

Consider the Human Work Experience when Integrating Robotics in the Workplace

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Abstract— Worldwide, manufacturers are reimagining the future of their workforce and its connection to technology. Rather than replacing humans, Industry 5.0 explores how humans and robots can best complement one another's unique strengths. However, realizing this vision requires an in-depth understanding of how workers view the positive and negative attributes of their jobs, and the place of robots within it. In this paper, we explore the relationship between work attributes and automation goals by engaging in field research at a manufacturing plant. We conducted 50 face-to-face interviews with assembly-line workers ($n = 50$), which we analyzed using discourse analysis and social constructivist methods. We found that the work attributes deemed most positive by participants include social interaction, movement and exercise, (human) autonomy, problem solving, task variety, and building with their hands. The main negative work attributes included health and safety issues, feeling rushed, and repetitive work. We identified several ways robots could help reduce negative work attributes and enhance positive ones, such as reducing work interruptions and cultivating physical and psychological well-being. Based on our findings, we created a set of integration considerations for organizations planning to deploy robotics technology, and discuss how the manufacturing and HRI communities can explore these ideas in the future.

Keywords— *work attributes; manufacturing; human robot collaboration; collaborative robotics; future of work; Industry 5.0*

I. INTRODUCTION

Since the dawn of 20th century industrial robotics, a common narrative is that robots will replace “dirty, dangerous, and dull” jobs, and create a more nimble workforce [1]. However, the narrative has shifted since this time: rather than robots replacing human workers, they are instead intended to work collaboratively with them. No longer is human and robot work strictly bifurcated by cages, but rather, the two work collaboratively, proximately, and in harmony.

This integration of human-robot work is not trivial. HRI research has explored many dimensions of this problem in manufacturing settings, ranging from the technical to the socio-technical [2, 3, 4, 5, 6, 7, 8, 9]. The socio-technical perspectives are particularly important, as all technology is disruptive to work, and robots that will be shifting or supplanting function even more so. As robots are designed and integrated into a workplace, it is important for organizations to consider how their disruption influences human resources. Even slight changes in the work tasks and environment can yield significant impacts on dimensions of the human experience, including motivation, satisfaction, fatigue, and cognitive demand. It is critical to consider how the design and integration of technology changes the human experience, thereby allowing an

organization to capitalize on opportunities and avoid unintended detriments to human resources.

One way to explore this change is to investigate the relationship between how an employer's goals of deploying robots impact the preferences of workers. For example, in manufacturing, where this paper is situated, employers' goals for robots could be to reduce waiting time, enhance time on tools, and improve material flow efficiency. However, workers' preferences include a desire for personal autonomy, social interaction, and work variety, which may or may not intersect with an employer's list. If these cross impacts are understood, the impacts of any technology on humans can be considered during the design of the technology and of its implementation. Such knowledge is important because, as technology like robotics is considered for integration, specific preferences can be targeted for preservation and enhancement. This knowledge would enable human-centered design that can positively impact worker well-being, safety, and performance [10].

Independent of technology, work preferences have been studied for many years across a variety of disciplines and industries [11, 12, 13, 14]. Job preferences are important because they link to work performance and long-term success via motivation and satisfaction [15]. In its extreme, unmotivated employees expend the least amount of energy as possible at work, avoid work whenever possible, and produce low-quality work. Motivation can be inconsistent and can fluctuate as organizations institute change [16]. When the positive attributes of work are present, workers tend to be more motivated and achieve enhanced work outcomes [17, 18]. Job satisfaction is also a principle mediator between job attributes and work outcomes. If negative work attributes are present or if work is oversimplified, job satisfaction and work performance decrease [19]. There is consensus that positive attributes of work promote motivation and satisfaction, which subsequently improves work performance, retention, safety, and general well-being which, in turn, benefits an organization's success.

Since the literature on preferences is fragmented (research on individual attributes or the combination of attributes varies across studies) and dispersed across industries, we thoroughly reviewed the literature to identify work preference generalities which are independent of context or work type. We then validated these findings within the manufacturing work environment through a social constructivism and content analysis research approach using open-ended interviews with workers. Over twenty hours of interview data was collected from fifty workers ($n = 50$). Over the course of a year, we engaged in an iterative process of reviewing the interviews both through discourse analysis and content analysis. This yielded a detailed and thorough understanding of the specific work



Figure 1: The factory where we conducted our research. Workers engage in assembly manufacturing in teams (left). Their work processes are entirely manual, including material delivery (center), and parts retrieval (right), which afford social interaction.

attribute preferences in this setting. Using the knowledge from this study, we explored the logical interactions between work preferences and attributes of automation.

We found that the work attributes deemed most positive by participants were human interaction, movement and exercise, (human) autonomy, problem solving, task variety, and building with their hands. The main negative work attributes included health and safety issues, feeling rushed, and repetitive work. We identified several aspects of automation that could help reduce negative work attributes, for example, using robots to adopt tasks that cause work interruptions, thereby allowing for workers to stay focused on their tasks and complete work on time. Our findings also suggest an opportunity for robots to cultivate health and safety, both physical and psychological. Our work also revealed some value tensions between employers and employees, such as their views on robot tasks from a monetary (and efficiency) perspective, which came at the expense of a highly enjoyable job people would engage in. Based on our findings, we created a set of integration considerations for organizations considering deploying robotics technology, and discuss how this knowledge can be used for future work.

II. BACKGROUND AND LITERATURE REVIEW

A. Focus of Current Research

Researchers often consider human resources to be flexible, adaptable, and trainable. However, humans are also fickle and prone to error and bias, making them sensitive elements of a complex work system [20]. Much technological research has focused on how technologies can improve efficiency in workflow and production [21], even though overall performance may degrade if the human resources are unintentionally displaced or if preferred work tasks are eliminated. While work attributes have been studied before, our research is a new contribution as it identifies work preferences from those directly affected by the integration of technology and uses this information to inform future integration. By understanding worker preferences, organizations can consider how new technology will impact the human work experience and to capitalize on opportunities or avoid unintended detriments to human resources.

To avoid such unintended impacts, this paper presents the robotics community with a summary of work attributes that should be considered before robots are introduced into new workplace settings to work with people. Robots can then be

introduced in such a way as to positively affect the workers by maintaining desired attributes, and replacing less preferable ones. The ability to weigh the benefits and drawbacks of different attributes as related to technology implementation fills a gap that has not previously been analyzed in manufacturing. We sought to establish common ground between worker job preferences and employer goals when deploying automation. Our goal is to understand and bridge this disconnect.

B. Robotics and Automation in Manufacturing

To cater to the needs of modern factories, industrial robots are increasingly becoming more mobile [22, 23], adaptive [24] and human-oriented [25, 26]. The cages that separate robots from people are coming down, and robots are being deployed into human-centric factory environments. Some assembly work, such as furniture and automotive final assembly, involves complex and highly dexterous tasks that will continue to require human capabilities. Manufacturing organizations, ranging from aerospace to modular construction, are accelerating the pace at which they are integrating automation [27]. This is driven by global competition to secure competitive advantages [28]. Such advancement has resulted in workplaces where humans and autonomous systems must collaborate to efficiently assemble a product [27, 29]. Often, automation is introduced to reduce cost and increase production [30].

When automation is introduced into a workplace, the common narrative is that it will replace human performance of dangerous, repetitive, or error-prone tasks. However, it is important to be cautious in the deployment of technology and consider the larger context of work. Failing to do so means it is possible that preferred work tasks will be replaced, human interaction will be reduced, and work paces will increase unsustainably. While the human-robot interaction (HRI) research community has been working for decades on leveraging the uniquely independent strengths of humans and robots to build effective teams, the manufacturing industry has been slower to adopt close integration, “[treating] automation and manual labor as separate issues” [31]. This disparate view has led to several problems which both disadvantage businesses economically and contribute to negative workplaces for workers. First, because the two laborers (robot and human) are viewed as separate entities, when problems occur companies have no means for collaborative problem solving, often causing work to be stopped entirely. Work stoppage is extremely expensive for companies, with tangible cost estimates ranging between \$1M-\$7M million dollars per hour [32, 33, 34].

Second, historically, robotics technology has been foisted onto workers without sufficient socio-technical workflow analysis or adequate training, leading to technology adoption and acceptance problems [35, 36, 37]. This lack of a human-centered approach toward systems integration adds further expense to companies by increasing its intangible costs [34]: it can lead to worker frustration, stress, and talent loss [37, 38, 39].

In a thorough literature review, we determined that there are four common goals of employing technology in manufacturing: (1) quality; (2); cost; (3) dependability; and (4) flexibility [40, 41]. Other goals included: improved time, customer service, coordination, and collaboration [42, 43]. Additional regional studies indicated cost (material or overhead), quality, schedule, supervision, forecasting and inventory and technological issues as considerations when implementing automation [44]. These goals and general considerations are typically related to the success of the organization as a whole and not specific to the tasks of the employees. If some focus is shifted to considering the preferred and less desired work attributes when implementing change, the goals of automation likely will also be positively affected.

C. Salient Work Attributes

People are not only motivated by rewards and recognition but they are motivated by the general satisfaction achieved from the actual work tasks (i.e., what they are doing) [45]. Literature researching the human experience across a variety of companies shows that people like their job for many reasons including: the enjoyment and sense of challenge of the work, the social environment, the ability to be creative, participating in satisfying, engaging work tasks, recognition of worker's personal lives, a sense of belonging, and engagement through inspiration, commitment and fascination [46-48]. According to Seitz, there are ten items that affect employee engagement which are connected to employee satisfaction: connecting with employees, clear vision from leadership, direct expectations and feedback, praise and recognition for strong performance, feeling empowered, autonomy, collaboration with a team, high ethical standards and credible reputation, and confidence [48].

Csikszentmihalyi [45] found eight primary reasons why people enjoy a specific work activity: enjoyment of the application of acquired skill; the activity itself; motions and patterns of the activity; development of personal skills, friendship, and companionship; extrinsic competition by measuring oneself against peers; intrinsic competition by measuring oneself against internal ideals; emotional release; and prestige. Similarly, Turner and Lawrence [49] found six attributes that define work preference: variety, autonomy, required interaction, optional interaction, knowledge and skill required, and responsibility.

Some have theorized that preferred job attributes can be modeled simply in the motivator-hygiene theory. The premise of this theory is that there are attributes of a job that produce either satisfaction or dissatisfaction [50]. They claim that the five factors of satisfaction (motivators) are (1) achievement; (2) recognition; (3) pleasure of the typical work activities; (4) responsibility; and (5) advancement. Alternatively, the factors of dissatisfaction (hygienes) are caused by (1) policy and administration; (2) supervision; (3) salary; (4) relationships among coworkers; and (5) work conditions. Subsequent studies

Table 1: Work attributes found in the literature and in our work

Positive Attributes	[6]	[7]	[8]	[12]	[13]	[18]	[33]	Our work
Human Interaction and Team Dynamics	*	*		*		*		*
Movement and Exercise						*		*
Variety						*		*
Autonomy								*
Upper Management and Communication								*
Building with Hands						*		*
Problem Solving								*
Easy Work Tasks								*
Pay		*	*	*	*			*
The Work Itself	*		*			*		*
Motions and Patterns of Activity	*			*				*
Extrinsic Competition	*							
Intrinsic Competition	*							
Emotional Release	*	*						
Prestige and Pride		*	*					*
Rewards and Recognition		*	*			*		
Responsibility		*	*					
Growth and Learning		*						
Involvement in Change		*	*	*				
Goals and Achievement								
Negative Attributes	[6]	[7]	[8]	[12]	[13]	[18]	[33]	Our work
Policy and Administration			*					*
Supervision			*		*			*
Salary			*		*			*
Coworkers			*					
Work Conditions			*		*		*	*
Policy and Administration			*					*
Supervision			*		*			*

supported this model and defined these factors in greater detail [51, 52]. For example, turnover has been found to be the result of poor supervision, a poor work environment (traditional problems such as heat, dirt and ventilation but also including flexibility and equitability), and inadequate compensation [53, 54]. Although there was some controversy surrounding this theory due to reliability of metrics and contextualization, later research led to the development of tools that are widely accepted to measure core human factors dimensions like job satisfaction [55].

Although this is not an exhaustive discussion of work preferences, the attributes found in these cases represent the dominant themes in the existing body of research. Table I summarizes both the positive and negative work attributes found through our literature review as well as our current study. This table was created using sources from across multiple industries (manufacturing, medical, academic, etc.) through a literature review. Current work preferences literature is fragmented across industries and often focuses on a single attribute, hence seven papers were used to build the table and our work added the eighth column. These papers were a subset of reviewed literature but represent the overarching themes. We used our literature review to determine overarching generalities of work attributes independent of industry. This was not an exhaustive discussion of work preferences, but was used to show how we selected the dominant themes in the existing body of research to code, analyze, and compare with our data for validation.

III. RESEARCH QUESTIONS

The objective of our work is to identify and document preferred and less favored work attributes related to manufacturing jobs, so as to better understand the context for the deployment of robots. These findings can inform a systematic assessment of human factors issues related to the use of robots in manufacturing settings. This may help to improve the human condition and work outcomes. To achieve these goals, we addressed the following research questions.

1. What attributes for work are generally the most desirable, and how do data from the literature and social constructivist research compare?
2. How can this information be used to design new technology and develop an implementation plan?

IV. RESEARCH METHODS

A. Research Approach

In this work, we explore the impacts of work attributes as they relate to human factors in the workplace through the use of social constructivist interviews. Social constructivism involves asking simple, open-ended questions and systematically analyzing both the responses and the nuances of how the responses were provided. Discourse analysis then reveals the complexities, consistencies, and inconsistencies in the way that people speak about their job preferences and the impacts of technology [56, 57]. After the interviews were complete, we analyzed the data using content analysis.

Social constructivism is the umbrella for theories related to culture and society and discourse analysis is the approach most widely used [58]. There are four premises shared by all social constructionist approaches: 1) critical stance to taken-for-granted knowledge; 2) historical and cultural specificity; 3) knowledge is sustained by social processes; and 4) link between knowledge and social action [59]. There are typical ways of using language in certain situations on particular topics. These “discourses” share specific meanings but also have characteristic linguistic features associated with them. What these meanings are and how they are realized in language is essentially discourse analysis.

Discourse analysis establishes a relationship between language and context. It examines patterns of language and considers the relationship between words and the cultural contexts in which it is used. This enables researchers to consider how world views vary, and examines relationships between participants. Discourse analysis is predominately used in the humanities and social sciences, including linguistics, sociology, cultural studies, education, and communication, however it is applicable in any discipline or industry [60, 61, 62].

There are many ways in which text data from interviews can be analyzed, including literal, interpretive, and reflexive approaches [63]. With literal analysis the researcher focuses on the exact use of words and language; with interpretive analysis the researcher must use logic and opinion to interpret the meaning of the responses; and with reflexive analysis the researcher focuses on the responses and their own contribution to the data collection and analysis process [64]. This study incorporated literal and interpretive analysis to learn from both

the stated words as well as interpreting the way ideas and issues were discussed by each individual. This process allows for themes and dominant discourses to emerge which can then be categorized into their related work attributes.

We employed a combination of structured content analysis and discourse analysis to present both a factual representation of what was said, a detailed understanding of how it was said, and the extent to which there is internal consistency within and among responses. The questions asked of the workers in our study were left general and open-ended to promote discussion and to allow the conversation to go in whatever direction the interviewee dictated. The purpose of this process is to avoid the systematic biases that exist when participants are asked closed-ended or leading questions and when interview data are presented only quantitatively.

B. Participants and Setting

We conducted a total of fifty face-to-face interviews with assembly line workers at a large US-based manufacturing facility. Thirty-six men and fourteen women participated in the interviews. The average years of manufacturing experience was twelve, with the longest being forty-one years and shortest being three weeks. Interviews were eight minutes and thirty-four seconds long on average, and a ten-minute time limit was imposed to avoid excessive work disruption.

The manufacturing facility engages in a nearly entirely manual work processes with the exception of a robotic welding machine and an underutilized Baxter robot. The welding machine is a fully autonomous manual parts sorter which uses computer vision to help workers check a build. Fig. 1 shows examples of several common manual work processes, including collaborative assembly, material delivery, and parts retrieval.

C. Interview Questions

We asked participants a series of open-ended questions in two parts. The first section involved general background questions about the participant’s job, while the second focused on their perception of technology and robotics. The questions were designed to standardize the collection process while allowing workers to lead the discussion on their terms. This questioning style leads to comfortable conversation that allows discourse to naturally emerge.

The general questions asked the workers to describe their jobs and how long they have done similar work. They were asked to discuss their preferences related to their job (specific attributes as well as specific tasks) and note any possible changes they thought could be implemented in the workplace. The technology questions remained open-ended as well, and asked the workers about their perceptions of robots in general and in their workplace. They were asked to describe any possibilities of robots assisting them in their jobs and outline the benefits and drawbacks (if any) to the use of robotics at work. While the same set of questions was used for each participant, we allowed the participants to set the direction of the conversation and used the questions as prompts.

D. Process

All research was approved by the Institutional Review Boards (IRB) of the authors and of the manufacturing company. Participants gave informed consent to be audio recorded, and their confidentiality was maintained and data stored securely.

The raw data were only analyzed by the research team, and not shared with the employer.

Each interview was manually transcribed to ensure accuracy. Throughout the data collection process, clear discourses developed, and repetition of themes and patterns occurred. Interviews were ended after no new perspectives were obtained. This saturation was achieved after 50 interviews and was later confirmed during transcription and analysis.

During transcription, we notated themes and patterns. We then imported the transcriptions into QSR Nvivo and coded them. This software is designed for qualitative analysis and modeling of patterns in large volumes of text data. Nvivo was useful in the analysis of the 21 hours of interviews because it allowed for the visualization of latent patterns and minimization of researcher bias [65]. The structured content analysis revealed the general themes of *what* was said and was complemented by the social constructivist approach, which reveals themes about *how* interviewees spoke. Similar to grounded theory, social constructivism creates reliability by external comparison among responses and internal comparison within responses to establish dominant patterns [66]. The combination of discourse analysis and structured coding allowed for an iterative approach and cross-validation of the methods [67]. Further, this mixed-methods technique allowed patterns to both evolve and disappear as the process was repeated and data were revisited.

V. RESULTS

A. Work Attributes

Table II summarizes the findings regarding work attributes and includes the dominant themes in the work preferences of respondents. Only attributes discussed by more than 5% of respondents were included. Each attribute was classified as positive or negative, depending on how the participants spoke about the attribute.

The most powerful themes in the findings include:

- Need for interaction with others was extremely valuable and coworkers were one of the most important attributes of their job
- Ardent desire to move around throughout the day and to feel that they have exercised physically
- Preference for job rotation, variety in work tasks and locations, and avoiding repetition
- Desire to work at their own pace
- Ability to problem solve and build with their hands

In addition to these general themes, participants had strong, positive feelings about management and their involvement in decisions. Participants felt that being involved in decisions and having managers who listen and respond to concerns is important to their satisfaction and success at work.

Although there was consistency in the general themes, there was some inconsistency for some specific attributes. For example, while some participants preferred physical exercise and the need to problem solve, others preferred working easier jobs with lower mental and physical demands. Thus, the general themes should be taken to represent dominant discourse but not consensus. Interestingly, this reveals the importance of recognizing that work conditions may be optimized by considering commonly desired attributes but that the desired

Table 2: Work attributes participants discussed most

Attributes Described Positively	% of respondents
Human Interaction and Team Dynamics	26%
Movement and Exercise	24%
Variety	24%
Autonomy	14%
Upper Management and Communication	14%
Building with Hands	12%
Problem Solving	12%
Easy Work Tasks	8%
Pay	6%
Attributes Described Negatively	
Health Issues	34%
Long Hours	30%
Upper Management Issues	28%
Repetitive Work	18%
Safety Concerns	12%
Early Shifts	10%
Pay	10%
Scheduling Concerns	8%
Being Rushed	6%
High Turnover	6%

attributes are not universal. This table shows the specific findings regarding positive and negative work attributes found in our data collection. We will define these attributes in more detail, by drawing on our literature review and adding direct interview quotations. For example, autonomy was listed as a positively described attribute by 14% of the participants. From the literature, autonomy at work is freedom and flexibility in completing a job, and from the interviews, one participant said "I just like working when I control what I do on that job."

Participants also expressed some attributes that are undesired. These major themes are summarized into five categories: health and safety, scheduling, communication, compensation and turnover. Health and safety included attributes related to unsafe and dangerous work; poor ergonomics and high physical demands; repetitive work tasks causing wear and tear, and discomfort with heating, ventilation, and air conditioning (e.g., high temperatures). Scheduling issues were related to assignment to undesired shifts and required overtime and feeling rushed more often than not to complete work quickly. Pertaining to both scheduling and communication, it was felt that there was an overall lack of communication from upper management including communication related to overtime and long work hour assignments. Compensation issues were discussed as an undesired attribute as well as high turnover. This turnover was believed to be a result of the ageing and retiring workforce combined with a younger generation that does not want to be in this industry.

It is important to note that some of these responses impact multiple attributes described in literature. For example, standing for long hours is a dislike that relates to many different attributes for work discussed in the literature including long hours, fatigue, health issues, and scheduling concerns. The overall findings in this study are consistent with the main attributes addressed in the literature review as represented in

Table 3: Correlation of preferred work attributes and goals of automation

	Attributes of Automation								
	Improve Safety	Improve Health	Reduce Repetition	Reduce Workload	Reduce Waiting	Increase Efficiency	Increase Production	Reduce Costs	Material Handling
Desired Attributes of Work									
Human Interaction				-		-	-	-	-
Movement/Exercise		+			+	-		-	-
Variety			+	-	+				-
Autonomy				-	+		-	-	-
Upper Management/Communication	+			+					
Building with Hands								-	-
Problem Solving						-	-		
Easy Work Tasks			-	+		-	-	-	
Pay				-	-				
Disliked Attributes of Work									
Health Issues	+	+	+	+				+	+
Long Hours	+	+		+	+	+	+	+	+
Upper Management Issues							+	+	
Repetitive Work		+	+			+		+	+
Safety Concerns	+	+	+	+				+	+
Early Shifts		+		+	+	+	+	+	+
Pay				-					
Scheduling Concerns		+		+	+				
Being Rushed	+	+		+	+	+	+		+
High Turnover		+		+				+	

Table I. Some preferred attributes were more specific to a manufacturing setting such as movement and exercise, building with hands, and simple work tasks.

B. Preferred Work Attributes & Automation Goal Correlates

As one of the goals of this paper was to understand how preferred work attributes affect the deployment of automation and robotics, we perform a direct comparison between the goals of automation and their effect on work attributes. After outlining the positive and negative attributes of work based on this research and determining the main goals associated with automation, we developed Table III with this aggregated information. Overall, this table represents the correlation between the preferred attributes of work and the goals of automation. Each cell is notated with a positive or negative to represent how automation attributes affect work attributes.

To create the columns, we used the generally accepted goals of automation from our literature review. We found that common attributes correlated with the introduction of automation include improving safety and health conditions, replacement of repetitive work tasks and idle time spent waiting, increasing efficiency and accuracy which likely can increase production, reduction of cost and handling of materials. The rows are the work attributes obtained from the data collection as previously reflected in Table II. The main desired attributes of work were interaction with coworkers, movement throughout the workday, and variety of work tasks. Upper management providing an avenue for employee suggestions was also an attribute noted as positive. The ability to work with their hands, solve problems, and complete easy

work tasks were noted, as well as adequate pay, as being desirable. The main negative attributes were health concerns (e.g., injuries, long hours, and early shifts), problems with upper management (e.g., lack of adequate communication), repetitive work tasks, and safety concerns. Others included: inadequate pay, scheduling concerns (particularly lack of communication for overtime), being rushed, and high turnover.

Based on this table, it is evident that the less desirable work attributes may be minimized via automation. For example, how long humans have to wait for parts (and thus stop work), may be aided by robotics technology, a concept which has been explored in other aspects of our work [68]. Ideally, this would eliminate or reduce many of the negative work attributes related to scheduling, as reducing waiting would improve productivity, allowing for more standardized work hours [69]. Another example is related to improving safety with automation; a robot that performs a repetitive task (negative work attribute) may help improve health by reducing injury incidence thereby leading to overall improved work experience and potentially improve productivity.

The reduction of waiting time as a technological attribute has mostly positive effects as people would have more time to work or to complete more interesting tasks. In one interview, it was described that a robot could be used for “grabbing the [materials] when they run out because then that’s one less thing for us to have to go out and search for and come back.” This would reduce time spent searching for materials and allow a worker to continue to stay focused on the required task.

Participants discussed how automation could improve health and safety by performing dangerous or repetitive tasks

that cause wear and tear over time. They noted there is room for “a lot of improvement with certain jobs that ergonomically hurt people” and robotics could likely aid in this area. Additionally, there was the belief that “robots can be used in many sorts of ways and programmed in many sorts of ways that possibly nowadays it’s not safe in general for humans to do.”

However, when it comes to desired work attributes, there are some areas of note. Implementing automation of material handling reduces human interaction, movement and exercise, variation of tasks, possible autonomy, and physical work. Most notably, reducing or eliminating social interaction through the workday was a serious concern commented on by many workers and it was noted that deploying robotics would likely reduce this interaction significantly. People enjoy working with other people and for many, this is the most desired attribute in a job. Some example comments include: “It’d be a lot less communicating with people. It would probably make the job more boring.”, and “I would rather be working with a person and talking to a person than a robot.”

Also evident from Table III is that there may be value tensions between the goals of the employer and the workers. For example, increasing production and reducing costs may decrease a worker’s human interaction and movement, two highly desired job attributes, as well as eliminating easier tasks and the need to problem solve.

A main theme derived from this study regarding the implementation of robotics is the lack of human expertise or touch; robots cannot see mistakes and make adjustments the way a human can, and with a high variation product, this could be a difficult hurdle to surpass. One participant stated that he thinks “robots are something that is somewhat of the future” but that “they are made and maintained by a human operator and they’re only going to be as good as the operator that programmed them.” He then said that “there’s still a level of error involved in that.” And while the majority of participants in this study discussed technology with a positive attitude, it was noted by one person that “technology is a really good thing and I think it’s going to bring a lot of progress but then I wonder what are the people who used to have that job going to do.”

Additionally, the possibility of a robot taking the place of a person in general was a major concern and job loss was discussed by over 50% of the participants. Many noted that “[robots] are more of a benefit to the company but not to the employees” as related to job loss due to deployment of robotics. Many noted that the possibility of working alongside a robot or actually running the robot would be desirable while the replacement of their jobs altogether would not be. One participant summarized much of the discourse on robotics quite simply – “robotics are a tool, not a replacement” – this was a prominent theme that emerged.

VI. DISCUSSION

A. Integration Considerations

Based on the findings presented in this paper, we derived a set of automation workplace integration considerations for manufacturing organizations. These can help employers leverage positive work attributes for the betterment of their human workforce, and pitfalls to avoid. Generally, positive work attributes included human interaction, movement and

exercise, (human) autonomy, problem solving, task variety, and building with hands. Negative work attributes included health and safety issues, scheduling concerns (feeling rushed, long hours), and repetitive work.

1. Augment, don’t automate: In robotics, many researchers have argued for a paradigm shift away from the notion of automation as replacement of human labor, and instead toward how robots can best augment and support people [70]. This theme was seen strongly in our data; job displacement is a common concern, particularly within the manufacturing industry [71]. Employers can instead consider ways to effectively use automation to improve worker productivity and well-being by decreasing negative job attributes, such as using robots to reduce wait times and feeling rushed. For example, our research indicated a common theme of people not wanting to lose jobs to robots but a willingness to work alongside them, which led us to the integration consideration of augmentation over automation. While others in the community have argued for this concept on the theoretical side of HRI (e.g., Mataric), our research provides direct support from users themselves for this claim.

2. Select tasks carefully: How robots augment work is also important. People want to engage in tasks that facilitate positive attributes and reduce negative ones; however, it may not be immediately clear to employers which tasks these are. For example, when we began this project, managers suggested their biggest pain point was the manual delivery of raw materials, i.e., “water spiders”. Delays in the delivery process was negatively affecting production. However, our data showed that being a water spider was the most coveted job at the factory, because it involved several highly positive attributes - human interaction, movement, variety, and autonomy. Though there were delivery tasks that participants frequently wanted robots to do, such as transporting large pallets of sheet metal, which is dangerous. Thus, it is important to balance these nuanced tradeoffs when making decisions about tasks, and consider repurposing robots. Participatory design approaches can be beneficial in this process.

Understanding which tasks people covet or dislike the most based on their work preferences can drastically affect technology adoption and implementation. There can be a difference in what management deems a reasonable place to integrate technology and what would maintain (or improve) the environment for the workers. Our research presents this as a new perspective, from workers directly affected by the potential introduction of technology, for understanding the impact of robotic integration in manufacturing.

3. Retrain and retain: The introduction of robotics into a workplace is an opportunity to empower workers to learn new skills. During the course of our research, several managers we spoke with suggested this may be a way to recruit and retain the next generation of workers, who are technology-savvy and interested in using new technology in the workplace. This idea has also been reported in the literature [72, 73]. The training itself can also leverage positive work attributes, such as social interaction and problem solving, particularly if workers train their colleagues on the floor.

4. Cultivate health and safety: Robots can be used to facilitate occupational health and safety. In addition to adopting tasks that can cause acute harm, such as welding or working

with corrosive chemicals, they can also be used to reduce the incidence of more insidious harms. For example, repetitive stress injuries from repeated tool use, chronic chemical exposure, or back injuries from unassisted lifting can all cause more serious injuries. Robots might also support psychological well-being by facilitating social behavior, either with the robot or with other workers, a finding also previously reported in the HRI literature [43].

B. General Discussion

The work presented in this paper can be leveraged by the HRI community as points for future research. For example, recent public and private research organizations in the United States and European Union have invested substantial resources to explore “the future of work at the human technology frontier” [75] and Industry 5.0, the 5th industrial revolution which explores new partnerships between human and machine [76]. These efforts directly raise fundamental HRI questions: What is the role of the robot? What tasks will it engage in? How will it affect workers and employers? How might autonomy be adjusted to incorporate human work preferences? The nature of work itself, and its positive and negative attributes, can be considered within this framing.

Our work also raised value tensions between employer and employee. Employers are often persuaded by the “automate to be competitive” narrative touted by “efficiency experts” far removed from the factory floor and its workforce. This disconnect was illustrated in the aforementioned example of the water spider; automating it could have deleterious consequences for morale and positive work attributes. There was a common juxtaposition between the benefit to the employer and job loss when discussing robotics: “For management, it would save them a lot of money and it would be more efficient” but “the other thing is losing jobs for people.” It was noted that while robotics would improve quality and speed while reducing error and risk, those are primarily benefits to the employer, and the potential job loss was a negative for workers. A few even commented on the ability of robotics to impress clients but that was also an employer-focused benefit.

It is further clear employers need to realign how work is imagined vs. how work is done. Inter-professional participatory design approaches are one way to support this. For example, at the facility where we conducted our research, quarterly design retreats are held that bring together people from across the workforce, including everyone from managers to line workers to delivery truck drivers. They use IDEO-inspired approaches to collaboratively and creatively problem solve. Others in the community have also demonstrated success by conducting value-sensitive design workshops with stakeholders to explore how human work is augmented by autonomy [4, 77].

C. Limitations

Although this study had interesting findings using a unique research method within the manufacturing industry, there were some limitations. Our sample size was relatively small and it only included participants from one manufacturing plant in the United States. The data came from a single source in that aspect and the participant pool was chosen at the discretion of the employer. However, the validity of this data is high because the data comes directly from the targeted population,

demographical variability was captured within this group and there was saturation of information within the data collected.

There is a level of subjectivity with social science data analysis such as what was used in this study. With the social constructivism approach, there is concern of the existence of interpretation of data and bias, however, this concern was mitigated by combining discourse analysis and content analysis. Within-method triangulation is the use of two or more different methods from within a particular methodological approach to measure the same phenomenon [78]. Additionally, continuous discussions within our research team throughout the data collection process provided an iterative process that ensured a mutual understanding of the information being gathered. Discussions of data interpretations and conclusions with multiple members of the research team as well as other peers in the form of a peer review was another method to create validity in the results [78]. We did not conduct a formal inter-rater reliability analysis due to budget limitations - only one researcher was able to fully analyze the interviews. However, we did follow recommendations from the literature (such as [79]) to ensure we engaged in rigorous analytical processes of our data at all stages. Often, with interview type data collection, there can be some concern that participants will be unwilling to be honest and answer the questions to the fullest extent. However, in this case, the anonymity of the process as well as the environment established by the social constructivism approach and the ability to opt out of the interview led to very detailed and thoughtful responses. In some cases, the time constraints did affect the length of interviews but this was out of the control of the researcher.

D. Future Work

While our results could likely be validated in a controlled environment, future studies may focus on addressing more specifically what technologists could consider from the literature review and the baseline assessment established in this study. The information presented here could be further investigated or used to provide robot design and implementation guidelines, with a focus on maintaining high levels of job satisfaction and motivation. It also would be interesting to consider using specific robots as design probes, as has been explored by others in recent work [6].

Following this study, as well as other recent work in critical settings [68, 81, 82, 83, 84], we have refocused our research program to consider how robots can best be used to facilitate health and safety. This framing can both improve worker well-being and can potentially engender acceptance and trust, as has been discussed by other researchers in HRI [7, 8, 43, 74, 76, 80].

We are also motivated to further explore the ethical implications of robots in the workplace, as others in the community have recently discussed [8]. Robots will undoubtedly cause disruption, and likely some displacement; careful consideration of these factors, and how they intersect with work attributes, will undoubtedly be relevant in the future.

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