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Choreographies of Care. A Dance of Human and Material Agency in Rehabilitation Work with Robots.

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This article seeks to advance the understanding of how human and material agency enmesh in human-robotic workplaces. By means of a qualitative study, the practical use of robots is investigated within two organisations for medical rehabilitation. The theoretical framework combines Andrew Pickering's 'dance of agency' with a process-oriented view of technology as technical rationality. It shows how resistances and accommodations are enacted by both humans and nonhumans as analytical loci of the dance of agency, and it explains how the experimental activities that are concerned with technology adoption and use are emergently fixed in formal or informal rules of coordination of action – the 'choreographies of care'. By extending the processual orientation of Pickering's 'dance of agency', and by further elaborating on the organisational implications of technological change within it, the article increases understanding of how the transformation of material agency may enact processes of change in the organisational culture.

Keywords

dance of agency, organising, process, rehabilitation, robots, technology, therapist, work

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Introduction

The increasing adoption of robotic technologies in the workplace is prompting extensive research endeavours on the future of work (Karakilic, 2020). Recent analysis finds that the effect of robotic automation on employment may be less significant than previously believed (Fleming, 2019), while new complementarities between humans and technologies are likely to emerge (Shestakofsky, 2017). However, concerns regarding the disruption of established work practices are manifold (Spencer, 2017). While technological unemployment seems to cause the greatest fear, another source of distress is the *transformation of work* when advanced forms of technology are adopted in the workplace (Pettersen, 2019). Prior research has explored this issue from various perspectives, and it has shown both opportunities and threats for workers. However, many analyses still suffer from a polarization between the positive and negative 'impacts' of technology on work; or they fear that robots and other technologies may steal people's jobs. Although more nuanced analyses have recently emerged (Casilli, 2021), a lack of empirical research on the practical use of robots in organizations persists (Lloyd and Payne 2021). To fill this gap, this article focuses on the transformation of work and seeks to advance understanding of *how human and material agency enmesh in human-robotic work settings*. For this purpose, the practical use of robots has been investigated by means of a qualitative study conducted within two organisations for medical rehabilitation in Italy. In doing so, a theoretical framework has been developed by drawing on Andrew Pickering's theory of the 'dance of agency' (Pickering, 1993; 1995). According to this theory, work processes can be studied by looking at the emergent and interrelated 'dance' of 'resistance' and 'accommodation' among three types of agencies: human agency, which introduces a tentative orientation to goals – a 'modelling' – into the action; the material agency of the technological artifacts, i.e. the doing of things in a posthuman understanding of action; and disciplinary agency, i.e. the agency of the existing culture which accompanies conceptual elaboration (Pickering, 1995: 6-9; 114).

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The theoretical background of the study combines these notions with a process-oriented view of technology as technical rationality, and it concentrates on Pickering's notion of 'choreography' in order to advance understanding of the organisational implications of human-robotic enmeshing within the dance of agency.

The analysis reveals how humans and robots are loci of the interactive stabilization of human and material agency within the 'dance' of therapeutic practices, and how the reconfiguration of work in human-robotic work processes is shaped by a bundle of dynamics of resistance and accommodation much more complex than mere change in the technical apparatus of the action. Moreover, the article shows how the technical plane of therapeutic action in human-robotic rehabilitation is transformed, and how the 'modelling' actions enacted by the therapists as they use the robotic appliances are emergently and tentatively fixed in 'choreographies of care'. These choreographies are part of the disciplinary agency of work processes, and they are conceived as the temporary introduction of formal or informal rules of coordination of action within the existing culture of rehabilitation at the organisational level. In this vein, as *choreographers* of their work process, therapists are not the 'supervisors of machines' described in many classic sociological studies on work and technology; rather, they perform both the role of 'dancers' and 'directors of the dance' as they contribute to the configuration of the choreographies.

The article's contribution is twofold. First, it provides an empirical account of the dance of agency between humans and nonhumans in the context of rehabilitation work. It shows how focusing on the process of interactive stabilization of work processes instead of the 'impact' of technology on work yields deeper understanding of work transformation as an open-ended process of becoming, and the role of humans and nonhumans in it. This makes it possible to overcome static and binary thinking on technology and work, and to discover the hidden possibilities of autonomy and creativity in human-robotic work. Second, at a theoretical level,

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it extends Pickering's 'dance of agency' in two ways. On the one hand, it strengthens the processual orientation of the theory by showing how humans and nonhumans do not have any given resistant (i.e., the technology) or accommodating (i.e., the humans) property, as instead envisioned in the original formulation of the theory by Pickering and in related research. Rather, it shows how resistances and accommodations may be enacted by both humans and nonhumans as the analytical loci of the dance of agency; also, it reveals that accommodations do not necessarily follow resistances; nor do resistances necessarily follow accommodations. On the other hand, it further elaborates on the organisational implications of technological change within the dance of agency by providing an original perspective on how the experimental activities that are concerned by technology adoption and use are emergently and tentatively fixed into choreographies. This elaboration enlarges the understanding of how the transformation of material agency may enact processes of change in the existing organisational culture.

The remainder of the article is organized as follows. The next section discusses prior research on the adoption of robots in organisations. It then outlines the theoretical background of the study and its method. The following section presents the findings, while the discussion section highlights the main contributions of the research. The final section draws conclusions and presents the study's limitations and implications for future research.

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Related research

Research on the adoption of robots in organisations has explored the transformation of work from different perspectives, showing both opportunities and threats for workers. Research reports, for example, reduced routine work (Huang and Rust, 2018), enhanced productivity and job satisfaction (Lacity and Willcocks, 2016); but it also suggests that workers may experience problems in learning new techniques and technology (Beane, 2019), and that both customers and workers may feel uncomfortable with robot interactions (van Pinxteren et al., 2019). Moreover, work autonomy, responsibility and skills may be hampered because work processes are often streamlined (Barrett et al., 2012; Beane and Orlikowski, 2015), thus generating work displacement and job commoditization (Fleming, 2019). However, evidence for technology's influence on work transformation is still unclear. Indeed, for every research study that foresees an enlargement of human skills and space of action in the future of work – the 'upskilling' idea (Martinaitis et al., 2020) – there is another one that foresees a minor role for humans, giving new impetus to the deskilling hypothesis (Braverman et al., 1998). Furthermore, the idea that new technologies, and in particular robots, will one day steal people's jobs is so deep-rooted that scholars have recently investigated explicit labour-saving heuristics within robotic patents, showing how labour-saving innovations are directed towards manual activities in services (e.g., in the logistics sector), activities entailing social intelligence (e.g., in the healthcare sector) and cognitive skills (e.g., learning and predicting) (Montobbio et al. 2021).

This article, however, is not interested in evaluating the 'impact' of robots; nor does it intend to give evidence for the deskilling or the upskilling/reskilling hypothesis, or even to corroborate (or not) the view that robots will one day steal people's jobs. Rather, it starts from a different point by arguing that technologies are always inseparable from their use (Suchman 1987/2002; Bruni, 2005), and that robots are no exception.

In the medical field, research has already shown the many significant implications that arise when a new technology is adopted, such as task redistribution between humans and non-humans (Star, 1999; Nicolini, 2010; Morland and Pettersen, 2018), a renegotiation of medical work practices (Introna et al., 2019), and a change of the discursive practices involved in telemedicine (Gherardi, 2010). However, while more extensive research focuses on specific medical professions, such as surgery and pharmaceutics (Korika and Molloy, 2010; Barrett et al., 2012; Beane, 2019; Menchick, 2020), less attention has been paid to studying how robots

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enter the everyday practices of rehabilitation work. Moreover, studies that focus on work autonomy suggest that, in such a structured organisational domain, robotic technology would impose further restrictions on therapists' autonomy (Petrakaki and Kornelakis, 2016), a result that seems interesting and warrants further study.

Although several nuanced understandings regarding the use of robots in work settings are currently emerging in general (Casilli, 2021), and in medical work settings in particular (Beane 2019; Santos et al. 2021; Hung 2021), there is still a polarization between the positive and negative 'impacts' of technology on work, a focus on the fear that robots and other technologies may steal people's jobs, and a lack of empirical research within established workplaces (Lloyd and Payne 2021). The present study intends to fill these gaps by providing an empirical account of how work transforms when robots are adopted in a context of rehabilitative care.

Theoretical framework

From these preliminary considerations, the article develops a theoretical approach that departs from any essentialist, idealized view of technology in itself (Grint and Woolgar, 1997), and its 'impact' on organizations. While many analyses maintain that machines and humans can coexist (Friedman et al., 2006), this study assumes a posthuman account of sociomaterial agency (Orlikowski and Scott, 2008) by drawing on the theoretical perspective of the 'dance of agency' of human and material artifacts originally proposed by Andrew Pickering (1993; 1995), and further developed in technology and work studies by Barrett et al. (2012), Jones (2014) and Eaton et al. (2015).

Within Pickering's view on sociomateriality, any representationalist account of descriptions as mirrors of nature is rejected (Jones, 2014) and agency is conceived as a temporally emergent phenomenon of humans and material artifacts constitutively enmeshed in processes of resistance and accommodation: 'the dance of agency'. Resistances are blockages on the path

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to certain goals that can arise in human dealings with machines or concepts (Pickering, 1995: 22; 113). Accommodations are the active human responses to such resistances that entail 'revisions to goals and intentions as well as to the material form of the machine in question and to the human frame of gestures and the social relations that surround it' (*ibidem*: 22).

There are two distinctive features of this theory that are relevant to the analysis of work transformation in human-robotic workplaces: first, it envisions transformation because it studies agency as a temporally emergent open-ended process of becoming; second, it supports a posthumanist displacement of the human subjects because it acknowledges a role for nonhuman or material agency that is thought-provoking when work is performed by humans and robots.

The idea that 'material and human agencies are mutually and emergently productive of one another' (Pickering, 1993: 567) is the key notion which helps to understand the 'dance of agency'. However, 'humans differ from nonhumans precisely in that our actions have intentions behind them' (Pickering, 1993: 565). The structure of agency reflects these intentions and plans in a process of 'modelling', although humans are not 'in control of history' (*ibidem*: 574). This lack of control derives partly from the social dimension of practices and partly from material agency and the 'impure' process of 'tuning' or 'interactive stabilization' of human and material agency. This notion of 'interactive stabilization' is crucial for the purpose of the present study because it conceives work transformation as the continual reconfiguration of human and material procedures within the open-ended trial-and-error variations of the existing culture that accompanies the dance of agency. When discussing this process, Pickering introduces another concept that is vital for this article: the idea that 'the open-ended dance of agency (…) becomes effectively frozen at moments of interactive stabilization into a relatively fixed cultural *choreography*' (Pickering, 1995: 102) encompassing captures and framings of material agency and human practices. Although

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Pickering does not fully develop the notion of *choreography,* he nevertheless introduces the idea that the *temporally emergent* process of modelling still 'produces' something that is 'relatively fixed'. Other studies have embraced Pickering's notion of choreography: for instance, Franklin's (2009) analysis of the emergent and co-constitutive entanglement of humans and nature in the 'choreography of fire'. However, nor does Franklin's study fully elaborate the notion theoretically, while others such those by Huvila and Sköld (2021) and Alarcón López et al. (2021) mention it only in passing.

The idea of the choreography is linked to the notion that the interactive stabilization between human and material agency involves an ongoing process of conceptual elaboration and knowledge production. These conceptual elaborations affect the disciplinary agency – the established culture of the work process – for example, how to do things or how to change current procedures when robots are adopted in the workplace. Although the trial-and-error activities concerned by the use of robots are open-ended, the interactive stabilization among material procedures, material performances and conceptual understandings is emergently and tentatively set forth in formal or informal rules of action, e.g., when to use conventional or robotic technology, how to combine different procedures, etc. These novel understandings became part of the disciplinary agency of work processes and are effectively frozen 'into a relatively fixed cultural *choreography*' (Pickering, 1995: 102).

Pickering's thought provides a distinct philosophy of technology that has an anti-dualist character (Collin, 2011: 160). However, the 'dance of agency' can still subtend the dominance of the human side over the material side, or the reverse. Nevertheless, a key tenet of the theoretical framework of the present study is that '[d]ualism is what prevents thought. Dualism always wants to deny the essence of thought, namely, that thought is a *process'* (Young, 2013: 4). Bearing this point in mind, in this article, Pickering's theoretical perspective has been combined with a process-oriented view of technology as the technical plane of organisational

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action, or its 'technical rationality' (Thompson, 1967: 14). In such a view, technology is anchored to the ancient etymological root of the Greek word τέχνη (tékhnē), since it frames it as art, skill, or craft, or, even better, as 'the principles or methods employed in making something or attaining an objective' (as stated in the Merriam-Webster Dictionary). From this perspective, technology is invariably incomplete, conditional, and not entirely separable from concrete action (Maggi, 2003). Instead of focusing on humans and nonhumans seen as entities entangled in a reciprocal dance interplay, the article proposes that humans and nonhumans are *analytical loci* of an open-ended posthuman dancing process. Adopting such a process-oriented view of Picketing's dance of agency means focusing on the posthuman *actions* rather than on the human or nonhuman *actors* with given resistant (i.e., the technology) or accommodating (i.e., the humans) properties. From this perspective, both resistances and accommodations may be *enacted* by both humans and nonhumans and what is researched is the process of 'interactive stabilization' of human and material agency, and how it changes when robots enter the workplace.

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Method

This article investigates the practical use of robots within two clinics for medical rehabilitation in Italy: Alpha and Beta (fictional names). The two organisations were chosen to leverage the logic of the most similar systems design (Anckar, 2008): that is, comparing cases as similar as possible to give robustness to findings while uncovering micro processual dynamics and refining results (see Table 1 for a summary of the characteristics of the two organizations).

INSERT TABLE 1 ABOUT HERE

Physiotherapists work side by side with many other professionals involved in the treatment of patients, such as physiatrists, occupational therapists, neurologists, etc. However, this article focuses on the work of therapists alone. Their work environment is usually a gym in the facility, but patients may also be treated at home. Moreover, patients may be assigned exercises to undertake on their own, under the surveillance of a therapist or sometimes a family member (at home). Therapists use technology to improve the effectiveness of the rehabilitation process and to accelerate the patient's recovery. Although a wide array of technologies is used, this article investigates only the use by therapists of robotic technology, and specifically: exoskeletons for the upper and lower limb, robotic gloves, and robot-assisted rehabilitation platforms (see Figure 1 for an image of each technology).

INSERT FIGURE 1 ABOUT HERE

All these technologies were employed in both the organisations studied (see Table 2 for the characteristics of each technology).

INSERT TABLE 2 ABOUT HERE

Data collection and analysis

Data were mainly collected between September 2019 and July 2020, although further data were gathered between May 2022 and July 2022 in order to refine the previous results. A combination of qualitative methods was used. It included meetings, interviews, participant observations, and document analysis. In both settings, in-depth interviews (N=32) were conducted with therapists and nurses (22), directors, managers, and biotechnical engineers (8),

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and patients (2). Moreover, *ad hoc* meetings (N=13) were held with directors and managers. The researchers spent two full days of participant observation in Beta, and one in Alpha, taking notes on the work practices of therapists, and holding further informal discussions with management and therapists.

Each author kept a diary, taking notes on impressions, interactions between patients and therapists, and specific working situations impossible to grasp by means of interviews. A formal approval from the ethical committee of the healthcare trusts involved was not required for this study because it did not involve drugs. However, informed consent was obtained from the participants. Moreover, both organizations were involved in all the research design phases, so that potential ethical problems could be discussed in advance and during the data collection phase.

To develop a processual understanding of the practical use of robots, the researchers constantly focused on capturing changes over time by paying attention to the unfolding of the work activities and flows of the interviewees (Abdallah et al., 2019). This was done, for example, by asking each interviewee to focus on and report about not only when and how the work (or the therapy, in the case of patients) changed over time, but also by asking them for a constant reflection on the unfolding of the interactions with the passage of time (e.g., 'How was your work before the introduction of robots, and how was your work soon after?'; 'Can you say how your work has changed in time and/or space?'; 'Could you provide a few examples that illustrate this process of change?').

While a common interview protocol was followed, an open-ended format was also adopted to obtain a description of the events and processes that was as rich as possible (Compagni et al., 2015). The interviews lasted between 40 and 90 minutes, and they were recorded and transcribed verbatim. Empirical data were analysed by means of template analysis (King 2004; King et al. 2018) assuming contextualism as a philosophical orientation, which implies an

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understanding of reality as not independent of human perceptions, whereas the knowledge of any phenomenon cannot be separated from the personal engagement with it (King et al. 2018). After the closest possible familiarity with the data had been gained, a preliminary coding was performed, relying also on *a priori* themes based on theoretical ideas that have guided research on the therapeutic use of robots and were expected to be relevant to the analysis. Reading through the data, items of text related to these themes were coded, also defining new ones to categorize data which did not fit with the *a priori* themes. After the coding of some interviews, an initial template of themes was defined and then applied through an iterative process of trying to code data with it, noting where difficulties arose when so doing, and therefore modifying the template in consideration of what emerged from the transcripts. This cycle was repeated until a final template was obtained (see Table 3 for a simplified version of the final template).

INSERT TABLE 3 ABOUT HERE

The following section illustrates the study's findings, and it is divided into four subsections. First, it describes rehabilitation work with and without robots; then it focuses on how resistances and accommodations are enacted by humans and nonhumans in rehabilitation work with robots; then it examines the role of therapists in configuring human-robotic choreographies; finally, it contextualizes the interrelated roles of humans and robots within the emerging and open-ended dance of rehabilitation.

Findings

The rehabilitation work with and without robots

Without robots, the hands and bodies of therapists are typically complemented by many simple technologies, such as mechanical supports or more mundane objects available in the gym or in

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the patient's home, such as pillows, books, etc. In fact, the traditional idea of rehabilitation implies that 'the therapist is the machine' (Director, Beta), but when robots enter the scene, the interaction with patients changes because the technological device occasions the transformation of the technical rationality of the therapy, and put simply, 'the therapist becomes the brain' (Director, Alpha). The story recounted by the therapist of a quadriplegic patient unable to reach the last degrees of flexion of the elbow is an example of the open-ended modelling work usually carried out in traditional rehabilitation:

'On the table of our refectory, we lifted the patient's elbow. First, we used books stacked to different heights and did tests. Then, with a rigid support and foam, we found the right position so that the patient could, with a doily and a custom-made fork, take food from the plate and then, with this adequate height, bring it to his mouth.' (Therapist 3, Alpha)

This do-it-yourself scenario focuses on autonomy because the therapists employed their technical knowledge and combined it with imagination and creativity to treat patients according to their condition and the instruments made available by the work setting. Competence and intuition combine many means of coordination – such as medical protocols and individualized therapeutic plans – and therapists perform highly competent and creative modelling work, i.e., a trial-and-error variations of their work actions aimed at the best possible rehabilitation of the patient that may involve artefacts of various kinds.

When therapists use robots, the variation in the material technology enacts a change in the 'dance of agency' that involves all the components of organisational action: goals, technical rationality, and social relations. An example is provided by the following description of a robotic glove that complements the hands of the therapist during the rehabilitation of a patient's injured hand. Although this technology serves as a substitute for the therapist's work – it opens

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and closes the patient's hand – it was apparent that the substitution was just one part of the dance of rehabilitation and of the work process transformation.

'If I think of the hand rehabilitation glove […] therapists could never achieve the perfect synchrony provided by the machine. But the machine cannot close the hand completely, as the therapist does, nor can it evaluate how far it is necessary to 'push' in relation to the specificity of the patient when therapy is delivered. Sometimes it is the therapist who has the sensitivity (that the machine does not have) to stop and not hurt the patient. In other cases, it is the machine that has the parametric sensitivity that the therapist could never have.' (Therapist 13, Beta)

The work processes changed to encompass both captures of the robotic agency and newly-framed human practices. However, 'together with the robot there is always the physical and "manual" work with the patient' (Therapist 5, Alpha) because using robots is seen by therapists as an opportunity to refine their skills – 'robotics "refines" us a little bit' (*idem*) – such as 'attuning' to patients' needs and developing the ability to decide whether to use their hands, a robot, or a mix of advanced and conventional methods.

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Resistances and accommodations between humans and nonhumans

Now described is how resistances and accommodations emerge in human-robotic rehabilitation work. For instance, the robotic glove cannot support the total closure of the human hand; nor can it evaluate how much force to use in the closure. This is a material resistance to a human resistance. Therefore, therapists' responses to such material resistances entail a human accommodation because they use their own knowledge and sensibility to decide how to make the robot open and close the patient's injured hand (which is a human accommodation to a human resistance). They set the robot accordingly (which is a human accommodation to a material resistance); and they perform other evaluations and treatments (other human accommodations to human resistances) while the robot performs routine tasks (which are material accommodations to human resistances). It is worth noting that through this process resistances and accommodations arise from both human and robotic agency. Moreover, accommodations may also arise from – or at least be inspired by – robotic agency, as when therapists arrange the exercises assigned to the patient by imitating the way in which the robotic platform works. This reveals how human accommodations may even come from material accommodations. For example, therapists reported how they tried to reproduce robotic exercises, such as when they imitated the robot to create *ad hoc* destabilizations of the patients, make them work on their trunk and receive feedback:

'We work on the trunk […] I take my simple physiotherapy table, I put it under my patient's pelvis, under the buttocks, and I make him work in the same way as he works with the platform […] but with me alone, without technology.' (Therapist 2, Alpha)

Sometimes resistances of the work processes are reduced by material agency, such as when robots relieve the therapists of part of the physical workload of their activities. This entails even more composite dynamics because material accommodation supports human accommodation to overcome human resistance. This happens, for example, when an exoskeleton is employed, and the therapist's work activities tend to change from physical action to the design of the choreography of the workflow of rehabilitation. Another example is when robots provide the therapists with more 'limbs' with which to work more effectively:

'You can assign to the patient tasks you couldn't do with only your two hands and two legs, because sometimes the job requires you to have more than just four limbs to perform a task,

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and robots provide creative and alternative solutions from this point of view.' (Therapist 14, Beta)

Robotic accommodations may even occasion human accommodations, such as when therapists instruct the platform to move beneath the patients' pelvis so that, in the meantime, they can make further requests to the patients, such as to move their upper limbs. This may happen also in the case of exoskeletons, as therapists are allowed to perform more activities, like talking to patients while they are walking, or throwing things at them, such as tennis balls or other objects, that they are required to catch.

INSERT FIGURE 2 ABOUT HERE

To sum up (see Figure 2 and Table 4), in certain situations, material resistance is followed by human accommodation, such as when the robotic glove cannot support the total closure of the human hand and requires the therapist to adjust its setting (1) – which is the standard view of the dance of agency – but then many other combinations emerge, such as human accommodations reacting to human resistance – such as in conventional rehabilitation (2) – or material accommodation providing for human resistance – such as when robots perform the human rehabilitation (3) – or human accommodation coming from material accommodation – as when therapists arrange new exercises imitating robotic agency (4) – or even material accommodations supporting human accommodations in overcoming human resistances – such as when exoskeletons relieve the therapists from lifting the dead weight of the patient or when therapists use the platform so that they can perform additional exercises with the patient (5). However, material resistance can sometimes counteract human accommodations – such as when robots obstruct the path to therapeutic goals and must be removed (6) (see the next

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quotation). When therapists remove them, they create space for human resistance to material resistance that supports other human accommodations (7).

INSERT TABLE 4 ABOUT HERE

Acting as choreographers, configuring human-robotic choreographies

Therapists are dancers in the human-robotic dance of rehabilitation, but also directors of the dance, as *choreographers* of the whole process of rehabilitation. In contrast to what was expected from previous studies, the use of the robot did not reduce the autonomy of work, while it made it possible to overcome material resistances arising from the use of conventional tools, and the therapists seemed to devise their rehabilitation processes more freely. The robot performed part of the therapeutic activities, and the therapists could focus their attention on the design of the rehabilitation processes. The intentionality of human agency was preserved or even reinforced by the 'modelling' imposed by the therapist on the action process of the rehabilitation in the human-robotic dance of agency.

From this perspective, one of the therapist's key abilities is the capacity to understand when robotic agency is an obstacle to the achievement of therapeutic goals (when material resistance counteracts human accommodations). The following quotation explains how sometimes acting as choreographers requires 'removing the robot' from the dance and 'seeing' the patient:

'When the patient arrives here, maybe he is 50, 55 or 60 years old … and let's say we must re-educate his gait […] there are, obviously, some canons that, with the machine, we can set up […] but maybe *that* gait is not suitable for *that* patient. As I say, there is a moment, […] when

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you must remove the robot to really understand who you are dealing with … that is, a patient with certain specific characteristics.' (Therapist 6, Alpha)

The use of exoskeletons for the re-education of the gait furnishes other elements with which to understand the role of therapists as choreographers, such as that of providing an attentive guidance to patients, a task that cannot be performed by the machine:

'It's like if we are here and at some point, someone start speaking Turkish for an hour, but it's not a Turkish lesson! That is, I can put the patient inside the exoskeleton making him walk for an hour, but that is not a re-education of the gait. The therapist must always be there to say 'no, look, you are doing it wrong, pay attention to the inputs coming from the trunk'. […] The patient would not be able to decrypt the inputs by himself and consequently his attention would go away, and no learning would follow.' (Director, Beta).

The therapist-*choreographer* has therefore the fundamental role of guiding the patient. Also, the decision on when, how and how long, as well as who to put inside the robot is a therapists' decision that is locally situated, contingent and depends on several aspects:

'At the beginning we used to put all the patients in it [in the exoskeleton]. It was in order to understand a little what the advantages could be in one case and in the other, that is, patients with a lot of spasticity and those with less. We made many evaluations to achieve a certain model, that we then 'demolished', and now we use the machine only for those cases where the exoskeleton, let's say, is really useful for re-education of the gait, so that it is not used just because the robot is there, and people ask to make 'carousel rides'. […] In other facilities, however, they continue to put all the patients on it, and I have seen treatments that I personally

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would not have done. However, these are their choices. […] and our choice has been different.' (Therapist 18, Beta)

These considerations make it possible not only to again underline the role of therapists as choreographers, but also to highlight how the same rules are not applied in all organisations; rather, formal and informal rules are locally fixed into 'local' choreographies of care which therefore are contextual and designed for idiosyncratic needs.

Humans and robots in the choreographies of care

Although therapists play an active role in configuring the choreographies, the actual transformation of work is an emerging process shaped by dynamics of resistance and accommodation more complex than a mere 'interplay' between the new technical apparatus of the action and the modelling actions of the therapists. The point is that the interactive stabilization of the process of rehabilitation – as a tuning process – both develops from and delivers information. The patients are loci of interactive stabilization within this dance of agency because they generate information that is crucial for the therapists to adjust the machine according to needs, or even to 'remove the technology' (see above) and replace it with more traditional aids. However, patients' signals may reflect their direct dealings with robots, which are another locus of interactive stabilization of the process of rehabilitation. For instance, patients reported that they became more self-confident when they believed that the machine helped them in a more 'objective' and reliable way. In a patient's words, 'if it is the therapist that helps me do the exercise, a doubt still remains: was it me or was it the therapist?' (Patient 2, Beta). In fact, the strength that robots exert when they help patients to undertake an exercise is invariably the same: objective and measurable. This is not the case when it is the therapists who deliver the training, because they naturally have different amounts of energy at different

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times. Robots are loci of interactive stabilization also because many patients are emotionally attached to them and want to use them even when the robots cannot support an actual improvement of their physical condition (e.g., for patients who will no longer be able to walk), and this is reflected in the configuring of the choreography because therapists, who consider each patient case by case, may sometimes include 'a carousel ride' in order to help patients emotionally more than physically:

'Most of the patients want to make a 'carousel ride' [in the exoskeleton], because walking is always walking [...]. Then using the exoskeleton, even for someone who will probably never walk again, has some advantages, in terms of osteoporosis and blood circulation, […] and emotionally too' (Therapist 18, Beta)

These choreographies of care, therefore, far from being static and closed, have an open and dynamic nature, and they are local. They are continuously defined through a situated use and the unfolding of human and nonhuman relations, as shown by the therapist's story which highlighted the 'situated' choice of bringing only a few patients on the robot. The open and evolving nature of choreographies is further strengthened by a Director's (Alpha) consideration according to which 'we try and experiment, and continually review what we do, but only in the future will we know where we get it wrong'. Every choreography of care is therefore temporally fixed. It is in its own way stable, but not permanent, and thus subject to revisions, in a continuous and apparently endless process of refinement, dismantling and improvement.

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Discussion

By studying human-robotic rehabilitation, this article makes two main contributions to the debate on the transformation of work when advanced technologies are adopted in the workplace: one at the empirical level, and one at the theoretical level.

At the empirical level, it extends existing research on technology and work in the medical field (Korika and Molloy, 2010; Barrett et al., 2012; Beane, 2019; Menchick, 2020) by providing an empirical account of how work transforms when robots are adopted in the context of medical rehabilitation. By abandoning an essentialist view of technology and its 'impact' on organization, this study explains how the development of the technical rationality of rehabilitation in the human-robotic setting of work goes hand in hand with the continuous unfolding of local and temporary emerging 'choreographies of care'. When the therapists' action is not complemented by robots, their body is the core of the technical rationality of the action – its technology – whereas the core is the robot when it delivers the therapy. Nevertheless, the therapists, the robots, and the patients – in turn and simultaneously – are loci of interactive stabilization within the dance of human-robotic rehabilitation, and the mobile configuration of the choreography of care reflects the open-ended encounters of human and nonhuman realms at the organisational level. This perspective on work transformation in human-robotic settings is different from that of 'bounded automation' (Fleming, 2019), where organisational forces would shape the adoption of robots. In that view, 'robots might not want to steal people's jobs', but human activities are predicted to be poorer in terms of skill, responsibility and pay. Instead, as this article shows, when robots come into play, the dynamics of work change, and automation needs to be seen in combination with many other transformations that entail the human agency, the material agency, and the contextual culture of work processes. However, independently of each other, neither humans nor material artifacts determine new work practices, and robots cannot be predicted to 'impact' on human work,

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either positively or negatively. Rather, it is through ongoing processes of resistance and accommodation at the micro-level that the actual contours of human and material agency temporally emerge. This makes it possible to overcome static and binary thinking on technology and work. For example, in the therapeutic settings studied, the use of robots allowed some work displacements that were provisional (e.g., when the robotic glove opened and closed the patient's hand, or when the exoskeletons controlled the posture of patients and pushed their feet forward to support the walking). However, therapists are not 'supervisors of machines'; rather, they enact their autonomy as *choreographers* of their work process. The analysis conducted in this article has also revealed the hidden possibilities of autonomy and creativity that can be occasioned, at least in these settings, by the adoption of robots (e.g., when therapists assign patients additional tasks while they are already performing some exercise with the robot, or when they arrange new exercises imitating the way in which robots work). However, the perspective of mobile configurations of human-robotic choreographies means that in other domains – also in the field of medical rehabilitation – robots may even support transformations that eventually hamper the creativity of workers or hinder their opportunities to perform complex tasks, such as when the adoption and use of robots is part of labour-saving strategies at the organisational level. Nevertheless, this does not diminish the broader relevance of the study's findings. Instead, it reinforces the idea that when research departs from universalistic approaches of technology's 'impact' on work, 'no pre-existing principle explains or lies behind the trajectory of evolution of (…) material apparatus or its performativity' (Pickering, 1995: 92), and it therefore invites definitive abandonment of these approaches.

Just as human and material agency are reciprocally and emergently transformed within the dance of agency of rehabilitation work, so a parallel dance of agency – between the authors and their theoretical framework – has led to a second contribution of this study at a theoretical level, as it aims to extend Pickering's 'dance of agency', in two directions.

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On the one hand, this article strengthens the processual orientation of the theory by enlarging the *dialectical* view of resistances and accommodations as originally outlined by Pickering and previous research adopting Pickering's view in technology and work studies (Barrett et al., 2012; Jones, 2014; Eaton et al., 2015). By combining Pickering's dance of agency with a process-oriented view of technology as technical rationality, this article has tried to show how both resistances and accommodations may be enacted by both humans and nonhumans as the analytical loci of the dance of agency, rather than as actors with given resistant (i.e., the technology) or accommodating (i.e., the humans) properties. Further, the study has revealed that accommodations do not necessarily follow resistances; nor do resistances necessarily follow accommodations, as previous studies instead seem to suggest.

INSERT FIGURE 3 ABOUT HERE

While these accommodation/resistance dynamics (in grey in Figure 3) were observed in the contexts studied (as detailed in the Findings section on resistances and accommodations), others could be observed in other contexts and/or in the future, also in the same field or in others. It therefore makes sense to imagine other nascent dynamics: for example, it can be added the perspective of machine learning by robots – (8) and (9) – as well as that of human learning (10) (in black, in Figure 3), which obviously already had a place in Pickering's original formulation, given that he admitted that resistances can even arise in human dealings with disciplinary agency, such as when theorists struggle to extend the current understanding of a problem (Pickering, 1995, chapter 4). While those dances of agency are all-human, this study opens the way to considering all-material dances and other resistances and accommodations that are not dialectically enacted by humans and machines. The further elaboration of Pickering's dance of agency proposed here therefore reinforces Pickering's sociomateriality

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view as a relational ontology that eventually 'dissolves analytical boundaries between technology and humans' (Orlikowski and Scott, 2008: 455) and thus further broadens its processual orientation.

On the other hand, the article has further elaborated on the organisational implications of technological change within the dance of agency by explaining how the experimental activities that accompany technology adoption and use are emergently and tentatively fixed in formal or informal *choreographies*. This makes it possible to understand how the transformation of material agency may enact processes of change in the existing organisational culture, and how this change leaves a trace in the organisationally sustained routines of human agency that accompany the adoption and use of technology (consider, for example, the decision whether to put all the patients into the robot or only a few).

Analysing the configuration of human-robotic choreographies at the organisational level enhances the heuristic power of Pickering's dance of agency for the study of work transformation when advanced technologies are adopted in the workplace. On the one hand, it makes it possible to focus on the *emergent* and *experimental* unfolding of resistances and accommodation between material and human agencies; but on the other, it supports research on the *situatedness* of the dance of agency as reflected in formal or informal rules concerning the adoption and use of technological innovations, and on how this reflects, and is reflected in, the existing culture of an organisation. As such, the perspective of human-robotic choreography does not offer any interpretive simplification of, or shortcut to, a universalistic portrayal of the positive and negative 'impacts' of technology on work. Rather it reinforces the idea that technology and social structures coevolve in a nondeterministic way (Weber, 1910/2005) and that technologies are always inseparable from their use (Suchman 1987/2002, Bruni, 2005). Hence the study of the transformation of work occasioned by technological innovation needs

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to account for the complexity and the organisational situatedness of the open-ended process of becoming that it entails.

Conclusion

This article has combined Pickering's 'dance of agency' with a process-oriented understanding of technology as technical rationality, and it has studied how human and material agency enmesh in human-robotic work settings of medical rehabilitation. It has shown how resistances and accommodations may be enacted by both humans and nonhumans as analytical loci of the dance of agency. From this perspective, the material technology does not cause organisational change; nor does the human agent. Rather, the transformation of work occasioned by technological innovation takes place as an emergent and open-ended process of becoming; and this process comprises the goals tentatively imposed by the human agents, the material agency, the contextual culture, and the social dimension of practices. The study has explained how experimental activities concerned with technology adoption and use are emergently and tentatively fixed in formal or informal rules of coordination of action within the existing culture of rehabilitation at the organisational level, that has been labelled 'choreographies of care'.

This article has some limitations that, however, may open avenues of future research. Because it focuses on the work of therapists alone, it has the shortcoming of not taking all due account of the authority structure in which the therapists' work takes shape. Nevertheless, returning to the field enabled the researchers to investigate some aspects related to this issue and discover that certain choices, e.g., that of putting only a few patients in the robot, rather than all of them, could also, at least partly, depend on the pre-existing system of authority – in a context, however, where there exists a quite limited authority. This topic therefore needs further investigation. Moreover, even in a setting such as the one studied, which is knowledge-intensive *par excellence*, it is not taken for granted that labour-saving strategies cannot be

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adopted at the organisational level, and also this should be further explored. In this regard, the researchers were struck by a Director's observation (Alpha) according to which 'we have chosen to use the exoskeleton mainly to improve re-education of the gait. However, the commercial push is currently to sell exoskeletons to treat complete paraplegias, that is, people who will never be able to walk again. Therefore, an exoskeleton could be employed as a sort of wheelchair that instead of being on two wheels is on two legs.' This final valuable comment invites future research to explore how the configuring of the choreographies of care may be affected by pressures from outside the single organisation, at the ecosystem level, not only in this specific field but in others as well.

Finally, the theoretical approach adopted, and its further elaboration proposed by this article, could be employed to explore and reinterpret other contexts – e.g., labour-saving contexts – to highlight accommodations and resistances that may so far have remained in the background, thus opening up new emancipatory possibilities for workers, even in less knowledge-intensive contexts, such as that of manufacturing.

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Table 1 - Descriptions of the two clinics

Organization	**Alpha**	**Beta**
Headquarters	Italy (Liguria Region)	Italy (Lombardia Region)
Type of facility	- specialized in neurological rehabilitation that assists people with spinal cord injuries of traumatic or non-traumatic origin; it has the task of taking charge of people with pathologies, such as myelitis, starting immediately after the injurious event	- specialized in neurological rehabilitation that restores the best-possible level of function to people with problems deriving from disabilities caused by congenital or acquired diseases of traumatic or non-traumatic origin
Mission	Have people achieve the best state of health possible, the highest level of functional capacity, and the best-possible social participation	As Alpha
General care process	- An individualized life plan for each patient; - The facility accompanies the subject from the acute phase to social inclusion	As Alpha
Professionals involved	Doctors, nurses, social and health workers, psychologists, therapists, secretary for administrative work	As Alpha, plus bioengineers
Capacity	25 beds	90 beds
Main technologies employed	Exoskeletons; Robotic platforms; Hand robotic gloves	As Alpha
Rationales of adoption and use of robots	- Improving the effectiveness of rehabilitation; - The choices of adoption and use are rather free, namely guided by procedures rather than protocols; - Robots are employed as tools by therapists and are not part of a broader system, (as e.g., in manufacturing and surgical contexts)	As Alpha

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Table 2 - Robotic technologies: features and purposes

Type of technology	*Exoskeleton*	*Hand robotic glove*	*Robot-assisted platform*
Description	Wearable device for assisting people during different physical activities	Wearable device for functional hand rehabilitation	Rehabilitation system for the assessment and treatment of neurological conditions
Main purpose	It assists people in reacquiring their ability to walk after a trauma	It assists people in reacquiring their ability to use their hands after a trauma	It assists people in different types of rehabilitation due to stroke, Parkinson's disease and Multiple Sclerosis, but also sports' trauma
Functionalities	- it commonly uses a rigid structure with traditional actuation systems - it enables people with movement impairments to carry out normal everyday activities.	- it covers the hand and can mobilize fingers, detect the patient's active movements, and perform mirror bimanual training. - it works in different modes, e.g., it enables bimanual mirror training (the patient can actively guide the exercise) or works in a passive way (finger flexion and extension are generated by the glove according to customizable parameters).	- It consists of a platform, a seat, and a screen. The seat induces unidirectional as well as multidirectional movements. The therapist can adjust the trajectory, speed, and amplitude. - It allows for different types of therapy, including passive, proprioceptive, and assistive mobilization.

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Table 3 - Simplified version of final study template

1. Dancing in rehabilitation work	1.1. with robots 1.2. without robots
2. Resisting vs accommodating	2.1. human resistance 2.2. robotic resistance 2.3. human accommodation 2.4. robotic accommodation
3. Configuring choreographies	3.1. role of therapists 3.2. role of robots 3.3. role of patients 3.4. interrelated roles of humans and nonhumans 3.5. human-nonhuman modelling

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Table 4 –Human and material accommodations and resistances: some examples

Arrows 1 to 7 in Fig. 2	*Meaning*	*Example*
1	Human accommodation follows material resistance	The robotic glove does not support the total closure of the patient's hand (material resistance) and the therapist must adjust its setting (human accommodation)
2	Human accommodation follows human resistance	In conventional rehabilitation, therapists use their arms (human accommodation) to mobilise a patient's shrunken injured limb (human resistance)
3	Material accommodation provides for human resistance	The robotic glove performs some rehabilitation activities (material accommodation), such as when it opens and closes the patient's injured hand (human resistance)
4	Human accommodation follows material accommodation	Therapists arrange new exercises (human accommodation) by imitating robots performing similar tasks (material accommodation)
5	Material accommodation supports human accommodation in overcoming human resistance	The robotic platform moves beneath the patient's pelvis to treat his/her injured body (material accommodation to human resistance) and the therapists can in the meantime perform additional exercises with the patient (human accommodation overcoming human resistance)
6	Material resistance counteracts human accommodation	The standard canons of the gait performed by a working exoskeleton could be not suitable (material resistance) for supporting some patient-specific therapist's action of rehabilitation (human accommodation to human resistance).
7	Human resistance reacts to material resistance and supports other human accommodation	The therapists remove the robot (human resistance) when it obstructs the path to therapeutic goals (material resistance) and perform other conventional rehabilitation activities (human accommodation)

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Figure 1 – Robotic technologies: hand-robotic glove, exoskeleton, robot-assisted platform

Hand robotic glove

Exoskeleton

Robot-assisted platform

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Figure 2 – Resistances and accommodations within the choreography of care

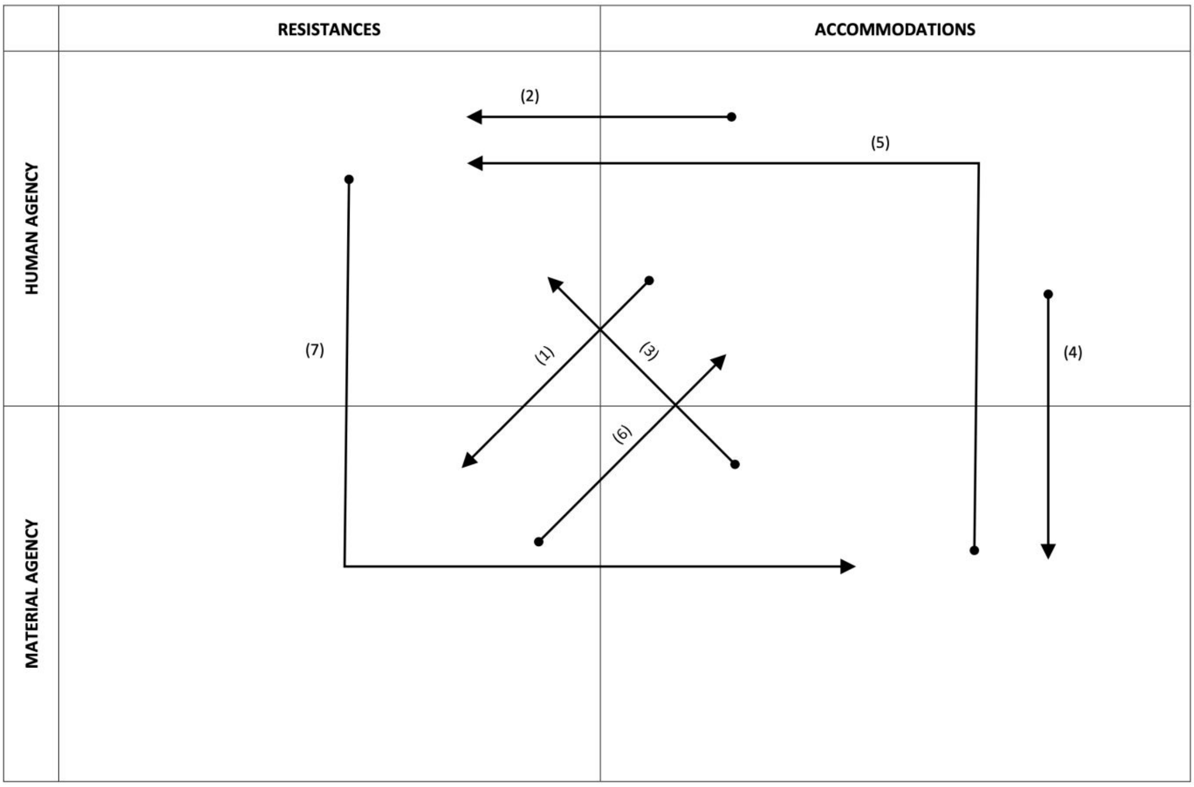

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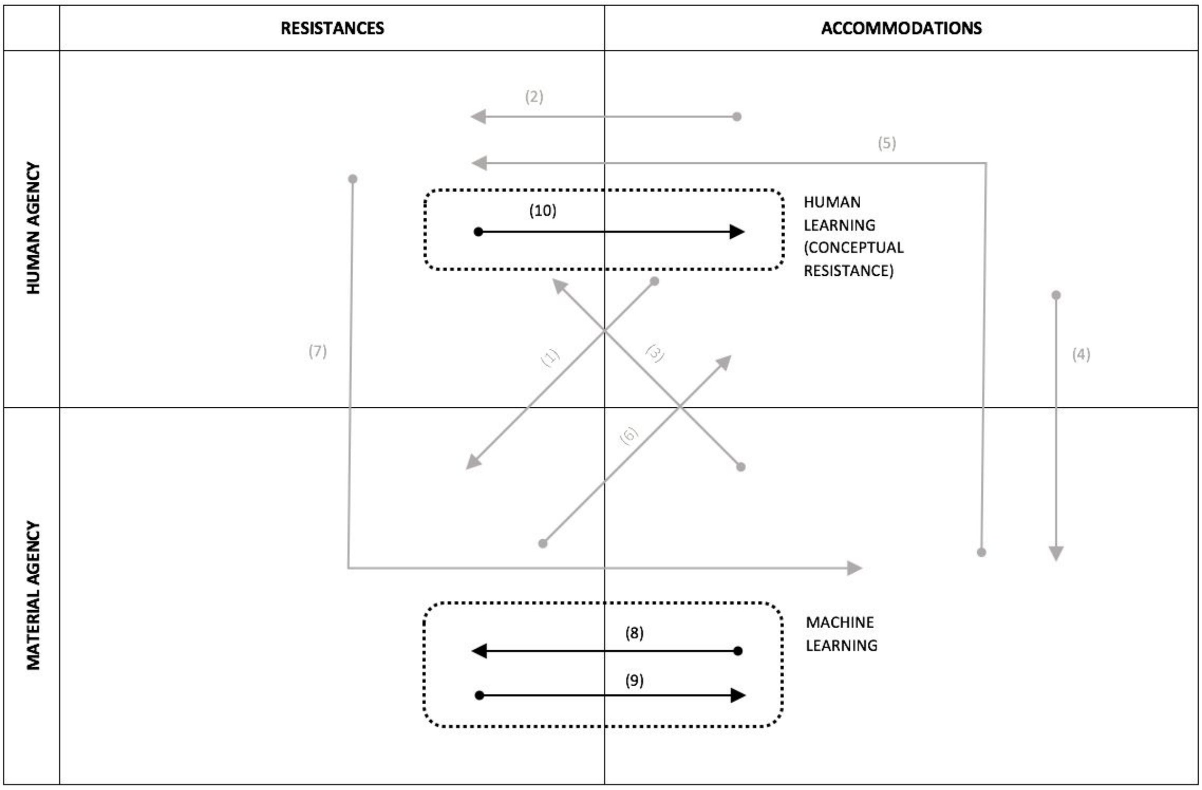
Figure 3 – Further potential resistances and accommodations within the choreography



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