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Original
Implementation of Inclusive Work Instructions in Manufacturing Processes / Stadnicka, D., Blandino, G., Antonelli, D., Montagna, F.. - 59:(2025), pp. 2286-2291. (11th IFAC Conference on Manufacturing Modelling, Management and Control, MIM 2025 Norwegian University of Science and Technology (NTNU) 2025) [10.1016/j.ifacol.2025.09.384].

Availability:
This version is available at: 11583/3004507 since: 2025-10-27T13:28:20Z

Publisher:
Elsevier B.V.

Published
DOI:10.1016/j.ifacol.2025.09.384

(Article begins on next page)

Available online at www.sciencedirect.com

ScienceDirect

IFAC PapersOnLine 59-10 (2025) 2286–2291

Implementation of Inclusive Work Instructions in Manufacturing Processes

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Abstract: This paper presents a novel approach to the execution of manufacturing processes, based on an inclusive strategy for developing work instructions tailored to the diverse needs of employees. The conventional approach to instructions frequently proves inadequate in accommodating the various modes of information processing, resulting in diminished efficiency and an elevated incidence of errors in production. The study examines the implementation of multimodal instructions that all together integrate visual, textual, auditory, and kinaesthetic elements, as well as the modes of presenting task sequences for execution. We argue that this approach not only helps neurodiverse employees in understanding and applying the instructions, but also benefits all workers by improving overall comprehension of the process, reducing execution time, and cutting the number of mistakes and non-conformities. Empirical data from studies conducted in a simulated manufacturing environment substantiate the efficacy of this approach in optimizing the production process and fostering a more efficient and inclusive work environment.

Keywords: Human-computer interaction (HCI), Manufacturing process control, Human factors/ergonomics, Production efficiency, Inclusive work instructions.

1. INTRODUCTION

Neurodiversity, encompassing a spectrum of conditions such as dyslexia, dyspraxia (Developmental Coordination Disorder, DCD), dyscalculia, dysgraphia, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorder (ASD), and Tourette Syndrome, significantly impacts how individuals perform their work tasks (Bruyère and Colella, 2022). Modern workplaces face a growing need to integrate employees with diverse predispositions (Levy et al., 2022) and unique cognitive abilities (Khan et al., 2023). Furthermore, the United Nations Sustainable Development Goals (Rollnik-Sadowska and Grabińska, 2024) address neurodiversity in their call for sustained, inclusive, and sustainable economic development, full and productive employment opportunities, and decent working conditions for all. Nevertheless, recent studies (Davies et al., 2023) and surveys (Umeokafor et al., 2024) indicate a significant trend of non-disclosure among neurodiverse individuals, particularly when seeking employment. This phenomenon is largely attributed to traditional workplace culture, stigma, and to the challenges faced during the hiring process (Ali et al., 2024). Another reason could be that they are unaware of their condition as it was never formally diagnosed.

In this study, we propose a different approach to the question. Instead of looking for a way to recognize cases of neurodiversity, we suggest modifications of work procedures to make them more inclusive with apparent benefits for both declared and undeclared neurodiverse workers. Everyone experiences neurodiversity on a spectrum, with variations ranging from subtle to pronounced, as there's no definitive dividing line (Doyle, 2020). Therefore, these procedures can benefit even neurotypical workers.

As a matter of fact, inadequate work instructions can foster production errors stemming from cognitive challenges (Wissell et al., 2022), such as difficulties with concentration, sequential memory and coordination, causing fatigue and stress for workers (Simões et al., 2019). These difficulties are not exclusive of neurodiverse operators. The study proposes a fail proof design approach that addresses potential barriers and leverages the individual capabilities of workers.

After a preliminary literature review to identify common cognitive challenges in this work, we designed and conducted an experiment in which volunteer master students performed an assembly process of different products with varying numbers and sizes of components. Participants were trained using a variety of paper instructions, as suggested by Peltokorpi et al. (2023), with different content and formats. Assembly times were measured for each task. This approach allowed us to examine the impact of different aspects of work organisation on worker performance and comfort.

The assembly process was deliberately supplemented with elements representing cognitive challenges. The goal was to understand which aspects of work could pose difficulties and how instructions and process itself could be adapted to reduce the cognitive load. Upon completing the experiment, we collected detailed feedback from participants. The findings were used to create guidelines for the development of work instructions that are universal and supportive of all employees, regardless of their predispositions or degree of neurodiversity. The proposed approach aims to create a more

10.1016/j.ifacol.2025.09.384

inclusive and efficient work environment that accept diversity minimising the risk of errors for every operator.

Section 2 of the paper outline the foundational framework for the research. It is followed by a detailed discussion on strategies for work organisation, highlighting approaches to accommodate diverse employee needs. Section 4 focuses on developing inclusive job instructions, providing insights into designing instructions that may address the requirements of a neurodiverse workforce. Section 5 presents the outcomes of the experiment, accompanied by a comprehensive data analysis and discussion in Section 6. Finally, the study concludes with Section 7, offering actionable insights and guidelines for fostering inclusivity and efficiency in workplace design.

2. WORK OBJECTIVE AND METHODOLOGY

The main objective of this study is to develop and validate strategies for creating inclusive job instructions designed as Poka Yoke (mistake proofing) solutions (Antonelli and Stadnicka, 2016), effectively addressing the needs of a neurodiverse workforce. **Table 1** sums up the methodology.

Table 1. Steps of the study and applied research methods

Step	Description	Research Methods
1 Work strategy	Analysis of literature on neurodiversity, common errors, work organization strategies.	Targeted review.
2 Planning	Designing job instructions, planning the experiment and data collection.	Experiment design.
3 Implement	Conducting the experiment with different types of instructions.	Research experiment
4 Survey	Collecting feedback.	Questionnaire
5 Data analysis	Analysis of operation times and survey data.	Statistics
6 Guidelines	Practical guidelines for work organization and instruction design.	Data-driven inference.

Step 1. Review of work organization strategies

The study began with a targeted review of common production errors associated with various neurodiverse profiles, and existing work organization strategies. The review provided a foundational understanding of challenges and opportunities in designing inclusive work environments and instructions.

Step 2. Experiment Planning

This stage involved designing five types of job instructions tailored to address potential challenges faced by neurodiverse employees. The experiment was meticulously planned, including defining the scope, selecting participants, and preparing tools for data collection, such as questionnaires and time recording sheets.

Step 3. Experiment Implementation

The experiment was conducted with 42 volunteer participants, divided into three groups. Participants have at their disposal different types of work instructions. Each type was used by three employees to execute identical operations. The number of assembled components varied from 4 to 28. Some assembly tasks required additional dexterity. Each worker assembled 6 products.

Step 4. Employee Surveys

After the experiment, the participants completed a survey on the clarity and usability of the job instructions. The survey included both closed and open-ended questions to capture quantitative and qualitative insights.

Step 5. Data Analysis

The collected data underwent statistical and qualitative analysis. This phase aimed to assess the effectiveness of the different types of instructions, identify recurring challenges, integrating employee preferences and remarks.

Step 6. Development of Guidelines

Based on the findings, guidelines were formulated to aid designing job instructions and the organization of work.

3. STRATEGIES FOR INCLUSIVE WORK

Based on the literature review, we have identified the following types of neurodiversity that may be present in a work environment, often in a light or undeclared form:

- ASD encompasses challenges with social skills, repetitive behaviours, and communication difficulties.
- ADHD causes difficulties with attention, impulse control, and hyperactivity.
- Dyslexia affects reading and language-based skills.
- DCD affects physical coordination leading to difficulties in tasks that require motor skills.
- Dyscalculia causes difficulties in the ability to understand and perform mathematical tasks.
- Dysgraphia refers to difficulties with writing, including handwriting, typing, and spelling.
- Tourette Syndrome is a neurological disorder characterised by repetitive, involuntary movements and vocalisations called tics.

Table 2 shows as common production errors can be caused by neurodiversity. It proposes a synthesis of the findings of several authors (Bonello et al., 2023; Cornoldi et al., 2022; Doyle, 2020) describing how neurodiversity leverages production mistakes.

Table 2. Neurodiversity's errors and related causes

Neuro-	Common errors	Errors causes

diversity		
ADHD	Skip process steps, prematurely end stages, confuse procedures, use wrong tools	Long and low-intensity tasks, multitasking, complex instructions
ASD	Incorrect task execution	Unclear directives, sudden changes, highly stimulating environment
Dyslexia	Incorrect task sequence, skip process steps	Text-heavy and sequential tasks
DCD	Errors in assembly or tool manipulation	Precise manual tasks and fast-paced work
Dyscalculia	Incorrect execution of calculations, incorrect measurements, record incorrect results	Numerical tasks and tasks requiring precise measures
Tourette Syndrome	Longer time to complete precise tasks, skip process steps	Work requiring continuous focus, and precise manual tasks in a stressful environment

Other authors proposed solutions in the form of inclusive communication strategies adaptable to manufacturing workplaces. Lamont et al. (2013) studied how to provide travel information to dyslexics. The authors suggested spreading graphical displays with text and/or lines and visual descriptions of the transport exchange locations; the same may be repeated in manufacturing systems by replacing transport stops with workstations. On the other hand, for numerical processing problems, the authors recommend graphics. According to Vajs et al. (2023), changing colours in the text and in the background of graphic representations facilitates communication, improving the reading performance of dyslexic people. In addition, customised colour solutions may optimise people's performance according to their preferences. However, Smith-Spark and Lewis (2023) recommend the adoption of low-tech solutions, such as the assistive and adaptive system developed by Grund et al. (2020), due to the inherent cognitive complexity of innovative software applications. Finally, Mazur et al. (2024) provides indications for the workstation's inclusive adaptation through customised solutions for the work screen size and speech recognition applications.

4. EXPERIMENT PLANNING

For the experiment it was crucial to design the tasks in such a way that they include elements known to pose challenges for individuals with every type of neurodiversity, namely:

- (C1) Long, monotonous tasks that require continuous concentration.
- (C2) Tasks where the order of steps is crucial.
- (C3) Tasks requiring precise motor control, such as assembling small parts or manual operations that require precise movements.
- (C4) Tasks where recognising visual patterns or subtle differences in elements is key.
- (C5) Tasks where the participant must monitor and respond to multiple processes simultaneously.

From Table 2, it is clear that there is an overlap of challenges faced by different neurodiversity. It is difficult to state a priori which work instruction overcomes each challenge. We identified instructions effective for neurodivergent individuals from literature and investigated which are also effective for neurotypical individuals. Our goal is to create inclusive work environments for all the individuals neurotypical and not. A number of different formats were tested (Fig. 1) combining text description and graphic:

- B/W schemes with component description (B.I),
- colour schemes (B.II),
- colour diagrams with component description (B.III),
- colour graphics showing step by step (O),
- several views of the assembled product (Z).

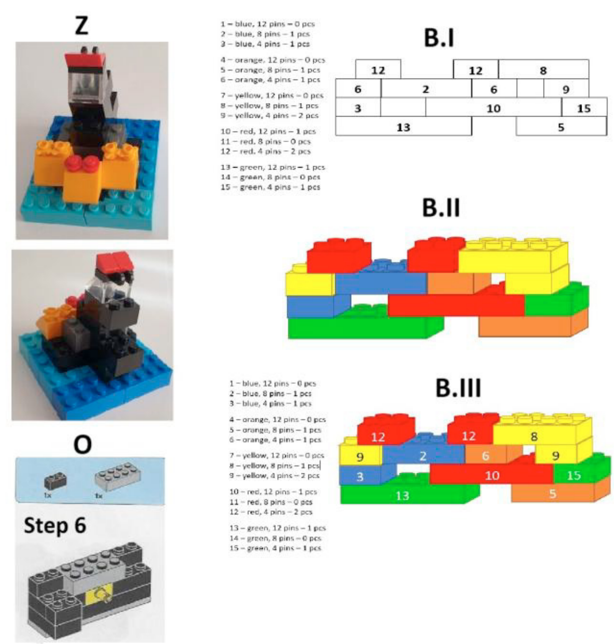

Figure 1. Examples of instructions used in the assembly process.

Instructions marked with the letter B are related to the assembly of larger products than instructions O and Z, which indicates that the assembly processes according to instructions O and Z required more dexterity.

The workers carried out the assembly process according to the following sequence: B.I – O – B.II – O – B.III – Z or B.I – O – B.II – Z – B.III – Z. Each employee assembled 6 products using a set of pieces selected in advance. Each product was assembled according to a different instruction.

Assembly times were collected. During the assembly process, there were downtimes caused by the fact that the assembly worker at the next station detected a discrepancy (assembly error) made at the previous station and had to correct the product before proceeding. Nonconformities were recorded.

After the assembly process was completed, the workers were asked to express their opinion on the work organization and the instructions used. They were asked to rank the instructions in order of their usefulness in the assembly process. The answers were rated on a 5 level Likert scale. Furthermore, they were allowed to add their remarks.

5. RESULTS OF THE EXPERIMENT

Instructions, ordered by employees according to their perceived usefulness in the assembly process, are presented in Figure 2. Figures 3 provides answers to specific questions.

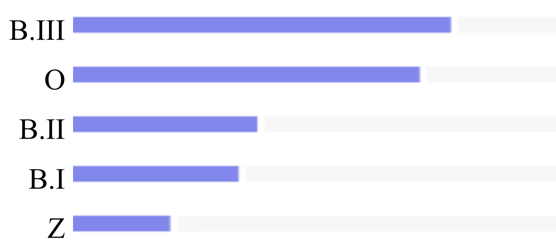

Figure 2. Instructions arranged according to their usefulness in the assembly process.

The comment section shows the challenges that emerged during the assembly process. The most relevant were:

- Excessive dexterity required.
- Difficulties in gathering assembly components.
- Working in a time-sensitive regime.
- Problems with instructions and documentation.
- Decision-making and time management challenges.
- Issues with work organization.
- Delays due to waiting for semi-finished products or components.
- Communication and teamwork issues.

6. DATA ANALYSIS AND DISCUSSION

The ranking and the collected answers show good uniformity among participants leading to draw effective conclusions concerning the most appropriate job instructions for the manufacturing processes. ANOVA analysis provides a F-statistic of 57.06 and a P-value of 0.001. The p-value is lower than 0.05 what indicates that the differences in ratings among alternatives are statistically significant. Specifically, B.III (colour diagrams) has been directly ranked by the participants as the most useful instructions, followed by O (see Fig.1). Based on the average ratings of the answers to the questions Q1-Q5, O with a score of 4.53 is lightly better than B.III, score 4.42.

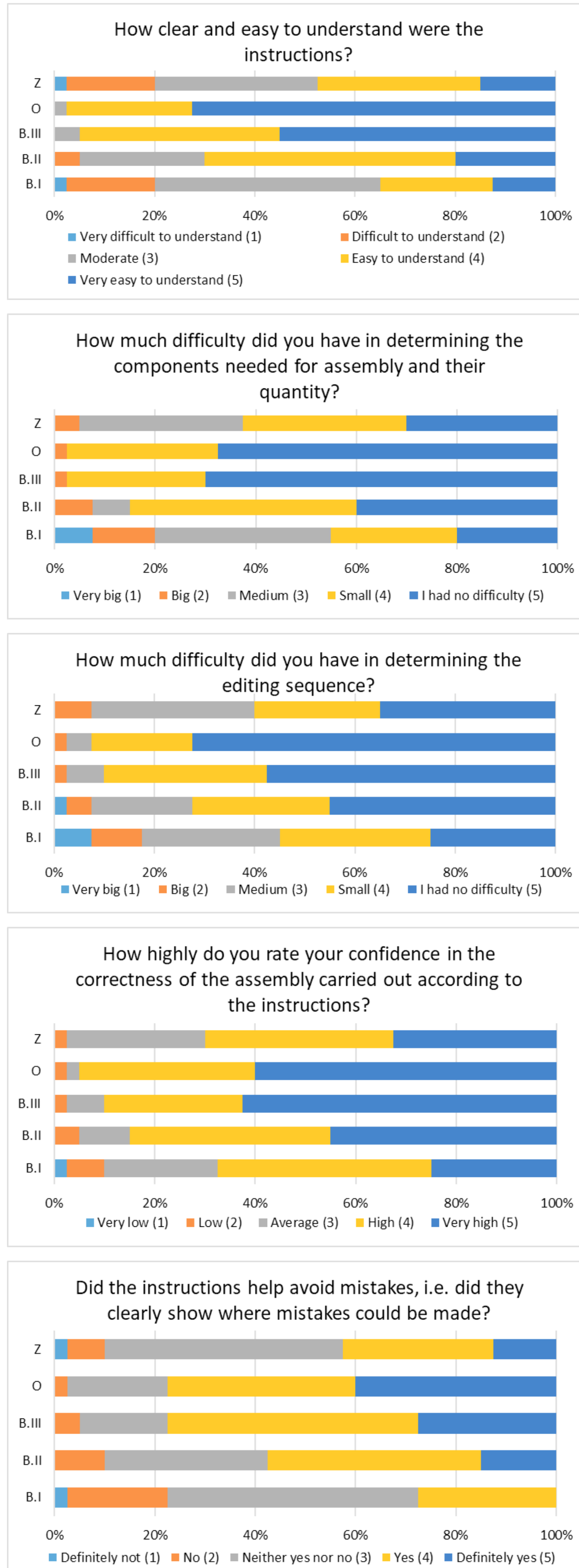

Figure 3. Answers to the questionnaire

Answers to the questionnaire show that O is perceived as the clearest and easiest information to follow. In contrast, B.III is more effective in selecting the correct component to assemble as well as determining the needed number of units for each component. Both the ranking and the questionnaire show an ambiguous placement for B.II. It ranks third for usefulness and earns a middle position in all the administered questions.

However, it must be emphasised that the respondents are not completely indifferent to the instructions, which received mostly positive ratings, but not enough to match B.III and O. Finally, the Z and B.I results suggest that these categories can be excluded from the potential information to provide for the execution of assembly tasks. Although the ranking shows that the usefulness of B.I is considerably higher than Z, the questionnaire demonstrates the exact opposite. Therefore, the ratings provided by the participants, which are consistent for all questions administered, prove that B.I is considered the most difficult instruction, but not the most useless. Consequently, the results show that graphic representations with colours are more useful and effective than both black-and-white graphic representations and final product pictures. Finally, extra information, such as explicating the number of components (as in B.III) and the sequence of steps to be followed (as in O), is preferred by the respondents over the graphic representation through a finished product diagram (as in B.II).

Based on the responses provided, it can be concluded that employees expressed concerns regarding certain aspects that align with challenges associated with neurodiversity (C1-C5). Here's an analysis for each aspect mentioned:

(C1) Long, monotonous tasks that require sustained concentration. There were no direct complaints, but some responses indicated issues with focus when working with instructions or organizing the workstation.

(C2) Tasks where the order of steps is crucial. Several responses indicate problems with incomplete instructions and a lack of clarity regarding the order of tasks.

(C3) Tasks requiring precise motor control, such as assembling small parts or manual operations that require precise movements. Difficulties were frequently mentioned.

(C4) Tasks where recognizing visual patterns or subtle differences is crucial. Difficulties emerged when instructions were solely image-based.

(C5) Tasks where the participant must monitor and respond to multiple processes simultaneously. Employees did not directly mention such difficulties with monitoring multiple processes simultaneously. However, several responses about organization and lack of understanding suggest that managing complex processes might have posed challenges.

In summary, employees expressed the greatest difficulties with assembling small parts requiring precision and with tasks where the order of steps was crucial. There were also some issues related to recognizing visual patterns and organizational challenges, which might have impacted the complexity of task execution.

7. CONCLUSIONS AND RECOMMENDATIONS

In light of the existing literature's emphasis on the evaluation of job instructions' effectiveness (Weber et al., 2024), this study aimed to examine the efficacy of various job instruction designs in the context of assembly tasks, particularly focusing on their applicability to a neurodiverse workforce. The results and subsequent discussions provided valuable insights into the usefulness, clarity, and applicability of different instruction formats, as well as the challenges employees faced during the experiment.

The rankings and survey responses consistently indicated strong preferences among participants, allowing effective conclusions to be drawn regarding the most appropriate types of job instructions for manufacturing processes.

The findings emphasize the preference for instructions that combine graphic representations with colours and additional explicit information, such as the sequence of steps (O) or the number of components required (B.III).

In addition to these findings, the study identified challenges specific to tasks requiring precision, step sequencing, and visual pattern recognition, aligning with aspects commonly associated with neurodiversity (Perracchione et al., 2016). Ambiguities in instructions and organizational inefficiencies also contributed to increased task complexity.

In summary, the study highlights the need for job instructions designed as Poka Yoke solutions that balance clarity, utility, and inclusivity. Instruction formats combining explicit textual guidance with visual cues proved most effective in supporting employees. The findings further emphasize the importance of tailoring work organization to minimize cognitive overload, foster inclusivity, and enhance productivity. Based on these results, this study provides actionable recommendations for designing job instructions and organizing tasks to meet the needs of diverse workforces.

Employees without diagnosed neurodivergence may also make mistakes for various reasons, such as fatigue, stress, lack of experience, or motivation problems. However, errors will occasionally occur due to special reasons, which can be seen, for example, when maintaining control charts.

General recommendations for supporting the instructions inside the work environment are:

- Structured tasks – Implement clear, simple steps that are easy to follow and verify.
- Visual indicators – Use colour codes, icons, and simple graphics to facilitate understanding.
- Real-time feedback – Introduce systems that inform when steps are completed correctly.
- Automatic locks – Apply automatic locks that prevent moving on in presence of errors.
- Space for individual approaches – Allow employees to customize tools or procedures to their needs.

The study can be used to design more inclusive work processes and job instructions in the industry, addressing the needs of diverse employees, thereby improving efficiency and minimizing errors in production.

Future research could involve conducting experiments with improved time measurement methods, to collect high quality data. Additionally, studies could explore the impact of different job instruction formats on employee stress levels and satisfaction. Moreover, the potential of Industry 5.0 technologies, such as augmented reality (AR) or personal assistants (Stadnicka, 2023), to support assembly processes and enhance the inclusivity of work environments is a promising area for further exploration.

REFERENCES

Ali, M., Grabarski, M. K., and Baker, M. (2024). The influence of neurodiversity management on affective commitment and turnover intention: the role of neurodiversity awareness. *Employee Relations: The International Journal*, 46(3), pp. 657-674.

Antonelli, D. and Stadnicka, D. (2016). Classification and efficiency estimation of mistake proofing solutions by Fuzzy Inference. *Ifac-PapersOnLine*, 49(12), pp. 1134-1139.

Bonello, A., Francalanza, E., and Refalo, P. (2023). Smart and sustainable human-centred workstations for operators with disability in the age of industry 5.0: a systematic review. *Sustainability*, 16(1), p. 281.

Bruyère, S. M. and Colella, A. (2022). Neurodiversity in the workplace: An overview of interests, issues and opportunities. *Neurodiversity in the Workplace*, pp. 1-15.

Cornoldi, C., Rivella, C., Montesano, L., and Toffalini, E. (2022). Difficulties of young adults with dyslexia in reading and writing numbers. *Journal of Learning Disabilities*, 55(4), pp. 338-348.

Davies, J., Heasman, B., Livesey, A., Walker, A., Pellicano, E., and Remington, A. (2023). Access to employment: A comparison of autistic, neurodivergent and neurotypical adults' experiences of hiring processes in the United Kingdom. *Autism*, 27(6), pp. 1746-1763.

Doyle, N. (2020). Neurodiversity at work: a biopsychosocial model and the impact on working adults. *British medical bulletin*, 135(1), pp. 108-125.

Grund, J., Umfahrer, M., Buchweitz, L., Gay, J., Theil, A., and Korn, O. (2020). A gamified and adaptive learning system for neurodivergent workers in electronic assembling tasks. *In Proceedings of Mensch und Computer 2020*, pp. 491-494.

Khan, M. H., Grabarski, M. K., Ali, M., and Buckmaster, S. (2023). Insights into creating and managing an inclusive neurodiverse workplace for positive outcomes: A multistaged theoretical framework. *Group & Organization Management*, 48(5), pp. 1339-1386.

LeFevre-Levy, R., Melson-Silimon, A., Melson-Silimon, A., Harmata, R., and Carter, N. T. (2022), Neurodiversity in the Workplace: Considering Neuroatypicality as a Form of Diversity, *Industrial and Organizational Psychology,* 16(1), pp. 1-19.

Lamont, D., Kenyon, S., and Lyons, G. (2013). Dyslexia and mobility-related social exclusion: the role of travel information provision. *Journal of Transport Geography*, 26, pp. 147-157.

Mazur, A., Tchakgarian, R., and Lochmann, V. (2024). Good practices and guidelines for dyslexia at work. Fédération Française de Dys. Retrieved from https://www.dyslexiaprojects.eu.

Peltokorpi, J., Hoedt, S., Colman, T., Rutten, K., Aghezzaf, E. H., and Cottyn, J. (2023). Manual assembly learning, disability, and instructions: an industrial experiment. *International Journal of Production Research*, 61(22), pp. 7903-7921.

Perrachione, T. K., Del Tufo, S. N., Winter, R., Murtagh, J., Cyr, A., Chang, P., et al. (2016). Dysfunction of rapid neural adaptation in dyslexia. *Neuron*, 92(6), pp. 1383-1397.

Rollnik-Sadowska, E. and Grabińska, V. (2024). Managing Neurodiversity in Workplaces: A Review and Future Research Agenda for Sustainable Human Resource Management. *Sustainability*, 16(15), p. 6594.

Simões, B., De Amicis, R., Barandiaran, I., and Posada, J. (2019). Cross reality to enhance worker cognition in industrial assembly operations. *The International Journal of Advanced Manufacturing Technology*, 105(9), pp. 3965-3978.

Smith-Spark, J. H. and Lewis, E. G. (2023). Lived Experiences of Everyday Memory in Adults with Dyslexia: A Thematic Analysis. *Behavioral Sciences*, 13(10), p. 840.

Stadnicka D. (2023) Systemy produkcyjne zorientowane na człowieka. Human-centric manufacturing systems. *Oficyna Wydawnicza Politechniki Rzeszowskiej*, Rzeszów.

Umeokafor, N., Emuze, F., Ibrahim, C. K. I. C., Sunindijo, R. Y., Umar, T., Windapo, A., and Teizer, J. (Eds.). (2024). *Handbook of Drivers of Continuous Improvement in Construction Health, Safety, and Wellbeing*. Taylor & Francis.

Vajs, I., Papić, T., Ković, V., Savić, A. M., and Janković, M. M. (2023). Accessible dyslexia detection with real-time reading feedback through robust interpretable eye-tracking features. *Brain Sciences*, 13(3), p. 405.

Weber, C., Krieger, B., Häne, E., Yarker, J., and McDowall, A. (2024). Physical workplace adjustments to support neurodivergent workers: A systematic review. *Applied Psychology*, 73(3), pp. 910-962.

Wissell, S., Karimi, L., Serry, T., Furlong, L., and Hudson, J. (2022). Leading diverse workforces: perspectives from managers and employers about dyslexic employees in australian workplaces. *International Journal of Environmental Research and Public Health*, 19(19), p. 11991.