University of Groningen / faculty of economics and business

An exploration of how personalised work instructions can support the inclusiveness of a neurodiverse workforce

By

Wessel Claassen **S4558766**

1st Assessor: Dr. J.A.C Bokhorst

2nd Assessor: Prof. Dr. C. Emmanouiilidis

Word Count: 11 005

University of Groningen

Faculty of Economics and Business

Supply Chain Management & Technology and Operations Management

26th of June 2023

ABSTRACT

Studies show that many working individuals within the neurodiverse spectrum feel that their skills are underutilised, indicating a mismatch between their abilities and the jobs they are assigned. As traditional workplaces may be unintentionally exclusionary to neurodivergent individuals, adjustments may need to be made to create a more neurodiverse-inclusive workforce. We suggest that personalised work instructions can be a key variable in designing jobs more inclusively for neurodiverse employees. The study identifies the managerial benefits and challenges of using personalised work instructions for people with a neurodiverse background. By exploring the instructional needs of neurodiverse employees while considering the personal characteristics of the employee, the study explores how work instructions can be adapted to create a more neurodiverse-inclusive workplace. The study found that participating companies are currently not deploying any sophisticated applications of personalised work instructions as mainly paper or simple forms of digital instructions were used. Based on this gap, accessible forms of personalisation were tested by conducting an experiment with different instruction types on paper instructions. While the participants of the experiment showed significant differences in cognitive and motoric skills, their instructional needs were found to be generally similar. Regarding the presentational form, visual instructions were found to be beneficial over textual instructions. With regard to the level of detail, step-by-step instructions were unexpectedly found to be more challenging than instructions in which a multitude of steps were combined. Overall, this research underscores the potential of adapting work instructions to the needs of neurodiverse individuals as they enabled participants to successfully assemble recognised abstractions of industrial pick-and-place tasks.

Keywords: Work Instructions, Personalised Work Instructions, Neurodiversity, Inclusiveness, Work Instructional Needs

TABLE OF CONTENT

1. INTRODUCTION

While many Dutch organisations are facing more and more challenges in filling in job vacancies (Deloitte, 2023), a large group of unemployed individuals with autism still has a hard time finding a job. According to several studies (Twaronite, 2023; Ortiz, 2020), less than one in six autistic adults is in full-time employment, while more than 77% of these unemployed individuals are indicating that they want to work. Also, these studies have pointed out that of the working group, 51% are saying that their skills are of a higher level than what their job requires of them, indicating a misfit between the skills of autistic employees and the work they are assigned to.

The inclusion of employees with an autism spectrum disorder can be seen as part of the neurodiversity concept that calls for a more inclusive workforce for people with cognitive conditions. Although there is an increasing awareness of neurodiversity in the workplace (Doyle & McDowall, 2021), there is still a lack of understanding about the personal characteristics of neurodivergent employees and how work can be designed to be more inclusive for them. Many traditional workplace practices may be unintentionally exclusionary to neurodiverse individuals, and adjustments may need to be made to create a more neurodiverse-inclusive workplace (Milton, 2016).

In this study, we propose that the use of work instructions can be leveraged as an important variable through which a job can be designed more inclusively for neurodiverse employees. Ortiz (2020) points out that these individuals show a resistance to change, are sensitive to sensory impulses, tend to have a hard time reading social clues, tend to take language literally, and as such, communication between the organisation and the individual can be classified as a key challenge (Doyle & McDowall, 2021). As work instructions can be used as a communicative tool to provide clear and detailed instructions, they can help counter this challenge to make neurodiverse employees better understand what is expected of them and how they can complete their tasks effectively (Pence & Sevyantek, 2016). Also, Ortiz (2020) argues that individuals that can be classified within the neurodiverse spectrum can have a wide range of symptoms, skills, and levels of impairment (Ortiz, 2020), making it difficult to provide a one-size-fits-all work instruction for all neurodivergent individuals. One topic that might provide a solution for this is the usage of personalised work instructions.

Personalised work instructions have been researched and often show a positive relationship to production performance (Fiorentino et al., 2014; Holm et al., 2017; Mourtzis, Xanthi, & Zogopoulos, 2019). These studies, however, are currently focused on neurotypical operators that do not have to deal with cognitive disabilities. Studies that do focus on personalising work instructions for individuals that can be considered under the neurodiversity spectrum mainly focus on comparing different instructional forms such as Augmented Reality, digital, paper-based or multimodal instructions. In doing so, personal characteristics are often overlooked or defined as a one-dimensional aspect. However, this study proposes that due to the excessive heterogeneity in personal characteristics of individuals within the neurodiverse spectrum (Bury et al., 2020), instructional needs, in both their presentation and level of detail, might differ for specific personal characteristics.

Therefore, this study aims to research the effects of personalised work instructions, considering the characteristics of the neurodivergent individual. It hopes to provide insights into how companies can use such instructions to enable the creation of more inclusive workplaces. Furthermore, it aims to identify the key challenges and benefits of using personalised work instructions for both individuals and organisations. Therefore, the following research question is formulated:

"How can personalised work instructions support the inclusiveness of the job for neurodiverse employees, considering the personal characteristics of the individual?"

In the pursuit of answering the research question, this study combines two different research methods. To gain insights into the challenges and benefits of personalised work instructions, a preliminary multiple case study was performed over nine companies partially or specifically employing neurodiverse individuals. Moreover, the multiple case study aims to identify the current state of how personalised work instructions or work instructions in general are being used to create a more inclusive workplace for neurodiverse individuals. Secondly, an in-depth case study was performed to further explore the application of personalised work instruction and their relationship with the personal characteristics of the neurodiverse individual. In the in-depth case study, an experiment was performed by five neurodiverse employees with differing personal characteristics to explore similarities and differences in instructional needs. In doing so, the study aims to identify the extent in which personalisation for work instructions is needed as well as the specific implications that personal characteristics have for the work instructional needs of the neurodivergent employee.

2. THEORETICAL BACKGROUND

2.1. Neurodiversity of employees within organisations

Neurodiversity is a concept that refers to a psychological perspective that highlights the life-long and positive aspects of natural cognitive differences rather than focusing on developmental deficits (Doyle & McDowall, 2020). The concept has gained increasing attention in organisational psychology, as research has shown that individuals with neurodivergent conditions, such as autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), and dyslexia, can bring unique skills and perspectives to the workplace (Hendricks, 2010; Grandin & Duffy, 2008). Thereby, the neurodiversity movement challenges the traditional negative views by valuing and enabling neurodiverse employees according to their strengths rather than being forced to conform to neurotypical standards (Milton, 2016).

Several studies have shown that organisations that embrace neurodiversity can benefit from a more diverse and innovative workforce (Hendricks, 2010; Grandin & Duffy, 2008). For example, individuals with ASD have been shown to excel in tasks that require attention to detail, pattern recognition, and logical reasoning (Grandin & Duffy, 2008), while those with ADHD may be particularly skilled at creative problem-solving and thinking outside the box (Prevatt & Yelland, 2013). The Employer Assistance and Resource Network on Disability Inclusion (EARN, 2023) have pointed out that employers that hire neurodiverse employees indicate that their skills are fitting to jobs that require attention to detail, high levels of concentration, pattern or error detections, inferential resounding, strong mathematical skills, coding or data-centred processes (Ortiz, 2020). Also, neurodiverse teams are reported to be more effective and productive because of the strong recall of information, detailed factual knowledge, reliability, persistence, and ability to excel at routine and repetitional work (Ortiz, 2020; EARN, 2023).

To support the integration of neurodivergent individuals into the workforce, organisations can implement a range of accommodations and support strategies, such as flexible work schedules, sensory-friendly work environments, and targeted training and development programs (Bury et al., 2021). In addition, many organisations have started to establish neurodiversity hiring initiatives and employee resource groups to promote a greater understanding and appreciation of neurodiversity in the workplace (Grandin & Duffy, 2008).

By promoting the inclusion of neurodiverse employees, recent literature has shown that the unique strengths and talents of all individuals can be leveraged, regardless of their neurological differences (Austin & Pisano, 2017). As the inclusiveness of a neurodiverse workforce has received an increasing amount of attention, most research and managerial support has been focused on the hiring aspects of neurodiverse individuals (Markel & Elia, 2016; Hendricks, 2010; Grandin & Duffy, 2008) and creating more supportive work environments and workplaces (Bury et al., 2021; EARN, 2023). However, neurodiverse research seems to miss out on the fact that certain aspects of the job design itself can also be tailored to the neurodiverse individual. In this study, we propose that one of these aspects could be the use of work instructions.

2.2. Work instructions for neurodiverse individuals

Work instructions are written or visual guides that provide step-by-step directions for completing a task (Li, Mattson & Salunkhe, 2018). Work instructions are especially relevant for neurodiverse employees as they allow them to understand better what is expected of them and how to complete tasks effectively (Pence & Sevyantek, 2016). As Tomczak (2021) identified effective communication as a primary barrier to creating a work environment for people with ASD, he underlines the usefulness of following instructions in written form as well as visual forms. More specifically, he argues that these instructions should be anchor-like, detailed and be used as guides or manuals which neurodiverse employees can consult. Markel and Elia's (2016) study found that people with ASD excel with their attention to detail, persistence, and strict compliance with instructions. Combined with the proper training and support, they can become incredibly reliable employees. Additionally, providing employees with ASD with a list of work to be done is much more effective than confusing them with additional talk and conversation (Seitz & Smith, 2016).

Haug (2015) identified informational quality problems that can be used during the design of instructions. The framework provides an overview of what aspects should be considered during the design of work instructions. Table 1 presents these 15 dimensions, grouped into five categories. While the author argues that all quality problems should be avoided, this study interprets some of these dimensions as variables through which instructions can be personalised. For example, while the aspect of incorrectness can be considered a general quality requirement, the conciseness of the work instruction is dependent on the need of the receiver. Whereas one might need concise descriptions, someone else might need a very elaborate description.

Table 1. Instruction information problems framework by Haug (2015)

Instruction information problems framework by Haug (2015)

Data quality category	*Aspect*	*Description*
Intrinsic problems	Deficient	Some necessary instructional element is missing
	Ambiguous	Additional explanation is needed
	Unneeded	Instructional information is irrelevant to completing the task
		Instructional information is relevant, but already possessed by the receiver and is therefore not needed
	Incorrect	Something stated in instructions is simply not correct
	Too repetitive	Information is repeated too often by instruction sender
Representational problems	Inconsistent	Inconsistent use of terminology, symbols, logic, etc. which may confuse the receiver
	Inconcise	Too elaborate descriptions
	Difficult to understand	Even though instructions are simple, they are stated in a form that the receiver cannot understand them
Unmatched information	Too complex content	Content given is too complex for the receiver to understand as some sort of pre-knowledge is required for the instructions to be understandable
	Too large amount	The amount of data given does not fit with the cognitive capabilities of the receiver
	Untimely	Instructions are not given at the time they are needed or do not describe the current situation
Questionable information	Poor believability	Instructions are prepared in a way that makes them hard to believe, the receiver will be inclined to figure out what to do themselves
	Poor reputation	Colleagues speak negatively about the instructions or instructor, making it less likely that instructions will be followed by the receiver
		…

Inaccessible information	Security barriers	Problems that relate to identifying relevant instructions
	Other accessibility barriers	Problems that relate to missing the appropriate access rights

2.3. Personalisation

As people within the neurodiverse spectrum can have very diverse characteristics (Tomczak, 2021; Ortiz, 2020), their needs in terms of effective communication might differ (Tomczak, 2021), meaning a one-size-fits-all work instruction for autistic individuals is unlikely. In line with these studies, Bury et al. (2020) argue that while the benefits and preferences of employing individuals with ASD are being reported in literature, the breadth and quality of the evidence for the existence of an advantage associated with core autism traits is often insufficient. They argue that while certain traits can be a genuine strength, they could also be related to difficulties in executive functioning, which in turn, could produce other challenges such as inflexibility and adapting to new routines (Scott et al., 2017; Bury et al., 2020). Moreover, because of the excessive heterogeneity in which autism can take form as well as the high rates of co-occurring conditions (e.g. ADHD, anxiety), Bury et al. (2020) question the ability of research to reliably show broad common abilities and advantages of employing individuals with autism. Rather than trying to identify broad skills, they therefore recommend for research to adopt an individual approach rather than a disability approach.

Personalised work instructions are a way to adopt this individual approach in which the instructions are being adapted to meet the needs of the individual (Kucirkova, Gerard & Linn, 2021). As personalised work instructions can include visual aids and step-by-step instructions (Fletcher et al., 2020), adapting both the content of the instructions as well as the representation of the instructions can be means of adjusting the work instructions according to the needs of the individual. Moreover, Fletcher et al. (2020) argue that personalised work instructions should take into account the workers preferred learning method (e.g. Visual or audible) to increase the understandability and memorability of the instructions for the individual (Santally & Senteni, 2013).

2.3.1. Means of Personalisation

In literature, different means through which work instructions can be adapted to the needs of the individual are discussed. This study distinguishes between the presentational form through which instructions are communicated and the level of detail the instructions entail. To my knowledge, such a distinction is not yet clearly stated in literature. As such, an overview of the identified aspects that are considered under the presentational form or level of detail of instructions, as interpreted in this study, can be found in Table 2.

While other aspects should be straightforward, multimodal work instructions are comprehensive guidelines that combine multiple modes of communication, such as text, images, videos, and audio, to facilitate task execution. By leveraging various formats, these instructions provide a more interactive and intuitive experience, enhancing comprehension and reducing errors (Bannat et al., 2008). Furthermore, this study interprets AR instructions projected through either head-mounted displays (HMD) or in-situ projected means. While these presentational forms are often defined as digital instructions, this study interprets digital instructions as instructions communicated via a computer screen or tablet.

Table 2. Means of personalisation in literature

Means of personalisation		
Distinction	***Aspects discussed in literature***	***Reference***
Presentational form	Augmented Reality (AR) instructions	Funk, Mayer & Schmidt, 2015b; Funk, Kosch & Schmidt, 2016; Korn, Schmidt & Hörz, 2013; Mourtzis, Xanthi & Zogopoulos, 2019; Vanneste et al., 2020a; Vanneste et al., 2020b; Wang et al., 2022; Pimminger et al., 2021; Wilschut et al., 2019;
	Digital work instructions	Lethmate & Rößler, 2022; Gräßler, Roesmann & Pottebaum, 2020; Pimminger et al., 2021;
	Paper-based instructions	Funk, Mayer & Schmidt, 2015b; Funk, Kosch & Schmidt, 2016; Korn, Schmidt & Hörz, 2013; Lethmate & Rößler, 2022 ; Vanneste et al., 2020a; Pimminger et al., 2021;
	Oral based instructions	Vanneste et al., 2020a;
	Multimodal instructions	Stöhr, Schneider, & Henkel, 2018;
	Textual and visual instructions	Li, Mattson & Salunkhe, 2018;
	Auxiliary Annotations	Mourtzis, Xanthi & Zogopoulos, 2019; Wolfartsberger et al., 2019;
Level of Detail	Total amount of instruction-steps	Haug, 2015; Tsutsumi et al., 2020; Funk et al., 2015a; Wolfartsberger et al., 2019;
	Number of Tasks communicated at once	Haug, 2015; Mourtzis, Xanthi & Zogopoulos, 2019; Tsutsumi et al., 2020; Wilschut et al., 2019;
	Amount of information (Text, Images, Auxiliary Annotations) per instructional step	Haug, 2015; Asklund & Eriksson, 2018; Mourtzis, Xanthi & Zogopoulos, 2019; Wolfartsberger et al., 2019;
	Complexity of instructions	Haug, 2015; Funk et al., 2015a;

2.3.2. Personalisation based on personal characteristics

Personal characteristics are often described as one of the bases on which personalisation should be applied. However, these personal characteristics can take many different forms and might imply different implications for the instructional needs of the individual. This section discusses five general categories of personal characteristics, being the users' experience level, cognitive skills, motoric skills, learning preferences and type of disability. Moreover, as personalisation can be group based or based on the individual, a more detailed discussion will be given in section 2.3.2.6.

2.3.2.1. Experience level

The relevance of experience level is the personal characteristic that is extensively included in research (Asklund & Eriksson, 2018; Gräßler, Roesmann & Pottebaum, 2020; Lethmate & Rößler, 2022; Li, Mattson & Salunkhe, 2018; Mourtzis, Xanthi & Zogopoulos, 2019; Tsutsumi et al., 2020; Vanneste et al., 2020a; Vanneste et al., 2020b; Wolfartsberger et al., 2019). These studies generally follow the reasoning best described by Wolfartsberger et al. (2019), which states that an unbalance in the needed information and offered information in a work instruction will result in either dissatisfaction or assembly errors. More specifically, when the information provided is not needed, it may frustrate the operator, while withholding information when there is a need for the information may result in errors. Based on this argument, these studies assume that different levels of experience require different instructions, in which a more experienced operator may need less information than a novice (Asklund & Eriksson, 2018; Wolfartsberger et al., 2019). As such, different instructions in terms of presentational form and level of detail are tested over categorised levels of worker experience (e.g. novice, intermediate & expert). Contrary to categorising, some studies calculate the experience level into a one-dimensional aspect. In the studies by Vanneste et al. (2020a; 2020b), the level of worker experience for a specific task is assessed by occupational therapists, whereas in the study of Lethmate & & Rößler (2022), participants assess their own experience level.

2.3.2.2. Cognitive skills

Work instructional studies frequently briefly mention the relevance of personalising work instructions based on cognitive skills (Gräßler et al., 2020; Tsutsumi et al., 2020; Wang et al., 2022) or interpret these skills in a one-dimensional aspect (Funk, Mayer & Schmidt, 2015b; Funk, Kosch & Schmidt, 2016; Korn, Schmidt & Hörz, 2013; Li, Mattson & Salunkhe, 2018; Stöhr, Schneider, & Henkel, 2018;). However, Vanneste et al. (2020a) argue that cognitive skills entail a multitude of aspects, being planning work, comprehension, attention, concentration, remembering, solving problems and the ability to imagine. Using the framework of Kleffmann, Weinmann, Föhres and Müller (1997), these cognitive aspects are quantitatively assessed for a group of neurodivergent participants on a five-point scale by occupational therapists. From this assessment, a one-dimensional score for cognitive skills is calculated.

Vanneste (2020a) used this score as a possible prediction variable for the preferred presentational form of work instructions and found that neurodivergent neurodiverse individuals using AR instructions outperform colleagues using more traditional presentational forms in terms of error-making. Moreover, their results indicate that AR instructions give rise to less help-seeking behaviour compared to oral instructions but not compared to paper-based instructions.

By calculating or interpreting cognitive skills into a one-dimensional score, the implications of the excessive heterogeneity in which conditions can occur, as noted by Bury et al. (2020), might be overlooked. In this study, we argue that work instructional needs might differ based on the different cognitive skills previously pointed out. This study aims to fill the gap in literature as to how specific cognitive skills relate to the instructional needs of neurodiverse individuals.

2.3.2.3. Motoric skills

Part of the Human-Robot Collaboration (HRC) system architecture by Stöhr et al. (2018) is the assignation of tasks to either the human or robot based on the capabilities of both actors, applying the study of Ranz, Hummel and Sihn (2017). Ranz et al. (2017) argue that motoric and cognitive skills characterise manual factory work in an assembly environment. Regarding motoric skills, they give examples of hand-eye coordination, control of applied force or haptic perception but do not discuss the measurement of motoric skills nor their instructional implications.

2.3.2.4. Learning

Fletcher et al. (2020) argue that personalised work instructions should take into account the workers preferred learning method (e.g. Visual or audible) to increase the understandability and memorability of the instructions for the individual (Santally & Senteni, 2013). The study of Letmathe and Rößler (2020) showed that digitally animated, interactive work instructions are an effective way to foster faster learning and enhanced performance for neurotypical individuals. Moreover, in the study of Gräßler, Roesmann & Pottebaum (2020), results indicate that adaptive instructions enable their users to learn more effectively. In the study by Wilschut et al. (2019), it was found that the chucking of work instructions should be avoided for novice employees.

2.3.2.5. Disability

In the study by Stöhr et al. (2018) focusing on impaired individuals, personal characteristics are partially considered by taking into account the type of disability of the end user. Next to the previously discussed motoric skills of the user, their HRC system architecture is designed to transform the content of general work instructions and the instructional form to the end user's needs. In their system architecture, general user types are based on visual, hearing, motor and cognitive impairments. However, specific implications for the work instructions for each user type considered, in terms of the instructional form or level of detail, are mainly lacking apart from a single example depicted in Table 3.

Table 3. Example of implications for work instructions based on user types by Stöhr et al. (2020)

Disability	***Interface***	***Accessibility Feature***
Visual Impairment: Macular degeneration	Display	- Zoom modes up to 10x - Contrast mode and color inversion
	Touch Panel	- Zoom gestures (OS) - Voice over (OS)
	Speaker	- Text-to-speech - Switch to audio content
	Microphone	- Step confirmation via voice-in (planned)
Cognitive Impairment: Attention loss	Display	- Several levels of detail for work instructions - Wait for robot steps (disable parallelism) - Guided and learning modes (simple or advanced)
	Touch Panel	- Step confirmation
	Speaker	- Switch to audio content to get attention

2.3.2.6. Adaptability

Regarding adaptability, this study makes another distinction based on the literature considered. This distinction entails the difference between personalisation on the individual level and at the group level. Individually personalised work instructions typically take into account the unique characteristics, skills, preferences and past performance of the end user and adapt their level of detail and instructional form to these unique needs (Wang et al., 2019). On the other hand, personalisation can take form by categorising employees based on specific or multiple characteristics, as described in the previous sections. In this study, we consider this form of adaptability as group-based personalisation.

With respect to the previously discussed argument of Wolfartsberger et al. (2019), one should expect that work instructions personalised to the individual offer the perfect amount of information for the user. Thereby the frustration of the operator stemming from unnecessary information and errors made by offering too little information should be minimised. Meanwhile, group-based personalisation is tailored to the general needs of multiple users. As such, the instructions should offer fitting instructions for the user but do not consider the full extent of the individual's needs. In this study, this phenomenon will be interpreted as 'the fit' between offered personalised work instructions and the instructional needs of the individual.

While the distinction is important to understand how personalisation can be utilised, they are not mutually exhaustive. In applying multimodal work instructions, group-based personalisation can be used as a starting point for individual personalisation (Tsutsumi et al., 2020). In the study of Tsutsumi et al. (2020), participants are handed one of three instruction types, and based on the reactions of the receiver, these instructions are then adjusted over several iterations, eventually arriving at an individually personalised work instruction.

In this study, the distinction between the two types of personalisation is considered as the extent to which instructions are personalised. Instructions adapted to individual needs are considered to have a relatively high level of personalisation, while group-based personalisation is considered to have a relatively lower level of personalisation.

2.3.3. Performance

In order to be able to assess the effectiveness of different means of personalisation, different outcome variables can be considered. Studies assessing the performance of work instructions in experiments including neurodiverse employees use different outcome variables, depicted in Table 4. Based on the identified outcome variables, different instructions can be compared. To identify the individuals' instructional needs, this study will use these outcome variables as indicators to assess what personalisation means do and do not work for the neurodiverse individual.

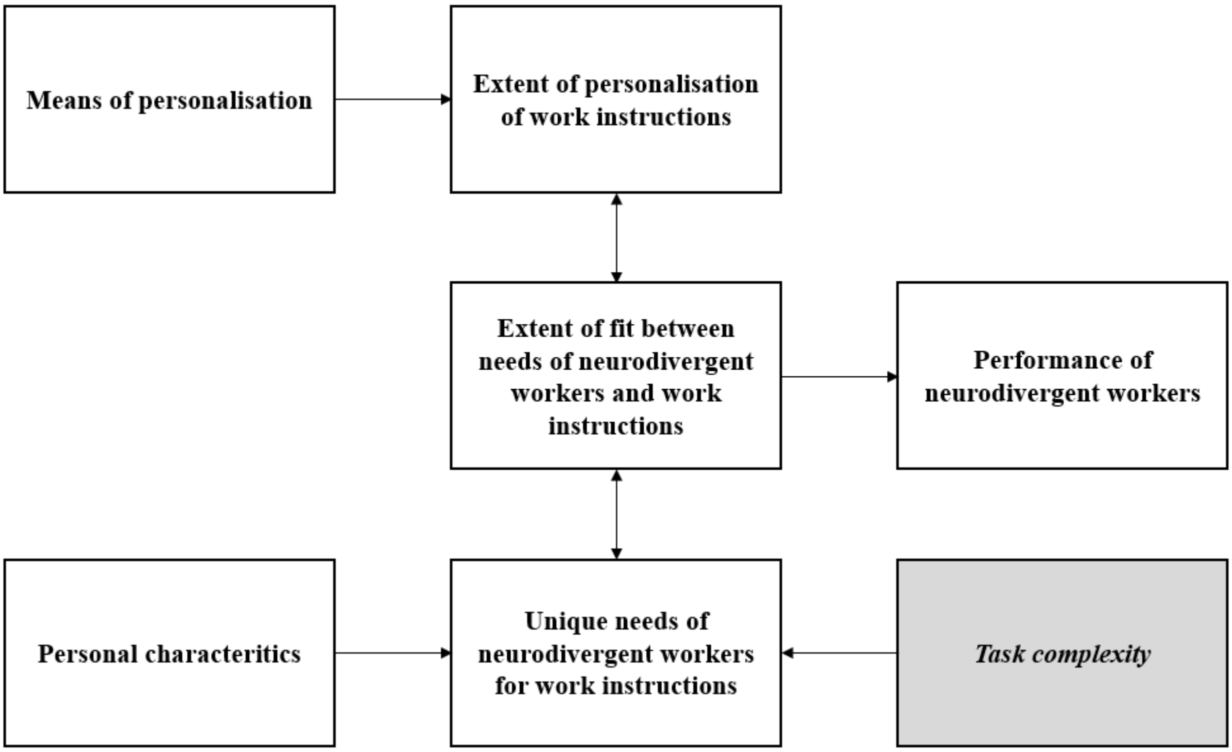
Table 4. Performance outcome variables identified in literature

Outcome variables			
Data	***Variable***	***Reference***	***Description***
Quantitative	Total assembly time	Funk, Mayer & Schmidt, 2015; Vanneste et al., 2020a;	Monitorisation of the total time in which the experiments' task is completed.
	Number of errors		The number of not corrected errors made during the assembly.
	Frequency of help-seeking behaviour	Vanneste et al., 2020a;	The number of times the participant asks help from the supervisor of the assembly.
Qualitative	Participants' stress level	Vanneste et al., 2020a;	Rated on a 4-point scale by an occupational therapist
	Perceived complexity		Combined questionnaire for the participant rating the variables on a 4-point scale.
	Physical effort		
	Frustration		

2.4. Conceptual Model

The discussed aspects in the previous sections are visually captured in Figure 1. While literature captures different means of providing personalised work instructions, relatively few studies focus on personalising instructions for neurodiverse employees. The studies that do focus on neurodiverse groups, typically overlook the excessive heterogeneity of personal characteristics for neurodiverse individuals. Therefore, this study aims to determine if the instructional needs in terms of the level of detail and instructional form differ for individuals with different personal characteristics. Worth noting is that the topic of complexity has not been discussed. While task-related complexity affects the instructional needs of the individual (Funk, Mayer & Schmidt, 2015), complexity is placed outside the scope of this research.

Figure 1. Conceptual model.



3. METHODOLOGY

This study aims to perform initial exploratory research to create a better understanding of the potential and challenges of implementing personalised work instructions focused on a neurodiverse employee. To pursue these aims, the research has been divided into two phases. In the first phase, a multiple case study was performed to identify the key benefits and challenges of using personalised work instructions from a managerial perspective. From the multiple cases, one case study was chosen for further research to explore how personalised work instructions, based on personal characteristics, can support the job design's inclusiveness for neurodiverse individuals by performing an experiment. During this experiment, knowledge gathered in the theoretical background as well as findings from the first phase, will be applied to test if identified expectations are valid. In this chapter, the research design as well as the data collection and analysis methods for both phases, will be discussed.

3.1. Phase 1: Multiple case study

3.1.1. Research Design

Semi-structured interviews were conducted within a network of organisations currently applying work instructions in a high variety and low volume context. As the network represented a group of companies with significant differences in both the appliances of work instructions as well as employee groups, the network provided an interesting setting to explore similarities, differences, and patterns of the ideas and insights (Coombs, 2022) of production companies regarding the use of personalised work instructions to create a more inclusive job design. Moreover, the network provides an interesting setting to identify how companies are currently applying personalisation in the deployment of work instructions. An overview of the case descriptions of the participants can be found in Table 5.

Table 5. Case descriptions of multiple case studies

Case description			
Case	***FTE***	***Organisational role of Interviewee(s)***	***Case Description***
A	3500	Senior Production Engineer	Sheltered workplace assembling an extensive range of products for a large range of customers.
B	225	Production Manager	A company focused on the assembly of elevators.
C	350	Production Manager, R&D Process Engineer & Assistant Unit Foreman	Production company offering a wide range of tools and parts for metal bending operations.
D	250	Production Manager & Head Business Office	Sheltered workplace performing an extensive range of assembly services.
E	700	Manufacturing Engineering Manager	Part of a large international organisation responsible for assembling a specific range of forklifts.
F	120	Manager Operations	Production side selling semi-finished electro-technical products.
G	180	Team leader Master Data & Team leader Process Engineering	Production of air suspensions with a large variety of products offered.
H	450	Production Manager	A company offering the design and production of, mostly, custom-made truck trailers.
I	95	Production Manager	Sheltered Workplace with a large variety of products. Mainly focusing on metalworking and electrical installation.

3.1.2. Data Collection and Analysis

The data gathered from the semi-structured interviews were part of a larger research project focusing on the appliance of work instructions within the network. The relevant questions from the interview protocol for this study can be found in Appendix 1.

During the analysis, the results from the interviews were transcribed, summarised and analysed by two researchers, including the author of this thesis, who validated and peer-reviewed each other’s work, preventing possible misinterpretations from being included in the results. Moreover, a secondary source of data in the form of an interview with an expert in the field of neurodiversity was performed, providing guidance and additional insights from the psychological field of research.

3. 2. Phase 2: Case study & Experiment

3.2.1. Research Design

One of the participating organisations made for an interesting case for an in-depth exploration of how personalised work instructions could be adapted to the needs of neurodiverse individuals. As the organisation of case D employs a multitude of individuals that can be regarded as being within the neurodiverse spectrum and as such, it made for a fitting setting to explore the specific challenges and benefits that can be found in the application of personalised work instructions. The information gathered during the experiment was directly collected from five participants from the neurodiverse spectrum. All participants work in the packaging department of the organisation, where typically low-complexity tasks are performed, such as packaging several parts into a tire patch box.

Based on the General Assembly Task Model (GATM) by Funk, Kosch, Greenwald and Schmidt (2015a), an experiment was designed to test multiple types of instructions for neurodiverse employees. The GATM provides a standardised experiment design for evaluating interactive instructions and allows these work instructions to be comparable (Funk et al., 2015a). To this end, they introduced a recognised abstraction for industrial pick-and-place tasks using Lego bricks. The appliance of pick-and-place tasks using Lego bricks has received criticism in literature. Some authors argue that the low complexity of assembling Lego bricks does not represent the complexity of industrial assembly tasks (Wolfartsberger et al., 2019; Radowski, Herrema & Oliver, 2015). In the setting of this case however, the level of complexity of the work currently done by the participants is considered to be lower by representatives of the organisation. Therefore, the argument of Lego assemblies not representing real-life does not apply to this study.

In their study, Funk et al. (2015a) present multiple different instruction types in terms of complexity levels. While the complexity of the instruction types increases in terms of the number of parts (4, 8, 16 or 32 pieces) assembled, the level of detail and presentational form of the instructions remain the same. As proposed in section 2.4, this study suggests that instructional needs in terms of the level of detail as well as presentational form might differ between neurodiverse employees because of their personal characteristics. To test if such instructional needs indeed vary, representatives of the participating organisation selected and asked several participants with various levels of cognitive and motoric skills to participate in the experiment. As all respondents agreed, five participants with varying personal characteristics assembled Lego models using different instruction types.

3.2.1.1. Complexity

As this experiment involved participants from the neurodiverse spectrum, the researcher had to consider the ethical considerations described in section 3.3. More specifically, as participants might be upset about not being able to complete the model which could have a significant impact on the participant's daily routine, the researcher tried to comfort the participants by letting them decide the complexity level of the experiment. The different complexity levels were determined by the number of parts present in the Lego model, following the same number of parts as Funk et al. (2015a) in 4, 8 and 16 parts. If the complexity level was deemed to be too low for the participant, the researcher tried to encourage the participant to try the assembly of a higher level of complexity. As this study leaves out the scope of complexity with regard to personalised work instructions, the findings in terms of instructional needs are only analysed on the decided complexity level determined during the experiment.

3.2.1.2. Instruction types

Three different instruction types were developed based on the three different instruction types similar to the group-based personalisation approaches of Tsutsumi et al. (2020) and Vanneste et al. (2020b). Based on the findings of both literature and results of the first phase, decisions were made about the applied means of personalisation in terms of the level of detail and presentational form. An overview of the differences between the instruction types is given in Table 6, while the visual implications can be found in Figure 2. The bases on which these decisions were made will be discussed in section 4.2.1. To control the learning curve effect and focus on the specific instructional needs of the participants, a different Lego model was designed for each instruction. The experiments performed with the chosen complexity levels are depicted in Table 7. By offering three different types of instructions, this experiment aims to identify similarities, differences and patterns between the instructional needs of the participants. In doing so, it seeks to determine if work instructional needs indeed differ for individuals with varying cognitive and motor skills.

Table 6. Experimental work instruction design decisions

Instruction type	***Means of personalisation***	***Design decisions included***
Beginner	Level of detail	Bill of Material (BOM) for full assembly
		Part-for-Part steps
		One part per page
		Show part for each step
	Presentational form	Highlight the position of part location through annotations
		Highlight the number of spots for positioning the first part of assembly
Intermediate	Level of detail	Bill of Material (BOM) for full assembly
		Part-for-Part steps
		One part per page
		Show part for each step
	Presentational form	No highlighting of each parts' position
		No highlighting of the number of spots for positioning of first part
Expert	Level of detail	Bill of Material (BOM) for full assembly
		Sub-assembly steps
		Show part for each step
	Presentational form	No highlighting of each parts' position
		No highlighting of the number of spots for positioning of first part

Figure 2. Visual differences in instruction types.

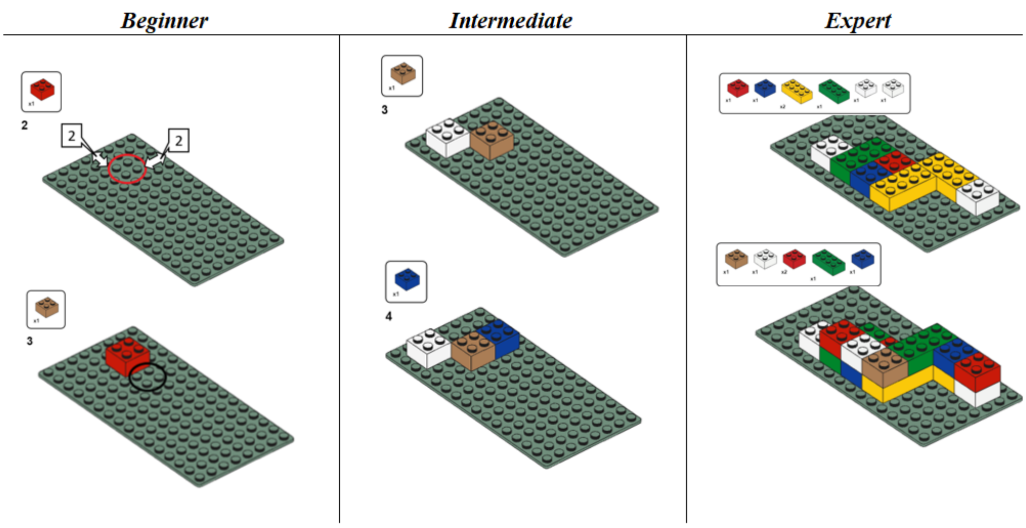


Table 7. Phase 2: Performed experiments

Performed Experiments				
Exp.	***Part.***	***Complexity***	***Instruction Type***	***Decision description***
1	1	Low	Beginner	Low complexity chosen by participant, after first experiment, the participant did not want to improve complexity level.
2	1	Low	Intermediate	
3	1	Low	Expert	
4	2	Medium	Beginner	Respondent did not know what level to go with, so intermediate was chosen by researcher. After becoming uncomfortable in experiment 5, experiment 7* was added to increase self-esteem of the respondent.
5	2	Medium	Intermediate	
6	2	Medium	Expert	
7*	2	Low	Expert	
8*	3	Low	Beginner	Respondent chose low level complexity, and after completing the first experiment (8*), was willing to increase the complexity level advised by researchers.
9	3	Medium	Beginner	
10	3	Medium	Intermediate	
11	3	Medium	Expert	
12	4	High	Beginner	High level of complexity chosen by participant.
13	4	High	Intermediate	
14	4	High	Expert	
15	5	High	Beginner	High level of complexity chosen by participant as participant regularly assembles Lego Assemblies.
16	5	High	Intermediate	
17	5	High	Expert	

As experiments 7* and 8* were performed to comfort the participant or as an indicational experiment to find the fitting level of complexity, the results of these experiments will not be considered.

3.2.1.3. Personal Characteristics

As the organisation did not apply an assessment method for personal characteristics, they could not provide an overview of the participants' unique characteristics. However, during the experiments, the researcher and peer researcher were able to identify and score the personal characteristics of the participants during the execution of the experiment. Using the cognitive skills considered in the study of Vanneste et al. (2020) as well as a general characteristic for motoric skills based on Doyle (2020) and Ranz et al. (2017), this study aimed to identify the personal characteristics of the participants. Based on these findings, possible differences in preferences regarding the work instructions could be explained. A general overview of personal characteristics considered in the continuance of this study and how they were assessed during the observations can be found in Table 8.

Because of related time constraints in which the experiment had to be performed, not all personal characteristics described in section 2.3.2. could be specifically included. As the neurodiverse spectrum focuses on the natural cognitive differences (Doyle & McDowall, 2020) and the motoric challenges they can come with (Doyle, 2020). Therefore, personal characteristics in experience level, preferred learning method and type of disability could not be explicitly included in the experiment design. However, relevant findings that relate to these remaining characteristics will still be discussed.

Table 8. Assessment criteria of personal characteristics

Characteristic	Assessment based on ...
Planning of work	... the full bill of material at the first page or bill of material for the specific page, the participant previously picks the required parts.
Comprehension	... the time it took for the participant to comprehend the information communicated in the instruction.
Attention & Concentration	... the number of times the participant was distracted during the task.
Remembering	... the number of times the participant needed to go back to the previous page or pages.
Solving Problems	... the ability to correct mistakes after finding out a mistake was made
Motoric skills	... the general motoric ability in placing the bricks and going to the next or previous page.

3.2.2. Data collection and analysis

Since the participants of the experiment are within the neurodiverse spectrum, they were expected by the researchers as well as organisational representatives to react negatively to them being real-time measured. Therefore, the decision was made to collect data using observations during the experiment and asking for the participant's experience with regard to the differing instructions. Apart from the number of errors made during the assembly, the researchers made a general qualitative assessment based on the performance measurements described in section 2.3.3. For this study, the performance outcome variables considered are the observed speed of the assembly activities, the number of errors made and the general level of participant satisfaction. The level of satisfaction was collected by asking questions after completing each of the assemblies to the participants. They were asked to provide feedback about the provided work instruction type on how the applied instructional form and level of detail for the respective instruction were perceived compared to the other instruction types.

3.3. Ethics

As this research included working with people with autism, it is important to consider the ethical aspects during the research. In line with the CITI guidelines of research involving human subjects, informed consent must be obtained from the participant or their legal guardians, and the researcher should ensure that the individuals understand the purpose and potential risks and benefits of the study (CITI, 2023). Additionally, the researcher took into account the potential impact of the research on the individual's daily life and ensured that the research design respects their general sensitivity to sensory impulses by closely cooperating with their caretakers.

4. RESULTS

4.1. Phase 1

For the first phase's findings, several topics were identified during the interviews and analysis process. First, a general description of the presence of neurodiverse employees among the participants is discussed to create an understanding of the general settings in which neurodiverse employees are being employed. Secondly, identified use cases of personalised work instructions will be discussed, followed by applied technologies for communicating work instructions. Specific insights from the respondents with regard to work instructions for neurodiverse employees are discussed in section 4.1.4. In section 4.1.5, insights into how personal characteristics are considered among participants are discussed. Finally, a general topic that almost all participants identified is discussed in 4.1.6.

4.1.1. Neurodiversity

The presence of neurodiverse employees within the participating organisations differentiated within the network. As sheltered workplaces are specifically designed to employ impaired individuals, neurodiverse employees entail a large part of their workforce (Cases A, D & I). Other respondents shared the presence of departments, workplaces or workstations that are specifically designed to include employees that, in one way or the other, typically have a hard time finding a job. Furthermore, a selection of the respondents noted that the presence of neurodiverse individuals was not actually known but that they would not be surprised if these individuals were among their employees.

4.1.2. Applications of personalised work instructions

Generally, the respondents perceived the use of personalised work instructions to be a huge, if not impossible, challenge as the general maintenance and revision management of non-personalised instructions is already a massive burden on their organisations. As such, the presence of personalised instructions was relatively low. Personalisation of instructions was somewhat present in several different cases. One of which (Case D) entails the personal, orally communicated instructions therapists apply for neurodiverse employees within one of the sheltered workplaces. The respondent did note that these instructional forms put a heavy workload on their therapists. Another case (Case H) of personalisation could be found in employees being responsible for the development of their own work instructions (Case B) or either being able to make small, personal notes on the general instructions (Case F).

4.1.3. Technologies used for work instructions

Work instructions are presented in various ways within the network. Half of the respondents acknowledged that instructions were communicated by paper, while the other half communicated digital instructions via computers or other more mobile devices present at the workplaces. Only two respondents shared the possibility of using individual user profiles for their work instructional systems. However, their application had never been seriously considered. Furthermore, the use of different presentational methods, such as augmented reality and virtual reality, was reported to be interesting. One of the respondents (Case I) reported using several smart beamers and argued that the beamers were positively experienced by its end users. However, the implementation of such systems took some years.

4.1.4. Work instructions for neurodiverse employees

As to the form and detail level of work instructions for neurodiverse individuals, two respondents were able to give some insights from their working experience. Participants of cases G and I highlighted the importance of using mainly visual forms of instructions using images and as little text as possible. Moreover, the presence of auxiliary annotations through arrows, circles and other insignia within these visual instructions was primarily experienced as negative impulses by the end users. On the other hand, the interviewee of case I argued that using a single arrow in the instruction would help the employee better comprehend the instruction. Typically, more extensive step-by-step instructions were appreciated according to both participants (G & I) as long as they were separated page by page.

One of the respondents (Case A) noted that by including the neurodiverse employees in the design of instructions, a general work instruction for a specific product could be deployed for all employees within the organisation. As such, both group-based as well as individual personalisation were deemed to be unnecessary by the respondent. Considering that employees spend only 18 months within their organisation, the respondent argues that personalisation of work instructions would require a lot of effort and time for someone likely to leave the company as soon. When asked about the satisfaction of the end users with regard to the work instructions, the respondent argued that as he did not receive any complaints, the end users are generally satisfied. Other respondents could not give insights into the relationship between neurodiverse employees and work instructions as they did not mention the use of work instructions for neurodiverse employees.

4.1.5. Personal characteristics

One of the participants (case A) shared the explicit measurement of personal characteristics, which is the largest sheltered workplace among the participants. Based on a skill assessment by psychological consultants of a new employee, a so-called 'wage value' of the employee is calculated. Within this organisation, this value represents the abilities and skills in a one-dimensional variable used to assign the individual to a fitting part of the organisation. This value can be changed throughout the individual's employment if the employee is willing to grow during their period. Among the other participants, no such method is being deployed. Case I noted the possible relevance of a personal characteristic in terms of information processing. While not applying any measurement of the characteristic, the respondent noted that the possible differences in information processing could be an interesting input factor on which the personalisation of work instructions can be based.

Another finding with regard to personal characteristics was shared by the expert in the field of neurodiversity. During the interview, the expert shared that due to the wide variety of personal characteristics and overlapping impairments, their needs for work instructions would vary significantly.

4.1.6. Pressure on the labour market

Another insight gained throughout the interviews was the increasing pressure the companies were experiencing in the labour market. As the search for new personnel becomes harder and harder, less qualified employees are deployed in the organisations' operations. As such, when the question about neurodivergent employees was asked, companies seemed to seriously consider changing aspects of their workplace to employ these groups better.

4.2. Phase 2

In this section, the results of the performed experiment will be discussed. First, the implications of the first phase for the second phase are discussed, followed by the assessment of the personal characteristics observed during the experiment. The third section discusses patterns, similarities and differences among the participants regarding work instructional needs.

4.2.1. Takeaways from Phase 1

The first decision based on the knowledge gathered in the first phase is that, as most participants are currently presenting work instructions by paper or basic digital presentations, the decision was made to adapt the experiment into a representational setting to the identified current state. Thus, the decision was made to experiment with paper instructions as it would give insight as to how, even with paper instructions, personalised work instructions can be deployed. By doing so, this research aims to provide organisations with an example of how instructions can be personalised without the need for high-end technology, thereby providing organisations with a low-level tool to offer a more inclusive workplace for neurodiverse individuals.

Additionally, respondents of cases D, G and I shared that work instructions for a neurodiverse workforce should minimise the use of text and use as many visual instructions as possible. Therefore, the decision was made to exclude text from the work instructions in the experiment. For the experiment, the included difference over the instruction types in terms of presentational form was the use of auxiliary annotations.

Concerning the level of detail, the total amount of instruction steps increased for each instruction type. With regard to the number of tasks communicated at once, the expert-type instruction communicated multiple steps at once. In contrast, the beginner and intermediate types communicated one step at a time.

4.2.2. Personal Characteristics

As per the metrics described in section 3.2.2, the researcher and peer researcher were able to assess the cognitive and motoric skills of the participants during the execution of the experiment. The scores for each of the individuals can be found in Table 9. Overall, the significant differences between these personal characteristics of the participants provided a fitting setting to explore possible differences in needs for work instructions.

Table 9. Personal Characteristics of experiment participants

Participant Assessment
(5-point scale: 1 = low & 5 = high)

	Participant				
Characteristic	***1***	***2***	***3***	***4***	***5***
Planning of work	3	3	4	3	5
Comprehension	3	2	3	4	4
Attention & Concentration	3	3	3	3	3
Remembering	3	3	3	4	2
Solving Problems	-	2	-	4	4
Ability to imagine	-	-	-	-	-
Motoric skills	3	3	2	1	4

As can be derived from Table 9, no differences could be observed among the participants for the ability to imagine, attention and concentration. For the attention and concentration characteristic, observations proved that participants were all similarly consecrating for their tasks as almost all participants were not distracted during their activities. The characteristic of the ability to imagine proved not to be observable during the experiment.

While all other participants shared to have no experience with building Lego assemblies, participant 5 acknowledged it to be one of his hobbies. While the assessment of his cognitive and motoric skills is still objectively assessed, his previous experience might influence the instructional needs of the participant. To consider this influence, the observed performance in terms of speed in the following section considers speed as a relative dimension between the instruction types.

4.2.3. Work instructional needs

When the participants were asked to participate in the experiment, they generally reacted a little hesitant as they were asked to perform a new task in a different setting, which typically can be quite confronting for neurodiverse individuals, according to their therapists. Participants 1, 2 and 3 noted that assembling the Lego models would prove to be a challenge for them. Still, after explaining that the researchers and therapist had no expectations about their performance, and with a bit of encouragement, the participants were willing to partake in the experiment and gave consent to use the observations of their actions for this study.

As described in section 3.2.2., the instructional performance was quantitively assessed in terms of errors and qualitatively assessed in terms of speed. As these two dimensions give insight into the general performance between the offered instruction types, an overview is given in Table 10. Based on the observed personal characteristics of the participants and the performance of the experiments, the identified insights into the instructional needs of the participants will be discussed in the following sections. First, the results will be discussed according to the considered personal characteristics in terms of cognitive and motoric skills of the participants. In the following section, general findings that were identified from the group of participants will be discussed.

Table 10. Observed performance

Performed Experiments					
Exp.	***Participant***	***Complexity***	***Instruction Type***	***Total assembly speed***	***# of errors***
1	1	Low	Beginner	2	0
2	1	Low	Intermediate	3	0
3	1	Low	Expert	4	0
4	2	Medium	Beginner	2	0
5	2	Medium	Intermediate	2	2
6	2	Medium	Expert	3	0
*7**	*2*	*Low*	*Expert*		
*8**	*3*	*Low*	*Beginner*		
9	3	Medium	Beginner	2	0
10	3	Medium	Intermediate	2	1
11	3	Medium	Expert	4	0
12	4	High	Beginner	1	0
13	4	High	Intermediate	4	0
14	4	High	Expert	4	0
15	5	High	Beginner	3	0
16	5	High	Intermediate	4	0
17	5	High	Expert	5	0

** Relative speed rated on a five-point Likert scale, where 1 was relatively slow and 5 was relatively fast*

*** Non-considered experiments as the instructional level was deemed too low*

4.2.4.1. Instructional needs based on personal characteristics

Participants with higher levels of planning skills (participants 4 and 5) typically went through all the pages to see what needed to be done in the instructions. A difference could be observed in how these participants handled the included Bill of Material on the second page of the instructions. Whereas the other participants briefly noted the BoM, participants 4 and 5 pre-selected the parts stated in the BoM.

While the comprehension levels were assessed to be largely similar between the participants, the second participant was assessed to have a slightly lower level of comprehension. Regarding the differences between the different instruction types, the beginner and intermediate type instructions were completed at a relatively lower pace than the expert type instructions. While the assembly of the beginner type were completed without errors in the end, mistakes were made during the assembly but were corrected. For the intermediate-type instructions, these mistakes would not be corrected. Interestingly, the expert-type instructions enabled the participant to complete the assembly at a faster pace while making no mistakes during the assembly. These findings possibly indicate that by including multiple parts into one instruction step, as done in the expert-type instructions, individuals with a lower level of comprehension can easily identify the location of parts when parts are presented relatively to one another.

With regard to the cognitive skill of remembering, it was found that the part-for-part instructions in the beginner and intermediate instructions provided difficulties for participant 5, with a relatively low level of remembering skills. This particular participant had to go back to the previous page several times, leading to slight visible frustration and confusion.

The cognitive skill of problem-solving was deemed relevant when mistakes needed to be corrected. As such, this skill could only be assessed when such mistakes were made. While participant 2 was able to correct mistakes for the beginner instructions, this could not be done for the intermediate instruction type. However, this was most likely due to the order in which the instructions were given. As the mistakes made were quite confronting during the first assembly, the mistakes made in the second assembly were even more confronting, leading to the participant giving up on correcting them. As such, these findings are deemed unrelated to the instruction type given. Similarly, for the participants with higher levels of problem-solving skills, mistakes made were corrected regardless of the instruction type.

While motoric skills did not notably influence the speed at which assemblies were completed, they did result in differences in how the paper-based instructions were handled. The paper instructions provide difficulties in handling for the two participants with a lower level of motoric skills. In particular, these participants had difficulties in selecting the right page. On the other hand, participants 1 and 3, with an average level of motoric skills, did not seem to have as much trouble. Participant 5 showed a high level of hand-to-eye coordination and was able to leaf through the pages easily.

4.2.4.2. General

All participants positively experienced the use of visual instructions. Participant 4 highlighted that the visual guides were better and easier to understand compared to the use of text. Also, the participant highlighted that this form of instruction was more pleasant than the form through which they typically receive instructions, which usually entails therapists showing how work should be done and the employee imitating their actions. The participant highlighted that he felt that the instructions enabled him to work more independently and decreased the need for validation from his therapist.

While mistakes were typically made when trying to find the position of the first part on the base plate of the model, the auxiliary annotations included in the beginner-type instructions to highlight these positions specifically did not prevent these mistakes from being made. Moreover, using these annotations was particularly difficult for the participants to understand. After completing the beginner instruction type assembly, participants 3 and 5 said they did experience the extra annotations to be helpful. However, compared to the other instruction types, these respondents confirmed that these extra annotations were confusing and difficult to understand.

Whereas the step-by-step instructions of the beginner and intermediate-level instruction types provided some difficulties for the participants, the expert-level instructions did none whatsoever. By presenting the assembly in layer-by-layer sub-assembly steps, participants could identify the positioning of the parts more easily as the relative positioning of multiple parts was more comprehendible. As a result, the models of the expert instruction types were assembled at a far swifter pace (Participants 1,3 and 5) then the instruction types. Moreover, no mistakes were made for the expert instruction type, indicating that communicating instructions that combine a number of steps is more efficient and effective than doing so in a brick-by-brick fashion.

As such, the conclusion can be made that the personal characteristics considered in terms of cognitive and motoric skills do not imply different instructional needs during the experiment.

5. DISCUSSION

This section will discuss the results of both phases of the research. The results of the study will be discussed by combining the findings of the two phases with each other and the literature.

5.1. Personalised work instructions

Almost all participants assessed the implementation of personalised work instructions as challenging as the management of revisions and updates of the current standardised work instructions is already causing problems. If individual personalisation of work instructions would be deployed and every employee had their own version of a work instruction, the number of instructions that would need management of revisions and updates would become an even bigger burden for the organisations. Moreover, group-based personalisation was deemed similarly challenging but to a more limited extent. On a critical note, the participants of this study all operate in a low-volume, high-variety setting, which is characterised by frequent design changes (Slack, 2019).

With regard to neurodiverse employees, the sheltered workplaces that focus on the employment of neurodiverse individuals differ in opinions about the promise of deploying personalised work instructions. Two out of the three sheltered workplaces deemed personalised work instructions very relevant but did not significantly use work instructions in their daily operations. Meanwhile, the sheltered workplace actually deploying work instructions deemed a one-size-fits-all to be sufficient even when employees have significant differences in personal characteristics, contradicting the expectations in the theoretical background (Tomczak, 2021; Bury et al., 2020).

Based on these findings, a significant gap can be found between the current state of personalised instructions and sophisticated applications such as multimodal instructions (Stöhr et al., 2018; Tsutsumi et al., 2020). As such, one can derive that the promise of providing work instructions to neurodiverse employees to create a more inclusive workplace is currently not being leveraged. As the aim of this study is to identify how personalised work instructions can be deployed by organisations to increase the inclusion of the workplace, the experiment of phase two was adapted to be of a more representative setting to the current state to offer insights into the effects of personalised work instructions for a neurodiverse workforce. The results of the experiment in terms of performance and satisfaction among the participants were all similar (the best for the expert-level instruction types), while their personal characteristics in terms of cognitive and motoric skills differed, indicating that a one-size-fits-all instruction actually did apply for this setting.

5.2. Work instructional needs of neurodiverse individuals

In both the first and second phases of this study, the use of textual instructions was verified to be non-fitting to the needs of neurodiverse employees. The use of visual steps in the instructions proved to be beneficial by both company representatives as well as the participants of the experiment. While significant differences were observed in the identified personal characteristics, all participants considered the expert-level instructions to fill their needs the best. In line with their feedback, both the pace at which the tasks were performed as well as the mistakes they made in doing so proved to be the best for the expert type of instructions.

Differences in needs that were observed with regard to personal characteristics mainly related to the step-by-step instructions, which were especially challenging for participants with a lower level of working memory. Moreover, all participants, even those with a lower level of comprehension, did not experience the more detailed instructions of the beginner type to be better than the expert type instructions. This finding contradicts the argument of Tomczak (2021), stating that instructions should be as detailed as possible. Additionally, it contradicts the findings of Wilshut et al. (2019), which state that the chunking of multiple instruction steps should be avoided and the argument that a step-by-step structure should be applied (Fletcher et al., 2020). This could be because sufficient context is needed for the neurodivergent employee to grasp the interconnections between components. Furthermore, in line with the argument of one of the company representatives, the use of additional annotations was experienced as confusing by the experiment participants.

While the study of Vanneste et al. (2020) mainly identified challenges in using paper instructions, the findings suggest that these challenges mainly relate to individuals with a lower level of motoric skills. As the participants reacted stressed to minor errors in the instructions, the framework of Haug (2015) to prevent the most common errors in generating work instructions is found to be especially relevant.

5.3. Inclusiveness through work instructions

As some participants of the experiment deemed the tasks of the Lego assemblies to be challenging, the general use of work instructions enabled the participants to successfully complete their tasks, which was surprising to the participants themselves. According to their feedback, the instructions provided a clear and concise guide as to what needed to be done, which was perceived to be better than instructions that were typically given by the therapist showing what needed to be done, similar to the findings in the study of Tomczak (2021). Moreover, the participants argued that the instructions enabled them to work more independently. Based on these findings, the deployment of work instructions was found to create a more inclusive workplace in the setting of the experiment.

Considering the identified challenges that organisations face due to the shortages in the labour market, organisations might be moved to consider investing more effort and time to offer more inclusiveness for neurodiverse employees. This makes the range of accommodations and support strategies, including the application of fitting work instructions for neurodiverse employees, even more relevant to integrate neurodivergent individuals into the workforce successfully.

5.4. Limitations & Further Research

While this study has found some interesting insights, it is subject to several limitations, which are important to point out. First of all, both phases of the study were performed within the high variety, low volume context, which impacts the generalizability of the findings as personalisation might be more attractive to organisations that typically have fewer variances in the products they make. For the generalizability of the second phase, it is worth noting that the sample size of only five participants may limit the generalizability of the findings. With a small sample size, it is challenging to draw broad conclusions or make definitive claims about the full population of neurodiverse individuals. While the insights gained from this limited sample should be interpreted with caution, they provide a preliminary understanding of the instructional needs of neurodiverse employees.

Due to time-related restrictions, not all personal characteristics considered in the theoretical background could be assessed during the experiment, leaving the instructional needs related to the experience level, learning curve and diagnosed disability largely untested.

Concerning the design of the experiment, it should be noted that the order in which the experiments were performed might have implications for the cognitive and motoric learning curve as they might increase over the number of experiments performed. Moreover, the performed experiments were limited to the specific complexity level chosen by the participant. The study acknowledges the importance of investigating instructional needs across various complexity levels, which could be performed in future research. Furthermore, while qualitative measurements provided rich insights into participants' experiences and perceptions, they could be complemented by quantitative measurements in future research to test their significance. Also, using Lego assemblies might not capture the full real-world work complexities.

As the decision was made to test an instructional form representative of the current state in which work instructions are typically communicated, different instructional formats may imply different results in terms of the level of detail or uses of auxiliary annotations. Therefore, future research might focus on the specific differences in instructional needs of neurodiverse individuals for differing presentational forms of instructions.

6. CONCLUSIONS

In conclusion, the findings of this research reveal several important insights regarding the deployment of group-based personalised work instructions and their impact on inclusiveness in the workplace for neurodiverse individuals. The study's first phase indicated a significant gap between the current state of personalised instructions and the more sophisticated applications described in the literature. Challenges in managing revisions and updates of standardised work instructions, particularly in low volume, high variety settings, hinder the implementation of personalised work instructions on a broader scale. However, due to the rising shortages in the labour market, the inclusion of neurodiverse employees might move organisations to invest more in offering more inclusiveness.

Regarding personalised work instructions, opinions among sheltered workplaces focusing on neurodiverse individuals differed. While two out of three sheltered workplaces recognised the relevance of personalised work instructions, they did not extensively incorporate them into their daily operations. As such, the following research question was central to the study:

"How can personalised work instructions support the inclusiveness of the job for neurodiverse employees, considering the personal characteristics of the individual?"

In answering the research question, the following conclusions can be made.

Contradicting the other sheltered workplaces, the sheltered workplace that did deploy work instructions for neurodiverse employees considered a one-size-fits-all approach to be sufficient. The experiment's results further supported this notion, as expert-level instructions proved to be the most effective across participants, regardless of their personal characteristics.

The study also highlighted the specific work instructional needs of neurodiverse individuals. While the tested work instructions were perceived to be better than regular, orally communicated instructions, personalisation on the individual level is not deemed necessary. Textual instructions were found to be unsuitable, while visual steps were perceived as beneficial by both company representatives and participants of the experiment. The expert-level instructions were favoured by all participants due to their clarity and ability to enhance task performance. Notably, participants with lower working memory and comprehension levels faced challenges with step-by-step instructions and did not find beginner-level instructions more effective. The use of additional annotations was also perceived as confusing by participants. Additionally, the study emphasised the importance of considering motoric skills in the presentational form of the instructions as well as the relevance of error prevention frameworks in generating work instructions.

In terms of inclusiveness, the deployment of work instructions, particularly the design decisions of the expert-level instructions, enabled participants to successfully complete tasks and work more independently. Participants appreciated the clear and concise guidance provided by the instructions, which were perceived as better than the typical instructions given by therapists. Consequently, work instructions contributed to a more inclusive workplace in the experimental setting.

Overall, this research underscores the potential of adapting work instructions for neurodiverse employees. The results of the experiment point out that personalisation on the individual level, based on personal characteristics, is not necessary. Moreover, the findings provide valuable insights that can be used during the design of instructions for organisations seeking to create more inclusive workplaces through work instructions tailored to the needs of a neurodiverse workforce.

Further research could focus on the influence of complexity on the instructional needs of neurodivergent individuals, as it was not within the scope of this study. As the instructional needs were collected for the instructional form of paper instructions, future research should focus on the instructional needs of other formats to explore if instructional needs differ for other communicational forms. Moreover, a quantitative assessment over a larger group of participants should be performed to test the significance levels of the findings found in this study for further validation.

REFERENCES

Aberdeen, T. 2013. Yin, RK (2009). Case study research: Design and methods. Thousand Oaks, CA: Sage. *The Canadian Journal of Action Research, 14(1)*, 69-71.

Ajoudani, A., Zanchettin, A.M., Ivaldi, S., Albu-Schäffer, A., Kosuge, K. and Khatib, O., (2018). Progress and prospects of the human–robot collaboration. *Autonomous Robots*, *42*, pp.957-975.

Asklund, Emil, and Rickard Eriksson. "Digital dynamic work instructions in a variant driven industry." (2018). (Master Thesis)

Austin, R. D., & Pisano, G. P. (2017). Neurodiversity as a competitive advantage. *Harvard Business Review*, *95*(3), 96-103.

Bannat, A., Wallhoff, F., Rigoll, G., Friesdorf, F., Bubb, H., Stork, S., Müller, H.J., Schubö, A., Wiesbeck, M. and Zäh, M.F., (2008). Towards optimal worker assistance: a framework for adaptive selection and presentation of assembly instructions. *In Proc. 1st Intern. Workshop on Cognition for Technical Systems*, Cotesys 2008, Munich, Germany.

Bokranz, R., & Landau, K. (2012). Handbuch industrial engineering. Produktivitätsmanagement mit MTM, 2, 2.

Bury, S. M., Flower, R. L., Zulla, R., Nicholas, D. B., & Hedley, D. (2021). Workplace social challenges experienced by employees on the autism spectrum: An international exploratory study examining employee and supervisor perspectives. *Journal of Autism and Developmental Disorders*, *51*(5), 1614-1627.

Bury, S.M., Hedley, D., Uljarević, M. and Gal, E., (2020). The autism advantage at work: A critical and systematic review of current evidence. Research in Developmental Disabilities, 105, p.103750.

CITI., (2023, March 12). Research involving human subjects. Retrieved from CITI: https://www.citiprogram.org/members/index.cfm?pageID=147#view

Coombs, H., (2022). Case Study Research Defined: Single or Multiple. *Southern Utah University*. https://doi.org/10.5281/zenodo.

Corbin, J. M., & Strauss, A. L. (1998). Basics of qualitative research : techniques and procedures for developing grounded theory. Sage Publications, Inc.

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A. and Sheikh, A., (2011). The case study approach. *BMC medical research methodology, 11(1)*, pp.1-9.

Deloitte., (2023, March 7). Talent shortages and workforce upsets: New paradigms for the long game. Retrieved from Deloitte: https://www2.deloitte.com/nl/nl/pages/human-capital/articles/talent-shortages-and-workforce-upsets.htm`

Doyle, N. (2020). Neurodiversity at work: a biopsychosocial model and the impact on working adults. *British Medical Bulletin, 135*(1), 108.

Doyle, N., & McDowall, A. (2021). Diamond in the rough? An “empty review” of research into “neurodiversity” and a road map for developing the inclusion agenda. *Equality, Diversity and Inclusion: An International Journal, 41*(3), 352-382.

Employer Assistance and Resource Network on Disability Inclusion (EARN). (2023, March 12). Neurodiversity in the Workplace. Retrieved from EARN: https://askearn.org/topics/neurodiversity-in-the-workplace

Fast, Y., (2004). *Employment for individuals with Asperger syndrome or non-verbal learning disability: Stories and strategies*. Jessica Kingsley Publishers.

Fermin, B., de Looze, M., & Hazelzet, A. (2019). Kansen van technologie voor mensen met een arbeidsbeperking.

Fiorentino, M., Uva, A., Gattullo, M., Debernardis, S., & Monno, G. (2014). Augmented reality on large screen for interactive maintenance instructions. *Computers in Industry, 65(2).*

Fletcher, S. R., Johnson, T., Adlon, T., Larreina, J., Casla, P., Parigot, L., & Del Mar. (2020). Adaptive automation assembly: Identifying system requirements for technical efficiency and worker satisfaction. . *Computers & Industrial Engineering, 139, 105772*.

Funk, M., Kosch, T., Greenwald, S. W., & Schmidt, A. (2015a). A benchmark for interactive augmented reality instructions for assembly tasks. In Proceedings of the 14th international conference on mobile and ubiquitous multimedia. pp. 253-257.

Funk, M., Kosch, T., & Schmidt, A. (2016). Interactive worker assistance: comparing the effects of in-situ projection, head-mounted displays, tablet, and paper instructions. In *Proceedings of the 2016 ACM international joint conference on pervasive and ubiquitous computing* (pp. 934-939).

Funk, M., Mayer, S., & Schmidt, A. (2015b). Using in-situ projection to support cognitively impaired workers at the workplace. In *Proceedings of the 17th international ACM SIGACCESS conference on Computers & accessibility* (pp. 185-192).

Grandin, T., & Duffy, K. (2008). *Developing talents: Careers for individuals with Asperger syndrome and high-functioning autism*. AAPC Publishing.

Gräßler, I., Roesmann, D., & Pottebaum, J. (2020). Traceable learning effects by use of digital adaptive assistance in production. *Procedia Manufacturing, 45,* 479-484.

Haug, A. (2015). Work instruction quality in industrial management. International Journal of Industrial Ergonomics, 50, 170-177.

Hendricks, D. (2010). Employment and adults with autism spectrum disorders: Challenges and strategies for success. Journal of Vocational Rehabilitation, 32(2), 125-134.

Hento, I., Lagerveld, S., Bleeker, Y., & Zuiderent-Jerak, T. (2020). Technologie voor inclusie werkt in de praktijk: De waarde van ttechnologie op de werkvloer voor mensen met een arbeidsbeperking. . *UWV Kennisverslag 2020-8*.

Holm, M., Danielsson, O., Syberfeldt, A., Moore, P., & Wang, L. (2017). Adaptive instructions to novice shop-floor operators using Augmented Reality. . *Journal of Industrial and Production Engineering, 34(5)*.

Ilmarinen, J. and Tuomi, K., (2004). Past, present and future of work ability. In *Proceedings of the 1st International Symposium on Work Ability, Helsinki* (pp. 1-25).

Karlsson, C. (Ed.). (2016). Research methods for operations management (Vol. 2). *London: Routledge.*

Kleffmann, A., Weinmann, S., Föhres, F. and Müller, B., (1997). *Melba–Psychologische Merkmalprofile zur Eingliederung Behinderter in Arbeit, Forschungsprojekt Az*. VB 1-58330/53, Universität Siegen.

Korn, O., Schmidt, A., & Hörz, T. (2013). The potentials of in-situ-projection for augmented workplaces in production: a study with impaired persons. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems* (pp. 979-984).

Kucirkova, N., Gerard, L. and Linn, M.C., (2021). Designing personalised instruction: A research and design framework. British Journal of Educational Technology, 52(5), pp.1839-1861.

Letmathe, P., & Rößler, M. (2020). Digital Work Instructions–Learning during Production Ramp-ups in Agile Manufacturing Environments. *Tacit Knowledge Transfer and Spillover Learning in Production Ramp-up–Results of Experimental Investigations*, 97.

Li, D., Mattsson, S., Salunkhe, O., Fast-Berglund, Å., Skoogh, A. and Broberg, J., (2018). Effects of information content in work instructions for operator performance. *Procedia Manufacturing*, *25*, pp.628-635.

Lotz, V., Himmel, S., & Ziefle, M. (2019, January). You're my mate–acceptance factors for human-robot collaboration in industry. In *International Conference on Competitive Manufacturing* (p. 10).

Markel, K. S., & Elia, B. (2016). How human resource management can best support employees with autism: Future directions for research and practice. *Journal of Business and Management*, *22*(1), 71-85.

McIntosh, C.K., (2016). Asperger's syndrome and the development of a positive work identity. *Journal of Business and Management*, *21*(2), pp.87-101.

Milton, D. (2016). Re-thinking autism: diagnosis, identity and equality: Re-thinking autism: diagnosis, identity and equality, edited by Katherine Runswick-Cole, Rebecca Mallet and Sami Timimi, London, Jessica Kingsley Publishers, 2016, 336 pp.,£ 18.99 (paperback), ISBN 978-1-78-450027-6.

Mourtzis, D., Xanthi, F., & Zogopoulos, V. (2019). An adaptive framework for augmented reality instructions considering workforce skill. *Procedia CIRP*, *81*.

National Autistic Society. (2023) Retrieved from The National Autistic Society website, www.autism.org.uk

Open-Source Psychometrics Project. (2023, March 23). Big Five Personality Test. Retrieved from openpsychometrics.org: https://openpsychometrics.org/tests/IPIP-BFFM/

Ortiz, L. A. (2020). Reframing Neurodiversity as Competitive Advantage: Opportunities, Challenges, and Resources for Business and Professional Communication Educators. Business and Professional Communication Quarterly, 83(3), 261–284. https://doi.org/10.1177/2329490620944456

Paul, J.B., Laird, M.D. and Tune, S., (2016). Autism at work: Calvin's journey of living and working with autism. *Journal of Business and Management*, *21*(2), pp.103-116.

Pence, S., & Svyantek, D. J. (2016). Person-organisation fit and autism in the workplace. *Journal of Business and Management*, *22*(1), 117-133.

Pimminger, S., Kurschl, W., Panholzer, L., & Schönböck, J. (2021). Exploring the Learnability of Assembly Tasks Using Digital Work Instructions in a Smart Factory.

Radkowski, R., Herrema, J., & Oliver, J. (2015). Augmented reality-based manual assembly support with visual features for different degrees of difficulty. *International Journal of Human-Computer Interaction, 31(5), 337-349.*

Renn, R.W. and Vandenberg, R.J., (1995). The critical psychological states: An underrepresented component in job characteristics model research. *Journal of management*, *21*(2), pp.279-303.

Richards, J., (2012). Examining the exclusion of employees with Asperger syndrome from the workplace. *Personnel Review*, *41*(5), pp.630-646.

Robertson, S. M., & Ne'eman, A. D. (2008). Autistic acceptance, the college campus, and technology: Growth of neurodiversity in society and academia. *Disability Studies Quarterly*, *28*(4).

Santally, M.I. and Senteni, A., (2013). Effectiveness of Personalised Learning Paths on Students Learning Experiences in an e-Learning Environment. European Journal of Open, Distance and E-learning, 16(1), pp.36-52.

Scott, M., Falkmer, M., Girdler, S. and Falkmer, T., (2015). Viewpoints on factors for successful employment for adults with autism spectrum disorder. *PloS one*, *10*(10), p.e0139281.

Seitz, S. R., & Smith, S. A. (2016). Working toward neurodiversity: How organisations and leaders can accommodate for autism spectrum disorder. *Journal of Business and Management*, *22*(1), 135-152.

Slack, N. (2019). Operations Management. *Pearson Education Limited*.

Stöhr, M., Schneider, M. and Henkel, C., (2018), July. Adaptive work instructions for people with disabilities in the context of human robot collaboration. In *2018 IEEE 16th International Conference on Industrial Informatics (INDIN)* (pp. 301-308). IEEE.

Tsutsumi, D., Gyulai, D., Takács, E., Bergmann, J., Nonaka, Y. and Fujita, K., (2020). Personalised work instruction system for revitalising human-machine interaction. *Procedia CIRP*, *93*, pp.1145-1150.

Twaronite, K. (2019, May 10). How neurodiversity is driving innovation from unexpected places: A neurodiverse world is a better working world. Ernst & Young. https://www.ey.com/en_us/diversity-inclusiveness

Vanneste, P., Huang, Y., Park, J. Y., Cornille, F., Decloedt, B., & Van den Noortgate, W. (2020a). Cognitive support for assembly operations by means of augumented reality: An exploratory study.

Vanneste, P., Dekeyser, K., Kim, J., Cornillie, F., Depaepe, F., Raes, A., & Van den Noortgate, W. (2020b). Personalised AR Instructions to Tailor Cognitive Support During Assembly Work. In *ICCHP* (p. 123).

Wang, Z., Bai, X., Zhang, S., Billinghurst, M., He, W., Wang, P., Lan, W., Min, H. & Chen, Y. (2022). A comprehensive review of augmented reality-based instruction in manual assembly, training and repair. *Robotics and Computer-Integrated Manufacturing*, *78*, 102407.

Watson, G., Butterfield, K., Curran, R., & Craig, C. (2010). Do dynamic work instructions provide an advantage over static instructions in a small-scale assembly task?

Wilczynski, S.M., Trammell, B. and Clarke, L.S., (2013). Improving employment outcomes among adolescents and adults on the autism spectrum. *Psychology in the Schools*, *50*(9), pp.876-887.

Wilschut, E. S., Könemann, R., Murphy, M. S., Van Rhijn, G. J., & Bosch, T. (2019). Evaluating learning approaches for product assembly: using chunking of instructions, spatial augmented reality and display based work instructions. *In Proceedings of the 12th ACM International Conference on PErvasive Technologies Related to Assistive Environments (pp. 376-381).*

Wolfartsberger, J., Heiml, M., Schwarz, G., & Egger, S. (2019). Multi-modal visualisation of working instructions for assembly operations. *International Journal of Industrial and Manufacturing Engineering*, *13(2), 107-112*.

Yin, R.K., 2018. Case study research and applications: Design and methods. Sage Books

APPENDIX

1. Phase 1: Interview protocol

General information and interviewees:

Date & Time:		
Location:		
Organisation:		
Interviewer:		
Note taker:		
Respondent 1	Name:	
	Function:	
Respondent 2	Name:	
	Function:	
Respondent 3	Name:	
	Function:	

General questions:

Number of employees (in FTE)	
Production Volume	◻ High volume
	◻ Low volume
	◻ Different, ...
Product Variation	◻ High variety
	◻ Low variety
	◻ Different, ...
Deployment of Work Instructions	◻ Directive during task performance
	◻ Administrative
	◻ Quality control
	◻ Different, ...

In-depth questions:

1. Generation phase of instructions
   1.1. Who is responsible for generating the work instructions and how does the generation process typically work?
   1.2. How are the (specific) end users taken into account during the generation of the work instructions?
   1.3. What software is being used during the generation of work instructions?
   1.4. How complex is the generation of work instructions?
   1.5. What is the impact of personalising work instructions with regard to the time and costs that are needed to generate such instructions?

2. Work instructions in the workplace
   2.1. How are the instructions communicated to the workplace?
   2.2. What is the scope of the work instructions? (Full product, Tasks, Activities, etc.)
   2.3. What informational streams are present regarding the instructions? (one way flow of feedback or does information flow the other way as well?)
   2.4. How much autonomy does the end user have during the performance of the task? Does the end user have to follow the instruction step by step or can they decide what steps to follow?
   2.5. How is the collection of feedback organised regarding the instructions?

3. Content of work instructions
   3.1. What information is communicated in the work instructions? (Bill Of Material, Activities, Tasks, Annotations, etc.)
   3.2. How would you describe the level of detail in the work instructions?

4. Form of work instructions
   4.1. In what form are instructions communicated to the end user? (text, visuals, audio, mix)
   4.2. What technologies and or software is being used in the communication of work instructions?

5. Personalised work instructions
   5.1. How personalised are work instructions currently within your organisation?
      5.1.1. What variables are being used to personalise work instructions? (Level of detail, Form, or both)
      5.1.2. Are instructions adapted to according to the different end users? Are instructions adapted to the individual or are certain user types being used? How are instructions adapted over a longer period of time?

        5.1.3. What personal characteristics are deemed relevant to personalise work instructions? (e.g. age, work experience, qualification, etc.)
        5.1.4. How are personal characteristics of the neurodivergent individual taken into account in the instructions?
        5.1.5. Are there any other factors, apart from personal characteristics, that are taken into account during the personalisation of the work instructions? (e.g. Product Complexity, previous performance, environmental factors, etc.)
    5.2. How beneficial is the deployment of personalised work instructions?
    5.3. Are there any opportunities in the organisation to further personalise work instructions?
    5.4. What are the benefits and challenges of personalised work instructions?

6. Performance of work instructions
    6.1. What is the impact of personalised work instructions on the process performance? (e.g. Speed, costs, flexibility, quality, etc.)