) address how actors respond to control attempts in relationships (Dunbar et al., 2016). When power differentials are high in dyads, control attempts are more likely to be successful (P5). In the exoskeleton context, wearers or the suit itself may have more power depending on organizational context. In the example of an active exoskeleton being programmed with management or surveillance capabilities, it is likely that when the suit attempts to control the wearer that the wearer will comply. Similar to P2 and P3, we argue that this proposition can be extended to human or machine actors:

> **P5:** In human-machine relationships with high power discrepancies, control attempts by the more powerful actor are likely to succeed.

In the sixth (P6) and seventh (P7) proposition, Dunbar et al. (2016) argued that in relationships where actors perceive equal power, small power differentials, or moderate power differentials, they are more likely to engage in counter-control attempts. These counter-control attempts can mitigate the control attempts that may be used to shape outcomes. We argue that in the exoskeleton context, P6 and P7 do not need revision but can be scalable similar to P4. Exoskeleton wearers (either at the individual or team level) who engage in control attempts with other exoskeleton wearers are likely to be met with counter-control attempts. Counter-control attempts mitigate the risk of one wearer or team from dominating their peers and may be needed to keep power balances in check.

Post-Interaction Propositions

The post-interactional phase in DPT addresses long-term impacts of power dynamics or power imbalances in relationships (Dunbar et al., 2016). Dunbar (2004) argued that relational satisfaction is a key variable that can be explained when power imbalances are investigated in long-term relationships. In the eighth proposition (P8) Dunbar et al. (2016) argued that perceived power has a curvilinear effect on satisfaction in relationships. This means that actors who perceive their power as extremely low or high will be less satisfied in their relationships when compared to relationships where power differentials are small or moderate. Although relationship satisfaction is more applicable to interpersonal dyadic relationships, we argue that power imbalances can impact key variables on the team or organization level such as team satisfaction or job satisfaction. In an organizational context, perceived power might not have the same curvilinear effect on job satisfaction as it has in relational satisfaction, because there are already large power discrepancies between organizational members (e.g., CEOs when compared to subordinate employees) in the workplace. However, perceived power imbalances, such as loss of autonomy, can have negative impacts on workers by increasing stress levels and reducing job satisfaction. For instance, Mahon (2014) found that nurses in lower positions of power felt less respected by fellow hospital employees, which led to higher feelings of stress, and ultimately had higher levels of attrition than nurses with more power. As these workers gained more knowledge, experience, and autonomy, they reported feeling less of a power imbalance and a higher intention to stay in their current position. Being under constant surveillance in an exoskeleton can make employees feel that they have less power and control than the technology that is being used to manage their performance. This power imbalance may lead workers to employ resistance tactics to find balance. Introducing new technologies into the workplace that fundamentally change the work being performed or make a worker's current skills obsolete will undoubtedly cause shifts in power, added stress, and uncertainty for workers as well. We revise P8 in the following way:

> **P8:** Perceived power imbalances between humans and machines will have a negative effect on overall job satisfaction.

In the following section we explore the concept of power domains in an exoskeleton context; power domains allow researchers to explore additional outcomes of power balances in relationships including conflict.

Power Domain Propositions

In long-term close relationships, DPT treats power as generalizable across a relationship. For example, a team member with expertise in accounting might have more power when making decisions about financial resources whereas an employee with expertise in design might have more power over product development, but both employees will average out to be a relatively power-balanced relationship. Dunbar et al. (2016) argued that, "the degree to which the domain contributes to that power dynamic depends on the importance of that domain to the relationship" (p. 86). In their ninth proposition (P9), Dunbar et al. argue that when particular domains are considered valuable, the dyad can be conceptualized as having higher power balances. Dunbar et al. also argued that a higher power balance is likely to make the actors more interdependent with one another. Since the amount of control attempts are correlated with the length of a relationship between actors, DPT predicts that a high-high power balance in the dyad will be positively associated with control attempts (Dunbar et al., 2016). We argue that P9 applies in this context as well because in organizations where exoskeleton technology is considered valuable, workers who use exoskeletons will have higher power balances and are likely to engage in more control attempts with one another.

In DPT, power domains can impact whether conflict is likely to arise in dyadic interactions. In their tenth proposition (P10), Dunbar et al. (2016) argued that in relationships with balanced power that conflict is more likely to occur in domains in which both actors have power rather than in domains in which only one actor has high power. It is likely that team members of equal status who have high power in the exoskeleton domain are more likely to engage in conflict over use of this technology than team member interactions in which only one member has power in the exoskeleton domain. We argue that P10 does not need revision and will hold true in the exoskeleton context. Similarly, P11 and P12, regarding culture and gender according to Dunbar et al. (2016) are not revised for this context.

A recent revision of DPT (Dunbar et al., 2016) argued that people negotiate the domains in which they want more power. If one team has more expertise in a domain that a group values (such as technical expertise with an active exoskeleton) then that should translate into more power in the relationship generally. Even a team member who has lower status (i.e., employees in nonsupervisory positions) than another might be able to exert more power in certain circumstances in which their expertise is valued. In a study on the fluidity of power dynamics on cross-functional teams, Aime et al. (2014) found that, "the expression of power actively shifts among team members to align team member capabilities with dynamic situational demand can enhance team creativity" (p. 327). While Aime et al. were not using the DPT concept of generalized power, their findings described a similar process in which team members had more power when work situations demanded their expertise or abilities. The finding that teams that embrace situational shifts in perceptions of power, expressions of power, and the legitimacy of power expressions were able to be more creative suggests that there may be other positive benefits for teams that embrace power based on situational needs or expertise instead of treating power as a fixed attribute based on position. Given this logic, we propose an additional proposition to DPT (P14):

> **P14:** Teams with the agility to shift power domains between members will increase their effectiveness.

Janss et al. (2012) provided another example of generalizable power domains from the world of medical action teams. These teams often are formed on an ad hoc basis with various multidisciplinary team members (physicians, surgeons, anesthesiologists, nurses) performing pre-determined roles, but leadership is often dynamic based on the situation. When there is a conflict within the team about how to proceed, it can hamper the team's effectiveness. Team members may have a shared history that affects their perception of team power relationships and they might have expertise that surpasses their official role in the team, such as an experienced nurse working with an inexperienced resident. In teams, a lower status team member may be more influential if they have valuable expertise. In using exoskeletons in the workplace, like any new technology, experienced team members will see their power within the group grow compared to inexperienced team members, regardless of their actual hierarchical status within the group.

Discussion

This paper represents the first attempt to extend DPT from human interactions to human-machine interactions. While DPT has centered on human relationships, there is nothing intrinsic to the theory that would limit its application to relationships between humans and nonhumans (including humans and forms of technology such as exoskeletons) and use in various organizational contexts (including multiple units of analysis within and between organizations). The shift to human-machine from human-human communication provides the opportunities for scholars to test the boundaries of human interaction theories, and to explore new dimensions of humanity as we create increasingly anthropomorphic machines.

It is important for researchers to recognize the organizational context when applying DPT to human-machine interactions in the workplace. These emerging technologies are not only complex in how the technology operates but also in how these technologies make people *feel*. For instance, active exoskeletons may make organizational members feel empowered or disenfranchised depending on individual perceptions formed from dyadic interactions with the suit and coworkers. Additionally, there may be second-order implications of exoskeleton use in the workplace that impact perceptions of power balances in the workplace. Some of these second-order implications involve to what extent active exoskeletons are used to surveil employees and the privacy and trust issues that will rise under these conditions. In this case the organizational context of surveillance practices will most certainly impact how powerful or powerless wearers feel while using the technology. Researchers who are interested in issues of power and trust in this context should pay close attention to how surveillance impacts the use of active exoskeleton technologies.

When a new technology is introduced into the workplace, a shift in power dynamics can occur as users adopt and adapt to technologies at different paces thus creating gaps in expertise (Barley, 1986; Burkhardt & Brass, 1990). Those who learn new technologies sooner can experience an increase in their relative authority in the organization as less knowledgeable users, including users with more legitimized authority, seek assistance or defer to the more experienced user. Early adopters of exoskeleton technologies in an industrial context will likely have a major influence on operations, and safety and training. For example, an exoskeleton user may be called upon to assist in warehouse layout changes to accommodate suit wearers, priority lists for tasks to be done with the exoskeleton, drafting safety and usage protocols, and assisting with training and adoption as early users will be seen as "testers" for a novel technology. Accomplishing these will require an increased access to organizational resources and an elevation in relative and/or legitimate authority.

The impact on invisible power also has implications for practitioners and researchers. The exoskeleton suit is designed to augment human strength which means that people who previously were unable to work in labor-intensive environments will, with the exoskeleton, have that option. Managers implementing exoskeletons will have a much wider pool of potential candidates, and possibly reduce employment costs from workplace injuries and turnover. How will the workplace dynamics of these organizations change with more diversity, particularly age and physical sex diversity? Researchers will have the opportunity to explore what can happen when physical abilities are no longer a limiting factor in labor-intensive employment.

Finally, exoskeletons provide a novel context for studying power dynamics between a human and a machine counterpart due to the high level of interdependence. Scholars in engineering have long pondered the question of when a human should be in control versus the computer (e.g., airplane autopilot versus human captain; Draper et al., 1964 as cited in Kirkwood et al., 2021; Major & Shah, 2020). There are different answers to the control question depending on context and user preference, but what about when the technology is embodied? How does a user's opinion of the agency of the technology impact their understanding of their own power relative to the machine? Users who are suddenly capable of lifting superhuman loads will likely experience some shifts in their self-concept. When and why do some users defer to the machine to control their movements while other users insist on retaining full control? Researchers will be able to gain a more nuanced understanding of relationships between humans and machines when the machines become inseparable from the humans.

We encourage researchers to test, challenge, or extend the propositions we have proposed in order to advance knowledge of power dynamics in human-machine interactions. Research on exoskeleton adoption and human-machine interactions is in its infancy and much empirical research is needed to understand the impact of these technologies as well as the viability of DPT in human-machine research. This paper is an early attempt at helping guide research in this area. We hope that the ideas and provocations within it are helpful for researchers interested in wearable technology, human-machine interactions, and the intersection between technology use and power dynamics in the workplace.

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