frontiers | Frontiers in Education

TYPE Opinion
PUBLISHED 24 January 2023
DOI 10.3389/feduc.2022.1047489

OPEN ACCESS

EDITED BY
Desiree Forsythe,
Chapman University, United States

REVIEWED BY
Diana Hernández Montoya,
Universidad Estatal a Distancia, Costa Rica

*CORRESPONDENCE
Ilana Kolodkin-Gal
✉ ilana.kolodkin@mail.huji.ac.il

SPECIALTY SECTION
This article was submitted to
STEM Education,
a section of the journal
Frontiers in Education

RECEIVED 18 September 2022
ACCEPTED 31 December 2022
PUBLISHED 24 January 2023

CITATION
Kolodkin-Gal I (2023) Underexplored outcomes of learning disabilities and neurodivergence in STEM graduate and post-graduate research.
Front. Educ. 07:1047489.
doi: 10.3389/feduc.2022.1047489

Underexplored outcomes of learning disabilities and neurodivergence in STEM graduate and post-graduate research

Ilana Kolodkin-Gal *

Department of Plant Pathology and Microbiology, The Robert H. Smith Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehovot, Israel

KEYWORDS

science, technology, engineering, and mathematics (STEM), diversity and inclusion, attention deficit hyperactivity disorder (ADHD), dyslexia (disturbed reading and spelling), education

Neurodiversity in sciences

Many brilliant scientists had dyslexia, including Michael Faraday, Galileo Galilei, and Thomas Alva Edison. Learning disabilities are often positively correlated with creativity (LaFrance, 1997; Everatt et al., 2008). Dyslexia, attention deficit hyperactivity disorder (ADHD), and other learning deficiencies provide a different point of view on scientific observations and may be seen as an advantage. However, recent literature strongly indicates that dyslexia and ADHD also introduce technical and emotional difficulties in affected adults (Davis and Braun, 1998; Mao et al., 2011; Fuermaier et al., 2021).

Professional success can be impacted by neurodiversity, inside and outside of STEM

It is established that medical professionals, undergraduate students (Pope et al., 2007; Canu et al., 2021), employees at all levels (Davis and Braun, 1998; Mao et al., 2011; Fuermaier et al., 2021), and drivers (Narad et al., 2018; Randell et al., 2020; Sani et al., 2020) can be affected by neurodiversity. Most studies indicate a poor outcome for neurodiverse individuals, such as decreased success/impaired performances (Davis and Braun, 1998; Pope et al., 2007; Mao et al., 2011; Fuermaier et al., 2021). However, specific examples of tasks compromised by neurodiversity are undetailed, except for driving.

One example of a well-documented correlation between neurodiversity and poor outcomes is ADHD. ADHD is characterized by pervasive functional impairments related to attention, hyperactivity, and impulse control (American Psychiatric Association, DSM-5 Task Force, 2013) and is associated with challenges in the workplace in adulthood that require specialized resources. Drivers with ADHD receive more speeding violations and reckless driving charges than drivers without ADHD and are more prone to accidents. Compared with non-ADHD employees, those with ADHD have lower occupational ranks and are more likely to be fired (Mao et al., 2011; Fuermaier et al., 2021). Research connecting ADHD with poor outcomes during driving, in elementary and high school performances, and general workplace adaptability is accessible (DuPaul et al., 2014; Sarkis, 2014; Robinson et al., 2015; Robbins, 2017; Sani et al., 2020), while data on individuals with ADHD as early and mid-career researchers in science, technology, engineering, and mathematics (STEM) are largely unavailable. However, it is reasonable to assume that

STEM-associated workplaces (universities, research labs, and the Biotech industry) are comparable and perhaps more venerable to ADHD-associated bias due to the high-pressure environment and complex technical demands (Bailyn, 2003; Freeman et al., 2016; Bielczyk et al., 2020; Treanor et al., 2021).

Adaptations in workplaces and research universities in STEM are insufficient

Neurodivergence and learning disabilities are continuously discussed in the context of non-academic workplaces (Davis and Braun, 1998; Shaywitz et al., 2021), as well as in undergraduate students (Pope et al., 2007; Pfeifer et al., 2020, 2021; Canu et al., 2021). The increased awareness of such issues has yielded specific adaptations, such as Harvard offering eligible students demonstrations of assistive software, including dictation, text-to-speech, note-taking, and other applications. Evidence that learning disabilities impact post-graduates in STEM comes from the field of medicine, where dyslexic physicians reported challenges in accepting their diagnosis and difficulties associated with dyslexia. This research provided important insights. Participants had a chance to reflect on whether the challenges they faced were exacerbated by their dyslexia or if these challenges were something they felt everyone (dyslexic or not) would experience. The studied healthcare professionals were then asked whether they had disclosed their dyslexia to others; the majority had not. It was commented that dyslexia was viewed as an excuse by others for underperformance or poor performance (Newlands et al., 2015). One concern is the lack of details regarding what mistakes could be correlated with dyslexia, making it impossible to determine what automated coping mechanisms will be helpful for prevention.

Graduate and post-graduate performance can be impacted by neurodiversity

Currently, undergraduate students are offered reasonable modifications, such as taking an open exam rather than a multiple-choice test or longer time allocated for neurodiverse students to perform demanding tasks. However, these simple modifications may need to be revised for at least two aspects of STEM research: dealing with visual data, thereby preventing publication errors, and generating a verbal output (papers) to summarize the research products. I will discuss them separately.

First, in biology, the assembly of visual data, especially in figures, is an issue, as up to 20% of scientific papers have errors in figure assembly (Woodhams, 2021). In the professional, scientific world, mistakes are considered evidence of carelessness at best and misconduct at worst (Eisner, 2018). However, to my knowledge, the role of specific learning disabilities or neurodivergence in published errors remains to be systematically explored. Graphical data analysis and assembly are highly affected by the visuoconstruction abilities of the author. However, it is difficult for an unrelated author who did not perform the experiments to assemble the data in a way that is consistent with the overall data. This can be especially difficult for those who are neurodivergent. A new category of non-verbal learning disability (NVLD) (Spreen, 2011; Fisher et al., 2022), a neurodevelopmental disorder with significant effects on visual-spatial processing in the presence of intact verbal ability, recently emerged and is problematic in assembling scientific data. As no data are available, it is only logical to assume that researchers with NVLD and ADHD are prone to issues with figure preparation and visual data analysis. Scientists with ADHD may also find it difficult to organize their laboratory notebooks and research products, an additional challenge, as indexing research products is currently done manually. More software needs to be developed to automate the assembly of multi-panel visual data, proof the assembled data, and organize/archive the research products. Notably, as errors are often perceived as carelessness or deliberate manipulation of data, it is challenging for an early-career scientist to be open about this specific vulnerability.

Second, dyslexia (e.g., difficulty in reading and frequently writing) is an ultimate challenge in communities that require extensive verbal products (books, manuscripts, and grants). The issue is especially challenging in social sciences, with lengthy books being the most appreciated research product. However, dyslexia also impacts STEM researchers who are judged by their productivity in continuously writing research papers. Poor structure, grammar, typos, and lack of coherence in texts are unacceptable and will prevent publication, regardless of the quality and creativity of the ideas and theories in the manuscripts. However, very few, if any, adaptations are taken. One reasonable adaptation could have been for institutes to cover the costs of scientific writers for early and mid-career researchers in STEM affected by dyslexia.

Personal perspective

My particular diagnosis (in addition to having multiple ADHD symptoms) for learning disabilities from 2001 includes (but is not limited to) difficulty in memorizing number sequences, difficulty in data retrieval in short problems, and remembering details from complex texts; difficulty in isolating specific details during visual scanning; lack of planning in relation to the page layout during figure copying and drawing tasks; attention deficits, poor memory of information of complex figures and individual symbols. Retrospectively, many of my issues also fall into the relatively non-characterized learning disorder, NVLD. Any of the above, and a combination thereof, makes one most vulnerable to sub-perform in STEM. Indeed, my earlier works included some mistakes now appropriately corrected/acknowledged by *Scientific* journals. I also recognize that the overall understanding of editors and collaborators with whom I shared the full diagnosis was untrivial. Only as an independent investigator did I become aware of artificial intelligence software to do quality control before publication. I have also developed 20 years of coping mechanisms with regard to these challenges to make sure that my scientific work is state-of-the-art and compliant with the highest standards. When reviewing papers, I use the same tools and often find myself self-copying the main figures to ensure the details are captured in full. However, I am also aware of the impact neurodiversity has on my performance. The current technologies are insufficient without safety netting, and I often find myself spending extra time double- and triple-checking work and preparing for tasks. My coping mechanisms are consistent with the recently isolated findings on medical professionals (Newlands et al., 2015), highlighting the insufficiency of existing technological tools to overcome the demands of their profession and potentially the need to develop additional automated tools for day-day research tasks.

Conclusion

From a personal perspective, as well as the unsatisfying available literature, the effects of learning disabilities (dyslexia, dysgraphia, dyscalculia, NVLD, visual stress, and dyspraxia) and neurodivergence [ADHD and autistic spectrum disorder (ASD)] on graduate and post-graduate STEM researchers are understudied. As in underperformance in driving, underperformance in STEM professions is not desired by individuals with neurodivergence. However, it is the likely outcome without reasonable adaptations coupled with encouraging full transparency and institutional protection of the affected individual. Consistent with potential acceptance issues, the literature on the effects of dyslexia/ADHD and neurodiversity on STEM researchers and their coping mechanisms is meager. Coping mechanisms have yet to be fully analyzed, and the acceptance of these issues may vary (Newlands et al., 2015). In my personal experience, neurodiversity is often connected to underperformance, viewed as an excuse instead of as a disability that needs additional tools of support. Therefore, it is the responsibility of the decision-makers to ensure this will not be the case and that those who are neurodivergent feel both accepted and supported.

The scientific community needs to have honest discussions and deep introspection to ensure the inclusion of young scientists with dyslexia, neurodivergence, and additional learning disabilities at the graduate and post-graduate levels. To enable discussion, information, literature, and potential collaborations from scientists, colleagues, students, mentors, and editors should openly discuss the effects of neurodiversity on their scientific performance. Research institutes also need to be actively involved in this discussion so that we can take action together to ensure that every researcher can realize their potential, regardless of the learning disability and neurodiversity they may face.

Author contributions

IK-G wrote the manuscript, contributed to the manuscript, and approved the submitted version.

Funding

This study was supported by the Israel Science Foundation (grant 119/2016 to IK-G).

Conflict of interest

IK-G was a consultant of a company Proofig Pvt. Ltd. aimed to reduce mistakes in Scientific Publications using AI. However, this software was not specified in the text, as alternatives were available.

Publisher's note

References

American Psychiatric Association, DSM-5 Task Force (2013). *Diagnostic and statistical manual of mental disorders: DSM-5™*, 5th Edn. Washington, DC: American Psychiatric Publishing, Inc.

Bailyn, L. (2003). Academic careers and gender equity: Lessons learned from MIT. *Gend. Work Organ.* 10, 137–153. doi: 10.1111/1468-0432.00008

Bielczyk, N. Z., Ando, A., Badhwar, A. P., Caldinelli, C., Gao, M., Haugg, A., et al. (2020). Effective self-management for early career researchers in the natural and life sciences. *Neuron* 106, 212–217. doi: 10.1016/j.neuron.2020.03.015

Canu, W. H., Stevens, A. E., Ranson, L., Lefler, E. K., LaCount, P., Serrano, J. W., et al. (2021). College readiness: Differences between first-year undergraduates with and without ADHD. *J. Learn. Disabil.* 54, 403–411. doi: 10.1177/0022219420972693

Davis, R. D., and Braun, E. (1998). *Adult dyslexia and ADD: Effects in the workplace.* Burlingame, CA: Davis Dyslexia Association International.

DuPaul, G. J., Gormley, M. J., and Laracy, S. D. (2014). School-based interventions for elementary school students with ADHD. *Child Adolesc. Psychiatr. Clin. North Am.* 23, 687–697. doi: 10.1016/j.chc.2014.05.003

Eisner, D. A. (2018). Reproducibility of science: Fraud, impact factors and carelessness. *J. Mol. Cell. Cardiol.* 114, 364–368. doi: 10.1016/j.yjmcc.2017.10.009

Everatt, J., Weeks, S., and Brooks, P. (2008). Profiles of strengths and weaknesses in dyslexia and other learning difficulties. *Dyslexia* 14, 16–41. doi: 10.1002/dys.342

Fisher, P. W., Reyes-Portillo, J. A., Riddle, M. A., and Litwin, H. D. (2022). Systematic review: Nonverbal learning disability. *J. Am. Acad. Child Adolesc. Psychiatry* 61, 159–186. doi: 10.1016/j.jaac.2021.04.003

Freeman, B. K., Landry, A., Trevino, R., Grande, D., and Shea, J. A. (2016). Understanding the leaky pipeline: Perceived barriers to pursuing a career in medicine or dentistry among underrepresented-in-medicine undergraduate students. *Acad. Med.* 91, 987–993. doi: 10.1097/ACM.0000000000001020

Fuermaier, A. B. M., Tucha, L., Butzbach, M., Weisbrod, M., Aschenbrenner, S., and Tucha, O. (2021). ADHD at the workplace: ADHD symptoms, diagnostic status, and work-related functioning. *J. Neural Trans.* 128, 1021–1031. doi: 10.1007/s00702-021-02309-z

LaFrance, E. D. B. (1997). The gifted/dyslexic child: Characterizing and addressing strengths and weaknesses. *Ann. Dyslexia* 47, 163–182. doi: 10.1007/s11881-997-0025-7

Mao, A. R., Brams, M., Babcock, T., and Madhoo, M. (2011). A physician's guide to helping patients with ADHD find success in the workplace. *Postgr. Med.* 123, 60–70. doi: 10.3810/pgm.2011.09.2460

Narad, M. E., Garner, A. A., Antonini, T. N., Kingery, K. M., Tamm, L., Calhoun, H. R., et al. (2018). Negative consequences of poor driving outcomes reported by adolescents with and without ADHD. *J. Attent. Disord.* 22, 1109–1112. doi: 10.1177/1087054715575063

Newlands, F., Shrewsbury, D., and Robson, J. (2015). Foundation doctors and dyslexia: A qualitative study of their experiences and coping strategies. *Postgr. Med. J.* 91, 121–126. doi: 10.1136/postgradmedj-2014-132573

Pfeifer, M. A., Reiter, E. M., Cordero, J. J., and Stanton, J. D. (2021). Inside and out: Factors that support and hinder the self-advocacy of undergraduates with ADHD and/or specific learning disabilities in STEM. *CBE Life Sci. Educ.* 20:ar17. doi: 10.1187/cbe.20-06-0107

Pfeifer, M. A., Reiter, E. M., Hendrickson, M. K., and Stanton, J. D. (2020). Speaking up: A model of self-advocacy for STEM undergraduates with ADHD and/or specific learning disabilities. *Int. J. Stem Educ.* 7:33. doi: 10.1186/s40594-020-00233-4

Pope, D., Whiteley, H., Smith, C., Lever, R., Wakelin, D., Dudiak, H., et al. (2007). Relationships between ADHD and dyslexia screening scores and academic performance in undergraduate psychology students: Implications for teaching, learning and assessment. *Psychol. Learn. Teach.* 6, 114–120. doi: 10.2304/plat.2007.6.2.114

Randell, N. J. S., Charlton, S. G., and Starkey, N. J. (2020). Driving with ADHD: Performance effects and environment demand in traffic. *J. Attent. Disord.* 24, 1570–1580. doi: 10.1177/1087054716658126

Robbins, R. (2017). The untapped potential of the ADHD employee in the workplace. *Cogent Bus. Manag.* 4:1271384. doi:10.1080/23311975.2016.1271384

Robinson, A., Simpson, S., and Hott, B. (2015). The effects of child-centered play therapy on the behavioral performance of elementary school students with ADHD. *Int. J. Play Ther.* 26, 73–83.

Sani, S. H. Z., Fathirezaie, Z., Sadeghi-Bazargani, H., Badicu, G., Ebrahimi, S., Grosz, R. W., et al. (2020). Driving accidents, driving violations, symptoms of attention-deficit-hyperactivity (ADHD) and attentional network tasks. *Int. J. Environ. Res. Public Health* 17:5238. doi: 10.3390/ijerph17145238

Sarkis, E. (2014). Addressing attention-deficit/hyperactivity disorder in the workplace. *Postgrad. Med.* 126:25–30. doi: 10.3810/pgm.2014.09.2797

Shaywitz, S. E., Shaywitz, J. E., and Shaywitz, B. A. (2021). Dyslexia in the 21st century. *Curr. Opin. Psychiatry* 34, 80–86. doi: 10.1097/YCO.0000000000000670

Spreen, O. (2011). Nonverbal learning disabilities: A critical review. *Child Neuropsychol.* 17, 418–443. doi: 10.1080/09297049.2010.546778

Treanor, L., Noke, H., Marlow, S., and Mosey, S. (2021). Developing entrepreneurial competences in biotechnology early career researchers to support long-term entrepreneurial career outcomes. *Technol. Forecast. Soc. Change* 164:120031. doi: 10.1016/j.techfore.2020.120031

Woodhams, J. (2021). *Jana christopher – image integrity analyst*. London: UK Research Integrity Office.