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WHO SETS THE PACE IN ROBOTISATION? 'WORKING AT A ROBOTIC PACE' ACCORDING TO THE JUSTIFYING, CRITICISING AND PROBLEM-SOLVING DISCOURSE FRAMES

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Abstract: *In a society driven by clock time and technology, it is no suprise that a robotic working pace is often viewed as inevitable, even ideal. However, ultimately discussions regarding robotic pace are shaped by different perspectives and contexts. In this paper, content-frame analysis was used to examine how 'working at a robotic pace' is addressed in academic discourse across scientific disciplines. The statements (N=22) were coded and examined for their positive, negative, or neutral appraisal, as well as the value base derived from either a human(e) or efficiency perspective. In academic communication, the concept has been framed by justifying, criticizing, and problem-solving discourses. The criticising frame was not found exclusively in the social sciences but across disciplines. It was the most common discourse frame, with its subjective perspective focusing on people and well-being. The problem-solving frame included a neutral, constructive and more objective approach associated with socio-technical ideals emphasized in engineering disciplines.*

Keywords: *frame analysis, robots, sociology of scientific knowledge, sociology of technology, values, working life.*

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INTRODUCTION

This study examines how the concept of 'working at a robotic pace' is portrayed in published academic works. This paper was inspired by the debate as to whether machinery, or rather clock time, is the root of industrialisation. If the clocks run our thoughts and actions, are the ideals of efficiency and expeditiousness presumed as axiomatic also prevalent in situations where people are expected to work at the speed of a robot?

The development of the steam engine in the 1800s is usually considered the starting point of the Industrial Revolution, which was followed by robotisation in the 1900s. However, challenging the idea of steam engines being the primary driver of the first major technological change in the world, Lewis Mumford (2010: 134) argued that the invention of the mechanical clock was actually the key to industrialisation. Although sometimes playful in his speculations, Mumford is primarily known as a sharp critic of rapid technological changes and he saw the idea of a mechanical society run by timetables as a red flag (Loeb, 2021). Mumford (2010: 269) criticised the clock-bound routine for its unnatural precision; for example, instead of waking up naturally, our sleep is curtailed by an alarm clock. Starting the day by the clock is only the first taste as to how the day will proceed in a predefined schedule of regular functions, limited durations and, just generally, keeping a keen eye on the time.

The clock has not lost its mastery of our lives in contemporary work culture. Digitalisation and new-generation robotisation have brought more recent technological changes to society and working life. Either as a separate development or in association with novel technologies, work is now more intense and time conscious than before (Aneesh, 2001; Mauno, Kubicek, Feldt, & Minkkinen, 2020). Robotisation has evident parallels with clock time dependence. Robots created for assembly work set the pace of work because, first, of the schedules and workflow that are planned in a robot-centred way and, second, how the work requires the people to keep a keen eye on the robotic pace.

Intense and hectic work can theoretically increase or decrease job satisfaction (Mauno et al., 2020; Sobczak, 2022), but how is this duality applicable in the demands of higher effectiveness associated with a robotic pace of work? How has this need for robotic speed been framed in academic discussions? This study investigates how working at a robotic pace is framed in academic communications, by which this study refers to the writings of scholars and students from any discipline (Park, 2008)[1]. In doing so, this study acknowledges that the academic discourse on technology typically varies among disciplines. Working at a robotic pace is a theme that regularly comes up in everyday discussions[2-3] - , but the question is, how has this idea been addressed in academic discussions occurring in various scientific communities?

The first research question of this content–frame analysis asks what the prevalence and content (Matthes & Kohring, 2008) of robotic pace discourse is. The second question is, how has the discourse on robotic pace framed the issue, whether that be positive, negative or neutral, and do such appraisals underlie human(e)- or efficiency-based values? Furthermore, from the framework of the sociology of knowledge, this work examines how scientific backgrounds, from the natural sciences to humanities, contribute to different perspectives on technology (Petrović, 2022; Östlund, 2004).

SOCIOLOGY OF SCIENTIFIC KNOWLEDGE IN ROBOTISING WORK

The sociology of scientific knowledge, as the communication-focused domain of science and technology studies, analyses here the way academic discussions are socially shaped or constructed (Park, 2008). According to this framework, structures can be found from various perspectives in academic discourse. Applied to the method of content–frame analysis, the structures are organised as found differences in the framing of a concept in question (Petrović, 2022). Thus, this study expects to find varied interpretations of the concept of 'working at a robotic pace' depending on the scientific discipline (Winskel & Radcliffe, 2014).

The premise here is the variance in perspectives among disciplines—more specifically, the difference between engineering and humanistic sciences—disciplines that both have a significant history in studying technology and technologising society. The engineering sciences have a tradition of using mathematics and physics to develop practical solutions. However, the humanities relies on interpretation and critical thinking in its objective of exploring human culture, thought and expression. These differences go beyond the methodologies used or the research questions set according to discipline. The engineering and humanistic disciplines differ in their understanding of the nature of knowledge. Technical research is set on applying analytical knowledge that is usually independent of context, whereas in the social sciences, epistemological interests lie more in ethical, behaviour-oriented and context-dependent issues (Östlund, 2004). In discourse ethics, pragmatic discourses of rational deliberation about means and ends are separated from moral discourses valuing justice and universalism (Habermas, 1997).

These epistemological differences have been concretised in studies of robotisation. New-generation robotics has resulted from advances in both artificial intelligence (AI) and sensor technology research. Developments in machine learning and more precise sensors for navigation and detection have made it possible for robots to work safely among people and to be mobile in their environment instead of being in fixed stations. Given these advances in technological development, the 'only' question is, how much can productivity increase following robotisation so that such developments are worth the investment? Robots' cost-effectiveness in given tasks and processes is calculated and estimated by the engineering sciences. This field of research concentrates on the instrumental rationality of robotising production, or other processes of work, to make them more efficient. From this perspective, it makes little difference whether the topic is robotising the industrial assembly line (Khan, Homri, Dantan, & Siadat, 2022) or healthcare (Huter et al., 2020).

The bracketing of 'only' in quotation marks in the previous paragraph was done to imply how, in reality, the social sciences also deliberate when robotising work is appropriate and justified. Aside from the availability of technology and the mechanistic rationality supporting it, human and social factors are also factors to consider when planning to introduce robots into a social environment. Although some human factors, such as security issues and user experiences, have been included in robotics studies (Ng, Chen, Lee, Jiao, & Yang, 2021), ethical issues have remained the purview of the social sciences and humanities (Östlund, 2004). Ethical issues associated with robotisation can be understood as work ethics and AI ethics. Working with robots raises ethical issues such as maintaining a sense of control in one's work, feeling safe while working and being threatened by technological unemployment (Deranty & Corbin, 2022; Melkas, Hennala, Pekkarinen, & Kyrki, 2020). AI ethics, then, include a range of ethical dilemmas, from normative issues to complex social relationships and the division of power (Lin, Abney, & Bekey, 2011; Zhu, Liu, Huang, & Guo, 2023). Ethical issues are at the heart of robot studies in the social sciences and humanities, and this too can apply to several contexts, from robotising the industrial assembly line (Braun, Tigard, Schönweitz, Lucaj, & von Janowski, 2022) to healthcare robotics (Turja & Parviainen, 2020).

In reorganising work after a technological shift, reskilling the staff is a topic that lands in between the values of cost efficiency and human factors. On the one hand, from a deterministic view, reskilling after robotising work embraces innovations, and the staff is expected to acquire new skills to adopt all novel technology (Sony, Antony, & Tortorella., 2023). On the other hand, reskilling is viewed as a means to support workers' job satisfaction, as reskilling can free them from routines and offer more gratifying tasks (Dølvik & Steen 2018; Sobczak, 2022). Contrary to reskilling, deskilling refers to a negative trajectory in which job descriptions are changed to take on a more modest and repetitive direction (Harju, Hakanen, & Schaufeli, 2014; Weinberg, 2016). In the rationality of clock time, efficiency and standardised work processes, robotising work comes with the risk of deskilling both job descriptions and entire professions (Turja, Särkikoski, Koistinen, Krutova, & Melin, 2022a).

The hypothesis is that the robotic pace is a continuum and an accelerator of the clock-centred culture. Under this assumption, working at a robotic pace is viewed as an ideal that reflects both positively (efficiency) and negatively (human factors) on working life.

However distinct from each other, the traditions of the engineering sciences and humanities can also be aligned, as shown in the sociology of technology. Interactions between technologisation and societies are studied in the sociology of technology and socio-technical systems. In an idealistic socio-technical system, research plans should always acknowledge both the technical and social domains (Trist, 1981). The socio-technical perspective originated from and has been widely accepted in attempts to find symbiosis between technological changes and well-being at work. Furthermore, the collaboration between humans and robots can even reach the ideal workflow when work and roles between these two quite different actors are optimised (Militello et al., 2013). In addition to the optimal workflow, ethical values play an important role in socio-technical systems. Pekkarinen et al. (2020) provided an interesting example of this, in which care robots can be accepted by staff only when they prove to be both useful and in line with the ethical values of care work.

Regardless of the theoretical ideal of socio-technical principles guiding studies on robotising work, it is still hypothesised – based on the premise that an ethical consensus can exist only within a single community (Habermas, 1997; Keulartz, Schermer, Korthals, & Swierstra, 2004) – that human factors, and ethical values in particular, are valued more commonly in social studies than in engineering studies. In a similar vein, this study presumes that working at a robotic pace receives more positive appraisals in the discourses found in the engineering sciences compared to discourses found in the social sciences.

METHODS

This qualitative study used content–frame analysis to identify meanings and describe discourses associated with 'working at a robotic pace'. The purpose of content analysis is to describe the characteristics of linguistic content by examining the source, the target audience and the intention of the discourse (Vaismoradi, Turunen, & Bondas, 2013). Content analysis is used to produce a collective understanding or parallel understandings of a phenomenon (Pfeil & Zaphiris, 2010).

In the more specific content–frame analysis, the themes derived from the analysed content are further identified as comprised and dominant frames (Tankard, 2001). Frame analysis originated from Erving Goffman's (1974) methodology for understanding and naming meanings by analysing the relationship between concepts and text. In the current study's design, frames represent the beliefs and purposes through which working at a robotic pace is interpreted (see Bergenheim, 2020). Frames define perspectives, and aside from the defining work, frame analysis can be used to examine the strength of the various forces creating these perspectives (Entman, 1993).

The data consisted of all English-language mentions of working at a robotic pace found in academic writings. The search was conducted using the Wiley Online Library, a multidisciplinary database, and complemented by Google Scholar, which provided an even wider scope that included also informal commentary pieces (see Park, 2008). The Wiley Online Library provides consistent search results independent of the institution possessing the licence for a work, unlike larger databases, such as ProQuest and Web of Science (Gusenbauer & Haddaway, 2020).

The search terms used were 'work' and various versions of the phrase 'robot/robotic pace'. The search was conducted in August 2023. After removing duplicates and irrelevant search results (e.g. pace referring to a robot's gait), the data consisted of 22 statements as the observatory units, given this study's design.

In exploring the use of the phrase 'working at a robotic pace' as a linguistic unit and as a social phenomenon, the statements mentioning robotic pace in a work-related context were themed according to their positive, negative or neutral nature as well as the value base and primary reason informing the stated position (Park, 2008). The value base was derived from the perspectives of efficiency or human factors. If both value bases were present in the statement, both were coded to be associated with the one statement.

In the first phase of content analysis, some of the neutrality codings had another parallel coding of either positive or negative appraisal associated with them. These placed consistently so that the value of efficiency correlated with neutral-positive appraisals and the value of human factors correlated with neutral-negative appraisals. In the next phase of the analysis, these double codings were dismantled, leaving the neutral category pure and without nuances of parallel positive or negative views. The statements were also categorised by their publication year, scientific discipline and the context of the robotising discourse for finding further intersections and discrepancies among the frames. The scientific discipline was determined by the first author of the document. The studies behind the statements were dominantly mono-disciplinary, as is common (Van Leeuwen & Tijssen, 2000). See Table 1 for the distribution of statements. Detailed descriptions with the original quotes can be found in Appendix A.

Table 1. Statement distributions (N = 22) for 'working at a robotic pace'

		n
Publication year		
	1988–1999	4
	2012–2019	5
	2020–2023	13
Appraisal of 'working at a robotic pace'		
	Positive	4
	Negative	11
	Neutral	7
Context		
	Industrial manufacturing	14
	Construction sites	2
	Warehouse work	1
	Medical surgery	1
	Creative work	1
	Working life in general	3
Discipline		
	Engineering sciences	11
	Social sciences and humanities	6
	Computer/data/information sciences	4
	Medical sciences	1
Value-base		
	Human factors	17
	Efficiency	8

The frame analysis then focused on the values underlying the appraisals. Viewing the statements as representing different perspectives in robotisation discourse, the analysis examined how the frames of discourse are constructed according to their value base and disciplinary tradition.

RESULTS

Statements on the theme of working at a robotic pace were quite uncommon in reflections on everyday discussions on the subject. The majority of the data came from the current decade, more specifically from statements published between the years 2020 and 2023. This implies a growing interest in the topic of working at a robotic pace.

The primary result of the content analysis was the statements that were divided into three thematic appraisal categories: positive, negative and neutral views towards working at a robotic pace. Negative appraisals were the most common. In some mostly critical statements, working at a robotic pace was considered almost more as a metaphor than a reality, describing the impossible demand of ultimate effectiveness. In some statements, the working pace of a robot was framed in a more simplified manner—as a robotic feature described as either positive or neutral in its effectiveness. The initial assumption that working at a robotic pace would be considered as an ideal and the mentions referring to effects of either positive or negative, was proven inaccurate. The statements in which working at a robotic pace was appraised positively due to the increase in efficiency held robotic pace as an ideal. However, the statements in which working at a robotic pace was appraised negatively due to compromised human factors did not hold working at the pace of a robot as an ideal but rather as an excessively mechanistic picture of our working life. In one of the statements, the maximum robotic pace was even considered unreasonable for both humans and robots (Guan & Liao, 2015).

The consistency between the value base of human factors and negative appraisal, as well as the value base of effectiveness and positive appraisal, was nearly perfect. Ethical values stood out as rationalising criticisms in social science discourses, not in engineering sciences discourses, which supported the set hypothesis. However, against the conservative hypothesis made, the data did not show a systematic divide, where discourse found in engineering sciences would include positive appraisals, and discourse found in social sciences would include negative appraisals. If anything, a division was found between the negative and neutral statements. Neutral statements from the social sciences and humanities discourses were non-existent.

Positive appraisals were few in number and closely connected with neutral appraisals because neither denied the value of robots' efficiency. However, frame analysis found a pattern differentiating positive appraisals from neutral ones. Whereas positive appraisals justified working at a robotic pace in a technologically deterministic manner, neutrality appeared to be a force in constructive and problem-solving discourses.

Frames and their Forces

In frame analysis, the themes comprised three identifiable value-laden frames. Working at a robotic pace was framed from a justifying, criticising or problem-solving perspective in the data. The results are shown in Figure 1. The considered forces creating the frames (Entman, 1993: 52) were the themes from before: the nature of the appraisal, context, discipline and value base. The publication year did not prove to be a significant force in the preliminary examination. Hence, the time of study was not included as a force in the final output. In the preliminary content analysis, the value base was divided into human factors and efficiency. In further frame analysis, human factors were categorised in more detail as ethical, reskilling, well-being and incompatibility issues.

Value base was considered the most consistent force behind the varying discourses. First, the discourse justifying working at a robotic pace relied on the technologically deterministic ideal of robotic speed. Second, the discourse criticising the idea of working at a robotic pace identified risks in a range of human factors. Third, the problem-solving discourse stood out with the overall widest value base, underlining its position as the least aligned frame of the three.

Justifying Robotic Pace

The efficiency value was the only actual force, in addition to positive appraisal, that was appointed to the frame of justifying robotic pace because of the small amount of data. The statements coded as positive towards working at a robotic pace valued efficiency in rationalising their perspective. This was identified as a frame of justifying working at a robotic pace. Working at a robotic pace was justified by the rationality of productiveness, where the maximum working pace is ideal and anything below that is likely to be identified as the bottleneck in production:

> Industry aims at accelerating production to operate more in real time and in feature of the overall product lifecycle, where pace is critical for everyone. (Fasuludeen *et al.*, 2022)

Criticising robotic pace

The frame criticising working at a robotic pace attributed forces of negativity towards working at a robotic pace, human factors as the value base, context of industrial manufacturing or working life in general and discourse found in social sciences. In the strength evaluation of the forces, context was considered the weakest and was left out of the figure presenting the main findings. The force was found to be weak for the reason that robots are dominantly used in industrial manufacturing, so the finding was hence redundant.

The critical discourse on working at a robotic pace centred around human factors, and the reasons were based on ethical issues, reskilling and well-being at work. The discourse on work ethics found in the social sciences focused on the inhumanity of placing workers alongside robots and expecting them to adapt to the robotic pace: 'What happens to those who cannot maintain robots' pace?' (Rosenmeyer, 2020).

Reskilling and reorganising work were other reasons underlying such criticism. In the rather future-oriented arguments, robotisation was predicted to deskill professionals and transform work into more routine-based tasks, thus making it less rewarding. In a negative scenario, people were viewed as competing with robots—if not over jobs, then over working speed:

> Development actors ought to consider how embodied intelligence can assist humans, for example, by freeing them to conduct more complex and meaningful tasks or by providing recommendations instead of simply replacing them or forcing them to keep up with the faster pace of robots or drones. (Addo *et al.*, 2021)

Well-being, as the third reason repeated in the data, referred to stress originating from robotisation and intensified work. Although mental stress and cognitive workload were most emphasised in the statements, well-being was framed as an overall risk:

> Organisational hazards, on the other hand, concern repetitive tasks performed at the pace of robots/cobot, potentially causing fatigue, musculoskeletal stress, psychological stress, and physical overload. (Costantino *et al.*, 2021)

In addition to the main reasons listed above, when working at a robotic pace was criticised from the perspective of engineering sciences, people having to adapt to robot-like efficiency was described as incompatible or unrealistic.

Problem-solving robotic pace

First, neutral appraisals were categorized for the seemingly nonaligned views on working at a robotic pace, which quite coherently, were observed as not having a strong value base behind their neutrality. For example, in Bourcier *et al.* (2017), surgeons were plainly stated as already working at almost a robotic pace. Next, in the frame analysis, the neutral statements were found to share a coding of ‘robotic pace adaptation’. Aside from being neutral, the discussions offered a constructive viewpoint: Working at a robotic pace is neither a positive nor negative *per se* but something that has to be adjusted to be just right for human safety and job satisfaction.

The neutral statements were framed as problem-solving discourse where value neutrality was complemented by the idea that robots are not only capable of superior speed but also of adapting their speed to an appropriate level. Two of seven adaptation codings consisted of discourse on synchronising robot and human working pace for efficiency and three for human factors. Two quotes consisted of discourse on both efficiency and human factors. These double-coded statements included deliberations on the safety of an employee working together with a robot.

Problem-solving discourse was found in engineering, computer, data and information sciences research. Engineering sciences were the most dominant domain for problem-solving discourse and, moreover, relatively neutral in their discourse, in general. As for context in the problem-solving frame, aside from industrial manufacturing, robotising was discussed in relation to construction work and working life in general. Context was again excluded from the final output because it was the weakest force in frame creation.

All in all, the problem-solving frame attributed forces of neutrality and technology-oriented sciences to working at a robotic pace. AI was found to play a part in the problem-solving discourse. The adaptability of increasingly intelligent robots was viewed as a solution to enable good socio-technical working conditions:

> Learning automaton suitably adjusts the production pace of the robot, thus influencing the dynamics of the cooperation. (Messeri *et al.*, 2021)
>
> Giving the operator the possibility to set the robot’s pace and choose the favoured mode of interaction with the robot increased usability and reduced perceived workload, as a sense of familiarity and predictability could be achieved. (Zimmer *et al.*, 2022)

The problem-solving discourse in engineering sciences acknowledged human factors in robotisation and alluded to references across disciplines. Most of these citations, however, were methodological references on monitoring or measuring workload. These cross-discipline citations can be viewed as a quite moderate deviation from the traditions of the natural sciences.

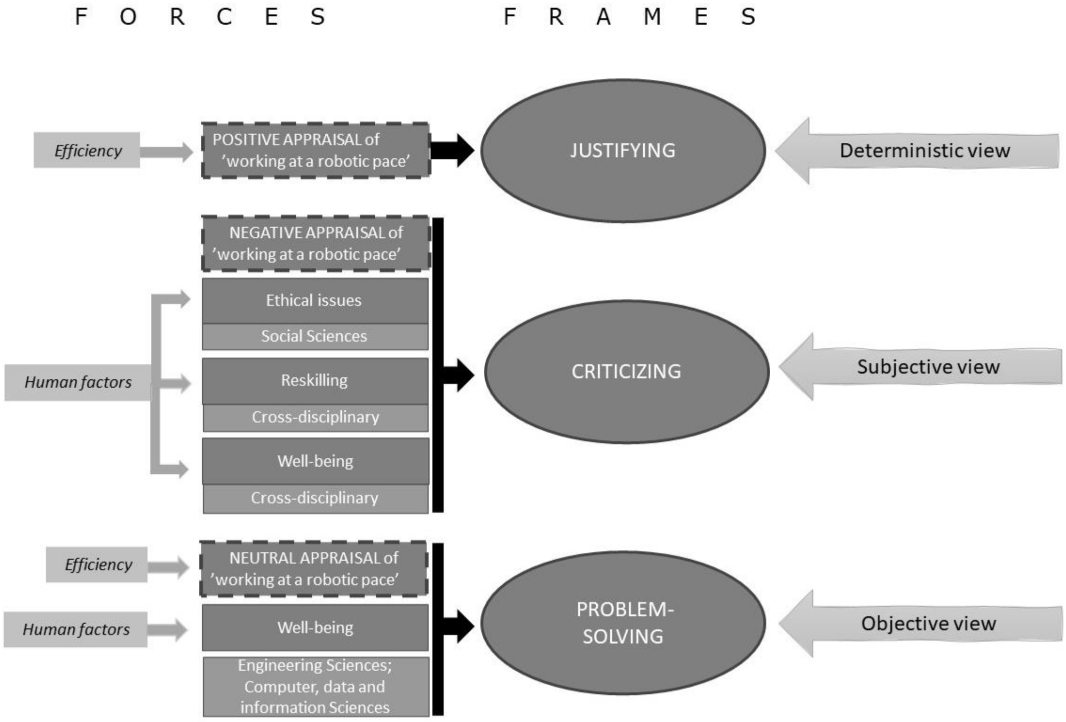

Figure 1. Value-laden discourses on 'working at a robotic pace' framed as justifying, criticising or problem-solving.

DISCUSSION

This study aimed to discern how the ideal of working at a robotic pace is appraised in academic communications. The ideal of robotic pace was understood as originating from a culture bound to the rationality of the mechanical clock (Mumford, 2010), underlying the idea that robotisation belongs on the continuum of mechanical clock time that underscores a mechanical society. Using content–frame analysis, this study examined academic writings involving a statement about 'working at a robotic pace'. The content was classified according to the statement's appraisal of the idea of working at a robotic pace, the value base underlying this positive, negative or neutral view, the robotisation context in question and the scientific discipline of the author.

The findings went against the presumption of robotic pace being a continuation and an embraced accelerator of the clock-centred culture. The idea of working at a robotic pace has received criticism, not only for it being a tall order for human workers but also as a symbol of intensified working life. Furthermore, the discourse on synchronising robot and human working pace not only included the idea of increased pace for efficiency but also moderated the pace for human needs. Although clock time runs Western societies, it seems the line is drawn at the idea of people working at a robotic pace.

However, there were different value-laden discourses on the theme of working at a robotic pace. The study identified three frames in which working at a robotic pace was discussed from a justifying, criticising and problem-solving perspective. Over half of the statements were framed as criticising the idea of working at a robotic pace. Forces of the criticising discourse were negative appraisals of the idea of working at a robotic pace and a value base of human factors. Ethical issues were emphasised in humanistic studies, whereas the human factors of reskilling and well-being did not have disciplinary emphasis. While this finding supports the existing understanding, as far as the idea that ethical issues are a topic for the humanities is concerned (Habermas, 1997; Östlund, 2004), it also reveals that human factors are an acknowledged force in the engineering discourse. In the critical communications produced by those with a technologically oriented background, robot pace was viewed as a challenge when it comes to reorganising work and maintaining well-being at work.

Quite unexpectedly, the neutral appraisals stood out as the most interesting category, featuring discourse on problem-solving the discrepancy between human and robot working paces. This constructive perspective with a neutral, or at the very least balanced, value base was found only in the communications pertaining to technologically oriented disciplines. Despite the diversity in the framing of the phrase 'working at a robotic pace', the role of disciplinary traditions was not as dominant as was initially assumed. It was not only humanistic studies to commit epistemologically to human factors of robotisation. In the discourse originating from the technologically oriented disciplines, human factors were not limited to issues of the availability of skilful labour but also included humanistic values of employee well-being and motivation. The diversity among disciplines in selecting and including relevant research topics and angles is the first implication of socio-technical principles being a viable factor in robot studies in the technological domain.

Deterministic, Subjective and Objective Views

The frames justifying, criticising and problem-solving robotic pace can also be interpreted as deterministic, subjective and objective views on the matter. Technological determinism in this context refers to how working at a robotic pace is an ideal not to be questioned. If a technological solution is available to make work more (cost-)effective, it will be realised. If there is an actor who is not willing or able to act as a supportive force in the proceeding course of technologisation, they form a predicament to be addressed and hopefully turned (see Gregor, Chandra, Kruse, & Seidel, 2020). The deterministic view associated with the statements appraising robotic pace in an unambiguously positive way was rare.

On the contrary, the frame of critical discourse was the most common. The critical discourse on working at a robotic pace is suggested to be associated with a subjective view. In the taxonomic contradiction between subjectivity and objectivity in research, 'subjective' should be understood here as the more interpretative outlook on the research topic. In subjective research, researchers draw from their experiences and insights and focus on the phenomena from the perspective of the study subjects (Williams, 2019: 56–60). Subjectivity and affect in producing knowledge are emphasised in the social sciences and humanities (Hillersdal et al., 2020). This arises from the perspective where societal (research) problems typically underlie the status quo, and finding them requires a critical approach instead of observing and measuring changes in plain sight.

Competing with this notion, the subjective view was also observable in the engineering science data. The discourse on well-being at work adopted a human-centered approach in numerous studies with a critical view of working at a robotic pace. However, the difference lies in knowledge-constitutive interests. Cognitive interest in truth can be associated with the engineering sciences and the social sciences and humanities because both disciplines seek to uncover truths. Yet, only the social sciences and humanities aim to disseminate truths about robotisation to make ethical evaluations, emphasising their knowledge-constitutive interest in moral correctness.

Neutral appraisals framed as problem-solving discourse are interpreted as building an even stronger bridge between engineering and the humanities. Because of the neutral or balanced view on values associated with robotising work, the problem-solving discourse is suggested to be associated with the most objective view. The problem-solving frame, derived from technologically oriented disciplines, can be viewed as looking past the epistemological traditions of disciplines where the engineering sciences are expected to measure the effective use of machines and the social sciences are expected to focus on the human(e) factors (Léna, 2012). This does not even refer to how boundaries are overcome in multidisciplinary research projects but rather the openness to a multi-epistemological approach in defining research questions within one discipline (Crawley, 2019). In multi-epistemology, the engineering sciences also take account of the human factors in technology development. In this interpretation, disciplinary independence and openness translate into a higher level of objectivity.

In the research topic of academic discourse on working at a robotic pace, the production of objective knowledge represents expert judgment outside of a regulatory setting (Laurent & Thoreau, 2019). Such objectivity is derived from experts viewing a phenomenon from their scientific backgrounds and from how they have learned a certain performance of objectivity (Cook, Turnhout, & van Bommel,, 2020). In the case of working at the pace of a robot, objectivity is neutrality, where using robots is rationalised only because it is the status quo. It is notable, however, that this identifying objectivity of natural sciences (Léna, 2012) is associated with appraising working at a robotic pace neutrally more often than positively.

Indeed, the socio-technical approach was evident among the statements made by scholars from the engineering sciences. According to the data, the engineering sciences acknowledged the need for a symbiosis between the objective of making production more efficient and maintaining a pleasant pace of work. The problem-solving discourses focusing on both human factors and efficiency reflected the language of socio-technical ideals. Thus, the engineering sciences emphasise not only practicality but also instrumental rationality. While practicality is reflected in either technological determinism where almost a naïve view is that production speed is everything or in the more constructive view where robots can be programmed to act at a pace and style that is acceptable for co-working humans, more holistic rationality is also evident in engineering studies.

Although neutrality and the socio-technical perspective were expressed more in the technologically oriented disciplines than in the social sciences, this finding is not perhaps that arresting. The engineering sciences traditionally dominate robotics studies because robotic technology would not exist without engineering. As a consequence of this ascendancy, the social sciences have played a role in criticising the status quo. Whereas the engineering sciences are expected not to turn a blind eye on human and social factors when it comes to technological developments, social scientists do not have the similar burden of needing to elaborate on the technological aspect of, say, robotisation. This is especially the case when the subject of the study is as provocative as ‘working at a robotic pace’. Furthermore, differences in research tasks play a part in this discrepancy between disciplines. The investigative function of the engineering sciences typically focuses on a single technology, whereas in the social sciences, the use of this technology is viewed from a wider and societal perspective. The narrower research subject in the engineering sciences reflects the possibility of adopting a wider theoretical perspective. A more holistic research subject in the social sciences requires a more carefully defined perspective. A classic way to direct qualitative and humanistic research is to say a lot about a little rather than to cover a broad set of determinants to ‘cover all potential aspects of the phenomena’ (Rapley, 2022: 265, citing Silverman, 2010).

Finally, the findings revealed that the discourse on synchronising robot and human working pace varied in terms of who is setting the pace. In the justifying, or deterministic, frame, studies discussed people adjusting their working pace to robots (Huber et al., 2013), whereas in the problem-solving, or the objective, frame, robots were viewed as being reprogrammed to be convenient for the needs of human workers (Liu & Jebelli, 2022). Additionally, between these opposing perspectives, Benbya, Pachidi, & Järvenpää (2021) described ‘employees needing to adjust to the pace of robots’ operation rather than being able to set their own pace’. Both discourses originated in engineering sciences, but whereas the study from 2013 laid the flexibility demand on humans, the latter study from 2022 saw an opposite dynamic in working at a robotic pace. Overall, the findings did not point to any general temporal correlation in the data.

Aside from the publication year, the context proved to be an insignificant force behind the discourse surrounding working at a robotic pace. The main reason for this is that robot use is centralised in industrial manufacturing. When academic discussions and studies on service robots reorienting our working lives become more common in the future, cross-context research will also become more feasible as well as relevant. As a limitation of the current study, the number of statements was modest, and the scope of contextual variation left something to be desired.

CONCLUSIONS

To conclude, this study found a small but growing number of statements about ‘working at a robotic pace’ related to studies on robotising work. All found statements published over a 35-year period were systematically collected and used as data in content–frame analysis. The statements were mostly excised from recent publications in the 2020s. This study’s novel value comes from its utilisation of content–frame analysis to uncover meanings and discourses related to robotic working pace. Content analysis encompassed consideration of linguistic features, sources, audiences and intent of discourse. The specific content–frame analysis in the study identified dominant frames shaping interpretations of the robotic pace concept.

The academic discourses drew on a range of perspectives in their representations of working at a robotic pace. Discourse on working at a robotic pace can be classified into three frames, each with a different value base. Statements justifying robotic pace are based on efficiency and technological determinism. Statements criticising robotic pace are based on more subjective concerns over work and AI ethics, such as ethical norms, reskilling or deskilling employees and well-being at work. Statements discussing the problem-solving robotic pace are based on multiple values resulting in neutrality and objectivity. Following the socio-technical principle, problem-solving discourse has deliberated on how human–robot collaboration can be optimised through a robotic pace made more flexible than unreasonable.

The study showed that the research task of considering well-being in robotised work is not confined to the social sciences. While the findings did not repeat the previously acknowledged gap between the natural sciences and humanities, they revealed evidence of multidisciplinary approaches within a single discipline. In problem-solving discourse found across technologically oriented disciplines, robotic pace was described not as a deterministic force but as a challenge to be tackled by technological means to build optimal working environments. Focusing this way on both human factors and efficiency, the findings spoke the language of socio-technical ideals applied providently in the engineering, computer, data and information sciences.

Implications

The study's breakdown of appraisals into justifying, criticising and problem-solving frames, backed by a value base analysis, contributes to understanding diverse perspectives on robotic work pace. It also underlines the relevance of employees' involvement in the design and implementation of robotisation because the best expertise on work and work pace lies on those who are involved with the concrete, daily work (Siderska & Alsaqoor, 2023).

As a scientific contribution, the findings in this study provide a useful framework for research on human–robot interaction, especially work-related robot acceptance. Socio-technically oriented study designs should include value-based evaluations in addition to more traditional measures of human factors. Alongside physical and psychological workload and user experiences in robotising work, empirical studies would benefit from including work and AI ethics in their study designs.

Furthermore, outside academia, this study highlights the multidimensional perspectives that shape discussions around robotic work pace. There are pressing questions about how existing social practices affect the cultural ideal of working at a robotic pace. Optimising collaboration between humans and robots is understood as a universal value that would have a positive influence on both efficiency and human values.

ENDNOTES

[1] See also: What is the difference between academic journals and scholarly (peer-reviewed) journals? *EBSCO Connect* (2018). https://connect.ebsco.com/s/article/What-is-the-difference-between-Academic-Journals-and-Scholarly-Peer-Reviewed-Journals?language=en_US

[2] How hard will the robots make us work? *The Verge* https://www.theverge.com/2020/2/27/21155254/automation-robots-unemployment-jobs-vs-human-google-amazon

[3] Why I was wrong to be optimistic about robots. *Financial Times* https://www.ft.com/content/087fce16-3924-4348-8390-235b435c53b2

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Appendix

Data Descriptives

			---Themed codings---				
Nb	*Reference*	*Quote*	*Nature of appraisal*	*Value base*	*Primary reasoning*	*Robotisation context*	*Discipline*
1	Addo PM, Verhulst S, Young A, Zahuranec AJ, Baumann D and McMurren J. (2021)	Development actors ought to consider how embodied intelligence can assist humans, for example, by freeing them to conduct more complex and meaningful tasks or by providing recommendations, instead of simply replacing them or forcing them to keep up with the faster pace of robots or drones.	Negative	Human factors	Deskilling	Working life in general	Data science
2	Arntz A, Di Dia A, Riebner, T Eimler SC (2021)	However, since prior studies revealed that the speed of the robot is crucial for the collaboration setup, lowering the working pace of the robot, which is already perceived as slow, is no option.	Neutral	Efficiency, human factors	Necessity, adaptation	Industrial manufacturing	Computer science
3	Beillon K and Wramsby W (2012)	In other words, to replace human beings in environments where there is high risk to health and safety, or in tasks where humans cannot keep up with the pace of a robot.	Positive	Efficiency	Necessity	Industrial manufacturing	Production development
4	Benbya H, Pachidi S and Jarvenpaa S (2021)	For example, employees may need to adjust to the pace of robots' operation rather than being able to set their own pace.	Neutral	Efficiency	Adaptation	Working life in general	Information systems and business analytics
5	Bourcier T, Chammas J, Becmeur PH, *et al.* (2017)	Robot-assisted surgery has expanded over the past 20 years in macrosurgical specialties; however, microsurgical specialties have seen little growth in the field. The main reasons for this discrepancy include that cataract surgeons work at a nearly robotic pace by routinely performing up to 20 procedures per day, the surgical robots are not specifically microsurgical robots, and the cost of robotic systems.	Positive	Efficiency	Inessential	Medical surgery	Ophthalmology
6	Corlett EN (1988)	The effects on people when they are set to work with robots are similar to those caused by the old paced assembly line. The operator works at the robot's pace, all the time the robot works, and of necessity on a repetitive task with limited content.	Negative	Human factors	Deskilling	Industrial manufacturing	Production engineering
7	Costantino F, Falegnami A, Fedele L, Bernabei M, Stabile S and	Organizational hazards, on the other hand, concern repetitive tasks performed at the pace of robots/cobots, potentially causing fatigue, musculoskeletal stress, psychological	Negative	Human factors	Stress and well-being	Industrial manufacturing	Mechanical and aerospace engineering

	Bentivenga R (2021)	stress, and physical overload, as well as additional damages caused by a monitoring decrease.					
8	Dhillon BS (1993)	One problem arising from robotization is the incompatibility in terms of work pace with humans	Negative	Human factors	Incompatibility	Industrial manufacturing	Engineering management
9	Ellegård K (1999)	The (unexpected) positive social effect of this technically motivated buffer was that the workers were not completely bound to the pace of the robots. The buffer, however, was not installed for social reasons but for technical reasons in the case of machine break-down.	Negative	Human factors	Incompatibility	Automotive industry	Human and economic geography
10	Fasuludeen Kunju FK, Naveed N, Anwar MN and Ul Haq MI (2022)	Moreover, industry aims at accelerating up production to operate more in real-time and in feature of the overall product lifecycle, where pace is critical for everyone, digitizing document flows, being able to react faster in case of production issues, and so on.	Positive	Efficiency	Production speed	Industrial manufacturing	Computer and information sciences
11	Grant BK (1997)	Chaplin's tramp caught in the gears of the conveyor belt after struggling to maintain the inhuman robotic pace of the assembly.	Negative	Human factors	Inhumanity	Interpretation of a fictional scene of industrial manufacturing	Communication and film studies
12	Guan Y and Liao H (2015)	Time allowances are created to take into consideration fatigue and other factors that affect human employees, creating more realistic time standards instead of assuming a robotic pace that would otherwise be unachievable by a person working 8 hours a day. In terms of machines, allowances are also incorporated to take into account down times and other aspects such as cool downs or inspections. These realistic times allow for a better estimate to what a line can produce without the expense of operator health and machine lifetime.	Negative	Human factors	Unrealistic	Industrial manufacturing	Industrial engineering
13	Huber M, Lenz C, Wendt C, Färber B, Knoll A and Glasauer S (2013)	Each assembly step has a fixed time interval, so the human worker needs to adapt to the robot pace… The experiment subjects do not adjust their working speed to the pace of the robot. Instead they keep their preferred assembly behavior, which results in varying waiting times.	Positive	Efficiency	Adaptation	Industrial manufacturing	Sensorimotor research
14	Liu Y and Jebelli H (2022)	Another example is when workers are subjected to excessive cognitive load due to the working speed of robots. The robot will not adjust its pace to reduce the cognitive load; this imposition can cause mental fatigue and stress… When workers are under high cognitive loads, the Co-Path allows robots to provide an	Neutral	Human factors	Stress and well-being, adaptation	Construction sites	Architectural engineering

		enhanced sense of safety by staying a comfortable distance away from workers and gives them more stress recovery time by reducing the robot's pace.					
15	Liu Y, Habibnezhad M, Jebelli H and Monga V(2021)	Task #2 was designed to examine the performance in adjusting the working pace of the robot based on workers' cognitive load	Neutral	Human factors	Adaptation	Constructi on sites	Architectu ral engineerin g
16	Mateos JM (2019)	As the robots carry the pods quicker, the whole process is speeding on, and pickers have to do their job even faster, following the pace of the robots. The robots have raised the average picker's productivity… Robots are designed to accelerate the work process, but humans have physical limits, and sooner or later they will suffer from the commitment to follow such an inhuman pace… Because as it happened in the assembly line the Kiva robots, and other systems are the ones that set the pace of work, and the workers have to follow it.	Negative	Human factors	Inhumanity	Warehous e work	American studies
17	Messeri C, Masotti G, Zanchettin AM and Rocco P (2021)	We propose a novel paradigm where the robot is enabled to adapt its behavior online to simultaneously optimize in real time human physiological stress and productivity. The proposed control strategy exploits a game theoretic approach to model and locally estimate the state of collaboration in terms of human productivity and stress. Based on this estimate, a learning automaton suitably adjusts the production pace of the robot, thus influencing the dynamics of the cooperation.	Neutral	Efficiency, human factors	Adaptation	Industrial manufactu ring	Bio engineerin g
18	Rosenmeyer A (2020)	Are we willing to be cogs in the machine of the emerging post-industrial age? Whose machine is it? Will that truly make us winners, and what happens to those who cannot maintain robots' pace?	Negative	Human factors	Inhumanity	Creative work	Art
19	Turja T, Hakanen J, Krutova O and Koistinen P (2023)	This not only applies to knowledge work and the ever-growing service sector where the work pace has been accelerated, but also to industrial manufacturing where automation has made work faster, endorsing the speed of robots… Whereas working at a robotic pace is easy to categorize as a negative stressor, high demands of digitized work can have either a hindering or a challenging effect	Negative	Human factors	Stress and well-being	Industrial manufactu ring	Social sciences
20	Turja T, Minkkinen J	Technological systems and computer software have a higher probability to	Negative	Human factors	Deskilling	Working life in	Social sciences

	and Mauno S (2022b)	increase workers' autonomy at work while a robotic device entails always a risk of work changing to mechanistic and more routine-based in nature. In such case, the working pace of everyone is connected to the working pace of a robot.				general	
21	Zanchettin AM, Marconi M, Ongini C, Rossi R and Rocco P (2020)	Nowadays, synchronisation between humans and robots and the corresponding turn-taking is explicitly controlled, via command channels, such as a switch or a button. Synchronisation does not necessarily entail a rendezvous between the two agents, but can also require to adjust the pace of the robot according to the one of human.	Neutral	Efficiency	Adaptation	Industrial manufactu ring	Bio engineerin g
22	Zimmer M, Al-Yacoub A, Ferreira P, Hubbard E and Lohse N (2022)	Giving the operator the possibility to set the robot's pace and choose the favoured mode of interaction with the robot, increased usability and reduced perceived workload as a sense of familiarity and predictability could be achieved.	Neutral	Human factors	Adaptation	Industrial manufactu ring	Software engineerin g