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Physical workplace adjustments to support neurodivergent workers: A systematic review

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Abstract

Derived from the concept of neurodiversity, neurodivergence is an umbrella term for various conditions such as Autism-Spectrum Disorder (ASD), Attention-Deficit/Hyperactivity Disorder (ADD/ADHD), Dyslexia, or Dyspraxia, which affect approximately 22% of the population. Sensory difficulties and overload are a common symptom. The provision of physical workplace adjustments for neurodivergent workers, such as workplace design solutions, has become popular in practice, yet their utility remains unsubstantiated. This review evaluates the evidence for physical workplace adjustments and their link to occupational longevity, performance and health/well-being in neurodivergent workers. A systematic review (PRISMA guidelines) of studies published in English between 2000 and 2021 focused on these inclusion criteria: adult office workers clinically considered neurodiverse, their families, colleagues, employers, experts and vocational programme staff; at least one physical workplace adjustment; and all types of empirical study designs. The theoretical framing was based on the ecological model of person–environment fit supplemented by the International Classification of Functioning, (ICF) disability and health and environmental stress theory. Quality

assessment and data synthesis were undertaken. Of the 319 studies identified, 20 met the eligibility criteria; the majority addressed ASD. Most studies described a combination of adjustments to address different environmental stimuli. The most frequent adjustments addressed sound distractions (e.g. single-person offices) and light sensitivity (e.g. light control), which were related to occupational longevity, performance and health/well-being. A range of other adjustments addressed aspects such as environmental control, crowding or decompression rooms. There is insufficient evidence to fully evaluate the usefulness of adjustments, partially due to methodological shortcomings. Despite the variety of challenges with the sensory physical environment acknowledged in the literature for neurodivergent conditions, there is a paucity of evidence. Given the potential of physical adjustments to improve work and health outcomes, we highlight the necessity for more theoretically driven and methodologically sound research.

KEYWORDS

neurodivergence, neurodiversity, occupational longevity, performance, well-being, workplace adjustments

INTRODUCTION

Derived from the broader concept of neurodiversity (Singer, 1999), neurodivergence (ND) is an umbrella term for various developmental conditions estimated to affect approximately 22% of the population (Doyle, 2020), such as Autism-Spectrum Disorder (ASD < 2%), Attention-deficit/hyperactivity Disorder (ADD/ADHD 5%), Dyslexia (10%), or Dyspraxia (<6%). Neurodivergent individuals have been systematically excluded from the labour market, partially due to particular sensory needs and the lack of required adjustments at work (Doyle & McDowall, 2021).

Regarding such sensory needs, difficulties in modulating sensory responses[1] and over-responsivity (overload) are common symptoms shared by the main ND groups; either as part of the diagnostic criteria (ASD), as comorbidity or as an explanatory (developmental) theory (ADD/ADHD, Dyslexia, Dyspraxia). To illustrate, according to the Diagnostic and Statistical Manual of Mental Disorders (5th ed.; DSM–5; American Psychiatric Association, 2013), people with ASD[2] 'may struggle with hyper- or hyporeactivity to sensory input or unusual interest in sensory aspects of the environment. This may present as indifference to pain or temperature and adverse responses to specific sounds or textures, excessive smelling or touching of objects,

visual fascination with lights or movement' (p. 50). While the two response patterns/sensitivity states, hyper-responsiveness/hypersensitivity (exaggerated response to stimuli) and hyporesponsiveness/hyposensitivity (lack of response to stimuli) are most prevalent in autistic populations, they are also present in populations with ADD/ADHD (Panagiotidi et al., 2018; Perrachione et al., 2016) and Dyspraxia (Mikami et al., 2021), affecting different sensory domains. In ADD/ADHD populations, hyper- or hyposensitivity concerns visual (Panagiotidi et al., 2017a), auditory (Ghanizadeh, 2009), tactile (Hern & Hynd, 1992), olfactory (Romanos et al., 2008), vestibular modalities (Sergeant et al., 2006) and multisensory integration (Panagiotidi et al., 2017b). In dyslexic populations, hypersensitivity or hyposensitivity concerns visual, visual–spatial and auditory modalities (cf. Goswami, 2015). In populations with Dyspraxia, multiple sensory modalities related to movement planning and processing are affected, including vestibular, tactile, visual–spatial but also oral and auditory sensory domains (Allen & Casey, 2017; Blank et al., 2019; Gomez & Sirigu, 2015; Goyen et al., 2011; Loh et al., 2011; Mikami et al., 2021).

Hence, it is unsurprising that sensory difficulties of ND workers in office environments have been reported. Regarding ASD, studies report hypersensitivity towards noise (Hayward et al., 2019; Landon et al., 2016; Pfeiffer et al., 2017; Robertson & Simmons, 2015; Schreuer & Dorot, 2017), artificial light (Davidson, 2010; Hayward et al., 2019; Richards, 2012), olfactory stimulation (Davidson, 2010; Robertson & Simmons, 2015) and socio-environmental stimulation, such as closeness of others and crowdedness (Krieger et al., 2012; Müller et al., 2003; Smith & Sharp, 2013). Unmet sensory needs in neurodiverse worker populations are likely to be varied and severe, although academic research is scarce and limited (e.g. qualitative descriptive predominance, unsystematic and patchy evaluation of sensory modalities, and neglect of hyposensitivity). The little evidence available suggests that hypersensitivity is linked to loss of concentration and performance (Carrington & Graham, 2001; Kirchner & Dziobek, 2014; Landon et al., 2016; Müller et al., 2003; Pfeiffer et al., 2017; Schreuer & Dorot, 2017) and reduced physiological (e.g. discomfort, headaches and migraines, and nausea; Robertson & Simmons, 2015) and psychological health (e.g. emotional distress, anxiety, fright or anger; Landon et al., 2016; Robertson & Simmons, 2015; Smith & Sharp, 2013). In addition to such threat to health/well-being and productivity, unmet sensory needs at work threaten workplace integration/inclusion and successful employment outcomes for neurodiverse workers (e.g. Kammeyer-Mueller & Wanberg, 2003; Schreuer & Dorot, 2017).

Sensory interventions and adjustments such as promoting optimal arousal, using sensory modalities for self-regulation or lower over-reactivity for ND individuals appear to be widely applied, accessible and well researched, especially in childhood (e.g. Case-Smith et al., 2015). However, a sound evidence base does not exist for the work domain, where a range of recommended adjustments was found to be poorly implemented and their efficacy poorly understood (Doyle, 2020; Doyle & McDowall, 2021). Despite the unclear evidence base, workplace design solutions have been proposed by the building industry and design advisor groups (e.g. Forbo Flooring System, 2020; Group GSA, 2020, 2021; HOK, 2019, 2020). Although such developments suggest a positive trend in a growing preoccupation within the design industry to build inclusive workplace environments, the utility of such design solutions is unclear. Physical workplace adjustments, which may benefit neurodiverse workers in regard to work performance and health/well-being, may have wider reaching benefits, such as occupational longevity and systemic inclusion (e.g. Doyle & McDowall, 2021). As posited by Doyle and McDowall (2019, p. 3), "the overarching issue of (lack of) social inclusion and equality ... creates a moral imperative to ensure any adjustments are substantiated by evidence and guiding theoretical frameworks."

We undertook a focused evaluation and synthesis of the available evidence, specifically of *physical workplace adjustments* (e.g. *design solutions*), on occupational and health-related outcomes for ND workers. In line with relevant guidelines, we adopted a broad conceptualization of environmental adjustments to the physical environment to elicit all relevant evidence.

Review aim

Given the need to identify the evidence base for physical workplace adjustments addressing sensory difficulties, this systematic review examined the following research question in line with the CIMO-logic: *What is the evidence (in terms of extent, nature, and quality) for physical workplace adjustment [I] to support occupational longevity, performance, and health/well-being [O] in ND workers [C] as of specific sensory needs [M]?*

METHOD

In conducting our review, we adopted a systematic approach as outlined by Briner and Denyer (2012) and informed by PRISMA guidance (Liberati et al., 2009) to locate all relevant empirical, peer-reviewed evidence for the relationship between physical workplace adjustment (that directly or indirectly address sensory needs) and occupational longevity, performance and health/well-being outcomes in ND office workers.

Eligibility criteria

We used the CIMO framework to guide the specific inclusion and exclusion criteria due to its appropriateness in social science settings (Denyer & Tranfield, 2009). We included all types of empirical study designs published in English from 2000 until September 2021 as follows: *Context*: adult neurodivergent workers including Attention Deficit Disorder, Autism Spectrum Disorder, Dyslexia, Dyspraxia, Tourette Syndrome, Dyscalculia, Dysgraphia (Doyle, 2020) and/or their family members, colleagues, employers, experts and vocational programme staff; office environments or mixed work settings; *Interventions*: studies referencing any types of physical workplace adjustments – for example, office layout considerations, special furniture, acoustic adjustments, ergonomics considerations, sensory/fidget toys, either in their results section or in any specific recommendations; *Mechanisms*: all mechanisms that explain the relationship between the intervention and outcome and the conditions under which these are activated or accessed; *Outcomes*: all outcome measures that encompass concepts relevant to changes in occupational longevity, performance and health/well-being.

Exclusion criteria were: participants that were exclusively self-diagnosed (studies with a mix of self- and formal diagnosis were included), under the age of 18 years; solely technological workplace adjustments, such as use of computer software or programmes; workplaces that were not/did not include office environments; non-empirical studies, such as secondary data analyses—for example, systematic literature reviews and meta-analyses, reports or guidelines. Although we had initially aimed to exclude any non-peer-reviewed studies, we revised our approach given the limited search and include such sources to ensure breadth of primary evidence (Kendall, 2013 = PhD thesis; Morris et al., 2015 = conference paper; Pierce, 2018 = PhD thesis).

Search strategy

We based our search terms on extensive scoping, including key texts of the research fields of neurodiversity, occupational health and rehabilitation (de Beer et al., 2014; Khalifa et al., 2020; Patton, 2019), as well as guidance documents for ND workplace inclusion and adjustments by charities, government and business, psychological and workplace design advisor groups (ACAS, 2016; British Psychological Society [BPS], 2017; Cassidy, 2018; Chartered Institute of Personnel and Development [CIPD], 2018; Dyspraxia Foundation, 2016; Forbo Flooring System, 2020; Forward Motion Coaching, 2009; GMB union, 2018a, 2018b; Group GSA, 2020, 2021; HOK, 2019, 2020; Job Accommodation Network [JAN], 2019, 2020; National Disability Authority [NDA], 2015; Scottish ADHD Coalition, 2018; Standifer, 2009; Trade Union Congress [TUC], 2014a, 2014b). A member of the author team (JY) with experience in occupational health and rehabilitation research reviewed the search terms. We tested and sample-checked subject strings and implemented these to include all four subjects at once, "S1 AND S2 AND S3 AND S4," in the title and/or abstract and/or text. Our search limits specified English language, the publication period 2000–2021, and adult populations, including alternate spellings (e.g. colour and color) and wild cards for derivations of the same root word (e.g. accommoda*, adapt* or adjust*). See Table 1 for subject terms.

To avoid unduly narrowing the search and excluding relevant text, the search strategy only specified (S1-C) general neuro-developmental condition (neurodiver*, neurological, "neurological condition") and variant terms of conditions considered neurodiversity (cf. Doyle, 2020); (S2-C) the occupational context of the study; (S3-I) variant terms of occupational intervention; (S4-I) general physical workplace adjustment terms; and specifications of adjustment characteristics or their sensory target. Where possible, MeSH terms were assigned. Mechanisms (e.g. hypersensitivity or hyposensitivity) and outcomes (occupational longevity, performance or health/well-being) were not specified in the search.

Data sources

We searched across multiple databases to ensure coverage of health, psychology and management research: (1) PubMed; (2) ABI/Inform; (3) PsychINFO; (4) Web of Science Core Collection and (5) Scopus. We then hand-searched reference lists of all included and excluded studies (non-eligible or non-empirical) and those within guidance documents by charities, government, business, psychological and workplace/design advisor groups.

Conducting searches

We completed iterative searches from July 2020 to September 2021 to locate as many relevant papers as possible (Greenhalgh & Peacock, 2005). These identified 312 records, which included at least one term of each search string in the title or in the abstract (S1–S4) or text (only S4) (see Figure 1). We identified seven records by hand-picking. After duplicate removal, two researchers (CW and EH) assessed the eligibility of studies using a four-step process: (1) screening titles; (2) screening abstracts; (3) full text skimming and (4) full text review and application of exclusion–inclusion criteria. At each screening step, we assigned sources to a different researcher (EH and CW). We discussed uncertainties at each screening stage on a regular basis to achieve consensus. A total of 20 studies remained for inclusion and synthesis.

TABLE 1 Subject terms

Subject	CIMO	Description	Search terms
S1	Context	Neurodivergent population (ND)	ADHD, "Adult ADHD", Alexia*[MeSH], ASD, "Asperger syndrome"[MeSH], Asperger*, "Attention deficit and disruptive behavior disorders" [MeSH], "Attention deficit disorder with hyperactivity"[MeSH], "Attention deficit*", Autis*, "Autism spectrum disorder"[MeSH], "Autistic disorder"[MeSH], DCD, "Developmental Coordination Disorder", Dyscalculia[MeSH], Dysgraphia, Dyslexia[MeSH], Dyspraxia, "High-functioning autism", Hyperactivity, Neurodiver*, Neurological, "Neurological condition", "Tourette Syndrome"[MeSH], "Word blindness"
S2	Context	Occupational context	Employ*, Employment [MeSH], Job, Occup*, Occupants, Occupations [MeSH], Organi*, Professional, Vocation*, "Work environment", Work*, work [MeSH], Workforce [MeSH]
S3	Intervention	Intervention terms	Accommoda*, Adapt*, Adjust*, Change*, Intervention*, Modifi*, "Occupational intervention*", "Reasonable accommoda*", "Workplace accommoda*", "Workplace adapt*", "Workplace adjust*", "Workplace intervention", "Workplace modifi*"
S4	Intervention	Physical workplace adjustment or their characteristic/sensory target	Access*, Acoustics[MeSH], "Air quality", Auditory, choice, Colo?r, Crowd*, Distract*, "Environment* stimul*", Equipment, Ergonomics[MeSH], Furniture, "Interior design and furnishings"[MeSH], Layout, Lift*, Light[MeSH], Material*, Natur*, Noise [MeSH], Office*, Quiet*, Sens*, Sound*, Spac*, Spat*, Technolog*, Temperature, Thermal*, Visual*, Wayfind*, Workplace*, Workplace [MeSH], Workspace, Workstation

Data extraction

Our bespoke extraction template designed by two members of the author team (CW, EH) included first author, year, country, study design (qualitative, quantitative and mixed methods), target population by condition, participants (e.g. family members, employers and co-workers of ND workers) and sample size, participants' characteristics (e.g. age, gender, education level and occupation), study objectives, methods/measures, key findings pertinent to this review, workplace adjustments suggested or implemented in studies (e.g. adjusting light and providing private offices) and outcome domain (occupational longevity, performance and/or health/well-being). Two researchers extracted and reviewed the data (CW and EH).

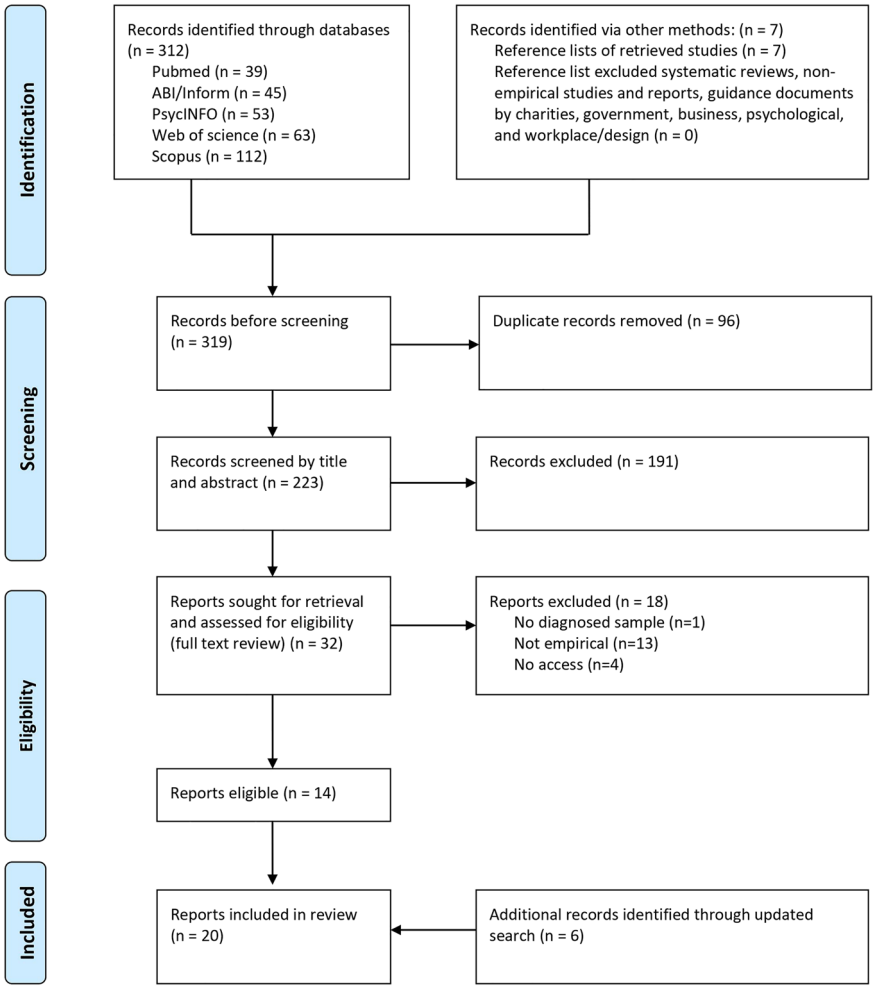

FIGURE 1 PRISMA flowchart

Quality assessment

To address the heterogeneous nature of the primary studies, we used widely accepted tools (Noyes et al., 2018) for quality assessment: the Critical Appraisal Skills Programme (CASP Qualitative Checklist, 2013 for qualitative studies ($n = 13$) and the Mixed Methods Appraisal Tool (MMAT, Hong et al., 2018) for mixed methods ($n = 6$) and for quantitative non-randomised studies ($n = 1$),[3] to evaluate (1) method appropriateness, (2) rigour in data collection and bias, (3) ethical issues, (4) analytical rigour and bias and (5) reporting. We elicited overall quality scores aligning with recommendations (Pluye et al., 2009) and prior practices (e.g. Bury et al., 2020) for further evaluation. The maximum overall score varied by tool and study category (10 CASP; 5–25 mixed methods MMAT; 5 quantitative non-randomised MMAT). In both tools, rating questions followed the format of 'Yes', 'No' and 'Cannot tell'. Aligning with Long et al. (2020, p. 36), 'we nominated to use "can't tell" when there was insufficient information reported to make a judgement (i.e. a reporting issue)'. Scoring procedure followed Pluye et al.'s (2009, p. 540) guidelines: 'Score presence/absence of criteria respectively 1/0 ...

Calculate a "quality score" [(number of "presence" responses divided by the number of "relevant criteria") × 100]'. Quality was assessed by three researchers (CW, BK and EH); any potential divergence was discussed in the wider group (CW, BK, EH and JY) to achieve consensus, but ratings did not result in exclusion to ensure an inclusive approach to the extant evidence base.

Data analysis: Idealist narrative synthesis

Neither quantitative meta-analysis nor qualitative meta-synthesis were appropriate due to the heterogeneous nature of the retrieved studies (Popay et al., 2006). Instead, we extracted, categorised and narratively synthesised relevant information from each study aligned to the six-step framework by Braun and Clarke (2006) with a hybrid approach to inductive and deductive thematic analysis (cf. Fereday & Muir-Cochrane, 2006). We combined a data-driven induction (e.g. Boyatzis, 1998) with a deductive a priori template of master themes (e.g. Crabtree & Miller, 1999) to conceptualise the sensory physical environment. Such hybrid approach to thematic analysis is considered useful in occupational contexts, provided a clear framework for the underlying phenomenon under investigation is available (Fereday & Muir-Cochrane, 2006; Ligurgo et al., 2018). Given the complexity of our research question, which referenced context as well as individual experience, our coding ensured consideration of all aspects of interest, such as comprehensive coverage of sensory modalities, while allowing specific codes and subthemes to be interpreted from the data.

First, we familiarised ourselves (CW and EH) with the data by reading and rereading with a data-led inductive approach through identification of relevant information, such as participant quotes and relevant information in the respective results and discussions. Second, we inductively coded the data set to represent nuanced types of demands or resources in the physical environment, concrete adjustments or related outcomes; we used a deductive framework-informed approach to refine the codes, e.g. Fereday and Muir-Cochrane (2006). Third, we interpreted subthemes from the initial codes through a deductive scan, where we clustered each code using the a priori template based on the master themes of the framework. We then collated codes in each of the five dimensions/master themes into subthemes (e.g. Dimension/Master theme 1: Adjustments for Managing Environmental Stimulation; Subtheme 1: Auditory; Example code: Reducing noise levels with tools). Fourthly, we reviewed and revised the subthemes by checking whether they represent the extracted codes adequately and whether any aspect (e.g. sensory modality) had been overlooked. Finally, we defined the subthemes through iterative analysis of the themes by relating them back to the framework and dimensions. Our approach was marked through an iterative and reflexive process, with several cycles of revision within the group of researchers (CW and EH) rather than linear rigidity as our illustration might suggest.

We took an idealist approach including quotes from participants or observational findings and authors' interpretations (Barnett-Page & Thomas, 2009; Noyes et al., 2018). This allowed us to include mixed-methods studies (of which the majority had rich qualitative participant data) and one cross-sectional study as the title authors' interpretations were treated as relevant data. Where possible, we retained the original participants' or title authors' wording for coding and subtheme development. We undertook outcome domain categorisation (occupational longevity, performance and health/well-being) from the evidence provided in each primary study. If authors were unclear or did not use any terminology that related to the broader outcome domains (e.g. health/well-being), we classified based on our own interpretation of participant

quotes (e.g. headache → health/well-being). We retained the title author's wording where possible to maintain transparency and minimise the risk of undue interpretations and categorisations. We undertook the narrative synthesis within- and across-study (Petticrew & Roberts, 2006).

Framework: Conceptualising the sensory physical environment

Our framework for the narrative synthesis is rooted in Lawton's (1987) revised ecological model of Person-Environment (P-E) fit, which has been widely used in vulnerable group research (cf. Cvitkovich & Wister, 2001) and in workplace design research (e.g. privacy fit; Weber & Gatersleben, 2021). This P–E fit model explains the multi-tiered subjective dimensions of P–E fit where behaviour and well-being are a result of how the environment meets the needs of the individual. Lawton (1987) specifies that the environment consists of social and physical dimensions, the latter differentiates between the objective measurable environment and the phenomenal environment. Thus, we frame the physical environment as offering demands, resources, affordances and meanings.

Thus, we conceptualised the P–E fit perspective and understanding of the physical environment by drawing on the International Classification of Functioning, Disability and Health (ICF), which considers physical environmental factors that facilitate or hinder the performance of daily activities (World Health Organization, 2009). In line with other ND researchers (cf. Pfeiffer et al., 2017), we focused on sensory physical factors that present demands or resources: hypersensitivity and hyposensitivity needs. We refined environmental demands and stresses using environmental stress theories concerning social stimulation (e.g. crowding and privacy) and environmental control (Evans & Cohen, 1987). The evidence was therefore categorised as outlined below in Table 2.

RESULTS

Study and participant characteristics

The full data extraction is summarised in Table 6.

Study design and methods of analysis

The study designs are further summarised in Table 3. The 13 qualitative studies and qualitative components of the six mixed-method studies used the following methods of analyses: Content Analysis = 4 (Black et al., 2019; Hedley et al., 2018; Kirchner & Dziobek, 2014; Lorenz et al., 2016), Thematic analysis = 7 (Diener et al., 2020; Dreaver et al., 2020; Harvery et al., 2021; Hayward et al., 2019; North, 2021; Schreuer & Dorot, 2017; Soeker, 2020), Phenomenological text analysis = 2 (Waisman-Nitzan et al., 2019, 2021), Grounded theory = 1 (Pfeiffer et al., 2017), IPA = 1 (Kendall, 2013), Case study analysis = 1 (Pierce, 2018), Unclear = 3 (Baldwin et al., 2014; Morris et al., 2015; Müller et al., 2003). There were seven studies including quantitative data. There was one quantitative non-randomised study of cross-sectional design and mixed-method studies using cross-sectional data collection. Of these studies, two (Harvery et al., 2021; Lorenz et al., 2016) used correlational analyses (e.g. logistic regression and Bayesian statistics) to test the main hypotheses; three examined

TABLE 2 P-E fit framework

Dimension	Conceptualisation	Further detail
Dimension (1)	Managing environmental stimulation regarding sensory modalities (cf., Dunn, 2001) and responsiveness patterns (hyper-and hyposensitivity, when applicable);	Environmental demand stimuli that create sensory stress through hypersensitivity (cf. Lawton, 1987; Pfeiffer et al., 2017). Environmental resource stimuli positioned as desired sensory stimulation related to hyposensitivity (cf. Lawton, 1987; Pfeiffer et al., 2017)
Dimension (2)	Managing social stimulation in space (cf. Evans & Cohen, 1987; Lawton, 1987; Pfeiffer et al., 2017)	Aspects that relate to reducing social interaction, demands, and sensory stress linked to hypersensitivity incorporating socio-environmental phenomena such as privacy, crowding, or personal. Aspects that relate to increasing social interaction in space
Dimension (3)	Environmental control which relates to a sense of control afforded by the environment (cf. Evans & Cohen, 1987; Lawton, 1987)	N/A
Dimension (4)	Captures all physical environment adjustments that are non-environmental- or social-stimulation specific.	N/A
Dimension (5)	Summarised occupational longevity, performance, and health/well-being outcomes of suggested or provided physical workplace adjustments (cf. Lawton, 1987; ICF, World Health Organization, 2009)	N/A

differences across conditions or groups (e.g. ANOVAs; Chi square; Baldwin et al., 2014; Black et al., 2020; Hayward et al., 2019), and one reported descriptive statistics only (Kirchner & Dziobek, 2014).

Sample size

Reported sample sizes ranged from 5 to 856 (qualitative $n = 5$–79, mixed methods $n = 66$–856, quantitative $n = 687$).

Sample types

Alongside ND participants, samples included family members of ND individuals ($n = 257$), employers ($n = 63$), service providers ($n = 149$), researchers ($n = 55$), co-workers ($n = 6$), supervisors/managers ($n = 25$), advocacy group representatives ($n = 5$) and support staff ($n = 7$). Further, two studies included neurotypical participants for comparison (Hayward et al., 2019; Morris et al., 2015).

TABLE 3 Study designs

Study designs	Included studies
Qualitative design	Black et al. (2019); Diener et al. (2020); Dreaver et al. (2020); Hedley et al. (2018); Kendall (2013); Müller et al. (2003); North (2021); Pfeiffer et al. (2017); Pierce (2018); Schreuer and Dorot (2017); Soeker (2020); Waisman-Nitzan et al. (2019); Waisman-Nitzan et al. (2021)
Quantitative design	Black et al. (2020)
Mixed methods	Baldwin et al. (2014); Harvery et al. (2021); Hayward et al. (2019); Kirchner and Dziobek (2014); Lorenz et al. (2016); Morris et al. (2015)

ND conditions

Overall, 916 participants in this review were indicated to be ND. Conditions included Autism (ASD; Asperger's disorder; high-functioning autism, PDD-NOS); attention deficit disorders (ADD, ADHD); dyslexia; and another learning disabilities, which were not specified. The majority of studies (18) focused on ASD, whereas one focused on attention deficit disorders (Schreuer & Dorot, 2017), and only one focused on a variety of ND conditions (autism, attention deficit disorders and dyslexia) (Morris et al., 2015). Regarding diagnosis, eight studies had participants with formal diagnoses, five with formal, informal and self-reported diagnoses, three studies gave no information and for three studies diagnosis type was not relevant as a non-ND sample. Results are not differentiated by type of diagnosis (self or formal). Furthermore, six studies had samples which reported ND-relevant comorbidities (e.g. ASD with underlying ADHD).

Sample demographics of ND individuals[4]

There was a wide range of participant ages, from 18 to 80 years, with most samples having a mean age from the mid-20s to early 40s. Most studies reported on participants' gender, educational level and occupation. The proportion of males and females was almost equal (male $n = 380$, female $n = 408$, others $n = 19$, no information $n = 102$). Further, 43% of studies that provided information on educational level reported their samples to have a university degree. Participants worked in various sectors, such as higher education, public sector, health care and financial services. Occupations included administrative workers, teachers, assistants, sales workers, employment specialists, graphic designers, chemical technicians and communication specialists. The most commonly held jobs by autistic participants (nine studies) were information technology-related jobs (e.g. software test analyst, software developer, computer system analyst or data entry specialist).

Work context

The majority of studies included varied work and office settings. Only four studies (Hedley et al., 2018; Kendall, 2013; Morris et al., 2015; Pierce, 2018) appeared to solely focus on office settings and one study was unclear (Kirchner & Dziobek, 2014). We inferred this by

participants' occupations, case study descriptions or by contacting the studies' authors who were not always responsive.

Study objective

No studies aimed to test the efficacy of physical workplace adjustments. Instead, the majority aimed to explore facilitators and/or barriers of maintaining employment (Black et al., 2019, 2020; Dreaver et al., 2020; Harvery et al., 2021; Hayward et al., 2019; Hedley et al., 2018; Kirchner & Dziobek, 2014; Lorenz et al., 2016; Müller et al., 2003; Waisman-Nitzan et al., 2021) and overall occupational experience (Baldwin et al., 2014; Kendall, 2013; Morris et al., 2015; North, 2021; Schreuer & Dorot, 2017; Soeker, 2020). One study explores the dual employment perspectives of adults with ASD and their supervisors (Diener et al., 2020), and two studies aimed to identify leaders' strategies for supporting autistic employees (Pierce, 2018; Waisman-Nitzan et al., 2019). Only one aimed to understand the impact of social and physical environmental factors on work performance and satisfaction (Pfeiffer et al., 2017).

Outcomes classified

None of the studies specifically focused on occupational longevity, performance and health/well-being but reported on components of these concepts. Twelve studies reported on aspects related to occupational longevity (such as maintaining employment, enablers and barriers to success at work), 11 studies on aspects related to performance (such as work ability or concentration) and 6 studies on aspects related to health/well-being (such as work satisfaction, adjustment fatigue or overstimulation symptoms).

Quality assessment

In answer to the research question on the quality of the available evidence, study quality was overall heterogeneous, meeting 20%–100% of the quality criteria across assessment tools. The assessment scores for the qualitative papers ranged from 60% to 100% (average 88%). Most qualitative methods were justified; however, some lacked robust data collection methods (e.g. conducting open-ended interviews via email) or recruited a sample that did not conform with the specified inclusion criteria or research aims (e.g. unemployed workers and students despite inclusion criteria being minimum 1 year in the workforce). A third of the studies did not adequately consider the relationship between researcher and participants (e.g. clear accounts on reflexivity); some provided limited detail in the presentation of the analysis or interpretations.

The assessment scores for the mixed-method papers ranged from 27% to 73% (average 47%). Predominant weaknesses of the mixed-methods studies included an unsatisfactory integration of the different study component-methods (qualitative/quantitative) and non-adherence to the quality criteria of each component-method involved. For the quantitative study, the assessment score was 20%. Recruitment methods were detailed but did not provide a clear justification of the arguably non-representative sample size, used non-validated measures and failed to account for confounding variables in their design or analysis. The quality assessments for the

quantitative and mixed-methods studies were the lowest and need to be interpreted with caution. The detailed quality appraisal for all studies can be found in the supporting information (Tables S1 and S2).

Study synthesis

Regarding the nature and extent of the available evidence, we present a summary of the results in Table 4 (adjustments) and Table 5 (outcomes). We synthesised findings with the five dimensions of the analysis framework (managing environmental stimulation and social stimulation, environmental control and sensory-unspecific adjustments, and outcomes) as particularly relevant to ND participants. This proved more difficult when evidence was provided for mixed groups in qualitative studies (e.g. Black et al., 2019). We have included the full results of the studies (neurotypical and ND evidence) in the data extraction table (Table 2). Where studies did not include any ND individuals but company directors, line managers, leaders, frontline supervisors or employers of ND workers (Dreaver et al., 2020; Pierce, 2018; Waisman-Nitzan et al., 2019), we embedded these with findings from studies that included ND participants. When results were solely retrieved from non-ND accounts, we have made this clear in the text.

Dimension 1: Adjustments for managing environmental stimulation

Auditory

Eighteen studies reported on available, desired or recommended adjustments to reduce auditory stimulation and environmental stress (hypersensitivity), which concerned ND conditions (Black et al., 2019; Diener et al., 2020; Dreaver et al., 2020; Harvery et al., 2021; Hayward et al., 2019; Hedley et al., 2018; Kendall, 2013; Kirchner & Dziobek, 2014; Lorenz et al., 2016; Morris et al., 2015; Müller et al., 2003; North, 2021; Pfeiffer et al., 2017; Pierce, 2018; Schreuer & Dorot, 2017; Soeker, 2020; Waisman-Nitzan et al., 2019, 2021). Only one study reported on auditory stimulation as a resource and seeking self-creating desired auditory stimulation (Hayward et al., 2019). Adjustments for the reduction of auditory input included tools and/or room/location. Nine studies reported on tools, such as noise-cancelling headphones, earphones or earplugs that were permitted to be used or provided (seven studies) or classified as facilitators of employment success (two studies) (Black et al., 2019; Dreaver et al., 2020; Hedley et al., 2018; Morris et al., 2015; North, 2021; Pfeiffer et al., 2017; Pierce, 2018; Schreuer & Dorot, 2017; Waisman-Nitzan et al., 2021). Room or location adjustments were suggested by 10 studies. Of those studies, seven studies specified the need for locating the workstation or office in a quiet area (corner and quiet corridor) and avoiding workstations in open-plan offices (Diener et al., 2020; Harvery et al., 2021; Hayward et al., 2019; Morris et al., 2015; Schreuer & Dorot, 2017; Waisman-Nitzan et al., 2019, 2021). Seven studies reported on workers' suggestions to have a soundproofed private office (or high cubicle) (Black et al., 2019; Kendall, 2013; Kirchner & Dziobek, 2014; Lorenz et al., 2016; Morris et al., 2015; Pfeiffer et al., 2017; Waisman-Nitzan et al., 2019). Further, one study reporting on leaders/managers/supervisors of individuals with ASD suggested the provision of a quiet break room to facilitate decompression when feeling anxious, overstimulated or stressed (Pierce, 2018).

TABLE 4 Adjustment types by neurodiversity condition

Adjustments	Example of adjustment	Autism Spectrum disorder	Attention deficits disorders		Other Dyslexia, and other learning disability
			ADD	ADHD	
Managing environmental stimuli					
Auditory stimulation	Reduction of auditory input included tools and/or room/location, providing a private office and a quiet break room	Black et al., 2019; Diener et al., 2020; Dreaver et al., 2020; Harvery et al., 2021[a]; Hayward et al., 2019[a]; Hedley et al., 2018[a]; Kendall, 2013; Kirchner & Dziobek, 2014; Lorenz et al., 2016; Morris et al., 2015; Müller et al., 2003; North, 2021; Pfeiffer et al., 2017[a]; Pierce, 2018; Soeker, 2020[a]; Waisman-Nitzan et al., 2019, 2021[a]	Morris et al., 2015[a]	Morris et al., 2015[a]; Schreuer & Dorot, 2017	Morris et al., 2015[a]
Visual stimulation	Adjusting the type of light and reducing light levels, reducing visual distraction	Baldwin et al., 2014; Black et al., 2019, 2020; Diener et al., 2020; Dreaver et al., 2020; Harvery et al., 2021[a]; Hayward et al., 2019[a]; Hedley et al., 2018[a]; Kendall, 2013; Lorenz et al., 2016; Müller et al., 2003; North, 2021; Pfeiffer et al., 2017[a]; Pierce, 2018; Waisman-Nitzan et al., 2021[a]			
		Pfeiffer et al., 2017[a]; Pierce, 2018			

TABLE 4 (Continued)

Adjustments	Example of adjustment	Autism Spectrum disorder	Attention deficits disorders		Other Dyslexia, and other learning disability
			ADD	ADHD	
Tactile stimulation	Tactile sensory reduction, adjusting the office temperature				
Olfactory stimulation	Putting pleasant smells in the rooms	Hayward et al., 2019[a]			
Gustatory stimulation					
Movement stimulation					
Managing social stimulation	Reducing social stimulation, facilitating social interaction	Black et al., 2019; Diener et al., 2020; Hayward et al., 2019[a]; Hedley et al., 2018[a]; Kendall, 2013; Kirchner & Dziobek, 2014; Müller et al., 2003; North, 2021; Pierce, 2018; Soeker, 2020[a]	Morris et al., 2015[a]	Morris et al., 2015[a]	Morris et al., 2015[a]
Providing environmental control	Physical modification to the work environment to suit sensory and general needs, providing a private office, providing owned/private space	Black et al., 2019; Diener et al., 2020; Dreaver et al., 2020; Hayward et al., 2019[a]; Hedley et al., 2018[a]; Kendall, 2013; Kirchner & Dziobek, 2014; Lorenz et al., 2016; North, 2021; Pfeiffer et al., 2017[a]; Pierce, 2018	Morris et al., 2015[a]	Morris et al., 2015[a]	Morris et al., 2015[a]

(Continues)

TABLE 4 (Continued)

Adjustments	Example of adjustment	Autism Spectrum disorder	Attention deficits disorders		Other Dyslexia, and other learning disability
			ADD	ADHD	
Non-stimulation-specific	Adequate furniture	Pierce, 2018; Pfeiffer et al., 2017[a]	Morris et al., 2015[a]	Morris et al., 2015[a]	Morris et al., 2015[a]
	Allowing working from home	Black et al., 2019; Diener et al., 2020; Harvery et al., 2021[a]; Hayward et al., 2019[a]; Kendall, 2013; Lorenz et al., 2016; Pfeiffer et al., 2017[a]	Morris et al., 2015[a]	Morris et al., 2015[a]; Schreuer & Dorot, 2017	Morris et al., 2015[a]

[a]Sample presents comorbidity of other ND condition.

TABLE 5 Relationship between environmental stimulation/adjustment and outcome (occupational longevity, performance, health and well-being)

	Occupational longevity	
Environmental stimuli/adjustment	**Inclusion/integration**	**Employment**
Dimension 1: Adjustments for managing environmental stimulation		
Managing auditory stimulation (headphones to reduce noise; quiet workspace /locating the workstation in a quiet environment; providing private office space/individual workspaces; reducing ambient noise in the office; avoiding open-plan office/cube farm office)	Facilitating inclusion/integration in the workplace (Hayward et al., 2019 – MMC [QLD + QTD + QTNRCS]; Waisman-Nitzan et al., 2019 – QLPH); Workplace accessibility (Waisman-Nitzan et al., 2021 – QLPH)	Facilitator of maintaining employment (Black et al., 2019 – QLD; Diener et al., 2020 – QLD; Dreaver et al., 2020 – QLD; Hedley et al., 2018 – QLD; Lorenz et al., 2016 – MMC [QLD + QTNRCS]; Schreuer & Dorot, 2017 – QLPH); Appropriate employment (Harvery et al., 2021 – MMC)
Managing visual stimulation (adjusting lighting; paying attention to lighting; replacing/removing fluorescent lights; dimming lights; removing light bulbs over work area; providing blinds; allowing wearing sunglasses; reducing visual distraction; providing clear space design to reduce visual distraction)	Facilitating inclusion in the workplace (Hayward et al., 2019 – MMC [QLD + QTD + QTNRCS]); Workplace accessibility (Waisman-Nitzan et al., 2021 – QLPH)	Facilitator of maintaining employment (Black et al., 2019 – QLD; Diener et al., 2020 – QLD; Dreaver et al., 2020 – QLD; Hedley et al., 2018 – QLD; Lorenz et al., 2016 – MMC [QLD + QTNRCS]); Appropriate employment (Harvery et al., 2021 – MMC [QLD + QTNRCS])

(Continues)

TABLE 5 (Continued)

	Occupational longevity	
Environmental stimuli/adjustment	**Inclusion/integration**	**Employment**
Managing tactile stimulation	-	-
Managing olfactory stimulation (mindful of scent, putting pleasant smells)	Facilitating inclusion in the workplace (Hayward et al., 2019 – MMC [QLD + QTD + QTNRCS])	Facilitator of maintaining employment (Hayward et al., 2019 – MMC [QLD + QTD + QTNRCS])
Managing general environmental stimulation (accommodating regarding sensory dysfunctions; providing sensory-friendly environment; understanding sensory sensitivity)	Facilitating inclusion/integration in the workplace (Hayward et al., 2019 – MMC [QLD + QTD + QTNRCS]; Waisman-Nitzan et al., 2019 – QLPH)	Facilitator of maintaining employment (Schreuer & Dorot, 2017 – QLPH)
Dimension 2: Adjustments for managing social stimulation		
(Reducing social demands in the environment; avoiding open-plan office/cube farm office; workspaces away from others; providing isolated work area; locating close to co-workers to facilitate interaction)	Facilitating inclusion in the workplace (Hayward et al., 2019 – MMC [QLD + QTD + QTNRCS])	Facilitator of maintaining employment (Black et al., 2019 – QLD; Diener et al., 2020 – QLD; Hedley et al., 2018 – QLD); Appropriate employment (Harvery et al., 2021 – MMC [QLD + QTNRCS])

TABLE 5 (Continued)

Environmental stimuli/adjustment	Occupational longevity: Inclusion/integration	Occupational longevity: Employment
Dimension 3: Adjustments for providing environmental control		
(Control over the physical environment; unspecified general physical modification; providing private office space/ individual workspaces/personal space; considering personal workstation placement and design; adjusting the room)	Facilitating inclusion/integration in the workplace (Hayward et al., 2019 – MMC [QLD + QTD + QTNRCS]; Waisman-Nitzan et al., 2019 – QLPH); Creating environment that can strengthen unique skill sets and minimise weaknesses (Pierce, 2018 – QLD); Workplace accessibility (Waisman-Nitzan et al., 2021 – QLPH)	Facilitator of maintaining employment (Black et al., 2019 – QLD; Diener et al., 2020 – QLD; Dreaver et al., 2020 – QLD; Hayward et al., 2019 – MMC [QLD + QTD + QTNRCS]; Hedley et al., 2018 – QLD; Lorenz et al., 2016 – MMC [QLD + QTNRCS])
Dimension 4: Non-stimulation-specific adjustments		
(providing appropriate work setting; working from home/ utilising telecommuting)	Facilitating inclusion in the workplace (Hayward et al., 2019 – MMC [QLD + QTD + QTNRCS])	Facilitator of maintaining employment (Black et al., 2019 – QLD; Lorenz et al., 2016 – MMC [QLD + QTNRCS]); Appropriate employment (Harvery et al., 2021 – MMC [QLD + QTNRCS])

Environmental stimuli/adjustment	Performance: Focus/concentration/attention	Performance: Organisation	Performance: Overall performance
Dimension 1: Adjustments for managing environmental stimulation			
Managing auditory stimulation (noise cancelling headphones; providing quiet working space/office in a quiet	Enhancing attention (Schreuer & Dorot, 2017 – QLPH); Focusing on work (Pierce, 2018 – QLD); Mitigating	Enhancing organisation (Schreuer &	Improving work performance (Dreaver et al., 2020 – QLD; Kendall, 2013 – QLPH; Kirchner & Dziobek, 2014 –

(Continues)

TABLE 5 (Continued)

	Performance		
Environmental stimuli/adjustment	**Focus/concentration/attention**	**Organisation**	**Overall performance**
corridor; sound-dampening high cube; acoustic isolation; providing (soundproofed) private office space; making alternative work arrangement rather than open-plan office; reducing the ambient noise; adjusting noise level; avoiding loud and noisy work environment)	environmental distraction (Morris et al., 2015 – MMS [QLD + QTD + QTNRCS])	Dorot, 2017 – QLPH);	MMC; Pfeiffer et al., 2017 – QLGT); Working productively (Müller et al., 2003 – QLD); Impact on performance (Soeker, 2020 – QLD; Waisman-Nitzan et al., 2019 – QLPH) Impact on Work ability (Morris et al., 2015 – MMS [QLD + QTD + QTNRCS]);
Managing visual stimulation (adjusting lighting; dimming lights; providing natural light; incandescent rather than fluorescent lighting; little screen to block sight; allowing ability to control the light)	Focusing on work (Pfeiffer et al., 2017 – QLGT)	-	Enhancing job performance (Dreaver et al., 2020 – QLD; Kendall, 2013 – QLPH; Pfeiffer et al., 2017 – QLGT); Working productively (Müller et al., 2003 – QLD)
Managing tactile stimulation (fidget toy; adjusting temperature)	Helping to concentrate on work (Pierce, 2018 – QLD)	-	Improving work performance (Pfeiffer et al., 2017 – QLGT)
Managing general environmental stimulation (considering sensory stimulation and distraction in work environment; understanding the sensory sensitivity)	-	-	Impact on performance (Soeker, 2020 – QLD; Waisman-Nitzan et al., 2019 – QLPH)
Dimension 2: Adjustments for managing social stimulation			
(alternative work arrangement rather than open-plan office; considering how many people are in the work environment; office in a quiet corridor not much "human traffic" passing; physically separating or relocating loud/noisy teams; providing the option to lock doors to limited access by co-workers; undisturbed working space; an office enabling worker to focus; opportunity to retreat)	-	-	Facilitator of work performance (Kendall, 2013 – QLPH; Kirchner & Dziobek, 2014 – MMC); Working productively (Müller et al., 2003 – QLD); Impact on Work ability (Morris et al., 2015 – MMS [QLD + QTD + QTNRCS]); Impact on performance (Soeker, 2020 – QLD)

TABLE 5 (Continued)

Environmental stimuli/adjustment	Performance		
	Focus/concentration/attention	Organisation	Overall performance
Dimension 3: Adjustments for providing environmental control			
(Control over the physical environment; providing private office space/single room; providing controllable environments such as small office; giving autonomy over the environment when a participant worked alone)	Mitigating distracting effects from open-plan offices (Morris et al., 2015 – MMS [QLD + QTD + QTNRCS])	-	Facilitator of work performance (Kendall, 2013 – QLPH; Kirchner & Dziobek, 2014 – MMC [QLD + QTD] [QLD + QTD]; Pfeiffer et al., 2017 – QLGT); Impact on performance (Waisman-Nitzan et al., 2019 – QLPH)
Dimension 4: Non-stimulation-specific adjustments			
(working from home; extending size of desk)	Enhancing attention (Schreuer & Dorot, 2017 – QLPH)	Enhancing organisation (Schreuer & Dorot, 2017 – QLPH)	Facilitator of work performance (Kendall, 2013 – QLPH; Pfeiffer et al., 2017 – QLGT)

Environmental stimuli/ adjustment	Health and well-being	
	Physical health	Mental health/well-being
Dimension 1: Adjustments for managing environmental stimulation		
Managing auditory stimulation (noise-cancelling headphones; providing quiet break room)	-	Impact on work satisfaction (Pfeiffer et al., 2017 – QLGT); Being critical to workplace well-being (Pierce, 2018 – QLD)
Managing visual stimulation (controlling the lights)	Being helpful when experiencing headaches (Pfeiffer et al., 2017 – QLGT)	Impact on work satisfaction (Pfeiffer et al., 2017 – QLGT)
Managing tactile stimulation (fidget toys; controlling temperature)	-	Helping to reduce anxiety (Pierce, 2018 – QLD); Helping to reduce overstimulation symptoms such as irritability, outburst (Pierce, 2018 – QLD); Impact on work satisfaction (Pfeiffer et al., 2017 – QLGT)

(Continues)

TABLE 5 (Continued)

Environmental stimuli/ adjustment	Health and well-being	
	Physical health	Mental health/well-being
Managing general environmental stimulation (providing a decompression room, a sensory break room with sensory reduction items)	-	Being helpful to alleviate stress (Pierce, 2018 – QLD)
Dimension 2: Adjustments for managing social stimulation		
(providing conversational break room)	-	Being critical to workplace well-being (Pierce, 2018 – QLD)
Dimension 3: Adjustments for providing environmental control		
Control over the physical environment; adjustment reducing sensory or physical aversions; providing (soundproofed) private office/personal space; providing controllable environments such as small office; giving autonomy over the environment when a participant worked alone	-	Impact on work satisfaction (Pfeiffer et al., 2017 – QLGT); Mitigating stressful effects from open-plan offices (Morris et al., 2015 – MMS [QLD + QTD + QTNRCS])
Dimension 4: Non-stimulation-specific adjustments		
(Treadmill desks; expanding desk; working from home; overall adjustment)	-	Alleviating anxiety (Morris et al., 2015 – MMS [QLD + QTD + QTNRCS]); Reducing stress from interpersonal interaction (Morris et al., 2015 – MMS [QLD + QTD + QTNRCS]); Improving work satisfaction (Pfeiffer et al., 2017 – QLGT); Isolation, if adjustment is provided inappropriately (North, 2021 – QLD)

Abbreviations: MMC, mixed-methods, convergent design; MMS, mixed-methods, sequential explanatory design; QLD, qualitative (descriptive); QLGT, qualitative (grounded theory); QLPH, qualitative (phenomenological); QTD, quantitative (descriptive); QTNRCS, quantitative non-randomised (cross-sectional).

Visual

Fifteen studies reported on available, desired or recommended adjustments to reduce visual stimulation and environmental stress (hypersensitivity) for workers with autism (Baldwin et al., 2014; Black et al., 2019, 2020; Diener et al., 2020; Dreaver et al., 2020; Harvery et al., 2021; Hayward et al., 2019; Hedley et al., 2018; Kendall, 2013; Lorenz et al., 2016; Müller et al., 2003; North, 2021; Pfeiffer et al., 2017; Pierce, 2018; Waisman-Nitzan et al., 2021). No other ND conditions were covered, nor did any study report on the provision of visual stimulation to accommodate hyposensitivity. Adjustments that specifically target light sensitivities of autistic workers included adjusting the type of light and reducing light levels. Six studies reported that natural, incandescent light is preferred/suggested and fluorescent light should be avoided (Diener et al., 2020; Harvery et al., 2021; Kendall, 2013; Müller et al., 2003); desk lamps were preferred over overhead lighting (North, 2021), and special lighting was suggested (Baldwin et al., 2014). Ten studies suggested giving autistic employees control to reduce the light levels by dimming lights, switching the light off, removing light bulb over work area or generally not working in a cubicle environment where the light is bright and not controllable (Black et al., 2019, 2020; Dreaver et al., 2020; Harvery et al., 2021; Hedley et al., 2018; Kendall, 2013; Lorenz et al., 2016; Pfeiffer et al., 2017; Pierce, 2018) or by using tools such as blinds or wearing sunglasses (Dreaver et al., 2020; Hayward et al., 2019). Adjustments that specifically target visual distractions (e.g. movement of other people) were reported by two studies and included visual screens (Pfeiffer et al., 2017; Waisman-Nitzan et al., 2021) and clear space design (Waisman-Nitzan et al., 2021).

Tactile

One study reported on requested adjustments to address undesired tactile stimulation and environmental stress (hypersensitivity) in an autistic sample, specifically adjusting the office temperature (Pfeiffer et al., 2017). Another study focused on study leaders/managers/supervisors' suggestions to provide tactile sensory reduction items, such as fidget toys, and a private decompression room to reduce overstimulation symptoms in autistic workers (Pierce, 2018).

Olfactory

No study mentioned specific adjustments to reduce olfactory stimulation, although one did suggest that the use of personal fragrances can assist autistic workers and that employers should consider this as a potential adjustment (Hayward et al., 2019).

Modality unspecific sensory accommodations

Several authors made general suggestions, such as providing a sensory-friendly environment (Hayward et al., 2019) and accommodating sensory sensitivity (Schreuer & Dorot, 2017; Waisman-Nitzan et al., 2019). The facilitation of a decompression room was one more specific adjustment suggested for autistic workers experiencing symptoms of overstimulation (Pierce, 2018).

Dimension 2: Adjustments for managing social stimulation

Nine studies reported on available, desired or recommended adjustments to reduce social stimulation, which concerned all included neurodiversity conditions (Black et al., 2019; Diener

et al., 2020; Harvery et al., 2021; Hayward et al., 2019; Kendall, 2013; Kirchner & Dziobek, 2014; Morris et al., 2015; Müller et al., 2003; Soeker, 2020). Adjustments included avoiding open-plan office/shared office spaces and providing private work areas. These could encompass a private office, workspace away from others, office in a quiet corridor with less 'human traffic' passing, offering withdrawal options, relocating noisy co-workers or other means of reducing social crowding (Black et al., 2019; Diener et al., 2020; Harvery et al., 2021; Hayward et al., 2019; Kendall, 2013; Kirchner & Dziobek, 2014; Morris et al., 2015; Müller et al., 2003; Soeker, 2020). Three studies reported on desired and available adjustments to facilitate social interaction in autistic samples (Hedley et al., 2018; North, 2021; Pierce, 2018). Adjustments included social break rooms and locating workstations close to co-workers. One study highlighted that, contrary to stereotypical assumptions, many participants who were provided with a separate workspace indicated that they did not want to work in complete isolation but with social interaction (North, 2021).

Dimension 3: Adjustments for providing environmental control

Twelve studies reported on available, desired or recommended adjustments to allow for environment control at work, which concerned all ND conditions relevant to our review. Of those, seven studies raised unspecified general physical modification to the work environment to suit sensory and general needs (Black et al., 2019; Diener et al., 2020; Dreaver et al., 2020; Hayward et al., 2019; Hedley et al., 2018; Pfeiffer et al., 2017; Pierce, 2018); four studies specified the control over physical stimulation (e.g. lighting, sounds, smells or temperature; Black et al., 2019; Hayward et al., 2019; Kendall, 2013; Pfeiffer et al., 2017). Seven studies specified the necessity of providing a private office to reduce sensory overload and distraction across neurodiversity conditions (Black et al., 2019; Hayward et al., 2019; Kendall, 2013; Kirchner & Dziobek, 2014; Lorenz et al., 2016; Morris et al., 2015; North, 2021). Furthermore, providing owned/private space ('his own corner' and 'my own space, my personal space') was not only related to increased control over the sensory and socio-spatial environment but also facilitated an increased sense of self and identification in two studies of autistic employees (Pfeiffer et al., 2017; Waisman-Nitzan et al., 2019). Interestingly, one study reported that workers with autism were significantly more likely to identify control over the physical environment as an employment enabler than neurotypical workers (Hayward et al., 2019).

Dimension 4: Non-stimulation specific adjustments

Three studies described sensory-unspecific adjustments, which we considered resources. These concerned workers with autism and ADD and included adequate furniture (suggested by leaders/managers/supervisors of individuals with ASD; Pierce, 2018), 'a good seat' (Morris et al., 2015), a treadmill desk to alleviate anxiety during the workday (Morris et al., 2015) and adequate/extended desk size (Pfeiffer et al., 2017). Nine studies highlighted being allowed to work from home as an environment-related and policy-related adjustment for managing sensory and socio-environmental needs (Black et al., 2019; Diener et al., 2020; Harvery et al., 2021; Hayward et al., 2019; Kendall, 2013; Lorenz et al., 2016; Morris et al., 2015; Pfeiffer et al., 2017; Schreuer & Dorot, 2017).

Dimension 5: Related outcomes

Regarding the available evidence for physical workplace adjustment to support occupational longevity, performance and health/well-being, we present a summary of the results in Table 6. Due to the heterogeneous quality, study designs, aims and outcomes explored, related outcomes are merely indicative.

Occupational longevity

Twelve studies indicated a relationship between adjustments and occupational longevity across ND conditions. Specifically, nine studies suggested that sensory adjustments, socio-spatial adjustments, such as private work areas, environmental control including enabling individuals to alter physical environment conditions, allowing working from home, understanding individual needs and provision of a sensory-friendly environment at baseline can facilitate obtaining appropriate employment (Harvery et al., 2021), maintaining employment (Black et al., 2019; Diener et al., 2020; Dreaver et al., 2020; Harvery et al., 2021; Hayward et al., 2019; Hedley et al., 2018; Lorenz et al., 2016; Schreuer & Dorot, 2017) and improving workplace accessibility and inclusion/integration (Hayward et al., 2019; Waisman-Nitzan et al., 2019, 2021). Such adjustments can also assist in creating an environment that can strengthen unique skill sets and minimise weaknesses, as suggested by leaders/managers/supervisors of individuals with ASD (Pierce, 2018). Conversely, a lack of adjustments to sensory sensitivities (e.g. inadequate temperature and type/level of light, noisy, open and crowded environment) and social regulation needs (e.g. isolated/private work area) were identified as challenges in the workplace (Harvery et al., 2021; Schreuer & Dorot, 2017), barriers to maintaining employment (Black et al., 2019; Diener et al., 2020; Lorenz et al., 2016) and to workplace integration, as suggested by employers of individuals with ASD (Waisman-Nitzan et al., 2019). Further, two studies indicated suggestive relationships between the physical work environment and both positive and negative experiences during employment (Baldwin et al., 2014) and between receiving workplace adjustments and having appropriate employment (e.g. not being underemployed or underutilised; Harvery et al., 2021).

Performance

Eleven studies indicated a relationship between environmental factors or sensory adjustments and various performance-related outcomes (Black et al., 2020; Dreaver et al., 2020; Kendall, 2013; Kirchner & Dziobek, 2014; Morris et al., 2015; Müller et al., 2003; Pfeiffer et al., 2017; Pierce, 2018; Schreuer & Dorot, 2017; Soeker, 2020; Waisman-Nitzan et al., 2019). Specifically, eight studies reported a relationship between enhanced performance and environmental modifications. These modifications included reducing light brightness and ambient noise, sound dampening high cube, providing natural and incandescent light, control over light and temperature, expending desk size, private office/room, office in a quiet corridor not so much 'human traffic' passing and alternatives to open-plan offices (Dreaver et al., 2020; Kendall, 2013; Kirchner & Dziobek, 2014; Morris et al., 2015; Müller et al., 2003; Pfeiffer et al., 2017; Soeker, 2020; Waisman-Nitzan et al., 2019) and opportunity to use a home office (Kendall, 2013; Pfeiffer et al., 2017). Acoustic isolation through workstations in quiet areas/private office, using noise-cancelling headphones or working at home enhanced attention and organisation skills at work by mitigating environmental distraction (Morris et al., 2015; Schreuer & Dorot, 2017). Two studies reported that participants used fidget toys, noise-cancelling headphones, and screens to block sight to improve concentration (Pfeiffer et al., 2017; Pierce, 2018). There were also suggestions that performance can be affected by

TABLE 6 Data extraction

Author/year/country	Study design	Sample characteristics as described in the study	Education level	Occupation
Baldwin et al., 2014, Australia	Mixed methods, convergent design (qualitative descriptive, quantitative descriptive and cross-sectional)	130 participants: Individuals with Asperger's disorder and high-functioning autism (68% male; aged 18–65; mean age 35.68; formal diagnosis)	Bachelor degree or higher (24), TAFE Diploma or Advanced Diploma (36), TAFE Certificate III–IV (14), TAFE Certificate II–III or HSC (38), TAFE Certificate I or School certificate (12)	Clerical and administrative worker, labourers, professionals, technicians and trades workers, community and personal services workers
Black et al., 2019, Australia, Sweden, USA	Qualitative (participatory research, descriptive)	79 participants: 19 autistic individuals (42% male; no information about diagnosis provided),18 family members, 21 service providers, 11 employers, 5 researchers, and 5 advocacy group representatives	No information	No information
Black et al., 2020, Australia, Sweden, USA	Quantitative non-randomised (cross-sectional)	687 participants: 246 autistic individuals (80% male; aged 18–70; mean age 36.9; no information about diagnosis provided), 233 family members (79% male; aged 6–50; mean age 21.2), 35 employers, 123 clinicians/service providers, 50 researchers	No information	No information about occupation, but industry: Retail, information media, financial insurance, administrative and support services, education, health care
Diener et al., 2020, USA	Qualitative (participatory research, descriptive)	20 participants: 10 individuals with ASD, 10 supervisors (55 male; aged 19–54)	All participants had high school diplomas	Retail, technical support, pharmacy technician, group home staff, software tester, programmer, customer service, executive assistant
Dreaver et al., 2020, Australia, Sweden	Qualitative (descriptive)	20 participants: 4 company directors and 16 line managers of individuals with ASD	No information	No information
Harvery et al., 2021, Australia	Mixed methods, convergent design (qualitative descriptive, cross-sectional)	149 participants: 149 autistic individuals (41% male; aged 25–80; mean age 41)	Year 10 qualification (6), Year 12 qualification (11), Certificates I, II, III, IV (19), Diploma (14), Advanced diploma, Associate degree (8), Bachelor degree	Managers, professionals, technicians and trade workers, community and personal service workers, clerical and administrative workers, sales

TABLE 6 (Continued)

Author/year/ country	Study design	Sample characteristics as described in the study	Education level	Occupation
			(49), Graduate certificate/ diploma (15), Master's degree (22), Doctoral degree (5)	workers, machinery operators and drivers, labourers
Hayward et al., 2019, Australia	Mixed methods, convergent design (qualitative descriptive, quantitative descriptive and cross-sectional)	76 participants: 44 with autism (aged 18–68; mean age 36.68), 32 neurotypical (aged 23–62; mean age 29.97)	Year 9 high school (1), Completion of Year 10 high school or junior vocational school (2), Completion of high school (19), Diploma (12), Bachelor degree (32), Master (7), Doctor (3)	No information
Hedley et al., 2018, Australia	Qualitative (descriptive)	28 participants: 9 individuals with ASD (89% male; aged 19–29) 6 family members (33% male; aged 24–55), 7 support staff (29% male; aged 25–51), 6 co-workers (67% male; aged 33–52)	Secondary (3), Secondary completed (5), Certificate (6), Diploma (2), Bachelor's degree (9), Postgraduate degree (1)	Software test analysts, experienced test analysts, consultant, software test analysts
Kendall, 2013, USA	Qualitative (phenomenological)	5 participants with Asperger's syndrome (80% male, aged 30–59)	Two-year associates degree (1), Bachelor degree (1), Graduate degree (1), Doctorate (1), MBA (1)	Software developer, tester in image analysis, subject matter expert, project/programme manager
Kirchner & Dziobek, 2014, Germany	Mixed methods, convergent design (qualitative descriptive, quantitative descriptive)	76 participants: Adults with Asperger syndrome (43.4% male; aged 19–60; mean age 36.1)	No school degree (2), basic school degree (14), vocational degree (12), superior school education (17), university degree (22)	No information
Lorenz et al., 2016, Germany	Mixed methods, convergent design (qualitative descriptive, quantitative cross-sectional)	66 participants: Employed individuals with autism (45% male; aged 22–55; mean age 35.96)	No information	Architecture, natural sciences, geography and computer science, business organisation, accounting, law, administration
Morris et al., 2015, USA	Mixed methods, sequential exploratory design (qualitative descriptive, quantitative descriptive and cross-sectional)	856 participants: Interview: 10 neurodiverse technology workers (90% male; aged 23–52; 4 ASD, 4 Asperger's, 1 ADHD, 1 PDD-NOS) survey: 846 participants: 781 neurotypical and 59 neurodiverse respondents (32.5% male; aged 21–71;	Survey: Bachelor (642, 75.9%), graduate degree (124, 14.7%), no undergraduate, graduate degree (55, 6.5%)	Software engineer, software tester, data architect, electrical engineering, data Centre management

(Continues)

TABLE 6 (Continued)

Author/year/country	Study design	Sample characteristics as described in the study	Education level	Occupation
		11ASD, 38 ADD, 16 dyslexia or another learning disability) -technology workers		
Müller et al., 2003, USA	Qualitative (descriptive)	18 participants: Individuals with ASDs (72% male; aged 18–62)	High school (2), College (2), Associate degree (4), B.A. (4), M.A. & MBA, MFA (4), PhD (2)	No information
North, 2021, UK	Qualitative (participatory research, descriptive)	15 individuals with autism (formal and self-diagnosis) female	No information	No information
Pfeiffer et al., 2017, USA	Qualitative (grounded theory)	14 participants: 9 individuals with Asperger disorder, 1 pervasive developmental disorder not otherwise specific (PDD-NOS), 4 high-functioning autism (43% male; aged 21–67; mean age 40)	High school (3), post-secondary (5), college courses complete (3), college degree (3)	Teacher, assistant, computer systems analysist, employment specialist, IT call specialist, data entry specialist, nurse, janitor, communication specialist, dog groomer, telephonic customer software developer, IT, patient care
Pierce, 2018, USA	Qualitative (case study, descriptive)	11 participants: Leaders, managers, frontline supervisors of individuals with high functioning autism (55% male; aged 27–66)	No information	Programme service specialist, social worker, job coach, tech specialist, executive director
Schreuer & Dorot, 2017, Israel	Qualitative (phenomenological)	11 participants: ADHD diagnosed women (aged 25–45)	All participants are tertiary educated	Teacher, social and health services workers, graphic designer, chemical technician, executive secretaries
Soeker, 2020, South Africa	Qualitative (descriptive)	15 participants: 10 individuals with ASD (aged 21–53), 5 informants working with autistic individuals in a skill-training programme	High school (1), high school diploma (3), Tertiary education (4), Diploma (2)	Project manager, lecturer, online student success manager, IT lab manager, general assistant, stockroom

TABLE 6 (Continued)

Author/year/country	Study design	Sample characteristics as described in the study	Education level	Occupation
Waisman-Nitzan et al., 2019, Israel	Qualitative (phenomenological)	11 participants: Employers of individuals with ASD (73% male; mean age 45.8)	High school (1), Tertiary (1), Academic (9)	Library manager, first line supervisor, chef, technical manager, computer systems manager, education administer, surveyor, archaeology teacher
Waisman-Nitzan et al., 2021, Israel	Qualitative (phenomenological)	19 employees with ASD (40% male; aged 22–41; mean age 26.8)	12 years of education completed (4), secondary education graduated (15)	Office and administrative support, food preparation, sales, education, art, design, helpers productions workers, computer, mathematical

Note: Study design categorisation based on the MMAT (Hong et al., 2018). Adjustments in *italics* are not associated with an outcomes.

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
Baldwin et al., 2014, Australia	To provide a detailed overview of the occupational activities and experiences of a large sample of adults who have an autism spectrum disorder	Questionnaire (quantitative outcome: Occupation; educational alignment; job contract; work hours; job search support; job support; qualitative: Open ended questions on three best/worst things during employment)	Poor working conditions and physical environment were reported as negative experience of employment with adults with high-functioning autism and Asperger's disorder. Modifications to working conditions (arranging special lighting) was reported as a support received in the workplace.	• special lighting	Occupational longevity (positive and negative experiences during employment) Health/well-being (health and well-being issues as negative experience of employment)

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
Black et al., 2019, Australia, Sweden, USA	To identify the factors perceived to determine gaining and maintaining employment for autistic individuals	Focus groups (5), interviews (12), community forum (1)	Results suggest that enhancing environmental facilitators (providing physical adjustment) and removing environmental barriers (sensory stimuli in the environment, open and crowded workspaces) may assist successful employment and reduce difficulties in the workplace.	• physical adjustments (adjusting the room, lighting, providing private office space) • opportunity to use workspaces away from others • products and technology to accommodate barriers in the environment (such as headphones to reduce noise) • allowing to work from home	Occupational longevity (maintaining employment)
Black et al., 2020, Australia, Sweden, USA	To gain the perspectives of autistic individuals, their families, employers, clinicians/service providers and researchers on the facilitators and barriers to employment for autistic individuals	Questionnaire (outcome measure: Self-developed items on barriers and facilitators to employment across the stages preparing for, gaining and maintaining a job; agreement items from prior study)	Whereas majority of autistic individuals strongly agreed that the lighting of the room can affect an employees' ability to work, only 20% of employers strongly agreed. Key stakeholder groups did not differ when considering the importance of making the workplace more accessible and friendly.	• adjustment of room lighting	Performance (ability to work)

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
Diener et al., 2020, USA	To explore the dual employment perspectives of adults with ASD and supervisors who worked with individuals with ASD.	Semi-structured interviews	Providing environment modifications to reduce social demands, such as isolated work area; changes to physical environment was a facilitator of success in the workplace	• quiet area to work in • replacing fluorescent lights • providing quiet office • providing isolated work area • changes to physical environment • adjustment with respect to ambient noise • allowing to work from home • allowing the use of headphones	Occupational longevity (person–environment fit, enablers and barriers to maintain employment)
Dreaver et al., 2020, Australia, Sweden	To explore the organisational and individual factors facilitating successful employment of adults with ASD from the perspective of line managers and directors	Semi-structured interviews	Providing a supportive work environment by considering the physical environment was identified as an important facilitator of successful employment for employee with ASD.	• enabling adaptations to the physical environment • adjustments to sensory demands of the environments • reducing the brightness of light (dimming lights)	Occupational longevity (maintaining employment) Performance

(Continues)

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
				• providing blinds • reducing ambient noise in the office • providing headphones	
Harvery et al., 2021, Australia	To describe the employment profiles and explore factors related to employment for Australian autistic adults	Questionnaire (quantitative outcome: Coded as "unemployment", "underemployment", or "underutilization" based on demographic information aligned with Australian and New Zealand standard classification of occupations system and Australian Bureau of Statistics guidelines; qualitative: Open-ended questions specifying workplace adjustments)	Among 31 people who indicated that workplace adjustment was implemented in their workplace, 9 responded that they had sensory adjustments. Besides, 28% or participants who desire workplace adjustments, reported desire of sensory adjustment. Those who received workplace adjustments were 3.14 times more likely to be appropriately employed. Comments mostly regarded adjustments for autism-specific needs, which included comments on sensory adjustments (e.g. "removed light bulbs over work area").	• removing fluorescent lighting • removing light bulbs over work area • avoiding open-plan/cube farm office • allowing to work from home	Occupational longevity (appropriate employment not underemployed, underutilised)
Hayward et al., 2019, Australia	To investigate the employment enablers for individuals with autism and determine whether these differed from those who are neurotypical	Questionnaire (open-ended questions, quantification of themes post hoc), focus group (1)	Adjustment in physical environment can facilitate employment and inclusion in the workplace. In particular compared with neurotypical individuals, autistic individuals significantly more often reported that control over the	• alterations to the physical environment to accommodate oneself to suit sensory sensitivities	Occupational longevity (maintaining employment; inclusion of workers with

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
			physical environment is an enabler of employment	• providing sensory-friendly environments • allowing single-office spaces and avoiding open-plan design • paying attention to lighting and scents • allowing to work from home	ASD in the workplace)
Hedley et al., 2018, Australia	To gain better understanding of the experience of transition to work, barriers and also the factors that promote workplace success	Focus groups (8)	Several workplace environmental modifications and adjustments such as changing lighting were identified as facilitators of successful employment	• changes to lighting (dimming light) • flexibility regarding environmental adjustment	Occupational longevity (enablers and barriers to maintaining employment)
Kendall, 2013, USA	To explore the lived experiences of software development team members with Asperger's syndrome/high-functioning autism on software development projects	Semi-structured interviews	Work environment emerged as the most important theme among participants.	• providing quiet private work area • sound dampening high cube • having natural light • allowing ability to control the light • providing own private office	Performance (in relation to software development)

(Continues)

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
				• office in a quiet corridor, not much "human traffic" • allowing to work from home • physically separating or relocating loud/noisy teams • providing the option to lock doors to limited access by co-workers	
Kirchner & Dziobek, 2014, Germany	To assess the special interest of adults with ASD and identify influencing factors on successful employment	Questionnaire (times spent on interests, facilitators and barriers of job performance, open-ended questions interests)	Sensory issue factors such as temperature, lighting, noise, body contact, smell, dirty work environment were found as factors interfering with work performance. In addition, adjustment in physical work environment was found as facilitator of work performance for ASD employees	• providing a single room • opportunity to retreat • providing quiet surroundings • undisturbed working space	Performance
Lorenz et al., 2016, Germany	To discover how individuals with autism succeed in entering the job market	Questionnaire (general and occupational self-efficacy, life and job satisfaction survey, open-ended questions)	Participants reported work setting and sensory issues as barriers of employment. Reducing distracting stimuli by providing individual	• reducing distracting stimuli through the creation of individual workspaces	Occupational longevity (maintaining employment)

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
			workplaces to autistic employees found to be important and necessary.	• allowing to work from home • providing an appropriate work setting • understanding of individual needs	
Morris et al., 2015, USA	To understand the perspectives and experiences of technology workers with ASD, ADHD, and/or other learning disabilities, such as dyslexia	Semi-structured interview, questionnaire (type of adjustments, on the job experiences/challenges, disclosure, and discrimination)	In both interviews and survey, participants found that environment distraction is challenging. In the survey, neurodiverse employees reported significantly higher perceived level of challenge when working in a shared office (neurotypical = 3.1, other = 3.7, $p < .001$) and working in a noisy setting (neurotypical = 3.7, other = 4.2, $p = .001$). Participants suggested changing the workplace arrangement to provide more quiet work environments or private office spaces.	• providing a private office, perhaps even soundproofed • providing an office which enables workers to focus • avoiding open floorplan "shared space" • allowing flexibility to work from home • providing a treadmill desk • allowing to wear headphones • *providing a quieter environment* • *good seat*	Performance (work ability) Health/well-being (feeling stressed, anxiety, well-being)

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
Müller et al., 2003, USA	To seek consumer perspectives on strategies for improving vocational placement and job retention services for individuals with Asperger syndrome and other autism spectrum disabilities	Semi-structured interviews	Participants indicated sensory difficulties with visual, auditory and tactile stimulation in workplace. They reported that they were able to work more productively if there was minimal sensory stimulation in workplace.	• providing space with minimal ambient sound • providing natural or incandescent rather than fluorescent lighting • providing a calm and tranquil workspace without a lot of distractions	Performance
North, 2021, UK	To gain a deeper understanding of the experiences of being an autistic woman by exploring their rich narratives of the difficulties, and the advantages, of being different in the workplace	Focus groups (2), semi-structured interviews (10)	Participants reported adjustments were prescribed by employers without discussion. Regarding sensory overload, some participants were provided with a separate workspace, which led to sense of isolation	• not providing inappropriate adjustment • *providing a separate space to work* • *providing a lamp rather than overhead lighting* • *providing noise-cancelling headphone* • *locating a desk in the corner rather than in a busy communal space*	Health/well-being (isolation)

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
Pfeiffer et al., 2017, USA	To understand the impact of (physical and social) environmental factors on work performance and satisfaction from the perspective of adults with ASD.	Semi-structured interviews	Participants in this study reported that physical environment factors in the workplace can influence their work performance and satisfaction.	• allowing to change the temperature • adjusting lights • avoiding loud and noisy work environment • providing expandable desk • providing own space, personal space • modifying the environment (e.g. private office) • giving autonomy over the environment when a participant worked alone • allowing to work from home • screen to block out visual disturbances • noise-cancelling headphones	Performance Health/well-being (work satisfaction)

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
Pierce, 2018, USA	To identify leaders' strategies for supporting autistic employees	Semi-structured interviews	Adjustment in physical work environment encompass various dimensions. No single facet applies universally to all employees, but each adjustment enables autistic employees to work optimally	• providing a decompression room (a sensory break room with sensory reduction items) • individualised adjustment • providing a quiet break room • providing a social break room • providing and promoting the use of noise-cancelling headphones • fidget toys • *dimming lights* • *providing earplugs* • *furniture*	Occupational longevity (strengthening unique skills, minimising weaknesses) Performance
Schreuer & Dorot, 2017, Israel	To explore the experiences of working women with ADHD and learn the strategies and adjustments that facilitate employment maintainment	Semi-structured interviews	Employees with ADHD have challenges dealing with too much/not enough sensory stimulation in workplace	• locating the workstation in a quiet environment at work • allowing to work in a suitable environment at home	Occupational longevity (maintaining employment)

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
Soeker, 2020, South Africa	To explore the experiences and perceptions of individuals living with ASD about transitioning from a skills training programme to the open labour market (barriers and facilitators when transitioning; individual adaptation strategies)	Semi-structured interviews	The work environment was found to be a significant influencing factor on work performance of individuals with ASD. Physical and sensory factors were emphasised as being participants. Participants reported that the sensory physical environment should be considered	• considering stimuli related to the sensory and physical environment • considering how many people are in the work environment/ social density • considering noise levels • considering distractions	Performance Health/well-being (e.g. overwhelmed/
Waisman-Nitzan et al., 2019, Israel	To learn from employers who experienced the successful employment of people with ASD, and to deepen understanding of the workplace adjustments	Interview (1 focus group for validation purposes)	Employers of ASD are aware of physical and sensory environment barriers and of possible adjustments for ASD employees; those are more related to auditory stimulation and not to the influence of other types of stimuli (e.g. lighting).	• providing personal space • understanding the sensory sensitivity and allowing a quiet working station	Occupational longevity (integration) Performance

TABLE 6 (Continued)

Author/year/country	Objective	Methods/measures	Key findings pertinent to this review	Workplace adjustment (available, desired or recommended)	Outcome domain
Waisman-Nitzan et al., 2021, Israel	To understand what an accessible working environment is, according to ASD workers' perceptions, and to use this understanding to recommend best practices to enhance workplace accessibility that facilitates their work diligence	Semi-structured interviews (2 focus groups for validation purposes)	Participants reported sensory processing difficulties in the workplace. They indicated needs for adjustment in physical and sensory environment such as allocating quiet space and the reduction of visual distractions.	• noise reduction: Allocating quiet space and tolerate frequent "escape breaks" • reducing visual distractions • clear space design to reduce visual distractions • considering personal workstation placement and design • providing earphones or allowing the use of earphones	Occupational longevity (maintaining employment, workplace accessibility)

Note: Study design categorisation based on the MMAT (Hong et al., 2018). Adjustments in *italics* are not associated with an outcomes.

sensory disturbances. These included smell, temperature, background noise, loud conversations, crowding, visual distraction (e.g. people passing by or cluttered desks; Black et al., 2020; Kirchner & Dziobek, 2014; Pfeiffer et al., 2017; Pierce, 2018; Soeker, 2020; Waisman-Nitzan et al., 2019) and a lack of environmental adjustments (Morris et al., 2015; Pfeiffer et al., 2017; Waisman-Nitzan et al., 2019).

Health/well-being

Six studies indicated a relationship between environmental factors or sensory adjustments and various health/well-being outcomes (Baldwin et al., 2014; Morris et al., 2015; North, 2021; Pfeiffer et al., 2017; Pierce, 2018; Soeker, 2020) Specifically, too much sensory information in the environment, such as large and loud work environments, left participants feeling overwhelmed. In contrast, control over sensory adaptations to the work environment were reported to reduce sensory and physical aversions (Pfeiffer et al., 2017; Soeker, 2020) and increase satisfaction (Pfeiffer et al., 2017). Lighting control was crucial when participants suffered from headaches (Pfeiffer et al., 2017). Working in a soundproofed private office and having the opportunity to use a home office relieved stress and improve work satisfaction (Morris et al., 2015; Pfeiffer et al., 2017). Access to breakout rooms that are quiet and to breakout rooms that are social was critical to general workplace well-being. Providing a decompression room (sensory break room with sensory reduction item) was reported by leaders/managers/supervisors of individuals with ASD to be helpful in alleviating stress in workers with ASD (Pierce, 2018). Regarding special equipment, fidget toys alleviated anxiety, relieved stress and reduced overstimulation symptoms, such as irritability and outbursts (Pierce, 2018). The provision of a treadmill desk was suggested for mitigating anxiety (Morris et al., 2015). Furthermore, working from home reduced stress from interpersonal interaction (Morris et al., 2015) and providing an expanding desk improved satisfaction (Pfeiffer et al., 2017). In contrast, a poor physical work environment and inappropriate/insufficient reasonable adjustments were linked to an overall negative work environment (Baldwin et al., 2014), leading to stigmatisation and isolation, which have a negative impact on career development (North, 2021).

DISCUSSION

It was our intent to examine the evidence regarding extent, robustness and quality of physical workplace adjustments to support occupational longevity, performance and health/well-being in ND workers with specific sensory needs.

Extent, nature and quality of evidence found

The review identified a number of adjustments available to ND workers and the perceived benefit that these adjustments afford. However, the review revealed an underdeveloped evidence base, comprising studies of varying methodological quality without any robust intervention study designs. Such lack of rigourous experimental work means that we do not yet know which types of adjustments yield robustly evidenced positive outcomes, neither do we know clearly under which circumstances or for whom. Such a vacuum is preventing the development of evidence-based practice, including quality control and return on investment specifications (Briner & Rousseau, 2011; Doyle, 2020; Doyle & McDowall, 2021). None of the studies focused solely on the efficacy of physical workplace adjustments but explored a mix of psychosocial and

physical adjustments in an unsystematic fashion. Therefore, it is difficult to draw firm conclusions for four reasons.

First, most studies used mixed work settings (only four studies used office-only settings). Second, most of the evidence concerns workers with a primary condition of ASD (although ND-relevant comorbidities existed, e.g. ASD with underlying ADHD), leaving other ND groups underrepresented, which is a common issue in ND research (cf. Doyle & McDowall, 2021). Third, studies ($N = 5$) used mixed-diagnoses-type samples that were formally, informally and/or self-diagnosed. This reflects a current debate in the field, where some recommend the exclusion of self-diagnosed individuals to ensure common diagnostic framing, whereas others point to the necessity of inclusion as the high number of under-diagnosis due to various barriers of receiving a formal diagnosis (e.g. access to clinicians, cost and potential stigma; Huang et al., 2020) and changes, for example in autism diagnostic criteria (Lai & Baron-Cohen, 2015). Although the present study differentiated self- from formally diagnosed individuals (cf. Harvery et al., 2021) in the data extraction table, it cannot offer this level of differentiation in the results. Fourth, validity of the study findings might be threatened by an overrepresentation of females in comparison to latest estimated prevalence in society. On the one hand, this could be due to under-diagnosed ASD conditions in females, which is currently widely discussed (Loomes et al., 2017). On the other hand, females might find their way into employment easier as they internalise more (Bauminger et al., 2010). Similarly, females might be more interested to report their experiences and participate in ND research due to their higher tendency for social camouflaging to increase their social acceptance (Cook et al., 2021; Dean et al., 2017; Nagib & Wilton, 2020). Hence, it is not entirely clear whether the results are a valid representation for both genders with ASD or whether any gender-differentiated adjustment needs exist in the first place.

Extent and nature of sensory adjustments

With regard to the extent and nature of adjustments to support ND workers with specific sensory needs, visual and acoustic adjustments were most prevalent. However, included studies addressed sensory modalities in an unsystematic way, and some modalities were not addressed at all, such as gustatory or vestibular modalities. This leaves a variety of potential sensory issues that could be perceived as barriers to working well unaddressed (e.g. affecting health/well-being and impeding performance). It remains unclear, whether, for example, vestibular adjustments are not required because those issues are less pertinent in an office context or not addressed due to an unsystematic approach. In contrast, generic charity and design guidelines list various vestibular adjustments to prevent accidents, such as stair lifts, special furniture and appropriately configured workspaces (Dyspraxia Foundation, 2016; NDA, 2015; Standifer, 2009).

Similarly, most studies addressed hypersensitivity by reducing environmental stimulation whereas none of the studies directly addressed hyposensitivity, yet this is a critical sensory response for ND individuals and a potential reason for impeded health and performance at work. Hypersensitivity and hyposensitivity are both arousal states where too much and too little can impede performance (cf. Yerkes-Dodson Law of Arousal; Cohen, 2011) if not addressed by through alternative workplace adjustments. This was also evident in participants' accounts of understimulation, which hampered concentration (Morris et al., 2015). The included studies did not address this directly; for example, stimulation items were only positioned to relieve overstimulation. In contrast, hyposensitivity has been considered in generic guidance documents (Cassidy, 2018; Group GSA, 2020, 2021; HOK, 2019, 2020; Resource Architecture et al., 2018; Standifer, 2009).

This review elicits indicative benefits of specific sensory adjustments to support occupational longevity, performance and health/well-being in ND workers. However, due to the methodological quality of available evidence, it is not possible to draw any firm conclusions about the cause and effect of specific adjustments. Such lack of evidence is surprising given the openly addressed social exclusion of ND individuals from the labour market (Australian Bureau of Statistics, 2017; Organisation for Economic Co-operation and Development, 2010; Roux et al., 2017; Shattuck et al., 2012), the well-documented problems of ND individuals in gaining and maintaining employment and the legal rights for adjustments, which vary by geographic location (cf. Doyle, 2020).

Indicative benefits of sensory adjustments

We derive indicative findings on the merit of adjustments from our review. The following sections discuss the research findings to signpost the need for future research framed in our person–environment fit perspective and include benchmarking against existing generic guidelines.

Environmental stimulation

Predominantly, adjustments targeted the reduction of sensory stress by reducing acoustic and visual stimulation. Very few studies touched on tactile and olfactory adjustments. Acoustic adjustments for various ND conditions included headphones or earplugs and private rooms or quiet locations. Only one study touched on pleasant acoustical stimulation. Visual adjustments, for ASD only, targeted light levels and types as well as screening out visual distractions (screens). One study pointed to the use of stimulation objects to *reduce* overstimulation. Overall, adjustments targeting too much environmental stimulation were indicatively related to occupational longevity, performance and health/well-being. Heuristic guidelines typically target hypersensitivity, considering all sensory modalities, by recommending the elicited adjustments too, but go further by additionally proposing, for example, white noise machines (JAN, 2020; NDA, 2015; Standifer, 2009), non-stimulating colour schemes (HOK, 2019), air purifiers for odour removal (JAN, 2019), being mindful of textures (HOK, 2019) and ensuring ample space exists to move between furniture and machinery that could be knocked over (NDA, 2015). To target hyposensitivity and/or creating desired environmental stimulation, guidelines propose natural stimuli (e.g. greenery, nature material, sound or imagery; Group GSA, 2020; HOK, 2019, 2020), sensory stimuli objects to help to focus when understimulated (HOK, 2019; La Trobe University, 2020), providing strongly scented planting (e.g. herb gardens; Group GSA, 2020), stimulating colour schemes (HOK, 2019) or activity areas (e.g. balancing boards or bouncy balls; Group GSA, 2020, 2021; HOK, 2019).

Social stimulation

Reduction of social stimulation across all ND conditions included private offices, areas with less human traffic, as well as options to withdraw and limit access to oneself. Very few studies addressed facilitation of social interaction. Adjustments for excessive social stimulation are indicatively related to occupational longevity and some with performance and health/well-being. It is

widely acknowledged that social demands at work can be challenging, particularly for workers with ASD and ADHD/ADD (e.g. Black et al., 2019; Diener et al., 2020; Morris et al., 2015; Pfeiffer et al., 2017). It is no surprise that guidelines also strongly recommend private spaces, preventing crowding, and single offices to reduce stress from social stimulation and demands (ACAS, 2016; Group GSA, 2021; HOK, 2019; Scottish ADHD Coalition, 2018; TUC, 2014b). However, as pointed out by North (2021), there appears to be an inherent bias and stereotypical assumption that certain groups, particularly those with ASD, do not want or require any social interaction, leading to inadequate adjustments 'serve[ing] to increase stigma and isolation, leading to reduced opportunities which limit their career development and perpetuate their marginalisation' (North, 2021, p.16). Heuristic guidelines from the design industry addressed this by creating spaces that facilitate social interaction (Cassidy, 2018; Group GSA, 2021).

Environmental control

Over half the included studies suggest provision of environmental control across neurodiversity conditions by specific (e.g. private office) and unspecific (e.g. providing control) means. One study pointed out that for workers with ASD, control over the physical environment was more important than for neurotypical workers (Hayward et al., 2019). Adjustments for providing environmental control were indicatively related to occupational longevity and performance; fewer health/well-being relationships were found. Environmental control (actual or perceived) is a well-researched moderator on the relationship between environmental stressors (including social stimulation) (cf. Evans & Cohen, 1987). As such, it is no surprise that heuristic guidelines also suggest sensory stimulation control by providing activity-based working environments that offer choice of settings or zones that vary in their intensity of sensory stimulation (Cassidy, 2018; Group GSA, 2020, 2021; HOK, 2019; Resource Architecture et al., 2018).

Other adjustments

Few studies listed sensory-unspecific adjustments, which we positioned as resources rather than stress reduction adjustments, such as adequate seating, treadmill desk or adequate desk size. Further, almost half of the studies indicated the value of a home office as a policy- and environment-related adjustment. Those were similarly related to occupational longevity and performance and health/well-being. Heuristic guidelines also listed sensory-unspecific adjustments, such as designing spaces that are intuitive to navigate through and which have good way-finding properties (Heasman et al., 2020; HOK, 2019; NDA, 2015; Standifer, 2009).

Considerations when implementing sensory adjustments

Several authors highlighted points of caution when implementing physical workplace adjustments, which we consider important for future research in the field and the academic discussion. These points included being cautious of one-size-fits-all approaches of using measures in isolation, of potential mismatch between employee and employer perspective/lack of education of employers, and unawareness of adjustment fatigue by taking an ableist perspective.

Firstly, Pierce (2018) argued that single facets do not universally apply to all (autistic) employees; thus, there is the need for adequate consultation of ND workers. Further, case-by-

case consideration of adjustment should prevent compliance-based adjustment by employers taking a blanket approach. Such failure to consider individual need carries the risk of increasing stigma and perpetuating marginalisation, leaving NDs 'stuck in a deskilling cycle of underemployment' (North, 2021, p. 16). However, North (2021, p. 16) also points out that 'universal [inclusive] design [in addition to case-by-case adjustments] ... may be regarded as too idealistic and vague for resource poor ... organisations', thus hampering social commitment to employment of ND individuals and adjustment despite appropriate government policies.

Second, the risk of applying isolated measures, such as only adjusting the physical environment without addressing psychosocial factors or having appropriate workplace and personnel policies in place (Pierce, 2018), carries the risk of ineffective smoke smoke-and-mirrors inclusion efforts (e.g., Diener et al., 2020).

Third, studies indicated a mismatch between employee and employer perspectives, which can result in unrealistic expectations from employers once adjustments are in place (Diener et al., 2020). This highlights the need for 'training employer stakeholders (support personnel) to recognize various facets of disabilities and to provide training related to acceptable support and adjustments for individual employees' (Pierce, 2018, p. 225) and manage expectations.

Fourth, closely related to unrealistic expectations and the need for employer education is an ableist perspective from management and/or co-workers and resulting unawareness of adjustment fatigue (Soeker, 2020). Such accommodative fatigue has been described in physiological research as 'reduced performance of the accommodative system due to prolonged and/or repeated effort' (Vilupuru et al., 2005, p. 191). This is summarised in this quote from Soeker's (2020) study:

> There's also the issue of adjustment fatigue from an autistic person's point of view ... you can make a person who's wearing a prosthetic leg ... walk up and down stairs, they can do it and they will do it well for a while but it takes more effort for them to do it than it does for someone with two normally functioning legs. So you have to recognize that it takes more effort to accommodate for that ... if you do not put in a lift then at least give them a bit more time to walk up and down the stairs.

Education and the development of a psychologically safe environment is a necessity. Participants frequently revealed a desire for cultural flexibility, greater awareness and sensitivity from neurotypical colleagues, which was balanced with perceived risks of disclosure and stigma (Morris et al., 2015; North, 2021).

Overall, this review highlights a lack of robust evidence on the efficacy of physical workplace adjustments. This is a significant shortcoming of the field. Studies in this review point to indicative findings that broadly accord with existing guidance documents.

Limitations

The study has limitations relating to three key points: the search strategy (search strings and search terms); the strict inclusion/exclusion criteria and the outcome domain categorisation.

First, the combination of four search strings may have limited the search as studies were only retrieved that matched all four search strings. Further, the specification of possible types of workplace adjustments (e.g. 'Light') or their sensory target (e.g. 'Auditory'; see Table 1) by S4 may also have constituted a reductionist approach as studies were only retrieved that included one of the listed search terms within S4 (see Table 1). However, piloting without the S4 string elicited too many papers, which were logistically impossible to review given the resources

available for this work. Furthermore, relevant papers may have been excluded if they used different wording from MeSH words or in the title, abstract or text. Specifically, there were concerns that the two search terms concerning olfactory and vestibular adjustments ('Air quality' and 'Lift*') might have limited the retrieval. However, post hoc trials that replaced the terms 'Air quality' and 'Lift*' with general terms 'olfactor*' and 'vestib*' did not render an improved search. Further, extensive handpicking aimed to retrieve any empirical evidence available.

Second, strict inclusion criteria excluded studies that only listed technological adjustments (excluded during screening); used adult and adolescent ND populations (excluded during screening); used populations that neither identified as ND via self- nor formal diagnosis (excluded during eligibility check) and non-empirical works (excluded during eligibility check).

Third, the outcome domain categorisation for occupational longevity, performance and health/well-being rested on the positioning of the evidence by the title authors. If authors were unclear or did not use any terminology that related to the outcome domains (e.g. health/well-being), the evidence was classified based on the review authors' interpretation of participant quotes (e.g. headache → health/well-being). As such, there is a risk that evidence might have been incorrectly classified. However, we have retained the title author's wording of the evidence in the manuscript and in the tables as much as possible to maintain transparency and minimise risk of wrong interpretations and categorisations. Further, including two researchers at each decision point aimed to reduce possible classification error.

Limitations recognised, we also note the contribution of our approach regarding the comprehensive database search, specific focus on sensory modalities, workplace setting, and physical adjustments, which address limitations in previous studies that lacked differentiation.

Implications for further research

Future studies will benefit from attending to four areas.

First, there is a need to develop a clear understanding of the sensory needs by ND condition/type, differentiating sensory modality and hypo- and hypersensitivity. Robust approaches should also control for potentially confounding individual characteristics and contextual conditions. These include self-diagnosis and gender. For this, we suggest the incorporation of Dunn's Sensory Process Model of sensitivity-environment interaction, which takes into account all sensory processing modalities and specifies processing patterns including seeking, avoiding, sensitivity, and low registration.

Second, we recognise that individuals with certain ND conditions, in particular ADHD and ASD, are found in the highest or lowest percentiles with respect to these sensory processing patterns (Dunn, 2001; Schreuer & Dorot, 2017). However, there is a need to develop context-sensitive outcome measures, which encompass employer and employees' perspectives. In other words, further research is needed to understand the impact of the sensory physical environment from multiple perspectives.

Third, we need to implement rigourous experimental designs to develop and test effective sensory interventions/adjustments to improve person and environment fit. This is a necessary baseline for the development of future evidence-based guidance.

Fourth, there is a need for a nuanced understanding of the factors influencing the implementation of adjustments employing process evaluation methodologies to enable a granular understanding of what works, for whom and under which circumstances.

CONCLUSION

This review examined the extent, nature and quality of the current empirical evidence for physical workplace adjustment to support occupational longevity, performance and health/well-being in ND workers because of their specific sensory needs. Our results indicate that the research is generally not well-developed, is methodologically weak and therefore confined to offering indicative effects. The majority of studies addressed a mixture of work settings, a mixture of adjustments/barriers and facilitators, and focused predominantly on workers with ASD. This means that the effects of required sensory adjustments have been researched without due consideration of specific environments and inclusive sampling. Given the necessity of physical workplace adjustments to support inclusion and occupational outcomes for ND individuals, this review highlights the need for more methodologically sound research to inform evidence-based (design) guidelines for ND office environments.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICS STATEMENT

Ethical review and approval was not required for the study.

DATA AVAILABILITY STATEMENT

Data sharing is not available as no new data were generated.

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ENDNOTES

[1] From here on we refer to 'sensitivity' not 'responsiveness'. The latter refers to 'out of the norm' response patterns with neurotypical assumptions and the former to alternating sensitivity states, implying a perspective of needs and preferences.

[2] As there is no universally accepted terminology, we use 'with the condition', to comply with scientific standards. We explicitly respect perceptions of community members that these are spectrum conditions.

[3] Although MMAT allows for the assessment of uni-method studies, we chose CASP due to it being referenced in quality guidelines (Cochrane, World Health Organization; cf. Noyes et al., 2018).

[4] This excludes demographics of three studies that only studied company directors, line managers, leaders, front-line supervisors or employers (Dreaver et al., 2020; Pierce, 2018; Waisman-Nitzan et al., 2019).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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